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A design framework for customer-oriented PSS based on three dimensional concurrent engineering approach

Hao Guan

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POUR OBTENIR LE GRADE DE
DOCTEUR DE
L'UNIVERSITÉ DE BORDEAUX

ÉCOLE DOCTORALE DES SCIENCES PHYSIQUES ET
DE L'INGENIEUR

Spécialité Productique

Par **Hao GUAN**

Un cadre de conception pour les PSS
basé sur l'ingénierie simultanée tridimensionnelle

*A design framework for customer-oriented PSS
based on three dimensional concurrent engineering approach*

Sous la direction de: Jean-Paul BOURRIERES
(Co--directrice: Thècle ALIX)

Soutenue le 14 octobre 2019

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Titre: Un cadre de conception pour les PSS basés sur l'ingénierie simultanée tridimensionnelle

Résumé:

Au cours des deux dernières décennies, l'économie industrielle a fait un pas dans l'économie des services. De nombreuses illustrations témoignent de cette évolution comme le montrent les nouveaux modèles d'affaires mis en œuvre par les industriels. Ceux-ci sont de plus en plus nombreux à passer de la logique traditionnelle axée sur la vente des produits à la logique «servicielle» qui se focalise sur les effets utiles et la performance d'usage de la solution par les parties prenantes. Dans ce contexte, les systèmes produits-services (PSS) sont considérés comme l'une des mises en œuvre possibles de la servitisation des entreprises manufacturières qui, de surcroît, s'annonce comme une possibilité prometteuse au plan du développement durable. Les PSS attirent en conséquence l'attention de nombreux praticiens et chercheurs en raison de leur potentiel à satisfaire les exigences des clients par des solutions plus économiques, plus personnalisées et plus durables. Cependant, dans le marché actuel, la plupart des solutions PSS sont poussées par les fournisseurs en fonction de leurs propres capacités et de leur potentiel interne d'innovation sans tenir compte, la plupart du temps, des utilisations et des valeurs réelles que représentent les offres proposées aux bénéficiaires. Il en résulte que les fonctionnalités des offres, souvent modulaires (différents scénarios de combinaisons de produits et de services), sont parfois inutiles, parfois redondantes et qu'une grande quantité de déchets est produite lors de la production et de la mise en œuvre de ce type de solutions ; ce qui est antinomique avec l'effet recherché.

Cette thèse associe un concept complémentaire au concept de PSS existant pour obtenir un PSS orienté client (COPSS) qui se concentre sur les exigences des clients et leur satisfaction, sur la performance économique de la solution, sur les autres exigences des fournisseurs de la solution, ainsi que sur la performance de la solution en terme de développement durable. Afin de concevoir des solutions COPSS répondant véritablement à ce cahier des charges, un cadre de conception intégré basé sur une approche tridimensionnelle d'ingénierie simultanée est proposé. Selon ce cadre, la solution est construite en considérant simultanément la conception de la solution (offre COPSS), la conception des processus et du réseau support à cette offre. Ce cadre adopte plus précisément la personnalisation de masse comme méthodologie de conception de base pour concevoir les offres et les processus supports et l'architecture multi-agent AGORA pour concevoir le réseau support. Afin d'être éprouvé, le cadre proposé est mis en œuvre sur un cas d'application.

Mots clés: Système de service aux produits orientés vers le client, Cadre de conception COPSS, Entreprise virtuelle, Ingénierie concomitante tridimensionnelle, Personnalisation de masse, Architecture multi-agents AGORA, Gestion de scrum, évaluation de la satisfaction de la clientèle, évaluation de la durabilité

Title: An integrated design framework for Customer-Oriented PSS based on Three-Dimensional Concurrent Engineering

Abstract:

The world industrial economy has been witnessing to step into service economy during last two decades. Evidence can be easily found to prove it, such as the shift of more and more manufacturers from traditional product-centric logic into service-oriented logic, sharing economy's growth in popularity over the last several years, changing their business model and renting the usage of the product they manufacture, etc. Product-Service Systems (PSS), under this context, are seen as one solution to help companies to address the servitization process. PSS captures a lot of practitioners and researchers' attention because of its potential to satisfy customers' requirements of more economical, more customized and more sustainable services in the modern service economy context. However, in the current marketplace, most PSS solutions are pushed by providers based on their own capabilities and their internal potential for innovations and unfortunately, they most of the time ignore real usages and values for beneficiaries. In this context, functions of offerings (different scenarios of combinations of products and services) are sometimes useless and overlapped and a large amount of waste is being produced when producing and implementing this kind of solution.

According to this motivation, this thesis proposes a supplemented concept for existing PSS, called Customer-Oriented PSS (COPSS), which focuses the customers' requirements and their satisfaction, the economic satisfaction among others of the suppliers of the solution, as well as the performance of the solution in terms of sustainable development. Accordingly, in order to design COPSS solutions with these requirements, an integrated design framework for COPSS based on Three Dimensional Concurrent Engineering approach is proposed. According to this framework, the developed solution is composed of three parts-offerings, processes and supporting network rather than only offerings. Particularly, the framework adopts mass customization as the core design methodology to design offerings and supporting processes and AGORA multi-agent architecture to support modelling network. Finally, an air conditioner PSS design case study is launched to show how to use this framework.

Keywords: Customer-Oriented Product Service System, COPSS design framework, Virtual Enterprise, Three-Dimensional Concurrent Engineering, Mass customization, AGORA multi-agent architecture, Scrum management, customer satisfaction, sustainability assessment;



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Table of Abbreviations

PSS	Product Service System
CNO	Collaborative Network Organizations
VE	Virtual Enterprise
KN	Kernel Network
SO	Supporter Organizations
3DCE	Three Dimensional Concurrent Engineering
COPSS	Customer-Oriented Product Service System
CO	customer-orientation
PSOs	Product-Service Offerings
VCCPs	Value Co-Creation Processes
HoQ	House of Quality
QFD	Quality Function Deployment
FAHP	Fuzzy Analytic Hierarchy Process
GERT	Graphical Evaluation and Review Technique
SA	Sustainability Assessment
LCA	Life Cycle Assessment
LCCA	Life Cycle Costing Assessment
SLCA	Social Life Cycle Assessment

General Introduction

The world industrial economy has been witnessing to step into service economy during last two decades. Evidence can be easily found to prove it, such as the shift of more and more manufacturers from traditional product-centric logic into service-oriented logic, sharing economy's growth in popularity over the last several years, changing their business model and renting the usage of the product they manufacture, etc. Product-Service Systems (PSS), under this context, are seen as one solution to help companies to address the servitization process. PSS captures a lot of practitioners and researchers' attention because of its potential to satisfy customers' requirements of more economical, more customized and more sustainable services in the modern service economy context.

However, in the current marketplace, most PSS solutions are pushed by providers based on their own capabilities and their internal potential for innovations and unfortunately, they most of the time ignore real usages and values for beneficiaries. In this context, functions of offerings (different scenarios of combinations of products and services) are sometimes useless and overlapped and a large amount of waste is being produced when producing and implementing this kind of solution.

According to this motivation, this thesis proposes a supplemented concept for existing PSS, called Customer-Oriented PSS (COPSS), which focuses the customers' requirements and their satisfaction, the economic satisfaction among others of the suppliers of the solution, as well as the performance of the solution in terms of sustainable development. Accordingly, how to propose a sustainable COPSS solution satisfying all stakeholders is the core problem in our thesis.

Regarding this background, the objective of this thesis is to build a framework for the collaborative design of COPSS involving in particular composite services in a usage-driven perspective. When adhering to customer orientation principle, customers' requirements should come first, which means that the framework should be able to well analyze and integrate the customers' requirements into PSS solution design. Additionally, this framework is also dedicated to achieving sustainability, which means that the solution should also integrate the environmental, social and economic aspects into consideration. A last significant point is that the organizations who have to collaborate to deliver the right offering to the customer should address good communications and interactions to avoid shedding of performance, time and money. Finally, our framework is dedicated to propose a win-win solution for all stakeholders.

To achieve this objective, two main issues should be figured out. The first one is the clarification of COPSS concept; and the second is what can be proposed in order to design a COPSS. In order to understand the concept of COPSS, this thesis made a systematic literature review in which 94 customer-orientation related papers from marketing and business development field, ICT related design field and PSS or Service System engineering field were collected and analyzed. Based on the analysis, the essence of "customer orientation" and the benefits of customer orientation are

extracted and five key findings can be concluded: (1) COPSS emphasizes on customer experience and customer satisfaction; (2) the customers in COPSS have more potential to reduce environmental impacts; (3) offerings provided by COPSS emphasizes on customers' requirements, as well as offerings' functions; (4) COPSS ideology advocates customer involvement along entire PSS lifecycle; (5) Despite of new PSS design challenges coming from customer-orientation, customer-oriented design will still take more advantages over traditional product-centric method and innovation-pushed PSS.

In terms of second issue, this thesis proposed "an integrated design framework for COPSS from Three-Dimensional Concurrent Engineering (3DCE) perspective". In this framework, a COPSS solution is not only a scenario of combination of products and services, but should also include corresponding supporting processes design and supporter organizations. Hence, the core of this framework is to address the integrated Product-Service Offerings (PSOs) design, Value Co-Creation Processes (VCCPs) design and Virtual Enterprise (VE) design. This thesis adopts VE as the supporting network manifestation due to its outstanding characteristics of flexibility, efficiency and effectiveness, more than traditional organizations. VCCPs are advocated instead of non-collaborative supporting processes, mainly because both VE members and customers can play active and important roles in such a collaborative environment. Mass customization, as well as modular design, are adopted to design PSO and VCCPs, while AGORA multi-agent architecture is adopted to model a new VE. As mentioned above, the framework tries to propose win-win solutions for any stakeholder, i.e., the solution should be able to satisfy both of them and bridge the gap between the expected results and perceived results. Therefore, a COPSS design cycle based on customer-provider satisfaction trade-off is necessary to optimize the solution scenarios, in which customers' requirements such as the functions of products and services, the price, quick response etc. and providers' requirements, such as the economic benefits, environmental impacts and social impacts should be taken into consideration.

In addition, to make the design framework more performant, this thesis proposes to add two management methodologies. Firstly, a stakeholder-driven lifecycle model aims to help stakeholders to define their roles and responsibilities during the PSS lifecycle and to reduce system complexity and uncertainty; secondly, this thesis integrates the AGORA multi-agent architecture with Scrum management methodology (a very popular agile management methodology) to propose a "multi-layer Scrum management framework based on AGORA architecture". In this way, the VE could perform more effectively and efficiently, so that the target of response to customers with high-quality offerings could be addressed.

The thesis is structured as follows: In Chapter 1, the background of PSS research is briefly introduced; then the PSS fundamental knowledge is illustrated, such as the definitions, the benefits, the basic construction components and the barriers to PSS adoption; additionally, Chapter 1 makes a brief literature review of existing PSS frameworks, design methodologies, tools and techniques. In Chapter 2, the core

concept of COPSS is proposed and analyzed based on a systematic review of the literature and a new reference typology is proposed for COPSS. In Chapter 3, the integrated design framework for COPSS from 3DCE perspective is proposed and the three main activities to carry out are detailed. Chapter 4 will supplement the lacking management methodologies for Chapter 3 in order to promote the design framework performance. In Chapter 5, an air conditioner service case study is launched in order to show how to use the proposed framework and methodologies. Finally, the thesis ends with a conclusion and some future research perspectives.

Key words:

Customer-Oriented Product Service System, COPSS design framework, Virtual Enterprise, Three-Dimensional Concurrent Engineering, Mass customization, AGORA multi-agent architecture, Scrum management, customer satisfaction, sustainability assessment;

Chapter1. Product Service System (PSS) fundamentals and the state of the art of PSS design frameworks and methodologies

1. Background Introduction

The world industrial economy has also been witnessing to step into service economy during last two decades, just like those pure service industries such as bank services, assurance services and consultancy services etc. Stahel (1986) advocated the need to distinguish between traditional industrial economy and service-oriented economy. In traditional industrial economy, manufacturers emphasize on technologies and techniques carried on products and try to find optimal solutions to promote the products' quality. Industrial economy places the central value on the exchange of the products that are consumed. On the contrary, the service economy emphasize the use or functions of products and try to find better solutions for promoting customers' value and experience. The service economy recognizes the value of utilization- a performance driven orientation where the consumer pays for utilization of the product (Mont, 2002). What's more, service economy advocate the highest possible value for longest possible time while consuming as few material resources and energy as possible; hence it is considerably more sustainable (Stahel, 1986). Mont (2002) also indicated that service economy has the potential to be more sustainable because it addresses current levels of material/resource consumption, seeking options that may provide function/service to consumers without minimizing their level of welfare.

With the development of the industrial services in last two decades, service itself has been capturing more and more attention and become more popular especially in recent years. In the latest released "2019 Manufacturing Trends Report" (Microsoft Dynamics 365, 2018), it explicitly indicated that (1) manufacturers now should shift to a more customer-centric approach, exploring new service-based business models to build value and grow relationships with customers in a modern, connected world. Adding services to their portfolios allows manufacturers to differentiate their offerings and gain a competitive edge in a rapidly changing industry; (2) the servitization of manufacturers is the mainstream trend in the future. Anything as a Service (XaaS) business models will be more popular. The most commonly known XaaS is Software as a Service (SaaS) recently; however, in the future, there will be more and more Platform as a Service (PaaS), Infrastructure as a Service (IaaS), Manufacturing as a Service (MaaS), and Transportation as a Service (TaaS), etc. ;(3) sharing economy also has grown in popularity over the last several years. The most commonly mentioned examples are Uber and Airbnb. Based on Uber, the owners of private cars could share their availability with travelers during their rest time; based on Airbnb, travelers are able to rent other individuals' home spaces for a short duration. The sharing economy is projected to grow to 865.million U.S. users by 2021, up from 44.8 million in 2016, as shown in Figure 1.

The author also found an earlier survey report in 2014 for US launched by PricewaterhouseCoopers (PwC), in which they indicated customers are showing a

robust appetite for the sharing-based economy. They borrow goods, rent homes, and serve up micro-skills in exchange for access or money. In US, 44% customers are familiar with sharing economy, 19% of total US adult population has engaged in a sharing economy transaction. Among US adults familiar with the sharing economy, they perceive many benefits to it: 86% of them agree it makes life more affordable; 83% of them agree it makes life more convenient and efficient; 76% of them agree it's better for the environment; 78% of them agree it builds a stronger community; 63% of them agree it's more fun than engaging with traditional companies; 89% of them agree it's based on trust between providers and users. What's more, 43% of them agree owning today feels like a burden; and 81% of them agree it's less expensive to share goods than to own them individually.

Sharing Economy Users and Penetration, 2016-2020

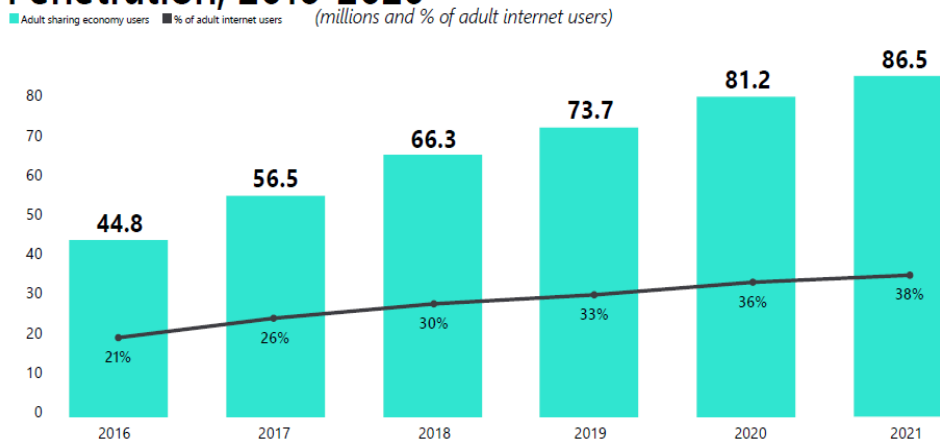


Figure 1 sharing economy users and penetration (Microsoft Dynamics 365, 2018)

This is not only happened in U.S., the following Figure 2 displays the sharing economy development in a worldwide range in 2017. Asia is an epicenter of the sharing economy. Nielsen company's research has found that the Asia-Pacific residents were the most willing in the world to participate in sharing, with 81% willing to rent or share others' assets and 78% willing to rent or share their own (vs. global figures of 66% and 68%). Furthermore, of the top 10 countries most likely to do so, four are in Asia: China, the Philippines, Thailand, and India. With 135 million outbound travelers (UN World Tourism Organization), China is well positioned to influence global trends (Wharton, 2019).

This kind of sharing economy is often based on renting or leasing business models. Under this model, customers are able to borrow and utilize products with lower cost, and they are able to access those goods they can't afford to buy before. Customers won't need worry about the maintenance and quality guarantee after buying these products. The providers will help them guarantee the quality during usage duration since customers don't own the products in a sharing economy context. Customers also will enjoy more flexible services according to their scheduling. What's more, this model also will satisfy customers' consciousness of environment

friendly since utilizing services will form a habit of reuse and recycling; therefore reducing large amount of industrial pollutions.



Figure 2 regional willingness to participate in sharing economy across the globe (Wharton, 2019)

Customers' willingness to buy more economical, more flexible, more sustainable services rather than buying products has been recognized as a mainstream trend in modern society. In order to satisfy customers' needs, researchers and practitioners have spared a lot of efforts. One of the most popular solutions is called Product Service System (PSS), which is recognized as a suitable way to address the traditional manufacturers' transition into a service economy. In order to obtain a general understanding of this notion, two targets need to be addressed in Chapter 1. First one is to make a brief literature review for PSS related fundamental knowledge. Secondly, due to my research work mainly focuses on PSS design, a literature review for existing PSS design frameworks as well as variety of design methodologies, techniques and tools is also necessary to be the foundation of my thesis.

Product Service System is adopted in order to satisfy customers' requirements of more economical, more flexible, and more sustainable services in a modern service economy context.

2. Product Service Systems (PSS)

In the introduction section, a concept called Product Service System (PSS) has been adopted. However, what is PSS, and why can PSS be adopted to satisfy customers' needs in modern economy? In this section, firstly, the concept of PSS will

be illustrated according to the review of different definitions in previous years. Then the benefits of PSS will be collected according to the review work in order to explicate the advantages of PSS over traditional manufacturing models. Additionally, this section also will introduce the basic elements of PSS to help readers to obtain a general understanding of PSS, followed by a short brief summary of PSS barriers. This section is structured as presented in Figure 3.



Figure 3 structure of PSS fundamental knowledge introduction

2.1 Defining PSS

One of the most cited and earliest definition of PSS was presented by Goedkoop et al. in 1999, who indicated the two basic components “product” and “service”, as well as the target of PSS that is to satisfy customers’ needs. Later, with the involution of this concept, more and more concerns were integrated in it. Sustainability is a main concern in along this involution. This thesis summarizes the extant PSS definitions as well as those notions which are similar with PSS, in order to achieve a general understanding of what they are. The articles from Baines et al. (2007), Beuren et al. (2013), Tukker (2015), Annarelli et al. (2016), and Kristensen & Remmen (2019) are the main sources of this definition summary. Along the evolution of PSS concept, the form of offerings, which is the combination of products and services and the two basic targets of satisfying customers’ needs and leaving less impact for environment have been considered; what’s more, the supporting networks as well as infrastructures provided by the networks are also very important. Particularly, in recent years, the PSS emphasizes the importance of customers. Customers should play an active role in a PSS solution rather than being a passive receiver as before. Therefore, customer involvement or value co-creation is referred. Hence, these definitions will be analyzed according to the following aspects (modified from Kristensen & Remmen, 2019): Offering (O), Customer needs (CN), Sustainability (S), Networks and Infrastructures (NI), Value co-creation (VCC). What’s worth mentioning here, sustainability indeed consist of three aspects; respectively are economical aspect, social aspect and ecological aspect, rather than only the meaning of environment friendly. Table 1 displays the review extant PSS definitions and other similar concepts.

Table 1 Extant PSS definitions and other similar concepts

References [↗]	Definition [↗]	Aspects in definitions [↗]				
		O [↗]	CN [↗]	S [↗]	NI [↗]	VCC [↗]
Product·Service·Systems[↗]						
1. Goedkoop et al., 1999 [↗]	A marketable set of product and services capable of jointly fulfilling a user's need. The PS-system is provided either by a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. Product and service can be equally important for the function fulfilment [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Manzini et al., 2001 [↗]	A business innovation strategy offering a marketable mix of products and services jointly capable of fulfilling clients' needs and/or wants - with higher added value and a smaller environmental impact as compared to an existing system or product. [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Mont, 2002 [↗]	PSS should be defined as a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models. [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
4. Manzini and Vezzoli, 2003 [↗]	An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Brandstötter et al., 2003 [↗]	A PSS consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally PSS tries to reach the goals of sustainable development [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Tukker, 2004 [↗]	A system consisting of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Wong, 2004 [↗]	Product Service-Systems (PSS) may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality. [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Halme et al., 2006 [↗]	Products and services which can simultaneously fulfil people's needs and considerably reduce the use of materials and energy [↗]	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Krucken, Meroni, 2006 [↗]	An advanced industrialized solution based on collaboration between social players, which gives rise to both effective and efficient, highly contextualized services [↗]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
10. Morelli, 2006 [↗]	PSS is a social construction, based on "attraction forces" (such as goals, expected results and problem-solving criteria) which catalyze the participation of several partners. APSS is the result of a value co-production process within such a partnership. Its effectiveness is based on a shared vision of possible and desirable scenarios [↗]	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

11. Baines et al., 2007	A PSS can be thought of as a market proposition that extends the traditional functionality of a product by incorporating additional services. Here the emphasis is on the 'sale of use' rather than the 'sale of product'.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> →	↔
12. Evans et al., 2007	An attempt to use existing industrial and commercial structures to create radically environmentally improved products by treating them as services.	<input checked="" type="checkbox"/> → <input checked="" type="checkbox"/> -	↔
13. Neely, 2008	A Product-Service System is an integrated product and service offering that delivers value in use.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> →	↔
14. Azarenko et al., 2009	Technical Product-Service System emphasizes the physical product core enhanced and customized by a mainly nonphysical service shell. The investment character of all PSS components, the relatively bigger importance of the physical core of PSS and the relation between PSS manufacturers and customers.	<input checked="" type="checkbox"/> -	↔
15. Zhu et al., 2011	PSS is defined as a solution for optimal resource operations in product life cycle through integrating tangible products with intangible services.	<input checked="" type="checkbox"/> -	↔
16. Geng and Chu, 2012	Products and services are integrated and provided as whole set to fulfill customer's requirements, and the product/service ratio can vary in different customer using contexts.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> →	↔
17. Boehm and Thomas, 2013	A Product-Service System (PSS) is an integrated bundle of products and service which aims at creating customer utility and generating value.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> →	↔
18. Centenera and Hasan, 2014	A product-service system (PSS) is an integrated combination of products and services for optimal consumption.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> → <input checked="" type="checkbox"/> →	↔
19. McKay, Kundu, 2014	A PSS is a system composed of a physical product and associated services that support the product through-life.	<input checked="" type="checkbox"/> -	↔
20. Reim et al., 2015	PSS are defined as a marketable set of products and services that are capable of jointly fulfilling customers' needs in an economical and sustainable manner.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> → <input checked="" type="checkbox"/> -	↔
21. Vezzoli et al., 2015	An offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> → <input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> →	↔
22. Annarelli et al., 2016	PSS is a business model focused toward the provision of a marketable set of products and services, designed to be economically, socially and environmentally sustainable, with the final aim of fulfilling customer's needs.	<input checked="" type="checkbox"/> - <input checked="" type="checkbox"/> → <input checked="" type="checkbox"/> -	↔

Industrial PSS	
23. Jiang and Fu, 2009	Industrial PSS can be defined as a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life-cycle
24. Meier et al., 2010	An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive sociotechnical system
Eco-efficient service systems	
25. James et al., 2001	An eco-efficient service is one which reduces the environmental impact of customer activities per unit of output. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient).
26. Brezet et al., 2001	Eco-efficient services are systems of products and services which are developed to cause a minimum environmental impact with a maximum added value

Take a panoramic view of this table, majority of the definitions agree with the list of components of a PSS: i.e. the final offering is a combination of products and services (23 of 26 definitions); regarding the first final target that is to satisfy customers' needs, 18 definitions out 26 agree with that. Besides, 10 definitions emphasize the importance of sustainability and advocate that PSS is developed to reduce environmental impacts. Obviously, the Networks & Infrastructures (5/26) are ignored by most definitions.

Based on the previous definitions, researchers propose design frameworks that mainly focus on the offering design. Sometimes supporting processes design is also included; this will be seen in the following literature review about design frameworks. However, majority of them ignore the importance of supporting networks and supporting infrastructures. Supporting infrastructures can be seen as resources provided by networks, such as agents for communications with customers, workplaces for design and development, plants for production, transportation systems, renting interfaces, information and communication technology platforms and so on. Based on these infrastructures, stakeholders in the system will collaborate with each other according to a series of processes. However, how do these stakeholders collaborate in the PSS context in order to satisfy customers' needs of more economical, more flexible and more sustainable PSS offerings? This is a main gap that needs to be bridged in my thesis since the reviewed frameworks haven't proposed a solution focusing on supporting networks design. The last significant point in the table is that existing definitions attach little importance to customers' involvement (3/26). Customers' satisfaction indeed not only is limited in the perceived offerings, but also is affected by the interactions with service providers along the whole PSS lifecycle. Just like Vezzoli et al. (2015), a modern PSS definition should contain all these aspects- Offering (O), Customer needs (CN), Sustainability (S), Networks and

Infrastructures (NI), Value co-creation (VCC).

Recommended PSS definition (Vezzoli et al., 2015): *an offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a 'unit of satisfaction'), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the economic and competitive interest of the providers continuously seeks environmentally and socio-ethically beneficial new solutions.*

2.2 Benefits of PSS

Benefits of PSS are the direct reasons for researchers and practitioners to keep concentrating on PSS in last two decades. In this section, several articles have been reviewed. According to the review, the general benefits of PSS are listed and illustrated from following aspects: benefits for customers, benefits for providers, benefits for governments and society and benefits for the environment.

For customers

- Receive greater diversity of choices in market, including variety of products, services, payment schemes, lifestyle, flexibility etc. (Mont, 2002; McAloone & Andreasen, 2002; Baines et al., 2007; Beuren et al. 2013);
- Obtain customized offerings with higher quality (Mont, 2002; Baines et al., 2007; Beuren et al. 2013);
- Release from the responsibility of owing a product (Mont, 2002);
- Learn about more features about environmental features and contribute more to minimizing environmental impacts (Mont, 2002).
- Product data collected during use in order to improve the products in different life stages (Beuren et al. 2013).

For companies

- To attach additional value to a product, for example, financial schemes or refurbishing or upgrading (Mont, 2002);
- To base a growth strategy on innovation in a mature industry (Mont, 2002; Baines et al., 2007);
- New markets, great market share and a redefinition of core-activities can be achieved (McAloone & Andreasen, 2002);
- To improve relationships with consumers because of increased closer contact and flow of information about consumers' preferences (Mont, 2002; McAloone & Andreasen, 2002);
- To improve the total value for the customer because of increased servicing and service components, which include activities and schemes that make the existing product last longer, extend its function (upgrading and

refurbishment), and make the product and its materials useful after finishing its life cycle (recycling and reuse of parts or entire product) (Mont, 2002; Baines et al., 2007);

- Achieve higher loyalty and trust customers (Beuren et al. 2013);
- Innovation potential from the monitoring of product and services while using them (Beuren et al. 2013);
- To anticipate the implications of future take-back legislation, and might have the potential to turn them into a competitive advantage (Mont, 2002).
- Extend and diversify the service (Mont, 2002);
- Safeguard market share by bringing the service component into the offer that is not so easy to copy (Mont, 2002);
- Facilitate communicating product–service information, because it is easier to convey information about more tangible products than about intangible services (Mont, 2002);
- Safeguard a certain level of quality that is difficult to change (product quality) (Mont, 2002).

For government and society

- PSSs have the potential to offer a new way of understanding and influencing stakeholder relationships and viewing product networks, which may facilitate development of more efficient policies (Mont, 2002);
- PSS can affect an increase in the sustainable dimensions due to increased product efficiency and a closer relationship between societal needs and the products that industry supplies customers (McAloone & Andreasen, 2002);
- Public pressure on environmental issues grows (Baines et al., 2007; Beuren et al. 2013)
- The promotion of new offerings use may assist in the creation of new jobs (Mont, 2002; Baines et al., 2007; Beuren et al. 2013);

For environment

- A PSS has the potential to decrease the total amount of products by introducing alternative scenarios of product use (Mont, 2002; Beuren et al. 2013);
- Producers may become more responsible for their product-services in case material cycles are closed (Mont, 2002);
- Producers are encourage taking back their products, upgrade and refurbish them and use them again; in this way, less waste is incinerated or landfilled (Mont, 2002; Baines et al., 2007; Beuren et al. 2013);
- Due to customers only pay for services or functions of offerings, PSS approach may change the technical development of dematerialization (Mont, 2002).

According to this summary, it can be concluded that basically PSS are able to satisfy customers' needs of more economical, more flexible, more sustainable services

proposed in the background introduction. In addition, PSS also takes other stakeholders into consideration. Providers as well as their partners and suppliers, government and society, and the environment are also concerned. PSS is dedicated to find out a solution to address win-win solution for both customers and providers, and even multi-win among different stakeholders in the network.

2.3 Three basic construction components of PSS

As introduced in PSS definitions, the basic components of PSS conclude product, service, supporting networks and infrastructures.

2.3.1 Product

In terms of the meaning of “Product”, there are two main explanations. For the first one, from the perspective of traditional manufacturing engineering, and then extending to PSS field, the product is “a tangible commodity manufactured to be sold. It is capable of falling onto your toes and of fulling a user’s need” (Baines et al., 2007). In this context, a physical product can be anything from a pen to an aircraft, which is artefact that can be touched, stored and owned by specific individuals or groups (Roy, 2000). For the second one, a product is an output that results from a process. Products can be tangible or intangible, a thing or an idea, hardware or software, information or knowledge, a process or procedure, a service or function, or concept or creation (ISO 9001:2000). For the rest, we consider that a product is an output that results from a process, is tangible and visible, i.e. a product in here is a physical item. What is necessary to be mentioned is that the role of product has been changing in a PSS. Just like the role of manufacturer is shifted towards provision of services, despite carrying on main values in the past several decades, the product now is shifted towards the distribution mechanism of service provision (Mont, 2002; Alter, 2012).

2.3.2 Service

According to Vargo and Lusch (2004), early marketing thought was built on a foundation of goods marketing, essentially the distribution and monetized exchange of manufactured output. Then during the past 40 to 50 years, service marketing emerged and the initial period of service thought (approximately 1950-1980) was a period of debate over the definition of services and the delineation of services from goods. At the beginning, majority of service’s definitions are derived from different characteristics comparing with product, and then in the following years, more and more researchers worked on this field, which boost the evolution of service and service engineering. Accordingly new concepts were introduced to explain service, such as service is kind of activity, output of processes, and even value co-created by both providers and clients. Table 2 shows the definitions of service. In Baines et al.’s review (2007), they not only gave the definition of product, but also gave a definition of service, indicating the aim of a service. Unfortunately they haven’t depicted what a service looks like. In here we will introduce the four characteristics of services when comparing with “product” (Wolak et al., 1998; Vargo and Lusch, 2004): (1) Intangibility-services lack the tactile

quality of goods; we are able to see the tangible results of services, but we cannot touch or feel it as a material object. (2) Heterogeneity-unlike goods, services cannot be standardized; indeed, some services can be relatively standardized, since we often utilize service process module to construct the final PSS offering. (3) Inseparability-unlike goods, services are simultaneously produced and consumed. Under this logic, a process can be a service process only when customers are involving in it. (4) Perishability-services cannot be produced ahead of time and inventoried. Alter (2012) indicated that researchers should use a broadly applicable definition of service and he also declared that a good definition of service should have following four characteristics: It would emphasize the essence of service and would conform to everyday understandings of what service is; it would differentiate products and services in typical real world situations; it would not introduce unnecessary restrictions on what service is; it would cover every type of activity that most people consider services.

Table 2 Service definitions

Service definitions	Resources
Intangible activities customized to the individual request of know clients	Pine and Gimore, 1999
A time-perishable, intangible experience performed for a customer acting in the role of a co-producer.	Fitzsimmons, 2006
The application of specialized competences (knowledge and skills) through deeds, processes and performances for the benefit another entity or the entity itself	Vargo and Lusch, 2004
An act or performance that one party can offer to another that is essentially intangible and does not result in the ownership of anything.	Kotler and Keller, 2006
The customer provides significant inputs into the production processes.	Sampson and Froehle, 2006
An activity (work) done for others with an economic value and often done on a commercial basis.	T S Baines et al., 2007
A provider-client interaction that creates and capture value	IBM Research, 2009
Value-creating support to another party's practices.	Gronroos, 2011
Services are acts performed for other entities, including the provision of resources that other entities will use.	Alter, 2012

2.3.3 Supporting networks and infrastructures

To be a component in a PSS, supporting networks play the core role in proposing a PSS solution. Supporting networks provide all the critical knowledge, capacities, and resources including capital resources, human resources etc. However, according to the articles referred in PSS field in my thesis, few articles really address the notion of supporting networks. Only those effective and efficient networks are able to respond customers rapidly with more flexible, reliable and sustainable offerings.

In order to address supporting networks modelling in PSS, this thesis introduces another concept called "Collaborative Networked Organization" into PSS field. A *collaborative network (CN)* is a network consisting of a variety of entities (e.g. organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals, but that collaborate to better achieve common or compatible goals, and whose

interactions are supported by computer network (Camarinha-Matos, Afsarmanesh, 2005).

The concept of Collaborative Networks is proposed to help those dynamic enterprises cope with the challenge of markets turbulence and continuously changing customer needs, resembling the emergence of PSS since 2005. Camarinha-Matos and Afsarmanesh claimed that “Collaborative Networks show a high potential, not only in terms of the survival capability, but also for value creation through new capabilities to cope with innovation needs, uncertainty, mass customization, and fierce competition (Camarinha-Matos, Afsarmanesh, 2006).” Besides, to be a member of CNOs, company is able to better perform other notions, for instance, the extended product, social responsibility, sustainability, etc. Thus, companies in the CNOs are expected to achieve the following capabilities (Camarinha-Matos, Afsarmanesh, 2007):

- (An apparent) larger dimension.
- Access to new/wider markets and new knowledge.
- Sharing of risks and resources.
- Collaborative environment for innovation, through the combination of synergies, competencies, culture, and experiences.
- Smooth integration of customers in the product development and innovation process.
- Joining of complementary skills and capacities which allow each entity to focus on its core competencies while keeping a high level of agility.
- Etc.

Although not all, most forms of collaborative networks imply some kind of their constituents, identifying roles for the participants, and some governance rules. Therefore, these can be called manifestations of **Collaborative Networked Organizations (CNOs)**. Other more spontaneous forms of collaboration in networks can also be identified as in case of **ad-hoc collaboration processes** that can take place in virtual communities, namely those that are not business oriented (Camarinha-Matos, Afsarmanesh, 2005).

This thesis highlights one of the often used manifestations of CNOs (Camarinha-Matos, Afsarmanesh, 2007), called Virtual Enterprise (VE), *represents a temporary alliance of enterprises that come together to share skills or core competencies ad resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks.* In our opinion, There will be a trend that Virtual Enterprise will be a prevailing organization when provide a PSS solution. Several articles have advocated the importance of VE in during PSS development and management. Product Service System and Virtual Enterprise can be seen as two perspectives of coping with continuously changing market and customers’ requirements for researchers and companies. Ming & Lu (2003) indicated the VE has started to form and apply in many business activities, such as the application to Small and Medium Size Enterprises (SMEs), the collaborative e-Market place and the fortune 1000 multi-divisional applications. They also indicated the value chain in

modern society should be composed of virtually integrated enterprises across the whole vertical and horizontal manufacturing industries by using internet technology to form a completely networked organization to leverage the core competencies of each member enterprise. They also proposed a business model called collaborative product services in virtual enterprise which is based on the framework and application of web service and process management. Pawar et al. (2009) proposed Product-Service-Organisation triangle (PSO triangle), aiming at finding out the link between emerging PSS literature and research on Virtual Enterprise and also other types of organizational networks. More recently, Peruzzini et al. (2013) indicated that interrelations between products and non-physical services are complex to model and they require managing new relationships between different stakeholders and by creating a Virtual Manufacturing Enterprise. Marilungo et al. (2015) also advocated the importance of VE in PSS design, which is used for modelling and managing complex interrelations between physical products and intangible services; besides, they proposed an integrated method to support PSS design within the virtual enterprise based on Quality Functional Deployment (QFD) method and Houses of Quality (HoQ) method. Also there is a typical example for developing services in virtual enterprise environment called Manufacturing Service Ecosystem (MSEE) from 2011 to 2015, Chen (2015) proposed a methodology to develop product related services in context of virtual manufacturing environment which relates and federates a set of models, methods and tools through a structured approach. Guan et al. (2017) indicated VE lifecycle also need to be integrated into PSS lifecycle phases, and they proposed two basic integrated PSS-VE lifecycle models.

Indeed, due to the characteristic of services' perishability and heterogeneity, supported networks also should be flexible and efficient. Virtual enterprise in this context takes more advantages over supply chain due to its temporary, flexible and effective characteristic. However, in modern market environment, it seems not enough to share resources and knowledge only among a few enterprises (**kernel network**), which means more stakeholders should involve in a new virtual enterprise in order to help a VE achieve better performances. These stakeholders may be **customers** and **other supporter organizations**, such as, a virtual team (Camarinha-Matos, Afsarmanesh, 2007), research centers, universities and so on. Thus, this thesis enriches the definition of a virtual enterprise. Hence, a **Virtual Enterprise** in here could be refined as *"a temporary alliance of kernel enterprise network, customers and supporter organizations (SO) that come together to share knowledge and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks."*

Supporting infrastructures are provided by supporting networks, which are utilized to support the development and implementation of PSS. Supporting infrastructures may include: (1) production plants- those places fulfill the production, assembly of products; (2) service agents- those places may provide variety of services, such as consultancies, communication with customers, maintenance and repair services etc.; (3) fundamental facilities- those things construct together to support service processes, such as the facilities in transfer station in a bicycle service system; and (4)

Information and Communication Technology Infrastructure (ICT-I)- the basic element in modern system-is able to provide a platform for a system to support variety of services, such as human collaboration services, knowledge sharing services, business processes interconnection services and system interoperability services (Rabelo et al., 2006).

The basic components of PSS contain products, services, and supporting networks& infrastructures; especially, Virtual Enterprise (VE) is the recommended manifestation of collaborative networks in the thesis.

2.3.4 Barriers of PSS adoption

Although PSS has been recognized as a useful and innovative strategy or business model for companies to promote their competitive advantage and customers to increase the value in use, it is still hard for them to adopt PSS solutions due to some barriers. Vezzoli et al. (2015) clarified three main aspects of barriers for adopting PSS; respectively barriers for providers, barriers for customers and context-related barriers. Based on this classification, this section reviewed several articles and summarized some barriers.

Barriers for providers

- Successful PSS solution depends on being sensitive to culture in which it will operate (Mont, 2002; Baines et al., 2007, Martinez et al., 2010; Vezzoli et al., 2015);
- Companies lack the experience of how to price such kind of offering to gain profits (Baines et al., 2007);
- Companies lack the experience on how to manage risks from adopting PSS as well as the involvement of customers Baines et al., 2007);
- Companies lack the experience of how to construct a network for the design, development, production, and delivery of a PSS (Baines et al., 2007);
- Companies need new competencies, skills and experiences in relation to both management and design activities (Vezzoli et al., 2015);
- Changing of systems and sources of gaining profits require companies establish medium- to long-term investments compared to short-term profits generated at the point-of-sale. This is more serious for small and medium enterprises (Mont, 2002; Vezzoli et al., 2015);
- The resistance of companies to extend involvement with a product beyond point-of-sale and historical practice has been identified as a major barrier to increase manufacturer responsibility for environmental impacts of products (Mont, 2002)
- Adding environmental consideration to PSS development is often seen as

lengthening the time to market, particularly this ideology is in mind during whole PSS life cycle (Mont, 2002);

➤ A further obstacle is the difficulty of quantifying the savings arising in economic and environmental terms, in order to market the innovations to stakeholders both inside and outside the company, or to the company's strategic partners (Vezzoli et al., 2015);

➤ Trade-offs between co-operation and internal environmental management in a network affect the efficiency of PSS solution (Mont, 2002);

➤ Development and delivery of PSS need strong collaboration in the value chain, which will lead to another barrier because of fear of sharing sensitive information about company's processes, products and technologies (Mont, 2002; Vezzoli et al., 2015);

➤ Another obstacle is that partnerships and entrepreneurial interdependence may result in reduced control of core competencies and reduced influence on business decisions (Vezzoli et al., 2015);

➤ In relation to the value chain, another barrier is represented by the potential conflict of interests between companies that aim to reduce sales volumes of material products and traditional interests of retailers that aim to increase sales (Vezzoli et al., 2015);

Barriers for customers

➤ Consciousness shift from owning a product and using it to involving in service processes and utilizing the functions of offerings, i.e. a main barrier for customers is also the cultural shift necessary to value an ownerless way of having a satisfaction fulfilled, as opposed to owning the product (Mont, 2002; Vezzoli et al., 2015);

➤ Lacking knowledge of PSS will lead to unclear risks, costs and responsibilities, so that will lead to misapprehend the benefits of adopting PSS (Vezzoli et al., 2015);

➤ PSS offering may be more expensive than purchasing products due to its sustainability concerns;

➤ Another barrier to the diffusion of ownerless-based solutions is the fact that the quantity and quality of accumulated goods is perceived as a measure of success in life, because it is an indicator of a certain position in society (Vezzoli et al., 2015);

➤ Customers' demands and purchasing behavior appears to be potentially more complicated than expected. Hesitation towards offers based on ownerless access and sharing can also be linked to the perception of independence, hygiene and intimacy usually connected to one's own products (Mont, 2002; Vezzoli et al., 2015).

Context-related barriers

➤ Since environmental and social costs connected to products are not included in their market prices, it can become difficult for PSS solutions to

complete with industrially produced products (Vezzoli et al., 2015);

- Governments should intervene by implementing policy measures capable of simulating the diffusion of PSSs (Vezzoli et al., 2015);
- A lack of external infrastructure and technologies, such as product collection, remanufacturing or recycling, may be also a context-related barrier (Mont, 2002; Vezzoli et al., 2015).

Among these barriers, we can find several main problems with PSS design. In terms of providers, companies need new competencies, skills and experiences in relation to both management and design activities; additionally, companies are always reluctant to add sustainability constraints into PSS design along whole lifecycle of PSS, due to its higher cost and longer response time when take sustainability into consideration; what's more, how to make the collaborate among stakeholders more effectively and efficiently is also a key barrier along the system creation and operation. Customers are more concerned with the possible higher price when purchasing services due to adding sustainability concerns; further on, the more important thing for customers is the experience they get from interactions with providers and other stakeholders along PSS lifecycle. In terms of context barriers, the key gap is lacking of well-performed technologies and infrastructures.

Until now, all the basic knowledge about PSS has been introduced, including its benefits, definitions, components, and barriers. Based on the introduction, we are able to obtain a general understanding of PSS. However, as mentioned above, PSS adoption indeed faces with many barriers. Particularly from design perspective, lacking of knowledge, skills and experiences are critical for companies, as well as sustainability problem, collaboration problem with other stakeholders, etc. Hence, during last two decades, a large number of researchers have spared no efforts on them and proposed plenty of frameworks, methodologies, tools and techniques. In the following section, some of them will be introduced.

3 PSS frameworks and design methodologies

We are aiming at proposing customer-oriented PSS solutions in a collaborative networked environment. To achieve this target, the literature review for existing frameworks as well as variety of design and management methodologies is necessary. On the one hand, we should investigate whether there is some extant framework able to tackle this problem; on the other hand, it is significant and necessary to obtain enough knowledge to construct my own contributions from extant articles. The following Figure 4 displays all the necessary perspectives of review articles, which conform to the design framework proposed in my thesis. Hence, according to this structure, section 1 will firstly make a literature review for existing frameworks of PSS; to support these frameworks, different methodologies, techniques and tools may be utilized. Thus, section 2, section 3 and section 4 will introduce some methodologies, techniques and tools respectively.

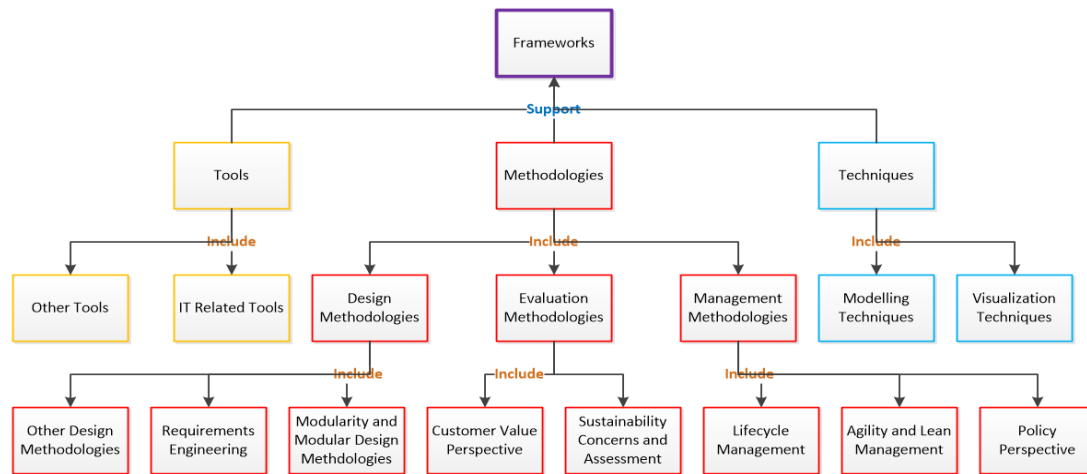


Figure 4 structure of frameworks and methodologies review

3.1 Literature review for frameworks

Research started with the following keywords “PSS design framework” and “Service engineering framework” proposed in the last decade from articles resources of “Google Scholar”, “Research Gate” and “Science Direct”. Besides, snowball research is also a main means during research. Snowball research means several articles coming from the references of selected articles. During this literature review, we are aiming at obtaining more knowledge; hence no filter is utilized in this phase in order to have a huge number of articles. According to the intensive reading, these articles are mainly categorized into five perspectives according to their main contents and the problems dealing with; respectively are lean and agility integration in PSS (4), PSS design related frameworks (4), customer-oriented PSS design frameworks (7), simulation and assessment related frameworks (4), Management related frameworks (3). To sum up, there are 22 articles included into the review work, as exhibited in Table 3.

Table 3 Some frameworks about PSS design and management

Perspectives	Resources	Framework	Aim
Lean and Agility integration	Minguez et al., 2012	A reference architecture for agile PSS	Support coordination and definition of goals in heterogeneous supply chains
	Resta et al., 2015	Conceptual research framework for the lean product-oriented PSS	Supplement the knowledge when combining lean thinking with PSS
	Azevedo & Sholihab, 2015	A proposed costing system framework for IPS ² function-oriented companies	Provide companies with comprehensive cost information through lean accounting
	Asmar et al., 2018	A framework for agile development of innovative PSS	Provide a guide for designers and companies to agile develop PSS
PSS design frameworks	Alter, 2008	Work system framework; Service value chain framework;	Identify basic elements in a service system; Outline service related activities and

Customer-oriented PSS design frameworks		Work system lifecycle model	responsibilities of customers and providers; Help handling the changes when system evolving
	Kimita et al., 2015	An organizational framework for PSS development	Clarify the roles in PSS development
	Andriankaja et al., 2016	A framework to design integrated PSS based on Extended FA approach	Aim at answering the gaps of decoupled design of services and the lack of operational solutions
	Trevisan, 2017	A system-based conceptual framework for PSS engineering	Bridge the gap in existing approaches and logics used in product-service integration in PSS
	Wu, 2010	A proposed service engineering process framework	Help explore true requirements of customers and set up effective process with support of IT
	Hussain et al., 2012	A framework to inform PSS conceptual design	Help conception of PSS at the conceptual design stage
	Vasanthan et al., 2013	A capability-based PSS design framework	Align customized PSS solutions to integrated stakeholders' capabilities
	Zine et al., 2014	The framework for customization and personalization through value co-creation	Help providers create value from the standpoint of customers
	Schmidt et al., 2015	A customer-oriented framework for PSS	Target on increasing customer acceptance
	Tran & Park, 2015	A strategic prototyping framework	Support customer's perception of value
Simulation and Assessment related frameworks	Song & Sakao, 2016	A customization-oriented framework for design of sustainable PSS	Supplement knowledge for PSS customization
	Abramovici et al., 2014	PSS sustainability assessment and monitoring framework	Help facilitate sustainability assessment of PSS solutions with multiple modules
	Rondini et al., 2014	Service Engineering Methodology	Support engineering of a new PSS by balancing the value perceived by customer and provider
	Pezzotta et al., 2015	A Service Engineering Framework based on Service Explorer	Integrate discrete event simulation test-bench into PSS design modelling
Management related frameworks	Kremer et al., 2016	A focus-activity framework	Help companies identify their current status
	Baxter et al., 2009	A knowledge management framework to support PSS	Capture, represent and reuse knowledge to support PSS development
	Bertoni, 2010	A classification framework for bottom-up knowledge sharing	Help designers communicate in a cross-functional environment
	Song et al., 2014	PSS innovation management framework	Provide useful guidance for PSS innovation

For lean and agility integration perspective, there are four articles included in the thesis. Minguez et al. (2012) proposed reference architecture for PSS, in which “goal definition & conflict resolution”, “PSS network performance” and “PSS network configuration” three aspects are clarified. This proposed architecture can help PSS

networks rapidly reconfigure and adapt when integrating new services; besides, the combination of semantic approach with service analysis methodology will permit PSS networks to tract KPIs across heterogeneous supply chains. Resta et al. (2015) proposed a framework for lean product-oriented product service systems, aiming at supplement the lacking knowledge when integrating lean thinking into PSS. This framework is able to (1) describe the existing PSS operations strategy; (2) identify its strengths and weakness, and (3) support the application of lean approaches and methods to improve PSS operations. Azevedo and Sholihab (2015) developed a costing system framework for IPSS function-oriented companies based on literature review. They integrated lean accounting into the costing system since lean accounting with its value stream costing (VSC) is able to provide comprehensive cost information to support company's long transformation journey towards a fully and successful IPS² company. Asmar et al. (2018) proposed a framework for agile development of innovative PSS, and establish it on an existing physical rehabilitation system. This framework consists of four phases: planning phase with several methods on ideation, building phase aiming at implementing the system, measuring phase aiming at testing the system with the help of customers, and learning phase which is used for evolving the system with the knowledge from measuring.

For PSS design frameworks, there are four articles founded tackling different problems. Alter (2008) presented three interrelated frameworks as the first cut at the fundamentals of service systems, respectively are work system framework that is able to identify basic elements in a service system, service value chain framework aiming at outlining service related activities and responsibilities of customers and providers and work system lifecycle model targeting on handling the changes when system evolving. The author indicated these frameworks are potentially useful in visualizing realities of moving toward automated service architectures. Kimita et al. (2015) proposed an organizational framework for PSS development which aims at decreasing the difficulties regard to constructing an organization for PSS development. This framework also clarifies several challenges when constructing an organization and recommends several methods to deal with these challenges. Andriankaja et al. (2016) proposed a framework to design integrated PSS based on Extended Functional Analysis approach. The proposed framework intends to smoothly integrate the whole PSS design process, including product-service design and the network configuration, in order to bridge the two main gaps of PSS design: the decoupled design of product and services and the lack of operational solutions. Trevisan (2017) A system-based conceptual framework for PSS engineering in order to bridge the gap in existing approaches and logics used in product-service integration in PSS.

For specified customer-oriented PSS design frameworks, this review summarizes seven frameworks with higher relevancy since these frameworks focus more on customers' value. Wu & Wu (2010) proposed a service engineering process framework. This framework is designed to help researchers and practitioners use available SSME (Service Science, Management and Engineering) tools and theories, at the same time help explore true requirements of customers and set up effective process with support of IT. Hussain et al. (2012) proposed a framework according to

interviews and case studies with industry to inform PSS conceptual design. The framework uses system-in-use (rather than just product-in-use) data from in-service records and receives needs regarding the use of large, capital-intensive, technical assets to generate solutions. Vasantha et al. (2013) developed a capability-based PSS design framework which is able to align customized PSS solutions to integrated stakeholders' capabilities. This framework emphasizes the importance of preferences and views of the stakeholders and the opposite alignment of responsibility; also, this framework could facilitate the interactions between the customer, the manufacturer and the supplier. Zine et al. (2014) developed a framework for customization and personalization through value co-creation. The framework consists of a business model, an engagement model which leads to value creation through customization and a detailed service execution plan which offers opportunities for value co-creation through co-design, co-production and co-delivery, leading to personalization. Schmidt et al. (2015) proposed a three-layer customer-oriented framework for PSS with the final target on decreasing the customers' barriers and increasing customer acceptance. This framework consists of three layers and strategy block: (1) customer layer describes the customer segmentations and targets groups of customers; (2) barrier layer describes all customer barriers to be reduced in PSS solution; (3) solution layer describes PSS elements constructing PSS solutions; (4) strategy block represents all the external factors generated by the company strategies. Tran & Park (2015) proposed a strategic prototyping framework including a design loop with six steps- demonstration, participation, refinement/analysis, visualization, evaluation and modification. The proposed framework can support customers' value perception, evaluation and improvement of PSS design. Song & Sakao (2016) developed a customization-oriented framework for design of sustainable PSS. The review work firstly supplements knowledge for PSS customization. The proposed framework is dedicated to deal with customization related challenges, such as hidden requirements in product use phase, potential conflicts of design attributes and internal complexity of service processes.

For simulation and assessment perspective, there are three articles. Abramovici et al. (2014) proposed PSS sustainability assessment and monitoring framework with multiple modules throughout their entire lifecycle. The proposed framework is developed to support decision making with complex situation by considering the most important aspects of sustainability. Rondini et al. (2014) investigated Service Engineering Methodology (SEEM) and integrated Discrete Event Simulations (DES) in SEEM for the purpose of assessing the performance of a new or revised offering. The new framework can support engineering of a new PSS by balancing the value perceived by customers and providers. Pezzotta et al. (2015) developed a Service Engineering Framework based on Service Explorer, which integrates discrete event simulation test-bench into PSS design modelling. This new framework enables the comparison of several PSS configurations considering both customer satisfaction measures and internal performance. Kremer et al. (2016) concentrated on a new aspect of PSS. They advocate it is necessary for companies to recognize the readiness of servitization path. Hence, a focus-activity framework is developed aiming at

helping companies identify their current status of product-service cooperation before to design integration activities.

The last perspective faces to management, which also includes three articles. Baxter et al. (2009) proposed a knowledge management framework to support PSS design scenario. The aim is to capture, represent and reuse knowledge to support PSS development in a collaborative enterprise context. Three kinds of knowledge are necessary to be dealt with; respectively are design knowledge, manufacturing capability knowledge, and service knowledge. Bertoni (2010) developed a classification framework for bottom-up knowledge sharing. The work proposed a visual approach to communicate how technologies may be beneficial for engineering working in the design of product-service combinations. This framework thereby can help designers communicate in a cross-functional environment or in a virtual enterprise environment. Song et al. (2014) proposed an integrative PSS innovation management framework which can help companies deal with variety of challenges of PSS operation and innovation, such as heterogeneity of stakeholders, interaction of product and service elements and complex performance measurement. This framework exhibits necessary elements of PSS innovation from three levels, which can provide detail and useful guidance for companies' PSS innovation.

To date, five perspectives of frameworks have been introduced. As mentioned before, the aim of current customer-oriented PSS is to provide more economical, more flexible and more sustainable offerings to customers in short lead time. However, comparing with design barriers, the reviewed frameworks are hard to cover all the concerns, including how to choose both design and management methodologies, how to integrated sustainability concern into design, how to make the supporting networks operate more effectively and efficiently, etc. This section only makes a summary for these frameworks; the detail analysis will be addressed in Chapter 3. From next section, we will go on reviewing the methodologies utilized in the frameworks as well as other relevant methodologies not in the reviewed frameworks.

3.2 Literature review for methodologies

Table 4 lists some methodologies for PSS that can be categorized in: design methodologies, evaluation methodologies and management methodologies. In each category, subcategory can be proposed that include:

- For design methodologies: requirement engineering, modularity & modular design related methodologies, and other design methodologies;
- For evaluation methodologies: customer value evaluation and sustainability assessment and;
- For management methodologies: PSS lifecycles, agile management methodologies and policy management methodologies.

Articles were collected along four years' literature review, as well as recent review works such as Tukker (2015) and Qu et al. (2016), etc.

Table 4 List of some methodologies for PSS

Perspectives	Methods	References	Brief Descriptions
Design Requirement engineering	Customer activity cycle analysis	Vandermerwe, 2000; Song et al., 2014	To extract customers' and stakeholders' requirements according to their activities during pre-use phase, use phase and post-use phase
	QFD, HoQ and AHP	Haber et al., 2018	To translate requirements into specifications
	Service Requirement Tree	Rondini et al., 2014	To define relationships between customer needs and provider's resources
	Rough Analytic Hierarchy Process	Song et al., 2013	To prioritize the fuzzy, subjective and uncertain PSS requirements
	Functional Hierarchical Tree	Andriankaja et al., 2016	To decompose and link requirements with product and service components functions
Other design methodologies	MEPSS	Goedkoop et al. in 2002	To develop and evaluate PSS according to a five-phase mind map
	Sustainable Product Service Development	Maxwell & Vorst, 2003	To provide most suitable function as well as the optimized way of providing the function during offering design
	Functional product development	Isaksson et al., 2008	To highlight customers' importance and design product according to customers' needs rather than traditional technology-based development
	Functional analysis	Alix & Vallespir, 2010	To define new sequences and activities for new product-service development from a project view
	design for various types of PSS	Tran & Park, 2013	To support clarify the distinctions between different types of PSS for designers and practitioners
	SEEM	Pezzotta et al. in 2014	To take both customers and companies' concerns into offering development and implementation
Modularity	PSS Modular development processes	Wang et al. 2011	To respond to the industrial trends of PSS and guide companies to develop PSS with modular development framework
	Ontology-based modular modelling and configuration method	Dong, & Su, 2011	To satisfy product configuration of PSS under mass customization and realize quick accurate product configuration
	An interactive modular design process	Li et al., 2012	To effectively improve the reusability of a product or service as well as reducing internal diversification
	Modular product architecture	Shikata et al., 2014	To advocate the importance of adoption of modularity to extend services and add value to products
Evaluation Customer value	A method for analyzing and optimizing customer	Du et al., 2006	To analyze and optimize customer satisfaction in product customization by analyzing product quality and introducing product quality into customer-perceived

		satisfaction		value
		Satisfaction-at-tribute approach	Kimita et al., 2009	To address customer satisfaction measurement based on the non-linear value function called the satisfaction-attribute function.
		Service Level Agreement	Minguez et al., 2012	To help customers and providers agree on a contract
		Satisfaction-capability function based evaluation method	Shimitsu et al., 2013	To support designers measure customer satisfaction according to satisfaction-capability function
		An integrated Balanced Scorecard and MCDM approach	Pan & Nguyen, 2015	To help manufacturing firms identify the key performance criteria for achieving customer satisfaction
Sustainability		Sustainability Assessment=LCA+LCC+SLCA	Peruzzini et al., 2013; Doualle et al., 2015	To address the PSS sustainability assessment in a lifecycle oriented view. Sustainability contains economical aspect, ecological aspect and social aspect. Hence sustainability assessment could be regarded as the sum of Life Cycle Assessment, Life Cycle Costing and Social Life Cycle Assessment
Management	Lifecycle modelling	Product-service lifecycle cross model	Goedkoop et al., 1999	To reveal product lifecycle and service lifecycle can interact in offering usage phase
		An integrated PSS lifecycle model	C. Hepperlet et al., 2010	To guide the designers along PSS lifecycle by simultaneously consider product-service lifecycles
		Two reference PSS lifecycle models in VE context	Guan et al., 2017	To bridge the gap of lacking network impacts in traditional product-service lifecycle models, and propose PSS lifecycle model as a real system
Agility management			Stare, 2014	To demonstrate the applicability of agile project management in the context of product development
		Agile reference NSD model	Lamberth-Cocca & Meiren, 2017	To make the initial steps towards an agile reference model for new service development
Policy management			Mont & Lindhqvist, 2003	To solid the foundation of policy research in PSS design field and indicate policy' importance in environmental innovations
			Ceschin & Vezzoli, 2010	To discuss the role of policy in PSS diffusion and provides a set of general measures to help address environmental benefits
			Durugho, 2013	To discuss the importance of relationship and policies in the implementation of PSS

Design methodologies

Requirements engineering always come first before PSS design and development processes. Requirements engineering always consists of two steps:

requirements collection from customers and stakeholders and requirements interpretation to design specifications. Customer activity cycle analysis was proposed by Vandermerwe (2000) as a customer-oriented solution for requirements extraction. This method can help managers assess opportunities for providing new kinds of value to customers at each critical experience- pre, during and post. This method was later further developed by Song et al. (2014), which also can be used for extracting companies' requirements, which is called industrial customer activity cycle analysis. Quality Function Deployment (QFD), House of Quality (HoQ) and Analytic Hierarchy Process (AHP) are often integrated as a whole methodology in recent years, which aiming at translate requirements into design specifications. Haber et al. (2018) summarized existing articles about requirements interpretation based on these three methods and proposed the Fuzzy Analytic Hierarchy Process (FAHP) augmentation to a service-oriented QFD as a means of addressing the intangibility and subjectivity of services. Song et al. (2016) also further developed AHP and proposed a Rough AHP method which can prioritize the fuzzy, subjective and uncertain PSS requirements. There is also another category of requirement engineering methods. For instance, service requirement tree, which can be found in the framework provided by Rondini et al. (2014), was developed to define relationships between the customers' needs and the providers' resources. The service requirement tree mainly deploys four levels, which starts from customers' **Needs**. Customers' needs usually define their **Wishes** (what the customer wants to satisfy its needs) and **Design Requirements** (how the company can satisfy customer wishes). In the last level, **Design Specifications** represent what a process is intended to do to deliver a certain requirement, and provide explicit information regarding the macro activities and resources that have to be used. There is also another similar method called Functional Hierarchical Tree (Andriankaja et al., 2016). Three levels have been developed in this method: **customer demands** level displays all the requirements from customers; **functions** level exhibits how the functions could be decomposed corresponding to the requirements; and **structure** level will indicate which components will be used and how the components can be used to satisfy these functions. In this way, products' different components can be linked with customers' requirements.

After introducing several typical requirement engineering methods, this thesis also lists several well-known **service design methodologies** chronologically. The first one is called Methodology development and Evaluation of PSS (MEPSS). MEPSS (Van Halen et al., 2005) was developed for industries to successfully implement new PSSs that will be in line with their business goals, offer optimal customer satisfaction and will minimize negative environmental and social impacts. MEPSS mind map is structured into five phases: **strategic analysis, exploring opportunities, PSS idea development, PSS development and preparing for implementation**. Between, different phases, there is also a node representing decision gate aiming at deciding whether to go further, to stop, to hold or to go back to decision nodes. Maxwell and Vorst (2003) proposed a PSS design methodology, particularly targeting on sustainability, called Sustainable product and/or service development (SPSD). SPSSD is about assessing the lifecycle of a function to be provided (from conception to end of life)

and determining the optimum sustainable (environmental, social and economic) way of providing that function (through a product, service or PSS) in line with traditional product and/or service criteria. The SPSPD mainly consists of four steps: **question the functionality** at concept stage, **determine the lifecycle stages**, **determine the supply chain dynamics and optimize sustainability impacts**. Isaksson et al. (2008) proposed the functional product development method, in which customer plays a more important role than traditional product development. The customer has a need, which will be expressed into requirements. Then designers will be able to develop PSS according to the requirements. Distinguishing from traditional product development, the functional product development will be realized by maybe hardware only for instance of machines, software only, services only or maybe an offering that combined products and services. Finally these kinds of outputs will be provided and delivered to customer. Alix and Vallespir (2009) also advocated the importance of function and customer value. They defined new sequences and activities for new product-service development from a project view. They assumed that the Product-Service development can be split as any project of product design in following for steps: starting sequence focusing on requirement analysis and firm positioning, definition sequence focusing on requirements specification and value proposition, realization sequence focusing on definition of processes from PS design to delivery, and closing sequence focusing on service delivery and capitalization of project. Besides, support activities mainly consist of delay, cost, risk, communication, knowledge and organization. Tran and Park (2013) proposed an integrated design methodology for all the three product-oriented PSS, use-oriented PSS and result-oriented PSS, aiming at providing the designers and practitioners a generic guideline when designing a PSS. The design process includes seven phases: **PSS idea development, PSS planning, requirement analysis, design and integration, testing and refinement, implementation and retirement & recycling**. Between different phases, gates are set up in order to guarantee each step is valid. Service Engineering Methodology (SEEM) was proposed in Pezzotta et al. (2014); whose methodology is developed to support companies take both customers and companies perspectives into consideration when proposing their offerings. What's more, there are also four main steps: i) **customer needs analysis**, ii) **process prototyping which consists of requirement and specifications design and process design**, iii) **process validation which can be decomposed into model validation and model-based what-if analysis**, and iv) **offering identification and analysis**.

Modularity, as a key method for companies to achieve mass customization, is an efficient way of reducing operation cost and improving efficiency of PSS. Modularity is an efficient way of reducing operation cost and improving efficiency of PSS. Wang et al. (2011) clarified six dimensions of modular product-service, including **product dimension, service dimension, process dimension, production dimension, interface dimension, and collaboration dimension**. They also proposed a modular development framework, which consists of three parts: **functional, product, and service modularizations**. Functional part discusses how to decompose functions of product-service into functional modules. Product modularization and

service modularization deal with how to interpret the functional modules into physical or service modules. Each three steps in horizontal are related, and the middle “functional modularization” is the virtual basis of both service and product sides. To satisfy the product configuration requirements of PSS under mass customization and realize quick accurate product configuration, Dong and Su (2011) developed an ontology-based modular modelling and configuration method. They utilized reachable matrix to modularize service elements to support configuration process; they also adopted Ontology Web Language (OWL) to formalize the structural knowledge inheriting from meta-ontology and Semantic Web Rule Language (SWRL) and Java Expert System Shell (JESS) to formalize the constraints of total product configuration and customer requirements. Li et al. (2012) proposed an interactive module design process according to the analysis of the relationship between a product/service of an integrated service product (ISP) and the analysis of product module and service module. They focused on the module partition principle of integrated service product (ISP), putting forward a three-stages module partition processes and methods, mainly including **service module partition** process based on the “Top-Down” and “Bottom-Up” methods, **physical module partition** process based on the “Top-Down”, and **module partition methods** based on Quality Function Deployment and mapping matrix. Shikata et al. (2014) conducted an analysis of product architecture and examined two specific cases, thereby proving PSS can result in company competitive advantage.

We conclude with the suggestion that companies should improve PSS performance by adopting modular product architecture, a strategy that can extend and diversify services and add value to products.

Evaluation methodologies

Customer, as the vital stakeholder in modern PSS, is acknowledged to paid more attention than before. Du et al. (2006) described a method to analyze and optimize customer satisfaction in product customization via an explicit requirement analysis of functional attributes and importance, experimenting with design alternatives, assessment of perceived utility of alternatives and an assessment of customization costs. Kimita et al. (2009) developed a non-linear value function called “satisfaction-attribute function”, and integrated it into an evaluation procedure based on IDEF0. The procedure consists of four steps: **define receiver, describe value features, determine satisfaction-attribute function and decide target quality**. This method enables designers to evaluate design candidates in the conceptual stage where little information is available, and therefore supports iterative improvements without design needing to hesitate under the weight of market analysis. Minguez et al., 2012 introduced service level agreement in the service oriented architecture. In a service-based interaction between two entities, the service provider states what he is capable of supporting, as well as the requirements for its potential requestors. This specification is called service policy. In order for requestors and providers to agree on a contract that stipulates the policy between both parties, a service level agreement (SLA) is needed. Shimomura et al. (2013) indicated human interactions in PSS are

critical factors for improving customer satisfaction. Providers, therefore, have to organize appropriate human resources from the viewpoint of customer requirements. Authors defined a concept of satisfaction-capability function to predict customer satisfaction, and then developed a five-procedure method to address the determination of human resource allocation. Pan and Nguyen (2015) proposed an integrated method based on Balanced Scoreboard (BSC) and Multiple Criteria Decision Making (DCDM) approaches, in order to help manufacturing companies to identify the key performance evaluation criteria for achieving customer satisfaction. The method was tested in 24 manufacturing firms. The results revealed that companies should focus more on customers' satisfaction, loyalty by value-added offerings and long term partnership.

Previously, **sustainability assessment** usually only tackled one aspect of sustainability. However, the methodologies evolution in recent years can bring researchers an entire view of sustainability assessment. This section chose several articles which achieve sustainability assessment from all the three aspects: Life Cycle Assessment, Life Cycle Costing and Social Life Cycle Assessment. Peruzzini et al. (2013) developed a methodology for integrated sustainability assessment including four steps: **lifecycle modelling based on Life Cycle Design (LCD), use scenario definition, lifecycle analysis and global sustainability assessment**. Further on, they utilized the methodology to evaluate a washing machine case, which demonstrated the reliability of this method. The authors also proposed a concrete application of sustainability assessment method to support decision-making during design or optimization phases within the extended enterprises. Doualle et al. (2015) supplemented the knowledge of sustainability assessment in particular field of PSS. They also analyzed the existing methods and tools for assessment, and tried found out the similarities and differences between them. The final aim is to identify the issues underpinning the development of methods for sustainable design in the particular case of PSS.

Management methodologies

In terms of **PSS lifecycle models**, this part only provides three typical models. Guan et al. (2017) had achieved a literature review for some existing lifecycle models. Goedkoop et al. (1999) indicated that product and service should have their own lifecycles. For product lifecycle, there are nine stages; respectively are **specification, sales, production, distribution, set-up, usage, maintenance, update, and the end-of-life management**; and in terms of service lifecycle, there are five stages including **design, tools production, test, usage and redesign**. There is a point of intersection between them called "usage" phase. This is first generation of product-service lifecycle. In recent years, researchers believe that product lifecycle and service lifecycle should consider as whole until decomposing very detailed processes. Hepperle et al. (2010) declared that "it is essential to anticipate the whole lifecycle of future PSS in order to allow fast responses to influences from the environment and moreover to adapt the portfolio of offered products and services as well as corresponding company processes to latest conditions with regards to content and time." They proposed an integrated lifecycle model of PSS, in which product and

service are considered as a whole during PSS planning phase, and then separately designed and developed but tightly communicated between each other during PSS development phase, and finally produced or implemented separately and then delivered as a whole offering and finally decomposed after several times of evolution during PSS production, delivery, and decomposition phase.

This section will introduce two articles which are dedicated to integrating **agility** into product/service development. Despite of the growing popularity of agile project management in the field of IT projects, it has not yet been established in other types of projects (engineering, research & development, organization of events) (Stare, 2014). Under this background, stare analyzed the product development in five manufacturing companies, and tried to analyzing the actual contribution of individual agile techniques to project's success. Agile approach may take the potential advantages over traditional methods in four groups: requirements/ specifications, project schedule, role of team and team work, and client collaboration. The final aim of the work is to demonstrate the applicability of agile project management in the context of development. Lamberth-Cocca and Meiren (2017) developed a real case about E-mobility service system. They indicated complexity is a key challenge during new service system creation. Since existing new service development (NDS) models are not sufficient to handle this problem, they proposed an agile NSD reference model which consists of three layers: engineering model, project management model and information model. This new model is an innovative first step to enhance more traditional models.

In terms of **policy management**, Mont and Lindhqvist (2003) were aware of importance of policy in early years of PSS evolution. They indicated that policies that establish the framework conditions for environmental improvement are preferable to detailed legislation as they favor environmentally superior PSS. However, there is also a need for more specifically targeted policy measures that stimulate knowledge creation and dissemination in the PSS area. This article suggests that informative policy measures should be used by authorities. Ceschin and Vezzoli (2010) also indicated that government can play a potential role to stimulate the introduction and diffusion of PSS innovations. And they argued governments have three ways of addressing the target: (1) create the economical conditions to encourage companies in shifting their business towards a PSS approach; (2) support dissemination of knowledge about PSS to companies and (3) raise customer awareness. Thus, they identified a set of general policy measure and even PSS-oriented policy measure in order to be capable of achieving environmentally beneficial target. What's more, they also suggested universities and research centers should integrate in sustainable PSS lifecycle. Durugbo (2013) adopted "work system theory" into PSS in order to investigate what and how information and service systems contribute to sustainability, technical and marketability themes for competitiveness when using PSS, in which they revealed an emphasis on relationship building and policy implementation for achieving PSS marketability and sustainability

When proposing a PSS solution, requirements engineering always comes first, this section advocates the **customer activity cycle analysis** method which was

developed by Vandemerwe (2000) and further developed by Song et al. (2014) since this method is able to extract detailed requirements from the viewpoint of stakeholders in the network. Then these requirements will be interpreted into design specifications by those commonly used methods such as QFD, HoQ and AHP etc. **Functional Hierarchical Tree** is also recommended in this thesis since it's able to link the requirements with product and service components. Product and service components can be combined to form a new product module or service process module. Hence, the "tree" is very important when decomposing the functions and connecting the functions with product and service modules. This is also the key thought of modularity, which is the base of **modular development** methodology. As mentioned in this section, modularity as well as modular product architecture is a key strategy to companies to enhance productivity and differentiate their product service offerings. What's more, during PSS design, **customer value** is the key target to be addressed; methodologies proposed by Du et al. (2006) and Pan & Nguyen (2015) provide the knowledge in enhance companies' performance or offering quality in order to enhance customers' satisfaction; while Kimita et al. (2009) and Shimitsu et al. (2013) tried to find solutions to assess customers' satisfaction from viewpoint of PSS, however, there are too many constraints when adopting them. At the same time, PSS design also need to concern sustainability, **sustainability assessment** (SA) now has reach a consensus that SA contains Life Cycle Assessment (LCA) for ecological aspect, Life Cycle Costing (LCC) for economical aspect and Social Life Cycle Assessment (SLCA) for social aspect. Hence, this lead to another problem that it is significant to understand the PSS lifecycle. Guan et al. (2017) has made a literature review of extant PSS lifecycles and proposed two new lifecycles in the context of Virtual Enterprise. As mentioned above, PSS offerings should be designed in a short lead time. In order to conform to this requirement, the thesis takes **agility management** into consideration, so that network stakeholders can collaborate in a more flexible and effective way. Policy management can be seen as external environment which can push the environmental and social requirements into system. The methodology Table in this section can be regarded as a repository, so that some of them will be selected in Chapter 3 in order to support the PSS design and framework formulation.

3.3 Literature review for Tools

This section will briefly introduce several tools for PSS design; these tools are divided into two categories: ICT related and others, as shown in Table 5.

Table 5 Some tools in PSS design

Perspectives	Name	References	Brief Descriptions
ICT Tools	Prot ég é	Baxter et al., 2009	To support PSS modelling and testing
	Service CAD	Komoto, 2009 Pezzotta et al., 2015	To design business models that increase eco-efficiency from a systematic perspective

	Service Explorer	Sakao and Shimomura, 2007; Pezzotta et al., 2015	To focus on service engineering and design product with a higher added-value from enhanced services
	MRPII & ERP	Lightfoot et al., 2011	To support better performance by utilization of remote monitoring equipment
	Integrated Service CAD and Lifecycle simulator (ISCL)	Hussain et al., 2012	To help designers model and simulate PSS design
	A selection method based on G/DES and HLA	Alix & Zacharewicz, 2012	To support decision-making between different service scenarios
	Discrete Event Simulation	Rondini et al., 2014; Pezzotta et al., 2015	To support optimize the service provision processes
Other tools	Interviews	Baxter et al., 2009	Interview is useful throughout whole PSS lifecycle for variety of information collection
	questionnaires	Tran & Park, 2015; Wu & Wu, 2010	Questionnaire is useful throughout whole PSS lifecycle for variety of information collection
	TRIZ	Altshuller et al., 1999)	To guide designers to solve design conflicts

Baxter et al. (2009) introduced Protégé as a useful tool to support PSS modelling and testing. Protégé is a free, open source ontology editor developed by the Stanford Center for Biomedical Informatics Research. It is used as a knowledge-based framework for knowledge solutions in various communities, including biomedicine, intelligence gathering, and corporate modelling. Partial service (test) process represented in the Protégé system. Service CAD and Service Explorer are developed based on the Service CAD methodology. Komoto (2009) indicated service CAD is to design business models that increase eco-efficiency from a systematic perspective. Sakao and Shimomura, (2007) and Pezzotta et al. (2015) selected “Service Explorer” – a software design tool conceived to engineer and to improve the quality of services – to focus on service engineering and design product with a higher added-value from enhanced services. In particular, Service Explorer supports the designer in the definition of PSSs with a customer-oriented perspective, and provides a ranking of the relevance of the various functions and attributes of a PSS based on a Quality Function Deployment (QFD) analysis. Lightfoot et al. (2011) utilized MRPII and ERP to be ICT infrastructure and remote sensor equipment to monitoring system performance in order to provide better maintenance and repair services. To help PSS designers' model and simulate PSS designs, a framework has been implemented in a software environment. Service CAD integrated with a life cycle simulator (ISCL) (Hussain et al., 2012) has been chosen because it provides both modelling and simulation facilities. Alix & Zacharewicz (2012) presented a new perspective of service modelling and distributed simulation environment based on generalized discrete event specification and high level architecture to support design validation. The simulation has shown that behavior of the client/supplier relation in the comparison of traditional

sales versus PSS market. Moreover, different innovative PSS scenarios can be simulated and tested regarding specific criteria, allowing decision makers to choose optimal strategy for PSS development. Discrete Event Simulation (DES) (Rondini et al., 2014; Pezzotta et al., 2015) also can contribute to the design of the service provision process and the evaluation of different systems created under different what-if scenarios. In particular, the adoption of DES as a tool for service engineering can offer great potential as a mean for describing, analyzing, and optimizing the service provision process of many types. Both Interviews and Questionnaires are often used tools for information collection.

In terms of non-ICT tools, Baxter et al. (2009) utilized interviews with design experts to identify the design details and processes. Wu and Wu, (2010) and Tran & Park (2015) referred that questionnaire can be used for market research, requirements collection of different stakeholders, updating requirements during PSS development, user satisfaction evaluation etc. The last tool set introduced in this section is TRIZ, when applying to service design field, the relevance of TRIZ will manifest from two aspects. The first is to eliminate the contradictions between two design parameters which make it possible to generate a win-win solution. Another overlap between TRIZ and services is the research on patterns of innovation, which make it possible to predict the service innovation. Different types of services could be achieved by 40 inventive principles proposed by TRIZ.

In this section, several ICT tools have been introduced; however, my thesis research scope hasn't included simulation. Other tools such as questionnaires, interviews and TRIZ are the common used tools during PSS design since we can use them to collect information from different stakeholders or help us make some decisions.

3.4 Literature review for Techniques

This section will introduce the common and often used techniques in PSS field. There are also two main categories: modelling techniques and visualization techniques, as shown in Table 6.

Table 6 Some techniques in PSS design

Perspectives	Name	References	Brief Descriptions
Modelling techniques	IDEF 0, scenarios and use cases	Morelli, 2006	Graphical representation of the logical, time-related and physical connections between the various functions of a PSS
	Business model canvas	Osterwalder & Pigneur, 2010, Kim et al, 2015, Ilg et al., 2018	To support depict PSS concepts
	Integrated PSS design modelling framework	Trevisan & Brissaud, 2016	To propose a PSS “multi-views” modelling framework for supporting integrated PSS design.
Visualization	Service Blueprinting	Boughnim and	To model all the products and services related

techniques		Yannou,2005; Morelli, 2006; Geum and Park, 2011; Hussain et al., 2012; Rondini et al., 2014; Song et al., 2014	processes, actions and interactions inside and outside the company
	Map of interactions	Morelli, 2006	To support the visualization of direct and indirect relationships and the dependence between the stakeholders of PSS with the first type of interaction map; to supports the visualization of how stakeholders of PSS participate in value creation with the other type.
	Ontology-based model	Kim et al., 2009	Supports the ontological visualization of the causal relationship and hierarchy of values, products, services, and stakeholders of PSS. Highlights how PSS elements realize values.
	PSS board	Lim et al, 2012	Chronological representation of the PSS on a board of five rows and nine columns.
	Functional Block Diagram (FBD)	Trevisan, 2017	Supports the visualization of physical objects (e.g., product components), service units (e.g., service divisions of company) of PSS, and outer environment. Divides blocks among the objects and units to show certain functional work of the service units. Highlights how products are used to provide specific services

A helpful tool that may support a systemic approach to the design of PSS is IDEF0 (Integration definition for function modelling) (Morelli, 2006). This tool, mostly used by system engineers, may help covering areas of the design process characterized by a complex systemic structure. IDEF0 is a modelling technique that allows for progressive detailing of the functions and actions in the system, while keeping the link between each element in the system. The system is modelled as a series of boxes, representing a function of the system. Scenarios and use cases are also often used. The use of such techniques in design discipline would help eliciting requirements for the PSS, but also would provide a broad picture of the PSS configuration which can be eventually defined with other systemic techniques. Scenario provides textual or visual description of future situations or processes during the PSS performance. Use case Description of the chronological PSS performance process of a particular customer or a particular customer group in a flow chart. Business model canvas is also a popular model to depict PSS concepts. Osterwalder & Pigneur (2010), Kim et al. (2015) and Ilg et al. (2018) have utilized this model. Business model canvas illustrates the PSS business concept with key partners, key activities, key resources, value propositions, customer relationships, channels, customer segments, cost structures and revenue streams. By coupling models currently used by product and service engineers, Trevisan & Brissaud (2016)

proposed a framework which provides a communication support for actors during PSS design. The “multi-views” modelling framework allow them to detail the design of the PSS components until the most technical phases while it also should ensure integration of these components through a shared perspective on the system modelling. The multi-views conclude result modelling (product view, service view, and integrated view), structure modelling (product view service view), and structural organization modelling (product view service view).

Second category of techniques focuses on visualization techniques. One of the most popular and recognized technique is service blueprinting. Boughnim and Yannou (2005) defined Service Blueprint as “a picture or map that accurately portrays the service system so that the different people involved in its development can understand and deal with it objectively regardless of their roles or their individual point of view.” The service blueprint technique in first generation mainly consists of five levels and three lines. Five levels include physical evidence level, customer actions level, onstage contract level, backstage contract level and support process level; and three lines are line of interaction between customer actions and onstage contract, line of visibility between onstage and backstage, and line of internal interaction between backstage and support processes. This technique was advocated and further developed by many other researchers (Morelli, 2006; Hussain et al., 2012; Rondini et al., 2014; Song et al., 2014) for to deal with different problems. Particularly, Geum and Park (2011) developed the design structure of product-service blueprint, in which the design area is divided into three: product area containing use area and management area, service area containing front office area and back office area, and support area containing production area and design area. What’s more, the lines are also changed, now there is a line of integration between product area and service area, a line of use in product area between use area and management area, a line of visibility in service area between front office and back office and a line of design between production area and design area. Song et al. (2014) proposed a product-extension service modularization approach based on modified service blueprint and fuzzy graph. Morelli (2006) summarized several visualization techniques; one of them is the map of interactions in a PSS which is used for identifying the actors’ network and the interactions between them. The author declares that “industrial products and services are not only a technical entity, but also the result of a socio-technical process”, which means that i.) The technological knowledge should be embedded into the artefacts used for service; and ii.) The social, technological and cultural frames of the actors should participate in or influence the development of the system. Other visualization techniques include (1) ontology-based model proposed by Kim et al. (2009), which aims to support the ontological visualization of the causal relationship and hierarchy of values, products, services and stakeholders; (2) PSS board developed by Lim et al.(2012), which is a matrix board where the customer activities, state of the products, services, dedicated infrastructures, and partners are placed in rows, and the general PSS process steps are placed in columns; the visualized PSS on the board shows how the PSS provider and its partners aid customers’ job execution process; and (3) functional block diagram (FBD) which can be found in Trevisan (2017). The

Functional Block Diagram (FBD) decomposes the external functional flows and represents the subsystem interactions. The functional flows represent interactions that confer ‘aptitudes’ on the related systems to enable further interactions. The FBD supports design negotiations between different layers of decomposition: the expected actions and the structure elements identified are questioned regarding the organization of the resulting interactions within the system.

Techniques make it easier for designers to describe and visualize different design processes and design scenarios.

Design frameworks listed here will be further analyzed later; while three tables of methodologies, tools, and techniques can be regarded as repositories, which can prepare for later framework proposal.

4 Conclusion and thesis objectives

In Chapter 1, we fulfilled two tasks about PSS. The first one is to make a literature review PSS basic knowledge, which can help readers achieve a general understanding of this notion. The second task is to make a literature review for extant PSS design and management frameworks, PSS design and evaluation methodologies, PSS design tools and techniques, from which we have learned a lot of knowledge which may be adopted and utilized for our own design framework in the following Chapters.

However, the experience of PSS in the past years indicates a big drawback of existing provider-driven PSS or technology-driven PSS. Since a large number of PSS solutions are proposed by companies based on their own innovation requirements, whereas they haven’t proposed solutions based on customers’ requirements, which violated the functional economy due to huge waste of useless and overlapping functions of offering components. Thus, the thesis highlights the importance of customer-orientation. Therefore, in Chapter 2, an innovative PSS type called customer-oriented PSS will be explicated in-depth.

Hence, the objective of the thesis is to propose an integrated design framework for customer-oriented PSS, which is able to provide customers with more economical, more flexible and more sustainable offerings in a short lead time.

Chapter2. Customer-Oriented Product-Service System (COPSS) and its Typology: A Review

1 Introduction

According to the illustration in Chapter 1, we have known that customers' requirements are transforming from traditional high-quality products to more economical, flexible and sustainable services in modern service economy. We have achieved the basic understanding of Product Service System (PSS), including its definition, benefits, construction components, and barriers. Based on key identified barriers, we decided to focus on PSS design field where there is a lack to remove the abovementioned barriers. Accordingly the first Chapter ended by a literature review about PSS design frameworks, methodologies, tools and techniques has been fulfilled. However, what is to notice is that PSS offerings are most of the time provider driven. Products or services providers hope to obtain benefits from their technologies or new business models, thus they integrate them into PSSs and push the PSS solutions to their customers. As traditional customers mainly play a role of receivers with fewer interactions with their providers, they also have less consciousness of function economy. In this way, huge wastes have been generated along PSS lifecycle. Hence, at the end of Chapter 1, we declared that the objective of this thesis is to propose an integrated framework for Customer-Oriented PSS, which is able to provide customers with more economical, more flexible and more sustainable offerings in a short lead time. Thus, now we encounter a new problem that what is Customer-Oriented PSS on earth? Why does the thesis advocate Customer-Oriented PSS (COPSS)?

In this Chapter, the concept of COPSS will be developed in-depth; the aim is to achieve a comprehensive understanding of customer-orientation in PSS field. Thus the concept of COPSS will be explicated firstly in five steps: after introducing the motivation of COPSS and the research methodology of systematic review of COPSS, the core contents of COPSS will illustrate what the customer orientation is, the reasons for advocating customer orientation and finally the most important knowledge is the key issues of COPSS and COPSS design. After explanation of COPSS, the new typology of COPSS will be naturally introduced since existing typologies always focus on PSS. COPSS typology is significant because it is dedicated to help categorize those PSS with customer orientation, and is able to help designers to generate a guide for what they can do to propose COPSS solutions.

2 Customer-Oriented Product Service System (COPSS)

2.1 Motivation of COPSS

Recent years, our economy has generated many product service systems and service systems of different size and complexity, answering different needs and also covering different usages. For instance, Goedkoop et al. (1999) provides almost 150 examples of variety of PSSs in their report covering all walks of life, from car sharing to mobile phone industry, even agriculture industry. At the same time, Mont (2002) introduces PSS concept

into practical use with 35 applications. This thesis selects several representative applications from these literatures detailed in Table 7. The criteria for choosing them was: (1) cases try to cover more industries; (2) cases must be put into real usage or at least be a pilot; (3) each example tries to achieve sustainability; (4) both product and service components are interesting to stakeholders.

Table 7 Some examples of PSS applications

Application	Resources	Objective	Approaches	Customer Concerned
An urban telecentre	Morelli, 2003,	Utilize a telecentre case to offer designers a new perspective towards PSS based on intense use of ICT	A model of project evolution Use case Blueprinting	No
Micro-factory retailing in automobile industry	Williams, 2006,	Introduce Micro-factory retailing at functional and system level in the automobile industry	MEPSS Methodology proposed by Mont	No
Coffee Yungas	in Devisscher and O. Mont, 2008,	Find new evidence for PSS solution in developing country	Mont's framework for analysis of PSS Interaction mapping	No
Smart Grid as a Service	Lopes and Pineda, 2013,	Update Smart Grid to be flexible, uniform and technology neutral interoperability framework	Service System Design Process	No
Car sharing	Liu et al, 2014,	Help investigate customer's decision making	Prospect Theory on a use-oriented PSS	Yes
Survey in automotive industry	Mahut et al, 2015,	Adopt PSS to achieve the shift from traditional product centered patterns into result-oriented PSS	Functional Product Development (FPD) Service Engineering Methodology (SEEM) Methodology for PSS (MEPSS)	Yes
PSS in electric car industry	Cherubini et al, 2015,	Aim at introducing a PSS-oriented business model to support customized production by hospitals	Methodology for CSFs Cognitive map Relevance/manageability matrix	No
The case of a cancer care facility	Stacey and Tether, 2015,	Investigate and understand how designers can create positive "emotional chain reactions for users"	User agency simulation Emotion-based blueprinting	No
Bicycle sharing system	Barquet et al, 2016,	Support companies to create models for selling functionality instead of product property	Scenarios planning Configurator of PSS proposals	Yes
A case study from the agriculture sector	Ziout & Azab, 2015,	Identify PSS metrics for agriculture industry	House of quality tool PESTEL metrics	No
A case study from power and automation technologies	Rondini et al, 2015,	Aim at understanding the industrial applicability of Service Engineering Methodology	Service Engineering Methodology (SEEM) Scenario planning	Yes

As shown in the Table 7, most PSS solutions are pushed by providers on the marketplace, based on their own capabilities. Unfortunately, they usually ignore the real usages and values for beneficiaries. From this beginning, their PSS solutions are always addressed through the combination of service components and product components rather than the combination of service functions and product functions. As is acknowledged, each component can perform one or more functions. If providers just combine these kinds of components and ignore the critical functions coming from customers' requirements, the designed PSS will probably include many useless functions or overlapped functions. Thus, this kind of design will lead to huge waste along the whole PSS lifecycle. Researchers and companies haven't paid enough attention on this problem since sustainability was not a topic of huge interest. Take this Table as a sample; few cases refer to real customer requirements and the sustainability problem. Mahut et al. adopts Service Engineering Methodology (SEEM) as vital means to analyze critical customers' requirements and offerings' functions (2015), as well as Rodini and his team (2015). Also Barquet et al. (2016) develops "Configurator of product-service system proposals" to support companies to create business models for selling functionality instead of product property.

Based on literature review, few works have been done from engineering perspective on deeply excavating what the customer-oriented PSS and customer oriented PSS design are. Thus, the first target of this Chapter is to address a comprehensive understanding of COPSS and COPSS design. Moreover, the typology of COPSS will be naturally introduced, as it plays an important role in guiding designers and companies to propose COPSS solutions.

Traditional provider-driven PSS solutions always ignore real usages of customers, which lead to huge waste along PSS lifecycle. Hence PSS should shift from traditional provider-driven PSS to customer-oriented PSS (COPSS).

2.2 Research methodology of state of the art of COPSS and Problem proposition

In the previous section, the main reason of advocating COPSS has been illustrated. However, this is not enough to achieve a comprehensive understanding of COPSS. Hence, it is necessary to launch a systematic literature review for COPSS related knowledge.

This section addresses the systematic literature review (SLR) for extant "customer-oriented PSS related" articles. Figure 5 displays the research steps. First, the articles were collected according to initial key words of "customer/ user/ consumer-oriented/centric" + "PSS/ Product-Service Systems/ Service Systems/ New product design/ New service design". New product design is also included mainly because product has a broader meaning recently and is also adopted by researchers. Additionally, since customer-oriented PSS is often based on function-oriented design, the key words "function-oriented/use-oriented" were also included in the forward part. According to these

key words, 116 articles were collected from “Science Direct”, “Research Gate” and “Google Scholar”. In the second step, to increase the persuasion of the review, the articles that are cited less than two times are screened (except those articles in recent two years), so that the number of rest articles is 105. In the third and fourth step, I read the abstracts as well as the articles extensively. I found there is a confusing concept of “use-oriented PSS”, which sometimes this title is one of the three typical PSS categories proposed by Tukker (2004). Thus the number decreases to 100. Then there are another 13 articles which have none relevant information with COPSS related concepts except title. Thus, 87 articles were selected after three filters. After intensive reading, another 7 useful articles were found using this research method. To sum up, the final number of articles is 94.

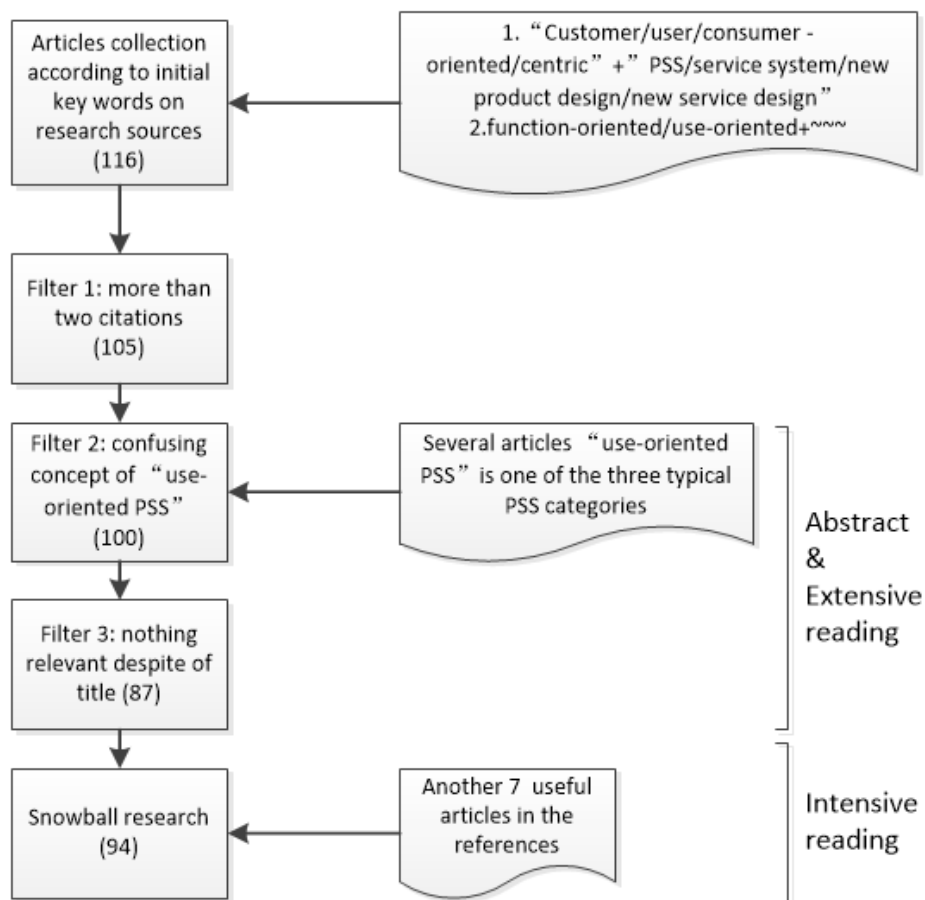


Figure 5 Research methodology of the state of the art of COPSS

Further on, according to the contents of each article, this review also makes two classifications for these articles. As shown in following Figure 6, the left one displays three main research fields about COPSS; respectively are marketing and business development (17, 18%), ICT related design (17, 18%) and PSS/ SS Engineering (60, 64%). What is worth mentioning that much relevant information could be obtained from marketing and business development field, many researchers in this field have proposed relevant articles about user-oriented theory, user centrality theory etc. (Agrawal & Rahman, 2015; Shah et al., 2006; Weryzer & Mozota, 2005; Alam 2002; Durugbo and Pawar, 2014; Heinoen et al., 2010). While, less information could be found from ICT related design field. In terms of PSS and Service System engineering field, another classification is addressed to the right

hand. These 60 articles are classified into five groups; respectively are concepts (2, 3%), design methodologies as well as tools and techniques, etc. (28, 47%), evaluation related (2, 3%), management related (6, 10%), and cases (22, 33%). Obviously, there are only 2 articles that are categorized into concepts. According to the analysis, we could conclude that there is an obvious lack of COPSS fundamental knowledge.

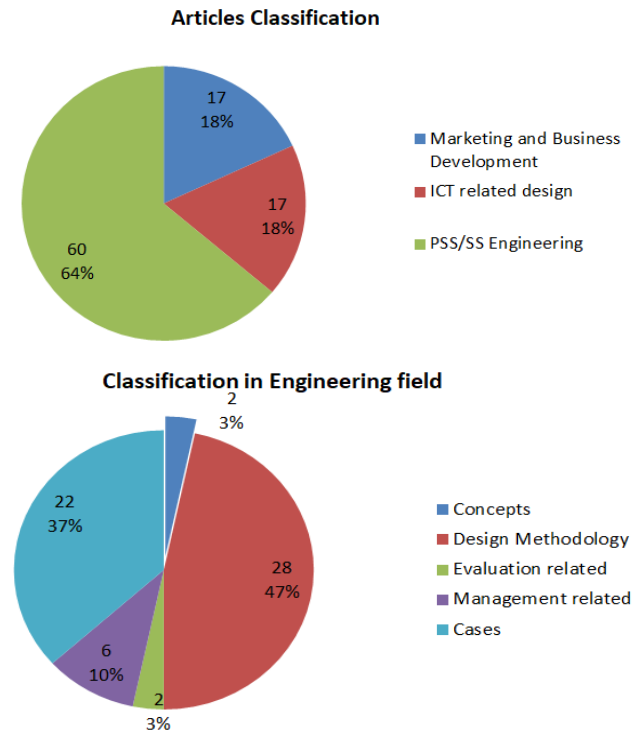


Figure 6 two classifications for collected articles

Hence, the target of this section is to supplement the lacking knowledge. In order to fulfill a comprehensive understanding about COPSS and COPSS design. The following sub-sections will be illustrated according to the structure, shown in Figure 7. In the following sub-sections, the first target is to introduce the notion of “customer orientation” into PSS field; hence the concept of customer-orientation will be illustrated firstly. Then, the benefits of customer orientation will be introduced briefly. In the third step, the concept of customer orientation will be integrated into PSS, so that the key issues for COPSS will be explicated.

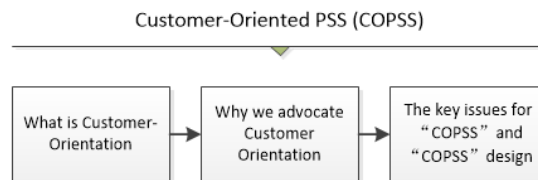


Figure 7 Structure of COPSS research

2.3 Customer-Orientation (CO) and Customer-Oriented Design (COD)

It's necessary to clarify the customer and user share the same meaning in this thesis. Customers could be companies in a business to business model or could be end users in a business to customer model, just like the users' definition: "firms, individual consumers or groups of consumers that expect to benefit from the set of a product or service" (von Hippel, 2005;Tolkamp et al., 2018). The ideology of emphasizing customers in the market or in a system could retrospect to 1950s. Drucker (1954) advocated that "it is the customer who determines what a business is, what it produces, and whether it will prosper." What's more Levitt (1960) proposed that firms should not focus on selling products but rather on fulfilling customer needs. All these statements refer to a concept called "customer centricity". As acknowledged, majority traditional companies in the past several decades essentially could be categorized into product-centric companies. They design and sell the products to customers according to their experiences and imagination, rather than based on customers' requirements. They always focus on their own products' quality, innovation. On the contrast, customer centricity provides companies a new way of thinking to approaching customers, in order to be more competitive. Transformation from product-centric to customer centric actually is to decide whether the customers should play the vital role in businesses. As Shah et al. (2006) indicated product-centric approach focus on selling products to whoever will buy; however, customer-centric approach emphasizes on serving customers, and all decisions should start with the customer and opportunities for advantage.

According to collected information from literature review, customer-orientation is a similar concept with customer-centricity which was developed in 1980s. Holt (1985) had launched an in-depth study for a number of leading companies in European countries, from which he summarizes the essence of marketing concept requires the firm to monitor the environment to discover new product opportunities, develop the marketing system to satisfy users' needs, and continuously reshape products and services to meet changing needs more effectively. ISO 9001: 2015 emphasized "the primary focus on quality management is to meet customer requirements and to strive to exceed customer expectations (Fonseca, 2015)." The review work found three definitions for customer orientation. Customer-orientation (CO) has been defined as "the set of beliefs that put the customer's interest first" (Deshpande et al., 1993; Alam & Perry, 2002). The second one, customer orientation concerns the degree to which an organization focuses on customers, recognizes their desires and places meeting their needs as a first priority (Giannikas et al., 2019). Smirnova et al. (2018) also defined customer-orientation (CO) as "a set of beliefs that establishes customers' needs and satisfaction as a priority for an organization". This definition views CO as a long-term commitment to serving customers' needs, and requires constant effort and a proactive approach to understand latent, unexpressed needs (Smirnova et al., 2018). They are largely identical but with minor differences. The common point is an organization should pay enough attention to customers and must take customers' requirements and experience into consideration when proposing new solutions. The differentia is to what extent they emphasize customers' importance, from "customers' interest first" to "customers as a first priority" to "customers as a priority". It seems that

customers' importance is decreasing. When it comes to real practice, it is the companies' strategies that determine the position of their customers. No matter how, the strong customer orientation of a firm is reflected in the great attention that is given to close contact with customers, even senior executives make frequent visits to retail outlets. Particularly, excellent companies focus upon making technology work for the user, upon satisfying user needs. Special attention should be given to innovative lead users (Holt, 1985).

In order to fulfill user/customer-orientation, customer-oriented design (COD) should be introduced. Indeed, there are also several other similar notions proposed to tackle this problem. Veryzer and Borja de Mozota. (2005) have mentioned "human-centered design", "customer-centric design", and "user-centered design". User-centered design actually originates from human computer interaction in 1980s as described by Preece et al. (1994) (Tolkamp et al., 2018). They suggested a central position for the users and their wishes through feedback from user involvement when designing hard and software. Later Norman (2004) pointed out that "to the practitioner of human-centered design, serving customers means relieving them of frustration, of confusion, of a sense of helplessness and making them feel in control and empowered". User-oriented design can provide an orientation that fosters a deeper appreciation of user needs and what delivers value to customers (Veryzer and Borja de Mozota, 2005). Grunert et al. (2008) also indicated the user-oriented innovation could be defined as "a process towards the development of a new product or service in which an integrated analysis and understanding of users' wants, needs and preference formation play a key role". When it comes to IT related design, Liang and Tanniru (2006) integrated customer centricity into information system design, they viewed customer-centric information system as one that is able to configure four major components-customer, process, technology, and product/ service – to satisfy a customer need. Especially, the customer is the kernel and the driving force behind the system. This is on the verge of a product service system. Taking a panoramic view of all the definition of user/customer-orientation and user-customer oriented design, customers play the key role in the customer oriented solution, in which customers' wants, needs, preferences must be clearly analyzed and addressed. Then due to the thorough understanding of customers' needs, firms are able to service customers effectively and efficiently; therefore optimizing customers' experience and improving customers' satisfaction. In order to support deeper comprehension of customer-orientation and customer-oriented design, here a comparison Table 8 is addressed in which exhibits several distinctions between traditional product-oriented approaches with customer-oriented approaches (summarized from Vredenburg et al., 2002; Veryzer and Borja de Mozota, 2005; Shah et al., 2006).

Customer Orientation highlights all business activities stem from customers, and focus on customers' experiences and customers' real usage requirements

Table 8 Comparison of customer-oriented and traditional product-oriented approaches

Perspectives	Traditional	product-oriented	Customer-oriented approach
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approach			
Customer	Customer's role	Customers are receivers and users of products	Serve customers; all decisions start with customers and opportunities for advantage
	Target customer groups	Focus on current customers	Focus on current and future customers
	Customer knowledge	Customer data are a control mechanism	Customer knowledge is valuable asset
Offering	Offering positioning	Highlight product features and advantages	Highlight customers' value during usage
	Offering validation	Development prior to user validation	Develop only user validated design
	Offering quality control	product defect view of quality; limited focus on user measurement	User view of quality; Prime focus on user measurement
Organization	Organizational structure	Product profit centers, offering managers, sales team	Customer segment centers, customer relationship managers, customer segment sales team
	Way of working	Limited multidisciplinary cooperation	Multidisciplinary team work
	Organization focus	Internally focused, new product development, new account development, market share growth; customer relations are issues for the marketing department	Externally focused, customer relationship development, profitability through customer loyalty; employees are customer advocates
	Performance metrics	Number of new products, profitability per product, market share by products/sub brands	Share of wallet of customers, customer satisfaction, customer lifetime value, customer equity

2.4 Briefly introduction of CO and COD benefits

It has been accepted that firms should be customer-oriented because customer-oriented firms are more likely to deliver better service quality and enhance customer satisfaction (Hartline et al., 2000; Alam & Perry, 2002). It also enables firms to differentiate their offerings to customer in a meaningful way, thereby helping them to enhance customer acquisition. For this reason, firms that apply service-oriented logic regard user and customer-oriented approaches and user involvement as more relevant and indeed use these strategies more commonly (Grönroos and Ravald, 2011; Vargo and Lusch, 2014; Tolkamp et al. 2018). Martínez-Costa et al., (2009) researched ISO 9001:2000 and indicated the big change in version 2000 that they added continuous improvement and customer orientation which are neglected in previous version. They are of great significance because the companies certified in 2000 are motivated to explicitly define ways to continuously improve quality and have customer satisfied rather than limited to implement quality management at a superficial level. Alam (2002) reviewed past articles from three research fields, and found that: (1) the market orientation literature suggests that customer-oriented product development efforts yield superior innovation and greater new product success; (2) the new product/service development literature suggests that customer interaction can increase product/service success; and (3) the relationship marketing and network literatures provides evidence that information exchange and collaboration with users are useful for new product development.

Veryzer and Borja de Mozota (2005) examine the fundamental relationships underlying the incorporation of a user orientation into New Product Development process, and generate four propositions, from which we could recognize the benefits of user-oriented design.

- ***Proposition 1: Greater emphasis on user-oriented design will induce a more collaborative new product development effort.***

This concerns integrating information and promoting cross-functional communication to developing and representing new levels of understanding a design problem/solution. User-oriented design provides excellent communication channels and cooperation nature for both customers and providers, which has a positive impact for producing successful offerings. More Cooperation and communication between R&D and marketing functions increase chances of success (Griffin and Hauser, 1996). Additionally, integration of user-oriented design is able to introduce different and typically unfamiliar perspectives into approach undertaken for the product development challenges, thus leading to a higher level of collective creativity (Maltz et al., 2001; Veryzer and Borja de Mozota, 2005).

- ***Proposition 2: Integration or inclusion of user-oriented design in new product development will have a positive effect on idea generation.***

Idea generation requires a high level of integration between the internal and the external company. The ideas should integrate the customers' minds, the product, and production considerations (including suppliers) in order to produce a number of promising ideas. Toward this end, user-oriented design can enhance idea generation in three important ways: visualization/conceptualization, form alignment, and transmutation of the design challenge.

- ***Proposition 3: Integration or inclusion of user-oriented design in the new product development process results in a superior product or service.***

User-oriented design involves balancing commercial concerns (e.g., target marketing, price points) and market realities with delivery of a set of capabilities or functionalities in the form of an integrated "product" that is both pleasant and effective to use. Another way that user-oriented design plays a role in the design process is through an understanding of cognitive and behavioral processes (Norman, 2004). What's more, user-oriented design also encompasses experiential aspects of the products that firms wish to create.

- ***Proposition 4: Inclusion of user-oriented design leads to products that are more readily adopted by users due to better product appropriateness.***

The deeper insights gained about consumers that come with user-oriented design approaches, along with the ability to ascertain reactions to visual representations of proposed products, provide product development teams the best opportunity to identify negative design issues and gauge customer reaction.

User oriented Design has positive effects on roles collaboration, new idea generation, better offering development and better customer acceptance.

2.5 Key issues for Customer-Oriented PSS (COPSS)

According to the systematic literature review, although there are a lot of articles advocating the importance of customer orientation, few of them is proposed in PSS engineering field. Thus, it is necessary to supplement the lacking knowledge for PSS designers to recognize what PSS looks like when integrating the concept of customer-orientation. During intensive reading of 94 articles, a lot of information of customer orientation were grabbed. In this section, the information will be integrated into PSS field, in order to find out the distinctions between customer-oriented PSS with traditional provider-driven PSS. Finally five findings have been achieved after generalizing and summarizing the common points among these articles.

Finding 1: Customer experience and customer satisfaction hold a vital position in a COPSS

As is acknowledged, the two main targets of PSS are satisfying customers' needs and bringing less impact to environment. For a customer-oriented PSS, the aim is not only to satisfy customers' needs by providing high-quality offerings in usage phase, but also to emphasize customers' experience and customer satisfaction through entire PSS lifecycle.

Holbrook and Hirschman (1982) proposed the experiential perspective in marketing, which represents "the behavior of people in general and of consumers in particular is fascinating and endlessly complex result of a multifaceted interaction between organism and environment." They emphasized that experiential aspects, such as fun and esthetics, are important determinants of consumption behavior, and they recommended a change in marketing from a product-oriented focus on transactions to a customer-oriented focus on interactions (Schallehn et al., 2019). A central construct of this experiential perspective is the customer experience, which is defined as a "multidimensional construct focusing on a customer's cognitive, emotional, behavioral, sensorial, and social responses to a firm's offerings" (Lemon & Verhoef, 2016; Schallehn et al., 2019). ISO 9241-210 provides a more concise definition for user experience, which is "a person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service." Thus it can be seen that the customer experience essentially is a kind of emotion or feeling when using the offerings, not only links to offerings' own value. Sutcliffe (2012) emphasized the customers' emotions and motivations during user-oriented requirement engineering and also approved Norman's statement (2004) that good design should inspire positive emotional response from users, such as joy, surprise and pleasure. Moreover, to create long-lasting hedonic products, it is suggested that designers should emphasize more on the experiential aspect of interactions between users and products, so as to understand potential user experience and to implement design or experience (Hassenzahl & Tractinsky, 2006; Zheng et al., 2017). Additionally, in order to optimize customer experience, customer experience testing is also necessary; Laing and K uhl (2018) proposed a method for user-experience testing in building environment comfort service field which includes three tasks as well as corresponding sets of suggestions. Adopting a wider scope, the customer's experience may include the relationship perspective. Here the customer is assumed to evaluate the service provider's performance in the relationship over time: the customer

experience arises through the combination of all points between the customer and the company (Grewal, Levy and Kumar, 2009; Heinonen et al., 2010). Good customer experience can directly impact on good customer satisfaction and loyalty. Customer satisfaction and value is exclusively perceived by the customer and usually involves trade-offs between what is received (e.g. quality and benefits) and what is given up to acquire this (e.g. money and time). Increased customer value implies increased loyalty and for the company expanding the innovation potential to new ways of working with external partners and customers/users, thus a reciprocal value expansion (Overvik-Olsen and Welo, 2011; Spiteri and Dion, 2004; Siakas & Siakas, 2016). Hence, it is suggested that companies should focus more on improving customer perspectives such as customer satisfaction and customer loyalty by integrating products and services innovation and providing diversified value-added product-service offerings as well as developing close long-term partnership with customers (Pan & Nguyen, 2015).

Finding 2: a COPSS' sustainable target could benefit from adopting a customer-oriented approach

Eco-design is a product development approach based on assessment of environmental impacts of a product throughout its whole life cycle (from raw material extraction to end of life treatment, including usage and transportation) and then the implementation of improvement strategies to reduce environmental impacts. This approach involves the participation of all the services of the company and all the actors of the value chain (Heslouin et al., 2017). Obviously, customers are no exception. Hienerth et al. (2011) argue that taking a user-centered approach to business model design can help a firm to learn about enticing values through interaction with stakeholders in the ecosystem, which is a key issue in developing sustainable business models. In other words, sustainable business models could benefit from taking a user-centered approach (Tolkamp et al., 2018). However, the role of users in green innovation processes is less understood (Slotegraaf, 2012; Zimmerling et al., 2017). This is surprising, considering the fact that authors focusing on transition to sustainable consumptions and production propose that the collaboration with users in green innovation process is key for success of final products or services, since they often lack market attractiveness and require changes in consumption behavior (Hoffmann, 2007; Zimmerling et al., 2017). Under this background, Zimmerling et al. (2017) launched an exploratory case study for several incumbent firms, from which they found that early and constant end-user integration into green innovation process could be served as a risk management tool, since it uncovered behavioral changes induced by the innovations among potential future users; therefore helping companies to overcome risk aversion towards the development genuinely new green products and service and to bring these to market. Other articles against his problem mainly focus on usage phase along PSS lifecycle. Heslouin et al. (2017) emphasize the customers should choose appropriate offerings and follow their own environmental performance during usage phase so that they can reduce CO₂ emission and save more energy based on their sustainable behavior. Lindström (2016) clarified a series of sustainability-oriented functional product customer values, in which seven ecological values are displayed, such as lower consumption of energy and water, lifecycle analysis or assessment of costs and environmental impact, as well as less maintenance during usage

and operation, etc.

Finding 3: Offering design should emphasize customers' requirements and offerings' functionalities

As mentioned in the beginning, majority of extant product, service or systems usually are the outcome of companies' technology innovation, whereas they ignore customers' requirements. However, according to literature review launched in this thesis, it seems that these articles reach a consensus that to achieve a series of clear and completed functional requirements is a vital task to address user-oriented solutions. Arguably, 13 IT related articles from 17 emphasize the importance of understanding customers' requirements when developing new IT systems. For instance, Däuble et al. (2015) indicated before system development according to user-oriented design, requirements of the users need to be considered; what's more, development is an iterative process due to the potentially new or altered requirements from the validation phase until the system copes with user requirements. In Yuan et al.'s (2013) research work, user requirements search behaviors also come first, so that they fulfill a detailed requirements engineering for real estate websites case. Cheng et al. (2011) proposed a new user-centric service-oriented modelling approach, which is able to translate a group of users' fuzzy requirements to services as well as model different levels of hardware and software as services to meet the requirements. This is more often in PSS engineering field, 51 articles of 60 have mentioned the importance of customer requirements, particularly functional requirements. For instance, Zheng et al. (2017) emphasize customer experience realization is based on offerings' functional performance; thus, for personalized offering development, both affective and cognitive requirements should be accompanied with functional requirements concurrently. Hussain et al. (2012) propose a framework which provides a way to depict customer requirements as determined by the value-in-use they experience by locating and measuring gaps within a capability and then affording a technique to adjust the system in various ways so that these gaps can be reduced to improve value-in-use. Isaksson et al. (2009) advocate the importance of customer voice during offering design; offerings should be designed on behalf of the customer; what's more, data from users, general theories and models of customer behavior will form the knowledge base.

Requirements are often translated into offering functionalities, and then decomposed to variety of product structures and service processes. Functional Hierarchy Modeling (Ostaeeyen et al., 2013) and Service Requirement Tree (Pezzotta et al., 2014) are often adopted to fulfill this task. It is necessary to shift the focus from the provision of products to the provision of functions and considering all options for providing the required functionality, to include whether it can be provided by a service, product or some combination of a PSS in Sustainable Product and/or Service Development process (Maxwell et al., 2006). Researchers are sparing efforts on this. Lindström (2016) outlines a set of potential sustainability-oriented functional product customer values, which comprises sub-sets of eleven economic, seven ecological and four societal ones. The customer values can be used by FP providers and customers as well as researchers when addressing planning, design, development, marketing and sales of FP offers. Andriankaja et al. (2016) integrate functional analysis approach into system design approach in order to

achieve requirements and functionalities to be fulfilled by the system. More precise to maintenance-repair-overhaul services, Chang et al. (2018) propose a function availability-based integrated product-service model, which is able to shown the function-product-service integration and implement-maintain-ensure mapping, so that effectively ensure the integration of product and maintenance-repair-overhaul (MRO) services.

Finding 4: COPSS ideology advocates customer involvement along entire PSS lifecycle

The main motivation for customer involvement comes from an ever-growing need for developing successful new services (Alam, 2002). COPSS ideology advocates but not forces customer involve in PSS design and be an active participant along entire PSS lifecycle, rather than be a passive receiver in product-centric logic and traditional innovation-pushed PSS. Customer involvement results in customer value co-creation, which was first to coin by Kambil et al. (1996) for emphasizing the role of customers in business strategy and marketing. The concept of value co-creation guides organizations to emphasize customer experience at multiple points of exchange at the basis of value co-creation rather on focusing only on offerings (Agrawal & Rahman, 2015).

Customer Involvement benefits

The more involved the customer is in the innovation process, the more customer value and satisfaction is created (Siakas et al., 2012, Straub et al., 2013). Alam (2002) identified six aspects of benefits of customer involvement: (1) ***Superior and differentiated service***: with user involvement, it is possible to develop a differentiated new service with unique benefits and better value for customers; (2) ***Reduced cycle time***: with user involvement, the overall new service development process can be stimulated. This may result in cycle time reduction; (3) ***User education***: with user involvement, the users can be easily educated about the use, attributes, and specifications of a new service; (4) ***Rapid diffusion***: user involvement in the new service development process helps in rapid diffusion of innovation, which accelerates the market acceptance of a new service; (5) ***Improved public relations***: the purpose of user involvement is to improve public relations before the introduction of a new services, which generally helps in building quick support for a new service; (6) ***Long-term relationships***: user involvement in the new service development process may improve the provider-user relationships. Agrawal & Rahman (2015) also indicated that the customer as an active player in value co-creation could enhance the efficiency and effectiveness of the value co-creation process. Value obtained through co-creation could help satisfy customers and simultaneously benefit firms. Even in the case of a service failure, the involvement of customers in the recovery process could enhance customer satisfaction and encourage repeat purchases. Better product quality, greater customers' satisfaction and reduced risk for the firm are the key benefits of co-creating value with the customer.

Customer Involvement categories and forms

Majority of researchers conclude the role of customers into two main categories:

passive role and active role. Durugbo & Pawar (2014) drew a picture (Figure 8) to depict customer involvement from received view to co-creation view. Customers play a passive role in the received view: designers capture needs from customers but don't involve them into the design and the production processes. Customers' main contribution is to be "test-subjects" and receiver of offerings, as well as a user with feedbacks. Guan et al. (2019) also indicate the type of shallow involvement, which means the customers only play as requirements inputter, passive tester and offering receiver. This is similar in customer-centric information system (Ting-Peng & Tanniru, 2007), customers in a passive role only leave certain clues for information system to capture their implicit preferences and needs, and expect to accomplish their goals. After needs input, the system will tailor its internal processes by itself. Under passive involvement condition, the co-creation form is limited to sending information, receiving information (Tolkamp et al., 2018), for instance, getting user feedbacks for concepts or prototypes (Tran & Park, 2015). On the contrast, customers play an active role in co-creation view (Durugbo & Pawar, 2014). The collaboration between providers and customers break the organizational boundaries and they can communicate and work together through production platform. Offerings and experiences are developed jointly by customers and providers. In the customer-centric information system (Ting-Peng & Tanniru, 2007), active customers are involved in operation of a system and are an integral part of its development. For example, both wikipedia.com and blogs are examples of customer-centric information systems in which customers influence the way the system is conceived, developed, and disseminated. Under active involvement condition, the co-creation form could extend to co-producing, co-innovating etc.(Tolkamp et al., 2018), such as open innovation, crowdsourcing, or customer participatory games or tests, etc.(Tran & Park, 2015). In relation to above, the thesis suggests in Guan et al. (2019), a deeper customer involvement in global value co-creation processes, such as ideation phase, design phase, production phase, delivery and use phase, and recycle phase, etc.

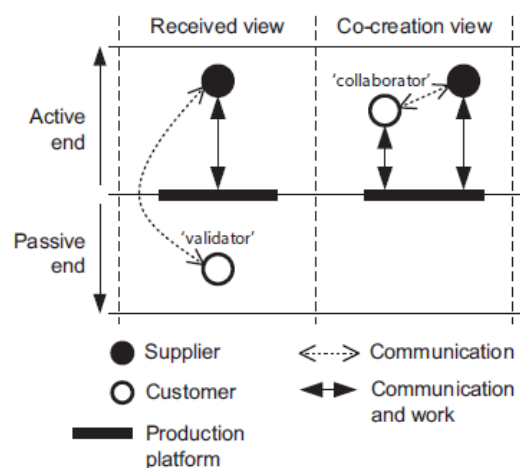


Figure 8 A comparison of the received view and co-creation view

Alam (2002) identified four levels of customer involvement: (1) **Passive acquisition of input**: at this level, the customers take the initiative to provide input into the development process. For example, a customer approaches the service provider with a new service idea;

the managers can thus acquire input passively, and the intensity of user involvement is considerably low. (2) ***Information and feedback on specific issues***: at this level, the service developers may approach major service users to obtain information and feedback on specific issues at various stages of the development processes. Thus, the intensity of involvement is somewhat high. (3) ***Extensive consultation with users***: at this level, the service producers take the initiative and invite user input by means of a planned process governed by predetermined objectives. Common examples include detailed interviews with the users, focus group research, and group discussions. Thus, the intensity of involvement is relatively high. (4) ***Representation***: at this level, the users are invited to join a new service development team, where they contribute to the specific stages of the development process in their capacity as team member. Hence the intensity of involvement is considered to be extremely high. Based on the level assessment, we can conclude that the customers who involve in fewer processes (limited to input requirements, receive and use offerings) must be passive. On the contrary, the customers who involve in more and higher processes (such as ideation, design, production, innovation, recycling etc.) also may not play an active role. If their contribution is limited to sending and receiving information, they are still not so active. Only those customers who are invited to do detailed and in-depth reviews or to be a member of a developing team are really playing as an active role. However, what is worth mentioning here, although we already know the benefits of customer involvement and COPSS advocates customer involvement; we shouldn't force the customers to deeply involve in value co-creation processes, since this kind of enforcement sometimes will lead to customers' antipathy and bad customer experience. Keep in mind that customer experience always comes first and we cannot violate the first finding. This conforms to Heinonen et al.'s basic ideology of customer-dominant logic (2010) about customer involvement, which advocated there is a need to contrast the established company-oriented view of involving the customer in service co-creation with a more radical customer-oriented view of involving the service provider in the customer's life.

Customers' involvements and their roles

This question refers to the roles that customers play during the COPSS (New service/product development) lifecycle, as well as their contributions when involving different processes or life phases. In terms of customers' roles, many articles have referred. Cui and Wu (2015) defined three conceptual roles for customers: information source, co-developer who works with the firm to produce new products and co-innovator develops the new products separately, which the firm merely adopts. Chang et al. (2006) treated the customers as co-developers when designing and updating software, since user feedbacks and evaluation will continuously impact on design and innovation processes. Zimmerling et al. (2017) indicated by making the customers co-innovators, co-creators, and co-producers in innovation process, firms not only value knowledge about customers' needs, but also tap into customers' solution knowledge. Liu et al. (2018) identified four statuses for the collaboration of customers and providers: co-exit, co-design, co-implement and co-evaluate. However, these articles haven't addressed the problem in detail. The review work found out another four articles respectively from value co-creation field, new service development field and PSS engineering field, which meticulously address the

customer involvement including their customer roles (CR), customer contributions (CC) (contributions refer to customers' inputs, main tasks or main influences) and involved processes or life phases (IP/ILP). The following Table 9 exhibits the details. According to the Table, we can conclude that customers have the potential to involve in each phase of PSS lifecycle to be co-ideator, co-designer, co-tester, co-manufacturer, co-producer, co-distributor, co-consumer, experience creator, co-promoter, co-innovator and co-evaluator. In order to fulfil such communication and interaction, following effective measures could be adopted: (1) ***Direct information interaction with customers***: Alam (2002) conclude six modes of involvement, including face-to-face interview, user visit and meetings, brainstorming, user's observation and feedback, phone, faxes and emails and focus group discussions. (2) ***Developing and implementing collaboration platform***: a collaboration and communication platform could be able to provide providers and customers with a more concise and transparent way to interact with each other, thereby promoting the effectiveness and efficiency. Sustainable Livinglabs (Liedtke et al., 2015) is a good example, which places users on the central stage and integrates other actors in cooperative value chain to develop and diffuse sustainable PSS innovations. (3) ***Collecting customer information from social media and devices***: customers are encouraged to propose their novel and innovative ideas on the web and forward to providers (Agrawal & Rahman, 2015; Pezzotta et al., 2017), so that maybe providers could elect the useful ones and implement the concept on the market. Besides, taking mobile phone as an example, the wide infiltration of mobile devices in end-users' life creates an open stream of valuable data that may affect product design and drive the design of manufacturing networks (Mourtzis et al., 2019).

Table 9 Several customer involvement methodologies

References	Customer involvement											
Agrawal and Rahman, (2015)	CR	Co-ideator	Co-designers	Co-tester	Co-manufacturer	Co-producer	Co-distributor	Co-consumer	Experience creator	Co-promoter	Co-innovator	Co-evaluator-
	CC	Novel briefs and ideas	Interact with firms and provide knowledge and experiences	Feedbacks help test new offerings	Innovative ideas incorporate in offering manufacturing	Participate in production and delivery	Self-service as a tool for service delivery	Create meaning experiences and value for oneself or others	Help enhance satisfaction and develop customizing offerings	Self-promoter, reviewer and brand evangelist due to propagation of their experiences	Help develop successful offerings in iterative innovation process	Help evaluate the ideas, products and services
	ILP	Requirements engineering	Design	Design and production	Production	Production and delivery	Delivery	Usage	Usage	Whole lifecycle	Whole lifecycle	Whole lifecycle
Straub et al. (2013)	CR	Service-specifier		Co-designer		Co-producer		Quality-controller		Co-marketer		
	CC	Specify the requirements; trigger actual service delivery		Help decision making and design by providing opinions and preferences		Provide work, know-how, information, money as a "part-time employee"		Help assure the quality of production and delivery through testing and timely feedbacks		Support marketing through "word of mouth " whose effect could be positive or negative depending on customer experience and customer satisfaction		
	ILP	Requirements engineering; Delivery		Design		Production		Production and delivery		Whole lifecycle, mainly in usage phase		
Alam and Perry (2002)	CC	Feedbacks on financial data	State needs, problems and solutions	Input preferences, purchase intent	Limited financial data, profitability of concepts	Join in top management in selecting team members	Help develop blueprints, observe delivery trial	Observe and participate in delivery process and give advice	Participate in simulated delivery process and give advice	Provide comments on marketing plan and their satisfaction on marketing mixes	Adopt the service as a trial, feedback about overall performance of the service; share experiences with other customers through word of mouth	
	IP	Strategic planning	Idea generation	Idea screening	Business analysis	Formation of cross-functional team	Service design and process system design	Personnel training	Service testing and pilot run	Test marketing	Commercialization	
Pezzotta et al. (2017)	CR	Co-ideator		Co-designer		Co-developer/ Co-producer		Co-tester	Experience Creator		Co-evaluator	
	CC	Submit ideas on the web to		Customize a specific offering		Support firms in creating relevant		Help test new	Lead customers' experiences	Mainly focus on idea evaluation		

		producer	most relevant to oneself	value proposition	offerings	help refine value proposition	
	ILP	Requirements engineering	Design	Design and production and delivery	Production	Whole lifecycle, mainly conceptual design and usage phase	Requirements engineering

CR: Customer Roles

CC: Customer Contributions (refer to customers' inputs, main tasks or main influences)

IP: Involved Processes

ILP: Involve Life Phases

Finding 5 Customer-Orientation may increase new obstacles for PSS

In here, we will not spare effort to discuss those inherent challenges of PSS. We are focusing on what customer-orientation may bring for PSS. According to literature review, four aspects of new challenges have been found as following.

Obstacles from Requirements Engineering

The core challenge for PSS design actually is to develop offerings that are technically feasible, economically profitable, and socially acceptable (Holt, 1985) and environment amicable. To design and develop such a PSS offering, the first and foremost task is requirements engineering. As Guan et al. (2017) mentioned that companies need to take many factors into consideration when proposing a PSS, for instance, more and more involved stakeholders, market situation, environmental impacts, governance policies, society responsibilities etc., which makes PSS itself more and more dynamic and complex. The following Figure 9 exhibits variety of requirements sources which are necessary during PSS design.

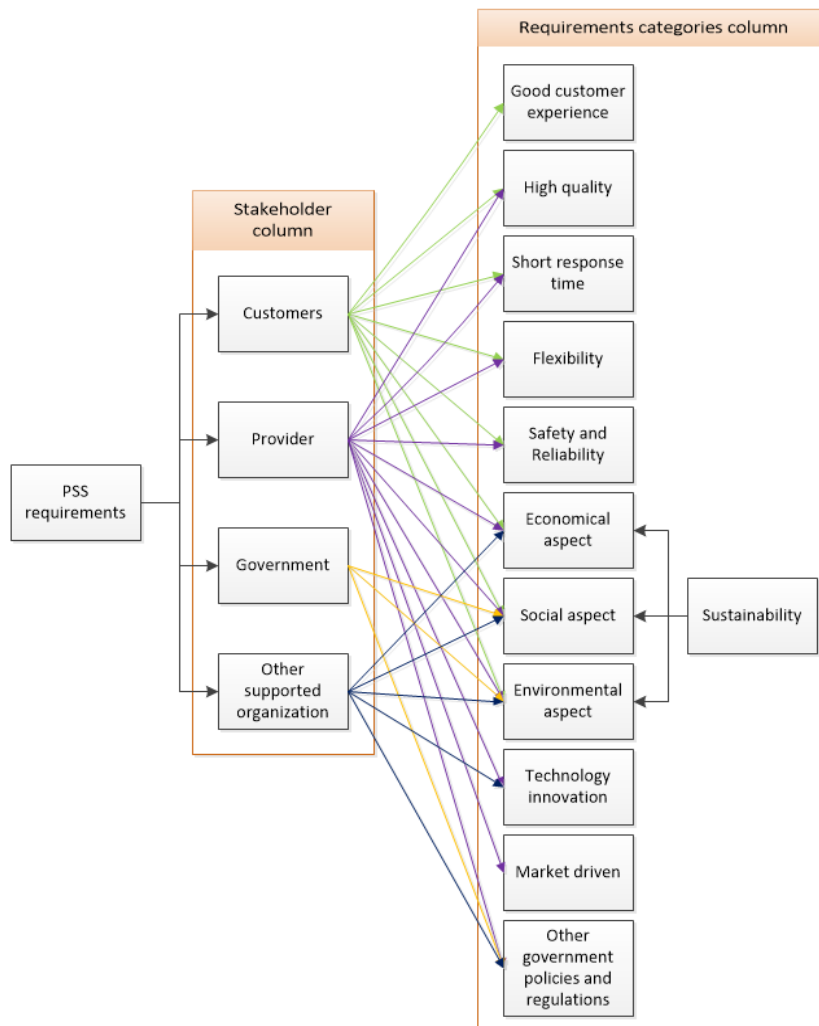


Figure 9 requirement classification for COPSS design

The thesis summarizes four categories of stakeholders. The customers come first in COPSS, and second is the main provider of PSS solution, which can be a product or a service company, or a set of collaborative enterprises, which is/are responsible for core businesses; government's influence cannot be ignored during system operation, for instance some existing public bicycle sharing systems; and last stakeholder is called other supporter organization, which may be a third-party logistics company, a banking company, an insurance company, a research center, an university and so on, or a set of collaborative organizations abovementioned. The requirements categories are identified for each stakeholder in the "requirement categories column". In terms of the customers in a COPSS, the first and most important requirement is the customer experience. Predictably, if customers haven't got good experience along involvement during PSS lifecycle, the project will progress very hard and hesitantly and even fail directly at any phase in the lifecycle, due to bad relationships and communications. Besides, customers may also have their own social and environmental requirements, the provided solution also need concern such aspect. Providers seem to shoulder most responsibilities according to this Figure. They should take following four aspects of requirements into consideration: (1) customers' requirements including good relationships with customers, good quality, short response time, flexibility, safety and reliability; (2) sustainability requirements including their own financial requirements, social responsibility, less environment impacts; (3) providers' technology innovation and requirements coming from market analysis and (4) policies and regulations coming from governments.

Fernández et al. (2018), when researching on customer-oriented risk assessment, indicated that quality perceived by the customers has a strong impact on the fulfillment of financial goals, positively increasing the demand and negatively increasing the risk of customer churn. Indeed, perceived quality of offerings is not occupied part of customer experience. Customer experiences emerge during all the involved processes created by providers, thereby bad experience will lead to high risk of customer churn. Thus, emphasizing on customer-orientation brings much more complexities and uncertainties for requirements engineering and PSS design. It is a big challenge for companies to make trade-offs between guaranteeing good customer experience and their own development requirements (financial targets, lead time and so on.)

Obstacles from Customer Integration

Siakas & Siakas (2016) identify three main obstacles that exist in customer integration.

First one is lack of customer motivation. Durugbo and Pawar define two views of collaboration modes: received view and co-creation view. In the past years, customers usually only play the role of a receiver, and they have been used to be a receiver. The transition from a passive receiver to an active participant in a short time is really hard. Besides, the customers may be reluctant to spare time and effort involving in those not relevant things. What's more, consumer experience is acknowledged as internal and emotional. Thus experiences do not consist only of cognition, calculation and overt behavior, but also by nature subjective and inseparable from feelings (Heinonen et al.,

2010). Under this condition, customers to be active or passive will be influenced by their own feelings from other aspects of their life conditions.

Second one is coordination and control of overhead costs, which was derived from Straub et al., (2013). Straub et al. (2013) launch an exploratory study to identify the status quo of customer integration and corresponding experiences in service industry, from which they find out the potential disadvantages of customer integration. It becomes obvious that especially increased costs are seen as an important issue for service companies. Hence, this leads to a problem that companies should make trade-offs between adopting and utilizing customer integration and their monetary strategies. Maybe they could benefit more from customer integration in a medium and long term horizon, while cost too much in a short term.

The last one refers to customers' loss of know-how, which is also the key risk proposed by Enkel et al. (2005). Whenever a customer is integrated into the company search field or innovation process, he almost unavoidably acquires company know-how while contributing with his own knowledge or ideas. Then when he integrates another company's innovation process, the learned know-how will bring to the new search group, which may be the competitor of the first company. Another risk of know-how is the possible conflict regarding the ownership of ideas which could arise in the course of the innovation process through the combination of company and customer know-how. Besides, the authors in this article also identify other corresponding risk points of customer integration, such as dependence on customers, being limited to mere incremental innovations and niche markets, and misunderstandings. All these risks impede the course of companies' customer integration strategy.

Obstacles from Customer Acceptance

The next obstacle is that customers may be still reluctant to accept the innovative offerings, although the providers have overcome the challenges from requirements engineering, as well as the challenges brought by customer integration. After all, customer acceptance has been identified as one of the most significant hurdles of the widespread implementation of PSS (Tukker, 2015; Mashhadi et al., 2019). Many researchers have spared their effort on reducing customers' barriers and increasing their acceptance. Rexfelt et al. (2009) found out two factors which are central to acceptance, uncertainty reduction and relative benefits. To achieve these, it is necessary to develop an understanding of how PSS impact on consumers' lives through the activities they engage in, also beyond the service encounter. Hussain et al. (2012) proposed a framework for PSS conceptual design, according to which they try to bridge the gaps between system's capabilities and customers' goal. Pezzotta et al. (2014) developed a Service Engineering Methodology (SEEM) to provide services for customers, in which service requirements tree are developed to deal with variety of customer requirements in order to enhance customers' acceptance and satisfaction. Schmidt et al. (2015) proposed a three-layer customer-oriented PSS design framework, including customer layer, customer barriers layer and solution layer, as well as the strategy space, which aims at demonstrating the mechanism for how PSS can increase customer acceptance by reducing influences of customer barriers to designers. Schmidt et al. (2016) again

developed five-procedure method for increasing customer acceptance and implemented it on a case study from construction machines industry. Despite of these efforts, when it comes to real cases, it is still not clear what contributes to the consumers' likelihood of acceptance of PSS (Mashhadi et al., 2019). Moreover, as Rexfelt emphasized, as consumer acceptance of PSS is complex and case specific, the extant frameworks and methodologies will be not enough to deal with variety of PSS real cases. What's more, due to the acceptance's characteristic of high complexity and case specificity, iterative studies with customers are also necessary and vital, which will cost a lot of companies' efforts.

Five key issues for COPSS:

- (1) COPSS emphasizes on customer experience and customer satisfaction;
- (2) The customers in COPSS have more potential to reduce environmental impacts;
- (3) Offerings provided by COPSS emphasizes on customers' requirements as well as offerings' functionalities;
- (4) COPSS ideology advocates customer involvement along entire PSS lifecycle;
- (5) Despite of new PSS design challenges coming from customer-orientation, customer-oriented design still take more advantages over traditional product-centric method and innovation-pushed PSS.

To date, the key knowledge of COPSS including the meaning of customer-orientation, the benefits of customer-orientation and five key issues of customer-oriented PSS is explicated in this section. Obviously, COPSS show more advantages over traditional provider-driven or technology-driven PSS, due to the fact that COPSS is able to obtain better customer experience and result in less environmental impacts according to the contents illustrated above. In the following section, another important task needs to be done, which is to propose an appropriate typology for COPSS since existing typology mainly focus on traditional PSSs.

3 A reference COPSS typology

3.1 Motivation of new typology proposal

The typology plays an important role in PSS design because it is a guide for designers and companies to adopt learn and utilize appropriate knowledge, skills and resources to design optimized PSS solutions for all stakeholders, especially customers, in a system. However, according to the review of existing typologies about products-services, product service systems or similar concept with PSS, there is no appropriate typology for COPSS, due to they cannot handle the following problems at the same time: (1) what a PSS could propose to satisfy customers' and providers' needs? (2) Who can support the development and implementation of PSS solutions? And (3) how to propose such solutions from an engineering perspective? The first

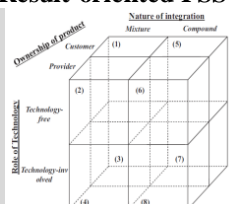
problem is often addressed in existing typologies; however, what is worth mentioning is that COPSS emphasizes value proposition for both customers and providers; in terms of second problem, majority of existing methodologies and typologies always focus on two PSS components: i.e. product and services, and always ignore the importance of supporting network; few of existing typologies addressed the problem of how to achieve the value propositions, for instance, Park & Lee (2012) integrated the technology into their integrated product-service typology; however, their proposal didn't focus on customer-orientation.

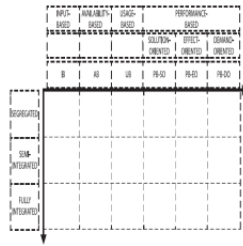
With these problems in mind, the next task is to make a literature review for existing PSS typology in order to find out relevant information.

3.2 Literature review for existing typologies

Table 10 shows some existing typologies of product-service related and PSS related concepts.

Table 10 Existing typologies

PSS related concepts	Typologies	References	Distinguishing characteristics
Bundling	Pure Mixed	Schmalensee, R. (1982)	Degree of offering integration
Service Package	Unique Selective Restricted Generic	Kellogg & Nie, W. (1995)	Degree of customization
Product Service	Pre-sale Sale Post-sale	Lalonde & Zinszer (1997)	Services offered periods
Eco-efficient producer services	SSP SSC Product-based services Electronic substitution services Infomraiton-based services	Mathieu, V. (2001) Bartolomeo et al, (2003)	Targets of services aiming to support Factors of change during service consumption
Product service systems	Product-oriented PSS Use-oriented PSS Result-oriented PSS	Tukker (2004)	Property rights Value proposition
Integrated product services		Park & Lee (2012)	Nature of integration Ownership of product Role of technology



The chosen articles from the year of 1982 to 2013 try to explain the typology evolution of product-service related concepts development as well as PSS related concepts development.

Bundling is defined as “the practice of marketing two or more products and/or services in a single package” (Guiltinan, 1987). Several literatures have researched on this concept and divided the bundling into two categories: pure and mixed. In pure bundling, products/services are offered only as a bundle and not as individual items, while in mixed bundling, the bundling as well as the individual component products/services are priced and offered separately. **Service package**, similar as bundling, can be defined as a bundle of goods and services with information that is provided in some environment (Fitzsimmons and Fitzsimmons, 1994). Four categories identified by Kellogg and Nie (1995), unique, selective, restricted and generic. Service package is a service-oriented concept in which physical goods are offered together as a group support the central service. **Product service**, which is defined as “the set of all potential additional services a supplier can supplement his product offering with, in order to differentiate his offering relative to the competitors” (Frambach et al, 1997). Lalonde and Zinzer (1976) proposed three types of product service: pre-sale, sale and post-sale. Also Mathieu (2001) also indicated the product services can be divided into SSP and SSC, which are service supporting the supplier’s product and service supporting the client’s action in relation with the supplier’s product. Product service indeed is the concept to supplement the services along with the products whose target is to try to differentiate offerings. **Eco-efficient producer services** (EEPS), can be defined as services which improve the eco-efficiency of business customer activities. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient). (Bartolomeo et al, 2003). EEPS is a certain product-service mix which has a higher added value and a smaller environmental impact (Zaring et al, 2001). EEPS are categorized into three types: product-based services (focus on products and other physical artefacts), electronic substitution services (focus on electronic infrastructure rather than physical infrastructure) and information-based services (focus on changing user practices through better knowledge, but also can have implications for both products and infrastructure). **Integrated product services** (IPS), was defined as any offering in which products and services are integrated, regardless of its types, objectives and features. An IPS cube is proposed for the typology, there are three dimensions: nature of integration (mixture and compound), ownership of product (customer and provider) and role of technology (technology-free and technology-involved). The **Typology of Eight types of PSS** proposed by Tukker is most commonly used, in which PSS can be categorized into product-oriented PSS

(contains product related services and Advices & consultancies), use-oriented PSS (contains product leasing, product renting/sharing and product pooling) and result-oriented PSS (contains activity management, pay per service unit and functional result) according to the property rights of products and the value proposition. Last, **refined PSS typology** proposed by Ostaeyen et al (2013) defined two dimensions of PSS typology; respectively are revenue mechanisms (RM) and level of integration. There are four types of revenue mechanisms on horizontal axis: input-based RM, availability-based RM, usage-based RM and performance based RM; and three levels of product-service integration on vertical axis, segregated, semi integrated and fully integrated. By this way, they conclude a series of blocks with double attributes.

When look inside the Table in depth, we can come out the first finding: almost all the typologies are built based on value proposition or contain the value proposition dimension despite different terms of expression. According to the Table, a commonly used distinguish characteristic is “the level of Product-Service integration”, such as the bundling, integrated product-services and Ostaeyen’s product service systems. This is because PSS offering indeed is a combination of products and services, different level of PS integration will result in different portion of value added by products and services. Take Tukker’s typology as an example: first, products play a dominant role in product-oriented PSS, so that the main value in this case is embedded in the products; services regarded as add-ons of products, such as the advice or consultancy, will show less importance during value co-creation. In the second category, value will be created during the usage phase, no matter renting, sharing or leasing. And for the last category, value can be created since the beginning of PSS solution development. Under this mode, providers need to discuss with customers to come out with a conjunct result, the value can be realized along the PSS lifecycle according to the common goal. Similarly, in the typology of eco-efficient producer services, product based services focus on products and physical artifacts, which means the main value is added in the products and physical infrastructure and so on, here I won’t specially repeat them.

Besides, we can also find that the typology evolve from simple unitary dimension to complex binary even trinary dimensions; and involved distinguishing characteristics extend from only value proposition to property rights, revenue mechanism and technologies, etc. The categories for each dimension are evolving more and more detailed. Also we can find that researchers’ view is transforming to an engineering perspective rather than only marketing perspective in the early years.

According to the literature review, we can conclude that there is no appropriate typology for customer-oriented PSS. None of them is able to answer all the three problems we have defined in the last section. Thus, a new way of PSS typology is necessary, which should take all the three dimensions into consideration.

3.3 Proposal of the reference COPSS typology

Two tasks need to be done in this section, the first one is to find out the answers for the problems proposed in the previous section; and the second one is to generate the reference typology.

3.3.1 Value Proposition Dimension

The first question refers to what the value proposition is. In this typology, “what” represents the value proposition dimension: this dimension answers where the customer value are embedded in. Provider provides differentiated product-service offerings to their customers. The value is added in these different kinds of offerings.

Figure 10 shows the value added in different categories of PS offerings. This Figure intuitively demonstrates the value added in each PS offering. The first category is pure product: providers sell products to the customers. Customer value is realized totally by the products, which is typically value-in-exchange. The second category is product with supporting services: in this case, products still hold the dominant position in the value creation. These services are simple services such as using advice, training or two years guarantee. In this category, the design of products and services can be separated easily. Hence these services are physically integrated into the products. We can call it “mixture” (derived from Park et al, 2012). The third category is product with differentiating services: in this case, products can be regarded as the service provision mechanisms, the differentiated services play more important role in value creation. Here PS offering is developed as a whole; they are organically integrated and can’t be separated easily. Thus we call this category “compound” (Park et al, 2012). The last category is product as a service: in this case, value-added by services occupies most or all the portions. We name it pure service in this typology.

Hence for the value proposition dimension, we finally come out four categories: respectively are pure product, mixture, compound and pure service.

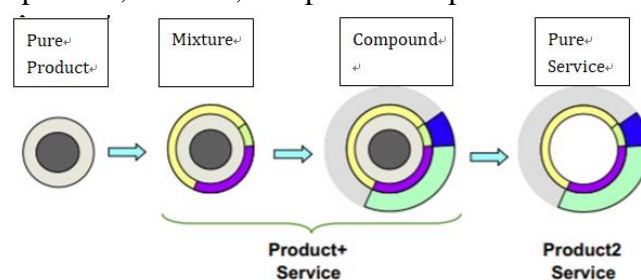


Figure 10 Categories of value proposition (modified from Thoben et al, 2001; Chen, 2015)

3.3.2 Organization Dimension

The second question refers to who supports value proposition? “Who” represents the organization dimension: value proposition is addressed by the collaboration of customer and provider. However, nowadays, the concept of provider keeps evolving, from a single company before to a collaborative network nowadays. It is necessary to clarify different categories of organizations mainly because the PSS solution design

and development methodologies as well as value co-creation processes and activities will be widely different under different network conditions.

The second dimension is also called organization dimension, still there are mainly four categories in this dimension. The first one is *single company*: a commonly used method for this kind of organization to fulfil servitization transformation is to change the business model, for instance, from only selling products to renting its products to customers. Second category is called *broker-centered network* (derived from Guan et al., 2017), which is commonly used by big companies who has large amounts of capitals, resources and skills etc. In this case, we can assume that, when there appears an opportunity on the market, a big company find it and try to develop a PSS solution. However, this company maybe also need the other companies help when taking efficiency, cost or lacking skills into consideration, so he selects partners and suppliers and create a new collaborative networked organization. Considering the temporary feature of the organization, we can categorize it into virtual enterprise (Camarinha-Matos et al, 2009). By this way, the big company is both the broker and the leader of the collaborative networked organization, because he not only is responsible for the creation of the virtual enterprise but also will be responsible for the main businesses in this network. The third one is called *coordinator-centered network*. This case is different from the second one. This case is more suitable for small and medium companies. Thanks to the limitation of their capitals, resources and skills, they will often collaborate with others to form a virtual enterprise in order to provide more differentiated offerings to their customers and enhance their company advantage. In this case, when an opportunity appears on the market, it may be found and captured by some small and medium company, and then he will discuss with his virtual enterprise members to develop PSS solutions. During this period, they maybe also find that they still lack other skills, resources, and they will also select new partners and collaborate with them to form a new virtual enterprise. In this case, they need to select a new leader to coordinate the new network members and to be charge of the main businesses. The last category is called *platform-based network*. This is a new form emerging in recent years. For example, Apple build an app store and provider variety of services based on this platform, also there are also other game companies developing phone games based on this platform.

Hence, the four categories of organization dimension are single company, broker-centered network, coordinator-centered network and platform-based network.

3.3.3 Customization Degree Dimension

Last two dimensions have introduced what to propose to customers in a COPSS and who will do this, the last problem is how to fulfill it. This section intends to adopt mass customization methodology into typology to deal with the last problem.

Mass customization as a solution for COPSS design

Customers usually purchase some product or service according to a series of value criteria. Walters and Lancaster (1999) have tried to define a customer value criterion as

“an attribute (or characteristic) of a product or service considered by a purchaser to be the primary reason for selecting a specific product (or service) because it enhances the value of the purchaser’s output (B2B scales) or improves their lifestyle (B2C scales)”. Traditionally, this kind of criteria consists of price, quality, delivery, technical attributes, product variety, new products, flexible volume, design, brand name, services, and customization (Squire et al, 2004). Nowadays, since customers also pay more attention to their involvement in the solution development, the experience during design and production processes etc. might be also a criterion. However, when a customer has purchased a new product-service offering, he/she will always measure whether he/she is satisfied with the perceived value. As Zeithaml (1988) stated, “perceived value is the consumer’s overall assessment of utility of a product based on perceptions of what is received and what is given.” By this way, perceived value essentially is the trade-off between benefits and sacrifices rather than only benefits (Zeithaml, 1988; Squire et al, 2004). Thus, on one hand, mass production theory is not good enough because it could reduce the lead time and prices, but may lose the quality, product variety etc. On the other hand, customization theory may increase the perceived benefits of an offering, such as customized products and services, flexible volumes, quality etc. however, in turn it may increase the sacrifices, such as response time and prices, etc.

Under this condition, the concept of “mass customization” emerged, which targeted on reducing the sacrifices. The term of “mass customization” was coined by David (1987), who stated that “the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously treated individually as in the customized markets of pre-industrial economies”. Later developed by Pine (1993), who defined it as “developing, producing, marketing and delivering affordable goods and services with enough variety and customization that early everyone finds exactly what they want”. Tseng and Jiao (2001) proposed a more detailed and pragmatic definition which indicated mass customization can be regarded as “the technologies and systems to deliver goods and services that meet individual customers’ needs with near mass production efficiencies”. More recently, Salvador et al. (2009) defined mass customization as “a process for aligning an organization with its customers’ needs”. Osorio et al. (2014) indicated that mass customization uses flexible design processes and manufacturing systems to produce a variety of customized products at a lower cost than standardized mass production systems; it can provide customers with products capable to fulfil most of their individual needs. To sum up, during the last three decades, researchers and practitioners are aware of that customers’ demands are more heterogeneous and rapidly changing than before. Accordingly, manufacturers and service providers should spare more efforts achieving customized offerings, and at the same time guarantee high production efficiency, short lead time, good quality, and high customer satisfaction. In this way, mass customization could be an approach to address these challenges, which also may be an appropriate methodology for PSS design, as Elgammal et al. (2017) advocated mass customization could be a new paradigm for product-service system development.

Mass customization could be a new paradigm for PSS development since it provides the opportunity to achieve mass customized offerings with high production efficiency, high quality, short lead time and high customer satisfaction.

The following Table 11 deploys the key properties of mass customization; this Table is derived from (Chen et al., 2009 & Tseng et al., 2017) with slight modifications:

Table 11 Basic properties of mass customization methodology

Perspectives	Mass customization methodology
Goal	Delivering affordable goods and services with enough variety and customization that every one finds nearly what they want
Focus	Variety and customization through flexibility and responsiveness
Product-service Offering	Standardized and customized product and service modules are assembled based on customer needs
Key features	Unpredictable demand pattern Heterogeneous niches Integrated products and services Agile development cycles Agile PSS lifecycles
Network	Flexible, adaptive and competitive network
Customer involvement	Customer involvement should cover whole PSS lifecycle in order to meet their requirements with efficiency and effectiveness.
Sustainability	Economics: economies of scale and customer integration Society: undertake more corporate social responsibility Environment: dematerialization etc.

- a) In order to conform to the thesis concept, “product-service offering” is adopted instead of “product”, since the concept of “product” has an ambiguity in the original Table. Besides, service processes modules are also included in the offering construction.
- b) Agile development cycles and agile PSS lifecycles could be more appropriate and short, since the heterogeneous and continuously changing requirements, as well as the reconfiguration of network resources will result in continuous and consistent agility loop during the whole lifecycles. For instance, Tsigkas et al. (2009) have tried to integrate mass customization with agility and lean methodology to propose new solution for manufactures designing processes from design to distribution.
- c) Sustainability is a new concern of mass customization in recent years. Sakao and Fargnoli (2006) proposed a general scheme of the augmented eco-design flow which integrated mass customization in it, in which they advocated that mass customization technologies have the potential to support product modularization or product family organization. Brunø et al. (2013) identified the relations between mass customization and sustainability in detail. What’s more, Osorio et al. (2014) proposed a series of guidelines for the “design for sustainable mass customization”

integrated DFX guidelines and design requirements.

Customization degree dimension

Customer-oriented PSS focuses on the system functions. The best solution should contain all the necessary functions without any redundancy and overlap, so that the objective of satisfying customers with least efforts can be achieved, and both providers and customers can benefit more from the solution. Hence, functional hierarchy modeling (FHM) is needed here to identify the most reasonable functions combinations. The Figure 11 demonstrates the PSS functions decomposition and modularization logic, which mainly modified from “main decomposition logic with in functional hierarchy modeling (Ostaeyen et al., 2013)” and “PSS modularization using functional requirements (Sun et al., 2017)”.

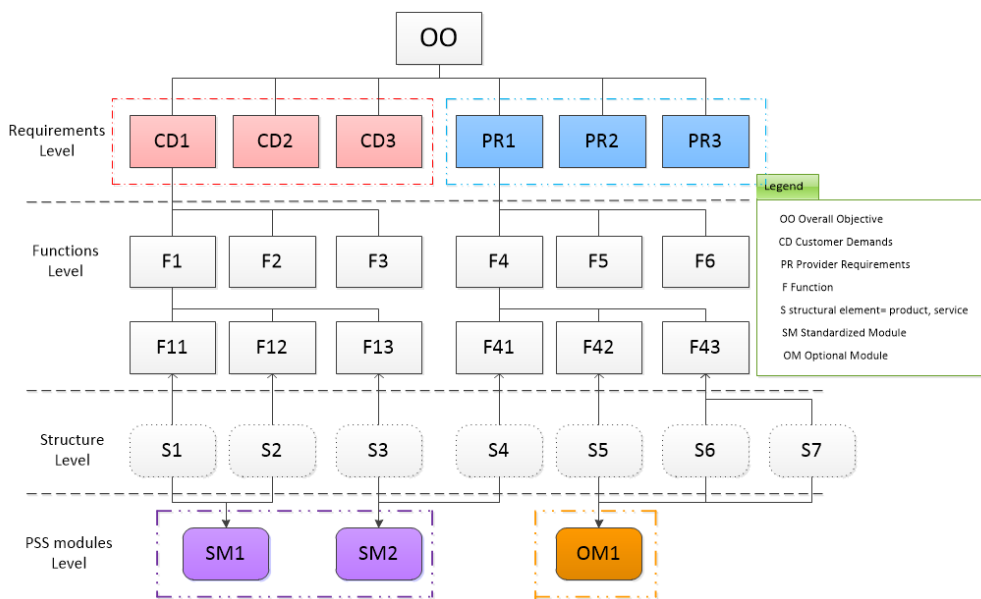


Figure 11 PSS function decomposition and modularization logic

The hierarchy model consists of three levels in (Ostaeyen et al., 2013): customer demands level, functions level and structure level. In my research, the hierarchy model is expanded to four levels. The *customer demands level* is updated into requirements level. Another constituent part of requirements level is called provider requirements. The overall objective will be addressed according to customer demands and providers’ technical requirements. On one side, customer demands highlight the main job to be done by the system and the main reason why the customer uses it (Ostaeyen et al., 2013). On the other side, providers need to push their new knowledge or technologies to their customers or have their own special constraints according to the solution; they will have their own requirements. The second level is the *functions level*. Functions are decomposed corresponding to the relevant requirement. The third level is the *structure level*, which contains products and services. These product and service elements will contribute to realize a higher-level function. The last level is the *PSS module level*. Different structural elements (product structure and service activity (Sun et al., 2017) will be combined to be a PSS

module.

Thus, when combining these PSS modules together to form new product-service offerings, there will be amounts of combination cases according to customers' requirements as well as providers' solutions. Some of them are standardized and some are customized. In this way, four levels of customization can be defined: fully standardized, mostly standardized, mostly customized and fully customized (derived from Kellogg& Nie, 1995). **Fully standardized** means almost all the PSS modules are standardized, and customer has little or none discretion in defining the how, what or where of the PSS solution; **mostly standardized** means majority of PSS modules are standardized, the customer can select from only a limited number of module options; **mostly customized** means some PSS modules are standardized, while the customer has considerable discretion in selecting from a wide menu of options; **fully customized** means almost all the PSS modules are customized, the customer has considerable discretion in defining the how, what and where of the PSS solution.

3.3.4 Integration of three dimensions

Until now, all the three dimensions of reference typology have been identified. Figure 12 shows the final reference typology toward the design of COPSS, in which the **horizontal axis** represents value proposition dimension which is categorized into pure product, mixture, compound and pure service; the **vertical axis** represents the customization degree dimension which is categorized into fully standardized, mostly standardized, mostly customized and fully customized; and the **last axis** represents the organization dimension which is categorized into single company, broker-centered network, coordinator-centered network and platform-based network. These categories segment the whole cube into 64 small cubes. Each one will own its proper three attributes. The final reference typology tries to completely answer the problems defined at the beginning. Predictably, this typology can be utilized to categorize for the future product service systems since more and more PSSs are paying attention to customers' importance and customers' value.

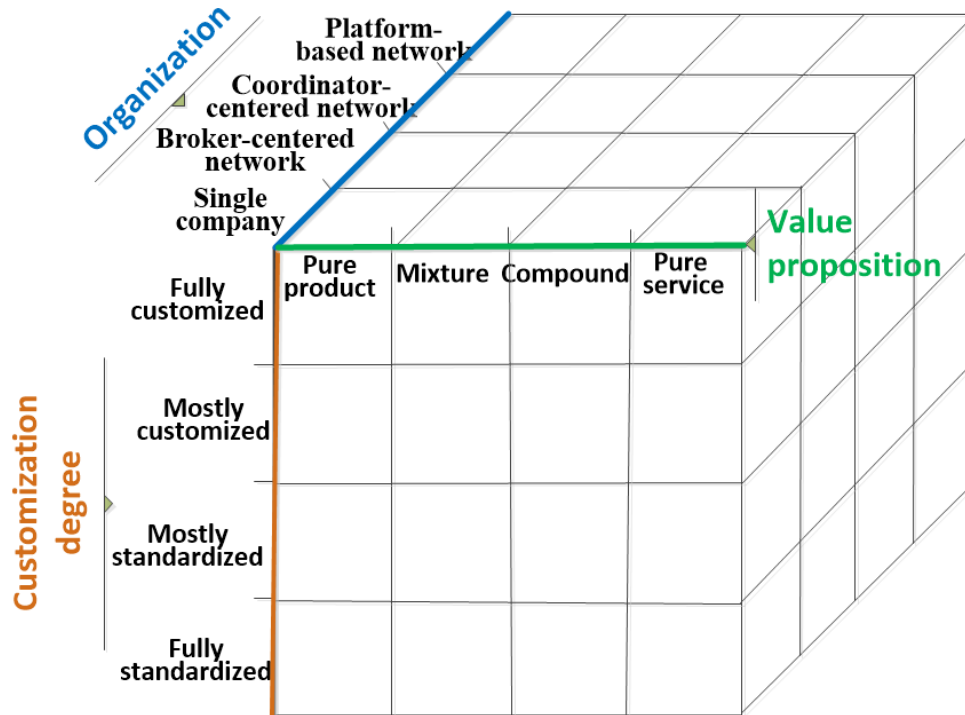


Figure 12 Reference typology toward design of customer-oriented PSSs

4 Conclusion

In this Chapter, two significant tasks have been fulfilled to prepare the COPSS design framework proposal. It is the first review work which is dedicated to customer-oriented PSS. This review work can lay the foundation of COPSS research. The second one is to consider COPSS typology. The typology provides a guide for designers and companies considering the three main dimensions when proposing COPSS solutions: (1) what kind of offering they could provide for stakeholders in the system; (2) who are able to involve in the supporting network in order to provide variety of knowledge, capabilities and resources and (3) to what extent they could provide the customized offerings to their customers in order to satisfy customers and their own needs. In next Chapter, the work will go on researching on customer-oriented PSS and try to propose a general framework to help design Customer-Oriented PSSs.

Chapter3. An Integrated COPSS Design Framework from Three-Dimensional Concurrent Engineering (3DCE) perspective

1 New framework requirements

1.1 new requirement analysis

In the previous Chapter, the basic concept of COPSS as well as its key findings has been explicated. What's more, a new typology toward the design of customer-oriented PSSs has been proposed that is used to both characterize the existing and future COPSSs and be a guide for designers to help them design appropriate PSS solutions. Three dimensions of the new typology show what customer-oriented PSSs should be; respectively are value proposition dimension, organization dimension and customization degree dimension. Since our research aims at the evolution of traditional manufacturing industries to servitization industries, the final Product Service Offerings (PSOs) will focus on mixture and compound that are the combinations of physical products and services. Additionally, due to mass customization's advantages of higher production efficiency, high quality, short lead time and high customer satisfaction, the PSOs design will be supported by mass customization; hence we focus on solutions that are mostly standardized degree, mostly customized degree and fully customized degree. Moreover, mass customization need a series of new supporting processes that are executed by a collaborative network, obviously a single company is hard to fulfill these tasks. Thus, our research will find a solution for companies to work in a collaborative and cooperative environment. In this way, the broker-centered network, coordinator-centered network and platform-based network will be selected. To conclude, from the viewpoint of this new typology, the final designed outcome should be an appropriate PSS solution including PS offerings, value co-creation processes in some customized degree and a supporting network rather than only the PS offering before (Figure 13).

According to the illustration of the previous Chapters, we can conclude that the objective of this thesis is to build a framework for the collaborative design of COPSS involving in particular composite services in a usage-driven perspective. When adhering to the customer orientation principle, customers' requirements should come first, which means that the framework should be able to well analyze and integrate customers' requirements into PSS solution design. Additionally, this framework is also dedicated to achieving a sustainable development of PSS which is able to take environmental and social aspects into consideration. Finally, good communication and interaction is also a primary concern in a product service system, since a system is in particular composed of a set of stakeholders interacting together.

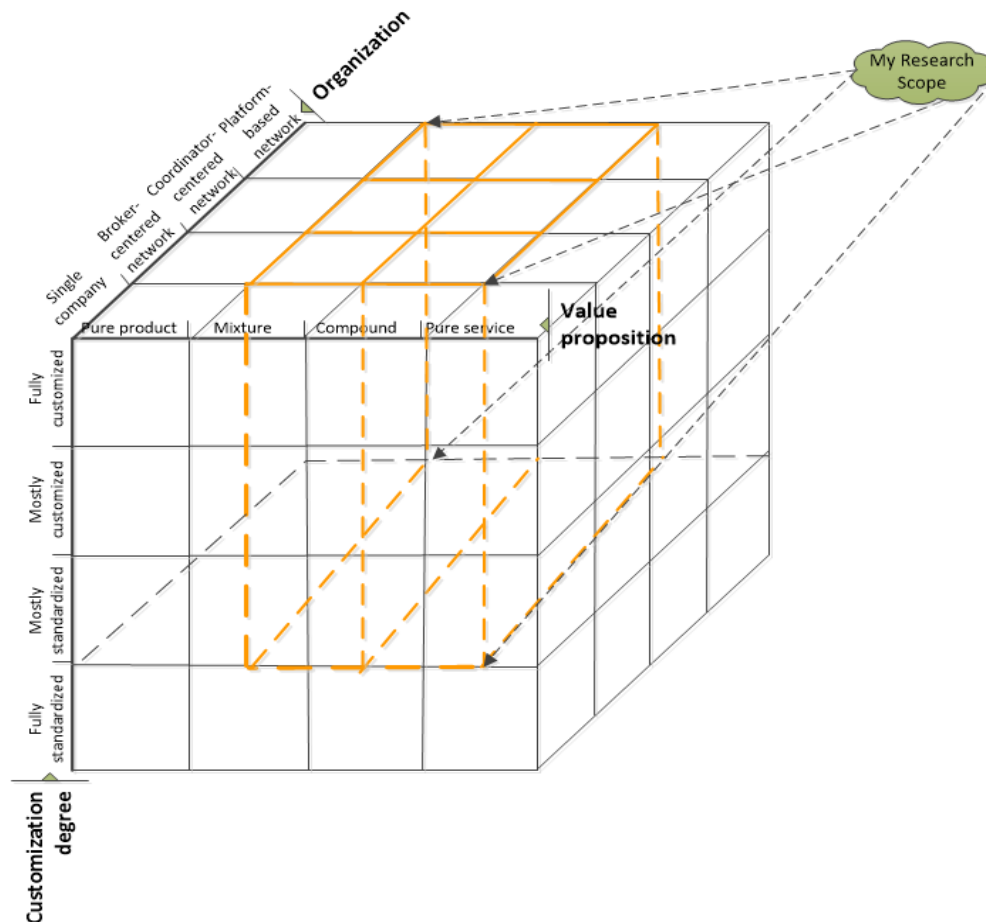


Figure 13 Research scope based on new typology

After overall considerations, the framework should cover the following aspects:

A1- customer orientation: the first and most significant framework requirement concerns **customer requirement analysis (A11)**. The framework should be able to deeply understand the customers' requirements and interpret them into design specifications. Previously, majority of PSS solutions actually are driven and pushed by providers, so that their new technologies or knowledge can be transferred to the customers. However, this is not enough for modern businesses. From the point of customers, this way may lead to a lot of useless and redundant functions in the provided solutions. These functions mean more useless modules in a product service offering, which will lead to more cost when buying products or services. Obviously, customers are reluctant to spare more money to buy useless function components.

Secondly, as mentioned in the findings of COPSS, modern COPSS advocate **deeper customer involvements (A12)** along PSS lifecycle. Customers' activities should be involved into the PSS design. Customers now are value co-creators rather than only value receivers than before. Customers now play more important roles than before. They can play the roles of co-ideator, co-designer, co-tester, co-producer, co-distributor, co-consumer, etc. (Agrawal & Rahman, 2015). This is also why the business models are transforming from "value in exchange" to "value in use".

Last, customer satisfaction assessment (A13) should be integrated during new PSS

solution design. The final PSS offerings should be able to satisfy customers. High customer satisfaction degree and high loyalty should be the real target of a PSS solution. In order to fulfill this target, customer satisfaction assessment can be a good way to optimize the final solutions since there are a variety of solution scenarios during design processes.

A2-integrated design: integrated design is not only the integration of products and services in the thesis. Integrated design in this framework indeed has a deeper meaning. PSS offering design actually only occupies one-third in the whole PSS design. What we should keep in mind is that the integrated design also contains the Value Co-Creation Processes (VCCPs) design and supporting network design. Integrated design also means the strong connection and interactions between these three design activities as well as decisions among them. VCCPs mainly consist of ideation processes, design processes, production processes, delivery processes, usage processes as well as recycling processes and innovation processes. In terms of collaborative networks design, this thesis tries to integrate virtual enterprise concepts mainly because of PSS's perishability characteristic. Virtual enterprise as a company set shows more flexibility, efficiency and effectiveness as illustrated in Chapter 1; therefore the thesis chooses the Virtual Enterprise (VE) as the main manifestation of supporting network. From now on, the VE will be used instead of supporting network. Hence, in this framework, integrated design is the **integration of PS offerings (PSOs), Value Co-Creation Processes (VCCPs) and Virtual Enterprise (VE) (A21)**.

Additionally, engineering design is the process of developing a system, a component or a procedure to meet desired needs. **Design For eXcellence (DFX) (A22)** research emphasized the consideration of all design goals and related constraints in the early design (Osorio et al, 2014), such as design for quality, design for testing, design for production, design for virtual enterprise, design for recycling, etc. DFX guidelines implementation have led to enormous benefits including simplification of products, reduction of assembly and manufacturing costs, improvement of quality, reduction of response time, etc. (Osorio et al., 2014).

At the same time, due to the vague and changing customers' requirements and market trends, the design should be able to quick respond to customers' changes; also, when customers are not satisfied with the solution after testing, the design should be able to be refined in a short time. In this way, **agility management (A23)** could be appropriate methodology to support PSS design.

A3-Customer-provider satisfaction trade-off: the customer-oriented framework should be dedicated to satisfy customers' requirements as much as possible. However, the providers' satisfaction shouldn't be ignored. On the one hand, providers' requirements, such as market responsiveness and sustainability should be satisfied. Especially, sustainability is nowadays accepted as a guiding principle for achieving highly competitive solutions and creating added value (Peruzzini et al., 2013). Sustainability includes three dimensions: economical viewpoint aims at reducing lifecycle cost and creating new market potentials and higher profits; ecological viewpoint aims at reducing environmental impacts along lifecycle; while social viewpoint aims at creating more jobs and geographical benefits. All these should be

assessed along PSS lifecycle phases. That is **sustainability assessment (A31)**. On the other hand, the framework should find appropriate methodologies and techniques to: (1) support requirements engineering, (2) design high-quality product service offerings (PSOs), (3) involve the customers into PSS lifecycle design (LCD) and (4) assess customer satisfaction, so that the framework is able to well serve the customers. Indeed, we all try to find a solution to satisfy both providers and customers. However, when encountering conflicts, it is the **customer-provider satisfaction trade-off (A32)** that should be done by the stakeholders according to their strategies.

Based on the abovementioned factors, this paper makes a literature review of existing PSS design related frameworks. We filtered the articles found in the second Chapter to see if they cope with the above-mentioned aspects. Finally, only 16 frameworks are exhibited in the following Table, mainly because these frameworks are more relevant to PSS design or service engineering, and they are more completed and trying to cover more critical aspects during design process while dealing with their problems. For instance, 3 articles are eliminated because of lower relevance since they propose the frameworks on product-service lifecycle management to support PSS design; another 3 articles are also eliminated because they are only focusing on the knowledge integration or management during PSS design.

We analysed the selected 16 articles according to the following measurement metrics: A1 Customer orientation (including A11-customer requirements analysis, A12-deeper customer involvements, and A13-customer satisfaction assessment), A2 Integrated design (including A21 PSOs-VCCPs-VE design, A22 Design for X and A23 Agile management), and A3 customer-provider satisfaction trade-off (including A31-sustainability assessment, A32-customer-provider satisfaction trade-off), exhibited in Table 12.

Table 12 Measurement Table of existing frameworks

References	Framework target	Measurement Metrics							
		A1-Customer orientation			A2-Integrated design			A3-satisfaction trade-off	
		A11	A22	A33	A21	A22	A23	A31	A32
Resta et al., 2015	Analyze PSS operations with lean thinking	☒	☒			☒			
Azevedo, 2015	Integrate lean accounting into IPS2 costing system		☒					☒	
Vijaykumar et al., 2013	Better satisfy customers' requirements using capability-based design framework	☒	☒			☒		☒	
Hussain et al., 2012	Support PSS conceptual design using system-in-use data	☒		☒		☒			

Andriankaja et al., 2016	Integrate Extended Functional Analysis Approach into PSS design	<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>			
Wu & Wu, 2010	Propose an interdisciplinary framework to help recognize SSME tools and theories	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>			
Alter, 2008	Propose three service fundamental systems	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>						
Kimita et al., 2015	Identify the roles and their relations in a PSS		<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>			
Pezzotta et al., 2015	Propose a design and simulation framework for product-service design	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Abramovici et al., 2014	Facilitate sustainability assessment and monitoring using PSS-SAM framework					<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Rondini et al., 2014	Integrate Discrete Event Simulations into SEEM to assess PS offering performance	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Zine et al., 2014	Discuss value co-creation through customization and personalization in a hybrid PSS model	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
Song & Sakao, 2017	Propose a customization-oriented framework to design sustainable PSS	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
Schmidt et al., 2015	Propose a three-layer customer-oriented framework to increase customer acceptance	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>			
Tran & Park, 2015	Propose a prototyping framework to improve the perceived value	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>			
Song et al., 2015	Support PSS innovation management using an integrative framework	<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	

Finally we find that four elements are missing in existing frameworks:

- None of them realizes that PS offerings, processes, and supported network should be designed as a whole. (A21)

-
- Short lead time is a critical requirement when design a PSS solution. Few frameworks pay attention to it. (A23)
 - Customer satisfaction and provider satisfaction should be balanced according to companies' strategies. (A32)
 - Customer involvements should not be limited into requirements inputs, testing, receiving and using the offerings and some feedbacks. However, majority of existing frameworks also ignore the increasing importance of customers. (A13)

In order to bridge these gaps, the thesis intends to propose a new general design framework for COPSS dedicated to address PSS solutions with short lead time, less environmental impacts and high customer and provider satisfactions. It is worth mentioning here that a good COPSS solution is an integrated design scenario of Product Service Offering with its supporting Value Co-Creation Processes and supporting Virtual Enterprise. This following section will illustrate the way of thinking to form the framework.

1.2 Holistic design logic

According to the thinking of a new framework and lacking points of existing frameworks, this section summarizes the holistic design logic in order to satisfy the necessary requirements exhibited in the previous section, as shown in Figure 14.

According to the Figure 14, all the new framework requirements will be addressed in the following Chapter 3 and Chapter 4. The explanation will start from the three key design activities for **PSOs, VCCPs and VE** since it is the most critical part of the new framework. Hence, in order to explicate the **PSOs-VCCPs-VE integrated design (A21)** clearly, in Chapter 3, three steps are necessary. The contents will start from the basic introduction of the three key activities from concurrent engineering perspective; then the detailed design processes for each design activity will be illustrated, as well as the methodologies, techniques and tools to fulfil these processes; finally, the deeper interactions and communications among the three activities in a Three-Dimensional Concurrent Engineering (3DCE) logic will be analysed. By the way, the **customer requirements analysis (A11)** can be done during the PSOs design process. Further on, during COPSS design activities, customers' and providers' requirements, values and their satisfaction are always affecting the design progressing; therefore the final solution may change according to these changes. Hence, the thesis proposes a model for COPSS design based on Customer-Provider Satisfaction Trade-off so that the designers are able to optimize the final solutions according to these changes. Once all these work have been done, the final integrated design framework based on 3DCE approach could come out.

However, only proposing a new framework is not enough; we expect that the proposed framework could do better such as reducing risks and uncertainties, gaining more customer satisfaction, being more sustainable and responding more quickly; hence, in Chapter 4, the thesis proposed the stakeholder-driven lifecycle models, together with VE modelling method based on AGORA multi-agent architecture to satisfy **Design for X (A22)** and **Deeper customer involvement (A12)**. What's more, **agile management (A23)**, particularly the SCRUM management methodology is

introduced and further developed based on the AGORA multi-agent architecture so that the VE can perform more effectively and efficiently. Finally, the Customer Satisfaction Index (CSI) and PSS Sustainability Assessment (SA) are adopted in the thesis in order to supplement the knowledge of COPSS design cycle based on Customer-Provider Satisfaction Trade-off in Chapter 3, so that the requirements of “Customer satisfaction assessment (A13)”, “Sustainability Assessment (A31)” and “Customer –provider satisfaction trade-off (A32)” can be completely satisfied.

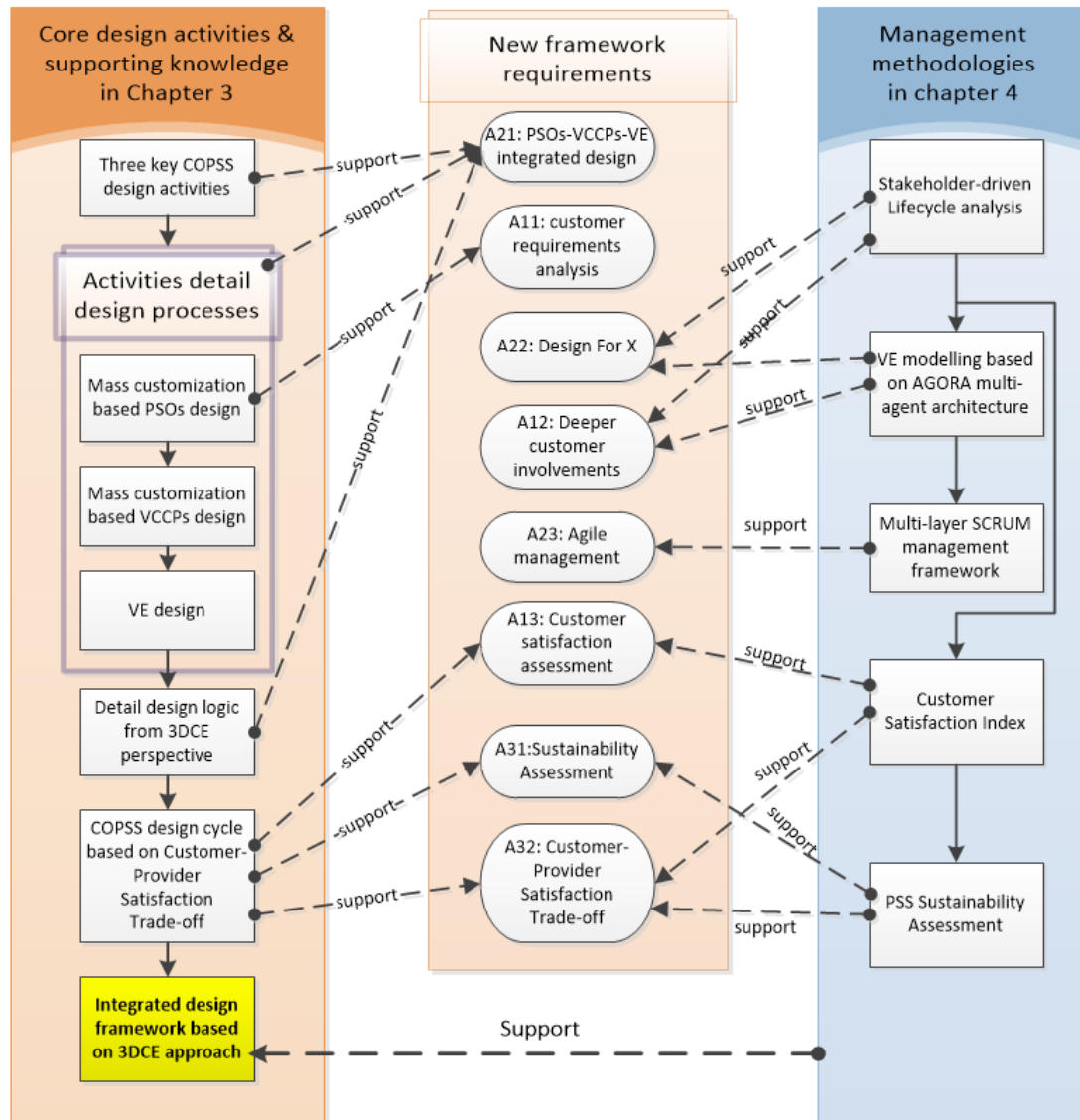


Figure 14 holistic design logic

2. Three key activities for COPSS design

As analyzed above in the framework literature review, existing PSS design framework usually focus on the combinations of products and services (PSOs design), some of them integrates the supporting processes into the offering design; but, few of them achieve the supporting network design at the same time in order to support the PSOs design and processes design. In this section, the reasons why the supporting

network is significant and cannot be ignored during PSS design illustrated. Under this background, an enhanced concurrent engineering methodology called “Three-Dimensional Concurrent Engineering” is introduced in here to deal with supporting network design.

2.1 Three key design activities from 3DCE perspective

2.1.1 The notion of 3DCE

Traditional Concurrent Engineering, as shown in Figure 15, is a way of working where the various engineering activities in the product and production development process are integrated and performed as much as possible in parallel rather than in sequence (Sohlenius, 1992). In this way, Concurrent Engineering is able to increase the competitiveness by decreasing the lead-time and cost while still improving quality. “3DCE” is three-dimensional concurrent engineering. This concept was firstly proposed in 1998 by Fine. The author argued that the design of the supply chain should also be taken into consideration while traditional concurrent engineering only focus on the parallel communication between product design and processes design. This notion has been widely recognized during the past two decades in the product design field. However, this is ignored in the PSS design field. 3DCE shows more competitive advantage than traditional concurrent engineering. As Fine indicated “when firms do not explicitly acknowledge and manage supply chain design and engineering as a concurrent activity to product and process design and engineering, they often encounter problems late in product development or with manufacturing launch, logistical support, quality control, and production costs...”. Ellram et al. (2007) also proved that there is a substantial theoretical grounding for 3DCE and evidence that it should provide beneficial outcomes to organizations. Other researchers (Pulkkinen & Riitahuhta, 2008; Marsillac & Roh, 2014) also indicated that 3DCE may provide an opportunity to improve performance and to address variety of challenges, such as issues with environment and resources, trade-offs between high quality and short lead time, haphazard conflicts when integrating supply chain into well-developed products-processes, etc. Matopoulos et al. (2015) also argued that 3DCE could be also a very useful tool to improve resource efficiency and resource utilization.

The Figure 15 shows the 3DCE mapping from the product design field (upper side, derived from Ellram et al, 2007) to PSS design field (lower side). Product is transformed into product service offering (PSO), which is a solution of combination of products and services. During PSOs design, according to customers’ requirements and providers’ design specifications, the designers are dedicated to satisfy customers with high-quality offerings; Processes are transformed into value co-creation processes (VCCPs). VCCPs, in this context, not only contain traditional testing, manufacturing, production, delivery, utilization and recycle, but also contain the requirement engineering, even concept design and detail design. VCCPs refer to all the stakeholders in the system; they need to fulfill their own responsibilities according to their knowledge, resources, business processes etc. What’s more, sometimes they also need to share these with other stakeholders to make the collaborations more

effective and efficient. Certainly, the customers may involve into all these processes. And last, all these knowledge, resources and business processes come from collaborative networks. In this thesis, traditional supply chain is transformed into VE.

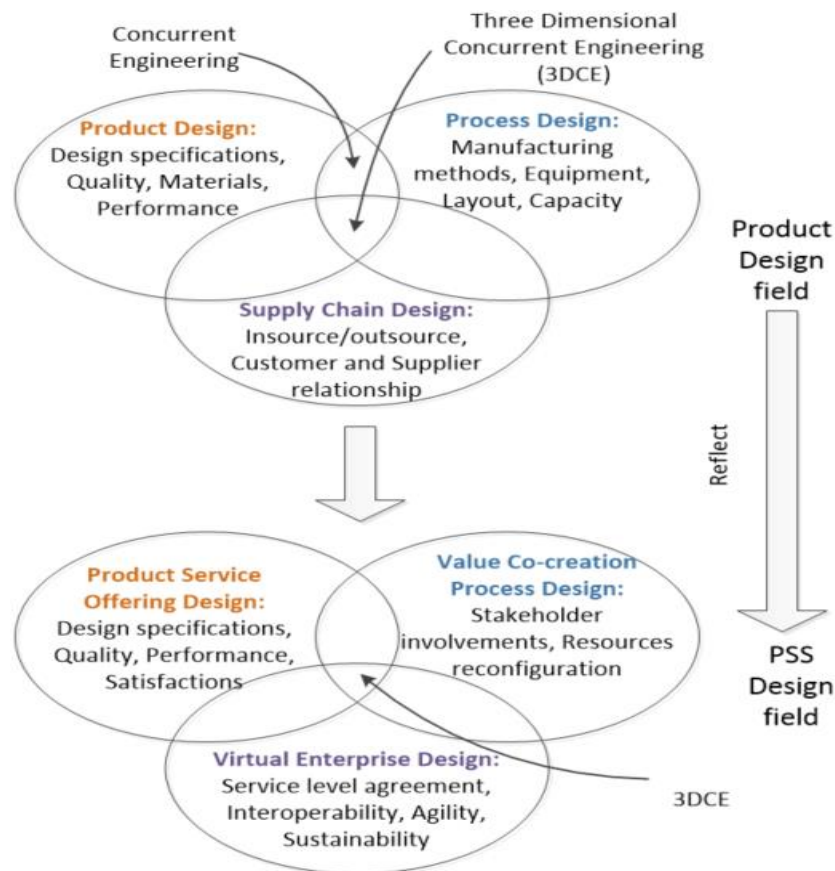


Figure 15 3DCE mapping from product design to PSS design

2.1.2 Introduction to the key design activities

Figure 16 displays a visualized comparison between sequence engineering and concurrent engineering. The core information is shown in the concurrent engineering layer. This Figure is developed based on IDEF 0, with some new icons. The three key activities in COPSS design are modeled; respectively are **Product Service Offering Co-design (A1)**, **Value Co-Creation Processes Co-design (A2)** and **Virtual Enterprise Design (A3)**. The design begins from PSOs requirements engineering. The market department collects customer requirements as well as other stakeholders' requirements (e.g., the kernel companies and supporter organizations' technique innovation requirements and knowledge integration) and sends them to the design department. The design department will analyze these requirements and decompose these requirements into PSOs functions. These functions later will be addressed by different product modules and service process modules (the module related knowledge refers to modularization, which will be explicated in the following section). After combining different modules, different PSOs scenarios will come out. VCCPs design starts when the decomposing function task has been fulfilled; VE design starts when PSOs designers start to identify corresponding modules to address the functions,

shown as the input of VCCPs design and VE design in Figure 16.

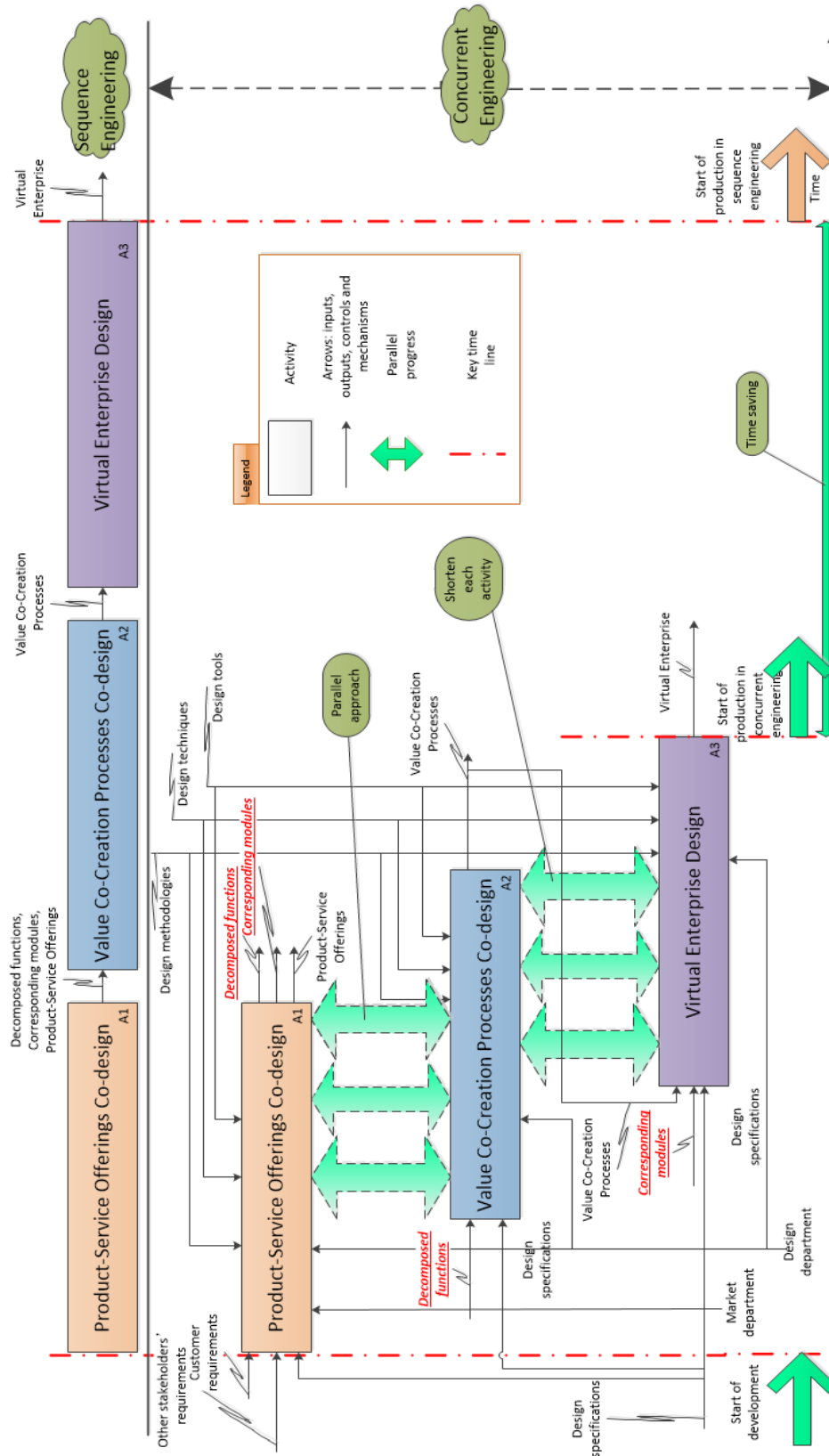


Figure 16 Key design activities from Concurrent Engineering perspective

By adopting concurrent thinking, the time spent on design processes has been

shortened due to the parallel approach among different activities. If this is extended to later production processes etc. Much more time will be saved, so that the responding time can be shortened. In this way, in a given time duration, several iterations of PSO development can be done, which may lead to high PSO quality. What's more, in concurrent engineering, communications and interactions between different processes will be more often and more effective, the PSO quality in this way can be promoted.

2.2 Detailed design processes for each activity

Previous two sections have achieved a general understanding of the three design activities from a concurrent engineering perspective. This section will decompose the three activities and integrate the design methodologies, techniques and tools in order to complete the detailed design processes. As mentioned in Chapter 2, the core methodology used in the thesis to enhance productivity and customer satisfaction with high-quality offering in a short lead time is Mass Customization as well as the modularization method. Hence, in this section, the way of using mass customization will be illustrated at first. Then, the detailed design processes of PSOs and VCCPs could be easily understood. In terms of VE design, the thesis will introduce the AGORA multi-agent architecture to deal with VE modelling.

2.2.1 Mass customization and modularization

In Chapter 2, a general understanding of mass customization was proposed. Additionally, customization has been chosen as one dimension of COPSS typology cube. Further on, to support the paradigm shift derived by the customization process, the companies should consider the entire chain to leverage upon three pillars: time-to-market, variety, and economy of scale (Osorio et al., 2014; Tseng et al., 2017). Many researchers spare their efforts to conclude the solutions to achieve the balances between the three aspects. Osorio et al. (2014) identified four challenges of mass customization; respectively are product parts reusability design, product platform development, process platform development, and integrated product lifecycle modelling. Tseng et al. (2017) indicated that “design for mass customization” should take the following aspects into consideration: customer, functional, physical, process and logistics. They also emphasized the importance of understanding customers’ needs and modularity & product family architecture. Hora et al. (2016) also summarized four basic mass customization enablers: co-creation, modularity, build-to-order & postponement, and platform. What's more, Salvador et al. (2009) clarified three fundamental capabilities for a company to customize his offerings, which was further used on Adidas case by Piller (2012); the three capabilities include *solution space development*-identify the product attributes along which customer needs mostly diverge, *robust process design*-reuse or recombine existing organizational and value chain resources to fulfil a stream of differentiated customers’ needs, and *choice navigation*-support the customers in identifying their own solutions, while minimizing complexity and the burden of choice.

According to the theories above, we can conclude that modularization is the key

technology to address mass customization. Both Product platform & process platform (Osorio et al., 2014) and modularity & product family architecture (Hora et al., 2016; Tseng et al., 2017) have advocated the importance of modularity.

Indeed, the PSS design processes in this thesis includes two steps. The first step is modularization (Figure 17) which aims at fulfilling product-service system decomposition and composition. The second step is to develop simultaneously the whole design processes for PSOs, VCCPs and VE.

For the first step, a large number of relevant articles could be found to address product and service modularization. Hence, in this thesis, what is necessary is to make a brief introduction to the modularization concept and the techniques to address modularization. As shown in Figure 17, the target of modularization is to reconfigure the system and decompose the system into product modules, service process modules and VCCPs modules, in order to conform to mass-customization. The second step is design integrated PSOs-VCCPs-VE scenario based on the results of modularization in the first step based on some design techniques and methodologies.

In this section, several points will be addressed according to the literature review: the benefits of modularization, the concept of product and service modularization, and the methods and tools for achieving modularization.

Modularization has been recognized as one of the most useful means to standardize product-service production, provide customized services and thus, achieve better customer value and profitability (Wang et al, 2011). Sun et al (2017) also indicated that modularization can not only improves the response speed of PSS and consequently meet individual requirements, but also greatly improve stakeholders' profits, including customer, manufacture, servicer, environment, and so on. Mons et al. (2010) has summarized the following benefits when adopting modularization to decompose complex systems, which is also very beneficial and relevant to PSS decomposition: module task specialization, increased number of product-service variants, economies of scale in component commonality, cost savings in inventory and logistics, lower life cycle through incremental improvements such as upgrade, add-on and adaptations, flexibility in component reuse, outsourcing, system reliability due to high production volume and experience curve, faster assembly and less production time, postponement of operations of differentiation for fast reaction of the market, parallel manufacture of modules, fast development of products and service processes.

The concept of Modularization or Modularity, stemmed from another concept, called "product architecture", which could be considered as a system for which designers have specified (i) the way the overall functionalities of the product or process design are decomposed into individual functional components and (ii) the way in which the individual functional components interact to provide overall functionalities of the system design (Sanchez et al, 1999; Voss et al, 2009). Later, recently, the modularity achieved great development. Modularity refers to the scheme by which interfaces shared among components in a given product architecture are standardized and specified to allow for greater reusability and commonality (or sharing) (Voss et al, 2009).

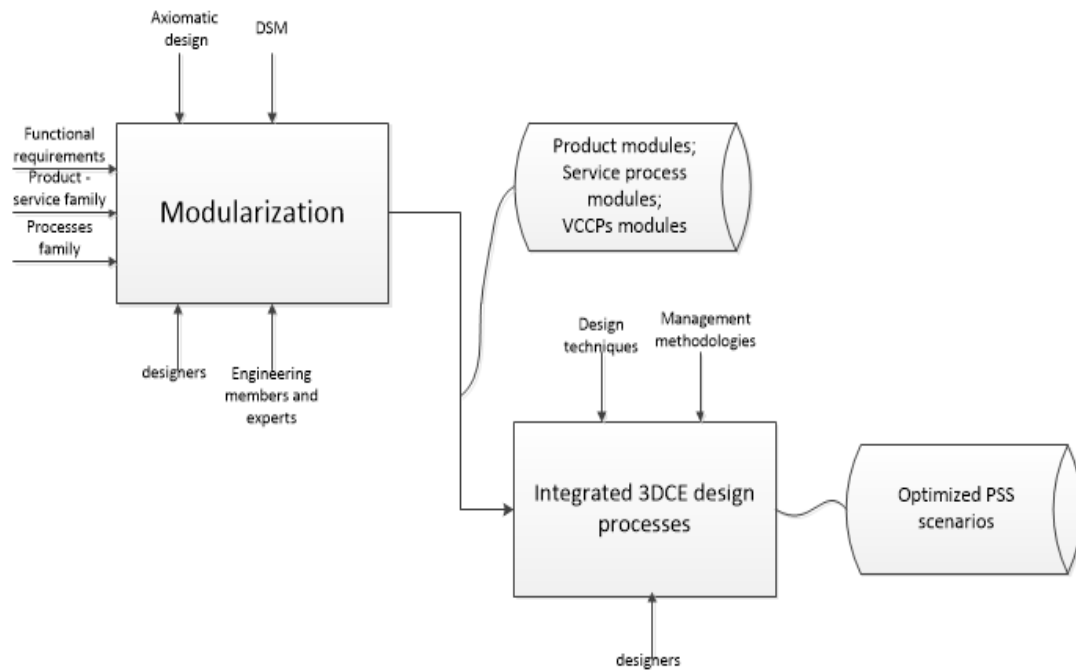


Figure 17 Core modular development processes by IDEF0

The concept of process later is also included in the concept of modularity, so that it's easier to reconfigure system in order to response the market and customers more quickly. Tu et al. (2004) indicated that modular organization of the manufacturing process combines the advantages of standardization and flexibility. Actually, product modularization in some other articles also is called Modular Product Design, and process resequencing is called manufacturing system reconfiguration (Paes et al, 2018). Paes et al. made a literature review for "Modular Product Design" and "Reconfigure Manufacturing System" based on the articles in past two decades. They indicated that modular product design or modularization provides high variety and flexibility with reduced cost (Fisher et al, 1999; Paes et al, 2018). Besides, the reconfigurable manufacturing systems is designed with the purpose of changing faster process architecture structures, as well as their components, in order to make rapid adjustments in production capacity and functionality respond to abrupt variations in market demands or in controlling requirements (Koren et al, 1999; Paes et al, 2018). What's more, they also recommend another concept called Integrated Modular Design (IMD), which aims to design, at the same time, the product and process, thus simultaneously identifying product modules and reconfiguring the manufacturing system to reduce cost and time, whilst improving product variety, efficiency and performance of the overall design process, operation and reconfiguration (Vickery et al, 2016; Paes et al, 2018). This thought conforms to the concept of Concurrent Engineering, which is also advocated in my thesis.

The abovementioned knowledge mainly focuses on product modularization, it's necessary to introduce the service side in a PSS design environment. It's worth noting that despite the different manifestation between product and service (product is tangible and can be intuitively constructed by different function modules, while

service is intangible and is not easy to visualize its construction components), they both play important roles in providing different functions of a PSO. Service has a distinctive characteristic from product: inseparability. Unlike goods, services are simultaneously produced and consumed (Vargo & Lusch, 2004). By this way, services essentially could be regarded as service processes, so that the concept of modular processes can be seen as being equally applicable to service and manufacturing processes (Starr, 2010; Voss et al, 2009). Song et al. 2015 regard service component in the PSS context as “a service activity (such as failure diagnosis) or service resource (e.g., human resources, physical resources and information) that leads to a partial function of the overall product-extension service. Generally, it is defined by a set of processes, operations, people or other objects. Different service components constitute service modules with different functions.” Further on, service module integrates service components with strong interdependencies among each other. This is similar with product module. Lai and Gershenson (2008) ever stated that each product module holds many components, which have a high level of dependency between them, whilst containing minimized dependencies and similarities among other components outside the module. Another common characteristic between product module and service module is that each module performs a unique function or several functions, which means that modularization indeed is a function-oriented design method, in which each module is responsible for executing one or more functions that can be integrated into distinct systems with small changes (Eppinger & Ulrich, 1995). This is also a main reason why this thesis adopts modularization as the core design logic for PSS processes design.

Another important concept of modularity is the interface. The input and output of a module present standardized interfaces which allow different modules to be linked and reused together? (Wang et al, 2011). Because the notion of interface is a set of design parameters describing how two objects mutually interact, this leaves much freedom in terms of the precise definition of the module in different contexts, including services (Salvador, 2007; Voss et al., 2009). Interfaces of PSS mainly include resources (personals, information, and tools), relations of components/ parts/ subassemblies, process interfaces, customer interfaces, specifications of division of labour, rules and so on (Wang et al, 2011).

Product-service modularization is the action of decomposing product service offering (PSO) into product and service components, analysing interdependencies between the products and service components and clustering them into modules to achieve simplification, standardization, customization, flexibility, and reusability (slightly modified according to Song et al, 2015). During last two decades, a large number of relevant articles have proposed different methods and tools to address product modularization or product-service modularization. In terms of product modularization, the literature review made by Paes et al. (2018) displayed several dozens of articles with variety of tools and methods, such as Design Structure Matrix (DSM), Genetic Algorithms, Clustering Analysis, Fuzzy Logic, and Axiomatic Design and so on. Some of these methods are also introduced to PSS design context in later research. A typical and popular method is Design Structure Matrix (DSM) (Browning,

2001; Hong & Park, 2009). DSM captures so much attention because it provides a simple, compact, and visual representation of a complex system that supports innovative solutions to decomposition and integration problems (Browning, 2001). However, DSM has a big limitation, which is that DSM can't consider the relationships between functions and the components of the system, as well as the design flow (Hong & Park, 2009). Thus, they introduced Axiomatic Design method to overcome this problem. Finally they proposed a rational method, merging Axiomatic Design and DSM, to define modules considering relationships between functional requirements and design parameters and interactions of design parameters within.

When it comes to service environment, Ho et al. (2009) developed a methodology to determine the modularization services of business processes which breaks process into modules, or groups of related services based on the observation that a module can be defined as a group of services having high cohesion and low coupling. Yang and Shan (2009) proposed a function relation matrix to define the relationships between the service elements in order to address service process analysis. Voss and Hsuan (2009) proposed a systematic decomposition approach to architecture modelling and service modularity function model to indicate the degree of modularity. Bask et al. (2011) introduce a systematic approach for analysing service modularity and customization, in which service offering, service production process and service production are combined and analysed.

More relevant to PSS context, Wang et al (2011) developed an integrated process of modular development that could be divided into three parts by order: **functional modularization, product modularization and service modularization**. Otto et al. (2012) proposed a new method to design modular products and services, which can lead to more effective insights and suggestions for product and service offers. Song et al. (2015) proposed a Product-Extension Service modularization approach based on modified service blueprint and fuzzy graph aiming at identifying service components and partition modules in the practical context. Sun et al. (2017) proposed a method based on modified clustering algorithm and fuzzy logic, which is able to give a clustering result for classifying PSS into several modules from a new aspect of function requirements.

Indeed, there are also many other articles which proposing different methods and tools to address modularization, the abovementioned ones are the recommended ones in my thesis. In the following section, a series of integrated design processes based on modular development ideology will be explicated.

2.2.2 Integrated 3DCE design processes based on modularization

This section will introduce the second step of modular development and the integrated design processes indeed are the decomposition of the three core design activities in the design framework above-developed. It is worth mentioning here that we are able to decompose existing product-service systems into product modules, service modules and VCCPs modules after last step. The product modules, service modules, interfaces and VCCP modules all could be found in the network repository. Repository here is a container, in which designers are able to find existing product,

service and interface modules, VCCPs modules and their corresponding enterprise members' information and businesses; designers are able to store new developed modules in it, which are prepared for new design and development; designers are also able to store and retrieve variety of data based on the repository; etc.

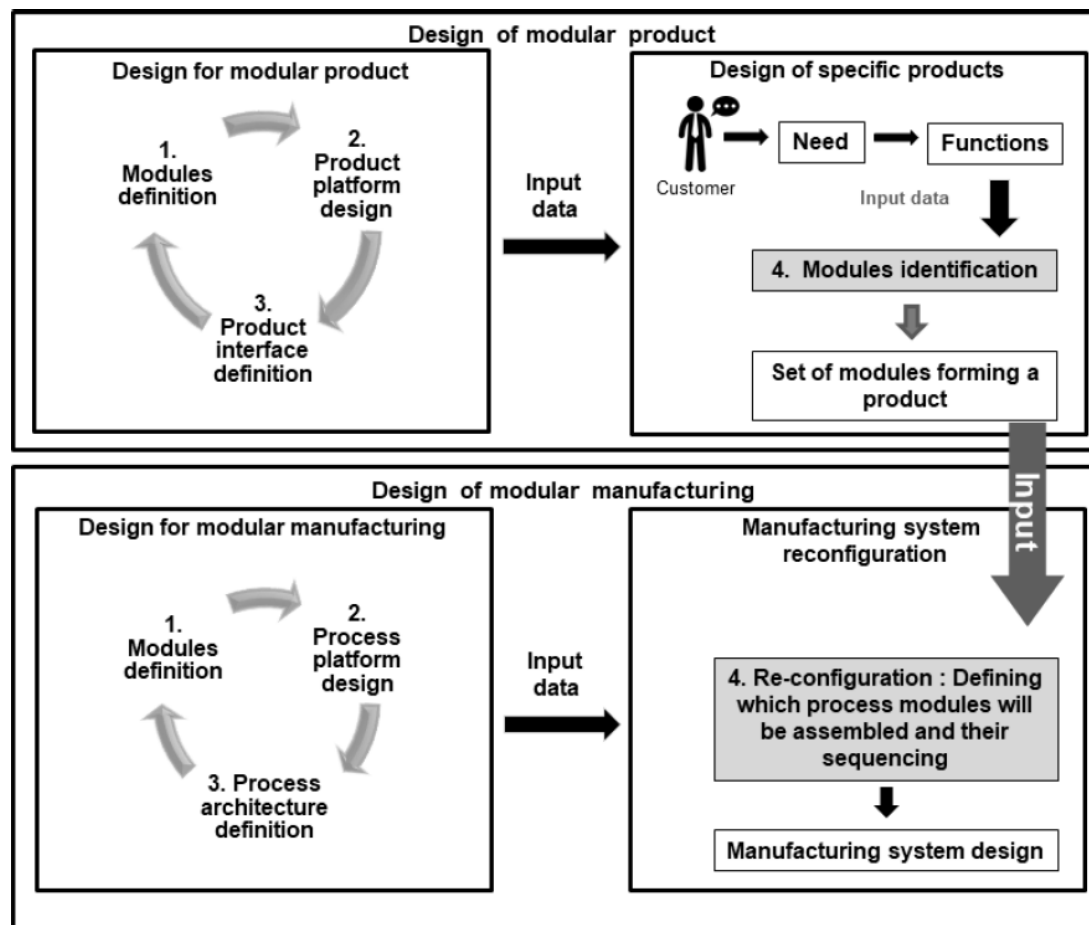


Figure 18 Modular design process for Mass-Customization (Paes et al., 2018)

The integrated design processes in my thesis are inspired by modular design process for mass-customization. The processes are deeply developed in the 3DCE context. The following Figure 18 shows the steps for product modular design and process modular design. The Figure comes from Paes et al. 2018, which only focuses on product side, which will be further developed in this section. Design of modular product contains four steps: product module definition aiming at establishing the cluster of components that form a module, product platform design aiming at clustering the modules that will compose a common base where the differentiation will take place, module interface development aiming at determining how the components will be arranged between/ within modules, and modules identification aiming at selecting modules that will be assembled together according to function analysis based on customers' needs. Similarly, process modular design also contains four steps: process module definition aiming at establishing the cluster of operations that composes a process module, process module platform design aiming at selecting process modules that will be common for several products, process module interface

development aiming at determining process modules sequence, operations and their layout, and system reconfiguration aiming at selecting and re-arranging process modules according to the required changes.

In the following three sections, PSO design process, VCCP design process and VE design process will be detailed as well as the supported techniques and methods utilized in the design processes.

Product Service Offerings (PSOs) design process

Figure 19 displays the processes of PSOs design, while Table 13 introduces the necessary supporting methodologies. Product-Service Offering (PSO) design process begins from PSO requirements identification. As mentioned in the 3DCE design framework, the PSO requirements usually come from two aspects: customers' requirements and providers' innovation. Requirements engineering mainly consists of two stages: obtaining requirements from both customers and providers and interpreting these requirements into design specifications. Customer Activity Cycle Analysis developed by Vandermerwe (2000) provides a good way of analysing customers' requirements from the perspective of customers' involvements along Product lifecycle from requirements engineering, design phase to use and recycle phase etc. This method can help managers assess opportunities for providing new kinds of value to customers at each critical experience: (i) Pre, or before: when customers are deciding what to do to get the desired result, (ii) During: when customers are doing what they decided on, and (iii) Post, or after: when customers are maintaining the result-reviewing, renewing, extending, upgrading and updating (Vandermerwe, 2000). This method was further developed by Song et al. (2013, 2015) to make it more useful in the context of PSS. This method is not limited to customer requirements engineering. It also could be used to analyse companies' requirements, which could be called Industrial Customer Activity Cycle Analysis. After we obtain requirements from customers and providers, the next step is to translate them into design specifications. Haber et al. summarized existing articles about requirements interpretation using QFD, House of Quality (HoQ), and AHP (Fuzzy AHP) and proposed the FAHP augmentation to a service-oriented QFD as a means of addressing the intangibility and subjectivity of services. This proposal resulted in a higher variation concerning the Customer Requirements priorities which facilitates the decision-making process and enables manufacturers a clearer choice when addressing Service Characteristics (Habler et al., 2018).

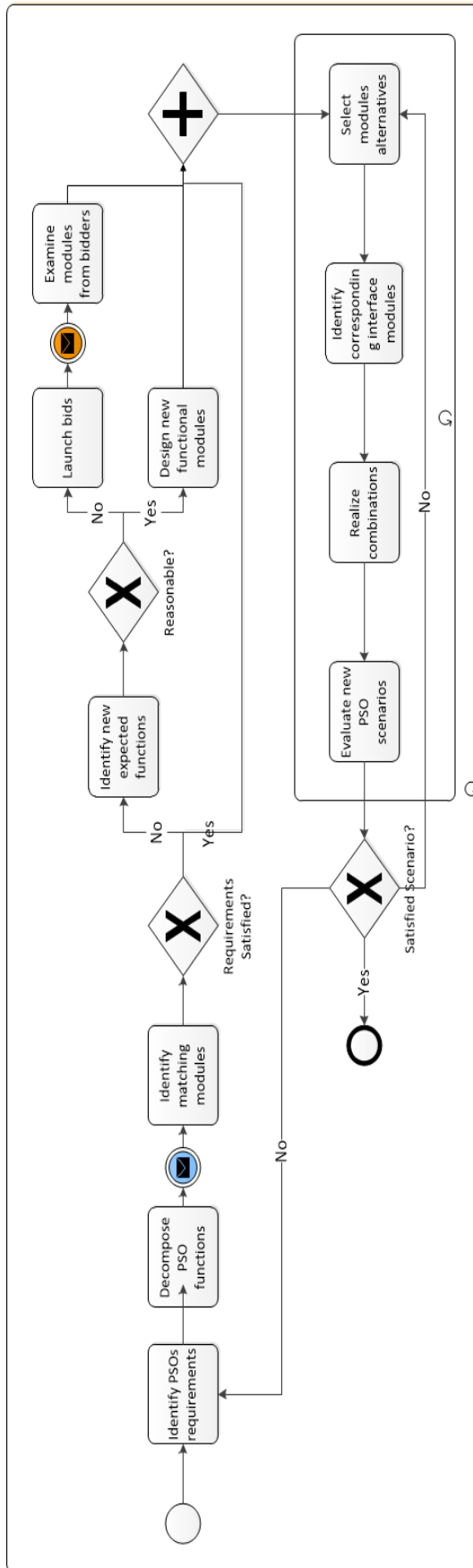


Figure 19 PSO design process

Table 13 Summary of supported methods during PSO design process

Task	Methods	Recommended References
Identify PSO requirements	Customer Activity Cycle Analysis;	Vandermerwe,2000; Song et al., 2013
	Industrial Customer Activity Cycle Analysis;	Song et al., 2015a
	Quality Function Deployment; Analytic Hierarchy Process	Haber et al., 2018
	Customer Satisfaction Index	Johnson et al., 2001
Decompose PSO functions	Function Decomposition Tree	Proposed in Chapter 2
Module related tasks	Modularization	Paes et al., 2018
Realize combinations	Service Blueprint	Boughnim & Yannou,2005;
		Song et al., 2015b

Second tasks in PSO design process is PSO function decomposition. The function decomposition tree proposed in Chapter 2 will be used here. Different functions could be analysed according to the requirements from customers and providers, and different functions should be achieved by different product and service components (structural level), finally these components should be composed to new modules according to modularization rules. Indeed, we have done these works in “product-service modularization” section. However, the second task actually keeps updating, similar with requirement engineering. Thus, when new requirements come, we should also re-do function decomposition.

Next step is identifying matching modules. There are two cases after this task. In the first case, after function decomposition, designers will find that existing modules in the VE network library (mentioned in last section, product modules, service modules, and process modules could be found in this repository) are able to satisfy all the requirements, so that next tasks will go directly to “selecting modules alternatives”. In this task, there are maybe several scenarios of combinations of product and service modules. For each one, designers need to fulfil interface module identification, realize combination and scenario evaluation. If a scenario is satisfactory, this scenario will be retained. If not, we will go back to “selecting modules alternatives”, which is a loop shown in the Figure 19. In the second case, if existing modules can’t satisfy decomposed functions, we should first identify new expected functions on the decomposition tree. Next, according to the VE own skills, resources, capitals, the VE need to make a decision to know who will realize the new module. If it's cost-efficient, they could design new function modules by themselves; on the contrary, the VE has to launch bids to find new partners to join in the VE, who is able to provide the necessary modules. Besides, if there are several bidders, the new module examination is also necessary. After we obtain enough modules, we could go on “selecting modules alternatives” step.

It is worth mentioning here that if we can’t address good scenario after fulfilling these tasks. Maybe there is some problem with requirements engineering, and we

have to re-do this task, which is second loop in PSO design process. This thesis adopts service blueprint technique (Boughnim & Yannou, 2005; Song et al., 2015b) to help realize combination, which is able to visualize main stakeholders, tasks, processes, interactions and so on. The evaluation of PSO scenario will be discussed later in Chapter 4.

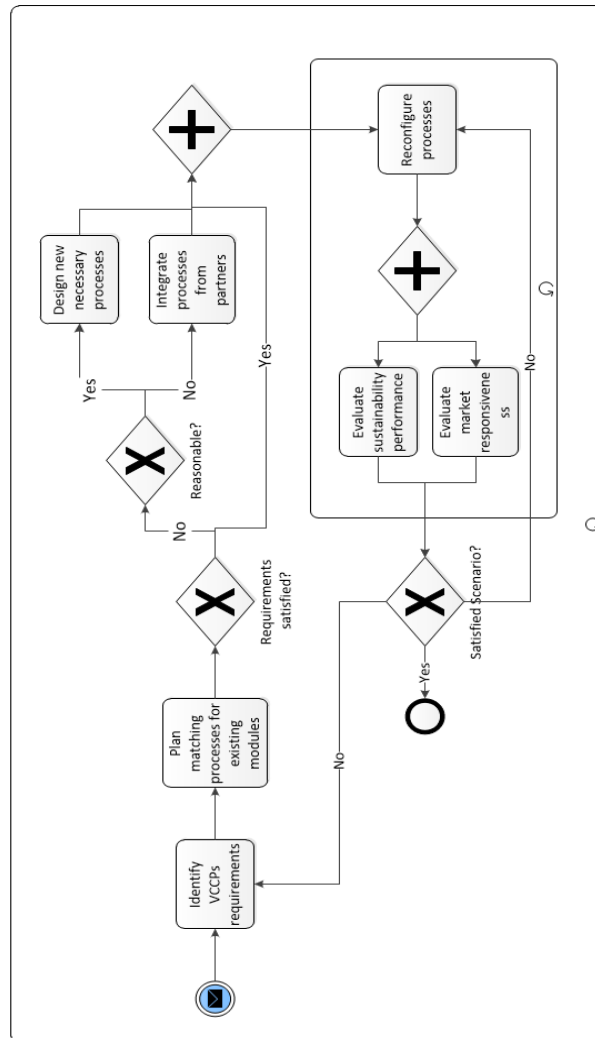


Figure 20 VCCP design process

Value Co-Creation Processes (VCCPs) design process

Indeed, the “value co-creation processes co-design” activity follows steadily the path of PSOs co-design. VCCPs co-design begins after PSOs requirement engineering and function decomposition. As shown in Figure 19 and 20, VCCP design begins from an intermediate event, i.e. only after fulfilling the offering functions analysing, the VCCPs could begin due to the requirement of VCCPs coming from PSOs’ functions. Then it runs parallel with PSOs co-design. In the VE repository, each product or service module will map at least one series of corresponding manufacturing, production, delivery (etc.) processes. Similar with PSOs design process, after identifying the requirements, second task is to matching processes planning for existing modules. There are also two cases here. In the first case, existing processes are enough to satisfy

VCCP requirements, and the task will go directly to “processes reconfiguration”. A scenario of reconfigured processes will be evaluated in sustainability assessment and market responsiveness assessment. If the scenario is satisfactory, it will be retained. If not, the designers will go back to process reconfiguration. Similar with PSO design process, if there is no satisfactory scenario after all the “process reconfiguration” loop, designers have to go back to requirements engineering and re-do all the tasks. In the second case, if existing process can't satisfy the requirements, there are two possibilities that comes from PSO design. Firstly, if the VE decide to design new modules, they are bound to design corresponding processes to support. Secondly, if they choose to outsource the necessary modules, so that new partner will join in this VE, and designers should integrate the new processes from partners into existing VCCPs.

Virtual Enterprise (VE) design process

VE design indeed is in the same strain with POS design and VCCP design. VE design process is partially decided by PSO design and VCCP design. In first case, when a VE is able to satisfy the requirements by its own modules and processes, a new VE design process for this VE indeed is an internal optimization process, since there are maybe several companies could address same requirements with different modules and processes. Obviously, if all the stakeholders will involve in the design process, there will be huge lost due to the redundancies and overlapping. The VE requirements come from both product and service modules in PSO design as well as process modules in VCCP design. Then who is able to provide what modules will be clarified. In this way, there are maybe several scenarios of combinations of stakeholders, so that it is necessary to evaluate each scenario to test the performance and justify the advantages and disadvantages, and finally to come up with a satisfactory scenario. If a scenario is not satisfactory, the designers should go back to another combination. If all the combinations do not work, maybe it's necessary to go back to re-analyze the requirements (corresponding two loops in Figure 21).

Actually Figure 21 exhibits the second case of VE design. As shown in Figure 19, there is also an intermediate event after “launching bids” task, which means that VE design could design after this task. In second case, the VE is not able to provide modules (including product-service modules and VCCPs modules) by itself, and has to launch bids to look for new partner join in the VE and supplement lacking modules. Of course, when new partner joins in this VE, a new VE is created. Certainly, the same tasks should also be fulfilled similar with the first case.

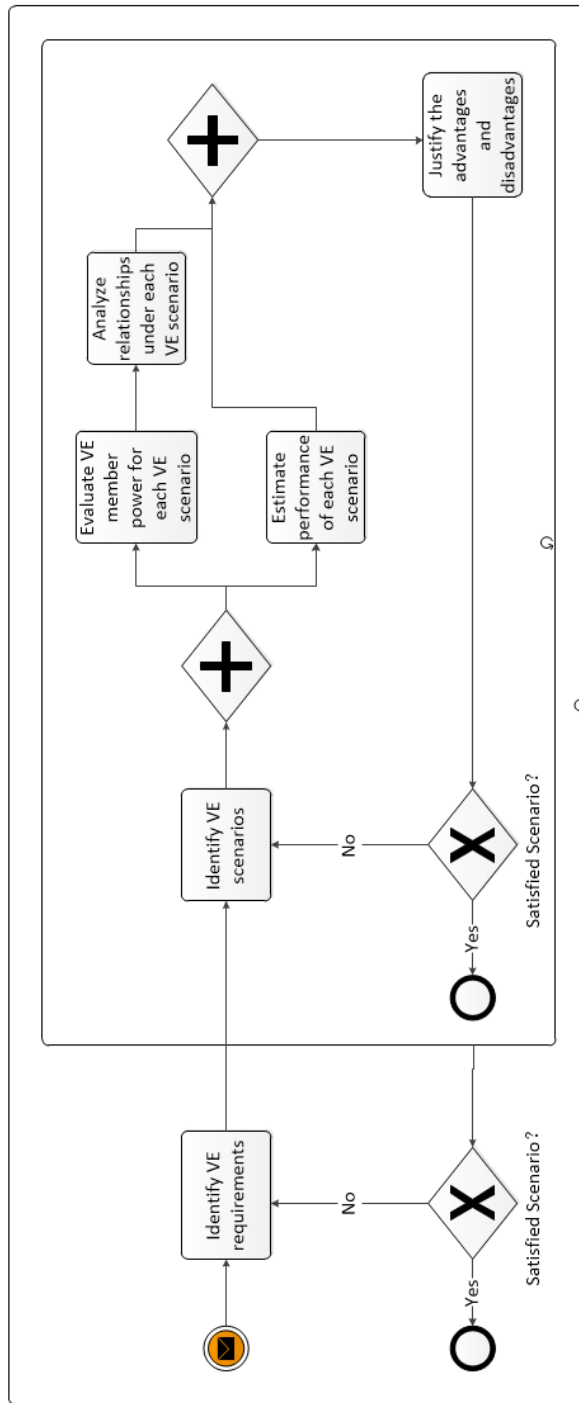


Figure 21 VE design process

3 Detail design logic from 3DCE perspective

When deeply digging into three key design activities, this thesis selects two project scheduling techniques; respectively are Gantt chart and Graphical Evaluation and Review Technique (GERT) to model the concurrent design processes.

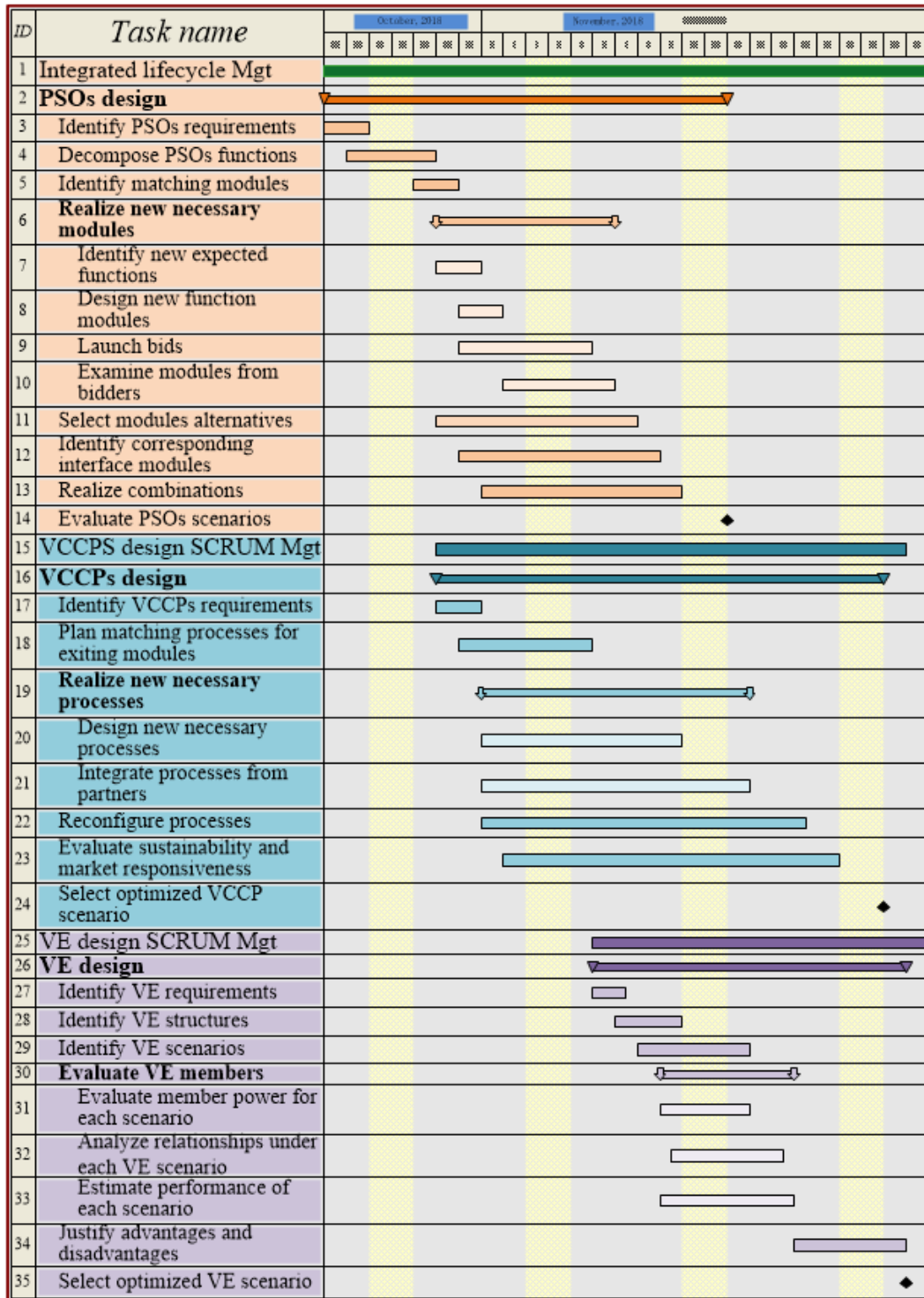


Figure 22 Gantt chart of integrated 3DCE design processes

According to the Figure 22, we can conclude that the integrated design activity begins from identifying PSOs requirements. Based on the requirements, designers are able to decompose PSOs functions, and go on next steps. As illustrated in Chapter 3, VCCPs design begins after PSOs functions decomposition, the same as VE design. In this way, the three-dimensional concurrent engineering could be addressed. As shown

in Figure 22, the Gantt chart lists general design processes for PSOs design activity, VCCPs design activity and VE design activity, as well as their bars corresponding to project schedule. The bars depict the concurrent status and dependencies between different processes.

Gantt chart is able to intuitively describe the concurrent processes. However, there are some weaknesses for Gantt chart technique, which make it not enough to model the 3DCE by itself, the same as the other two prevailing modelling techniques- Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM). They are difficult to model a complex system with many processes; they cannot describe the loops and stochastic models, etc. However, in this design case, loops and probabilistic branches are necessary and significant. Thus, “Graphical Evaluation and Review Technique” (GERT) (Pritsker, 1996) is introduced here to solve these problems. As shown in Figure 24, the Figure is constructed by nodes and arcs. Figure 23 exhibits six nodes coming from different combinations of input and output. In Figure 24, three categories of arcs are listed in the legend: solid lines represent processes listed in the Gantt chart; dash lines represent loops in a certain design activity; and dot dash lines represent the interactions between different design activities.







GERT NODES		INPUT SIDE		
		EXCLUSIVE-OR	INCLUSIVE-OR	AND
OUTPUT SIDE	DETERMINISTIC			
	PROBABILISTIC			

Figure 23 basic nodes of GERT, derived from Pritsker, 1996

The PSOs-VCCPs-VE 3DCE design processes starts from PSOs design, and core design technique is modularization. PSOs design activity starts from Identifying PSOs requirements (T3), after decomposing new PSOs functions (T4), the designers should identify matching modules in existing VE repository (T5). If existing modules are enough to satisfy design requirements, the process will directly go to select module alternatives (T11); if not, designers have to identify new expected functions (T7). Based on new expected functions, designers should make a decision that whether it is reasonable (cost too much/ waste too much time/ waste too much resources or not) to design new function modules by themselves. If reasonable, the process will go to T8, and then go on T11; if not, the existing VE need to launch bids (T9) in order to find appropriate modules outside the VE. Then designers also need to examine the modules coming from outside bidders and try to find the relevant ones. When all the necessary modules are prepared, designers sometimes also need to identify corresponding interface modules. Then combinations of these modules could be launched. Finally after evaluation according to customers’ and providers’ requirements, maybe several or at least one scenario will be selected.

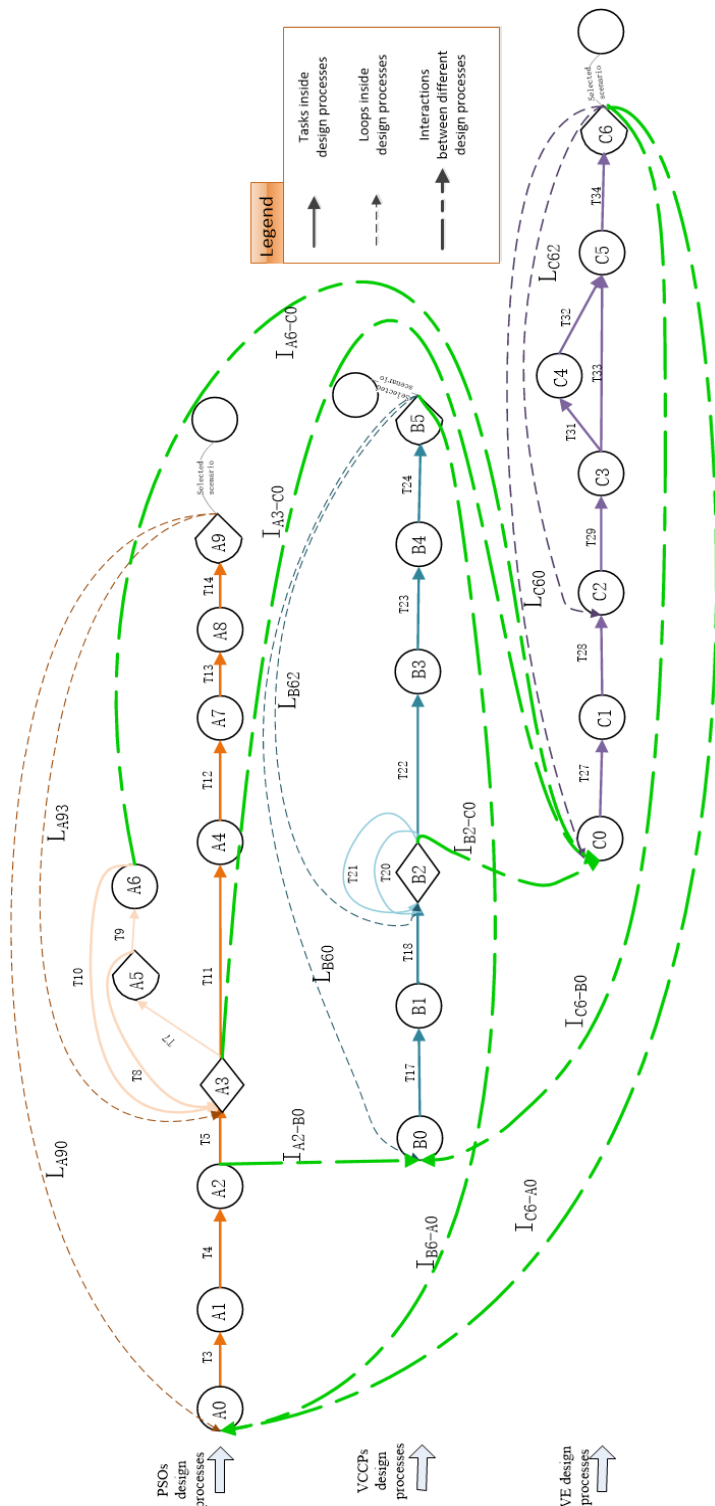


Figure 24 3DCE logic in COPSS design framework

However, if designers can't select the appropriate scenarios, they have to go back to node A3 (Loop L_{A93}), here they could re-select module alternatives, or re-design new function modules, or re-integrate modules from bidders. Even if this loop can't come up with a PSO solution, maybe there are some problems with requirements engineering,

the designers have to go back identify PSOs requirements (Loop L_{A90}).

In the concurrent engineering context, VCCPs design activity starts after decomposing PSOs functions (T4), as shown by interaction I_{A2-B0} . See line 2 of Figure 24. Similar with PSOs design processes, VCCPs design also need requirements engineering (T17) based on PSOs functions. Then, according to matching modules selected in PSOs design activity, designers should fulfil the matching processes planning for existing modules (T18). Corresponding to PSOs design, when all the matching processes can be found in VE library, designers could go directly to reconfigure processes (T22). Otherwise, designers maybe need design new processes by themselves (T20), or integrate processes from bidders (T21). Then different scenarios of reconfigurable processes will be evaluated based on providers' sustainability requirements and market responsiveness requirements (T23). Then appropriate scenarios will be selected. Similar with PSOs design, VCCPs design activity also has two loops – Loop L_{B62} and Loop L_{B60} . What's more, once Loop L_{B60} also can't come up with a solution, there is a link I_{B6-A0} between VCCPs design and PSOs design, so that designers could go back to PSOs design processes, and check whether there are some problems with PSOs requirements engineering or functions decomposition.

In terms of VE design See line 3 of Figure 24. There are mainly two cases here. In the first case, as mentioned above, the collaborative network itself is able to provide all the necessary products and service modules as well as the corresponding processes. VE design (processes are derived from Affonso et al. (2013) with some slight modifications) will start from VE requirement engineering based on the identified matching modules (derived from T5, shown as link $IA3-C0$) and identified corresponding processes (derived from T18, shown as link $IB2-C0$). Then designers will identify basic structures based on the requirements. Here, we will encounter a problem. Sometimes, the existing network maybe only contain several companies focusing on different knowledge, skills, products or services, etc. They won't provide the same or similar modules and processes corresponding to the same functions. In this way, indeed, it's not necessary to spare more effort to design a new VE due to the concern of sustainability. However, if the network members' businesses focus on similar or same fields, and designers ignore this problem and only do a simple addition operation, the overlapped modules and processes they provide will lead to huge redundancies and waste. Hence, the selection of partners and VE optimization must be achieved, so that different VE scenarios will be identified (T29). Then, designers need to evaluate each scenario, including member ability in each scenario (T31), relationships among members (T32), performance of each scenario (T33), and the competitive advantage of each VE scenario (T34), and finally select optimized scenarios.

In the second case, the knowledge, resources, modules or processes, etc. are not enough to propose new PSS solutions, the existing network have to launch bids (shown as link $IA6-C0$) and find partners outside the network. In this case, the interactions $IA3-C0$, $IB2-C0$ and $IA6-C0$ will run in concurrent way, the optimization is also necessary, the distinction is the range of VE member selection.

In this section, we identify the basic logic of three-dimensional concurrent engineering according to the integrated design processes. In real cases, due to the more precise and complex processes, it must be more complex to model the design processes in such way. However, this 3DCE methodology is able to provide designers and practitioners new thought when optimizing PSS design.

Until now, The PSOs-VCCPs-VE integrated design (A21) has been addressed through three steps: basic understanding of three design activities from 3DCE perspective, detail design processes for each activity, and the deeper interactions among the three activities from 3DCE perspective. By the way, the customer requirement analysis (A11) has also been satisfied during PSO design processes.

4. COPSS design cycle based on Customer-Provider Satisfaction Trade-off

As mentioned above, customers' and providers' requirements, values and satisfactions are also the main influence factors during COPSS design. How to deal with them and integrate them into the design framework? This section will propose a COPSS design cycle model based on **Customer-Provider Satisfaction Trade-off (CPST)**, as shown in Figure 25.

The cycle starts from "COPSS design activities". As illustrated before, the output of the "PSO design activity" is some PSO scenario---a prototyping combined by a variety of product modules and service modules. This PSO scenario needs to be approved by both customer side and kernel network/supporter organization's side (KN/SO). **On customer side**, the proposed PSO scenario links to customers' perceived value, while customer expected value links to their requirements; the gap between customers' perceived value and customers' expected value is customer satisfaction. The customer satisfaction assessment could be assessed based on Customer Satisfaction Index (Johnson et al., 2001). If the customers are satisfied with this PSO scenario, this prototyping can be feasible from customer side. If the customers deem this scenario is not feasible, the design activity must restart and the PSO scenario will be refined or even deleted.

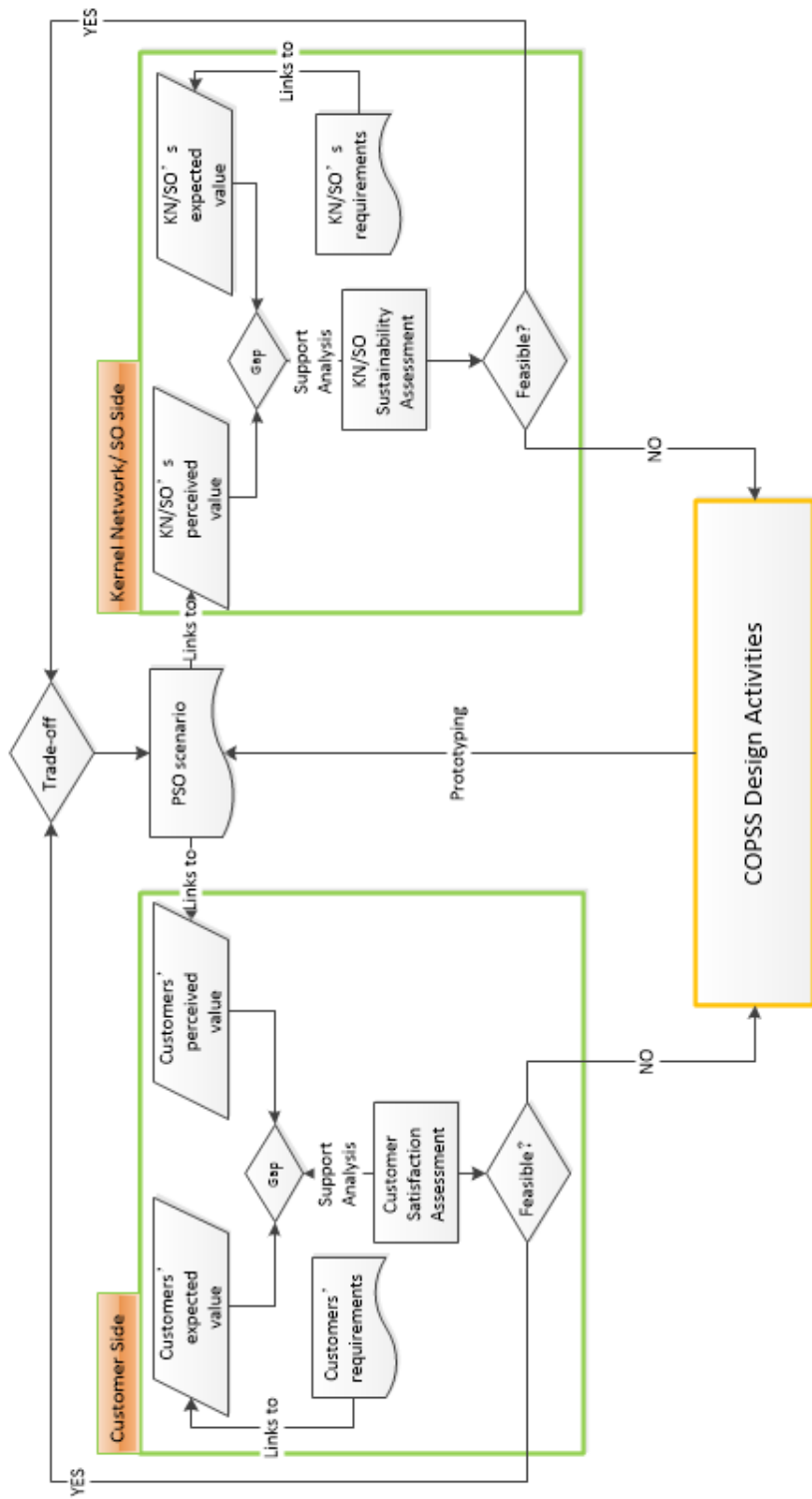


Figure 25 COPSS design cycle model based on Customer-Provider Satisfaction Trade-off

On **KN/SO side** or provider side, PSO scenario also links to their perceived value; while their expected value also links to their requirements. The gap between them is KN/SO's satisfaction. However, the provider side indeed needs to take many factors into consideration. One of the most important factors is **market**

responsiveness. Providers should be able to provide customers with more reliable and flexible offerings in a short lead time. In order to satisfy this requirement, the thesis advocates the mass customization methodology as illustrated above; what's more, in order to enhance the market responsiveness, Chapter 4 will introduce the AGORA multi-agent architecture and SCRUM management methodology, this will be explained later. Another most important factor should be **Sustainability Requirement**. Sustainability, as mentioned in Chapter 1, indeed consists of ecological aspect, economical aspect and social aspect rather than only leaving less impact to the environment. For economical aspect, designers should calculate how much profits the providers can obtain through a PSO scenario along the whole VCCPs; at the same time, they should integrate ecological (environmental) constraints and social constraints into calculation. Hence, indeed, **Sustainability Assessment (SA)** is a series of activities which must be based on the whole processes along PSS lifecycle. This is also why SA won't be illustrated here. In Chapter 4, the lifecycle modelling will be illustrated at first as a foundation, so that SA can be addressed. The same as customer side, if the KN/SO is not satisfied with the PSO scenario based on the results of SA, the non-feasible scenario will be refined or even deleted in next cycle of COPSS design activities.

So far, if both customer and provider agree with that the proposed PSO scenario, then the trade-off is necessary, which is also linked to the provider's strategy. For instance, if recently they have some problems with finance and must gain more profits from businesses, the provider may bid a higher price for this solution, which may lose some customers; if they want to achieve much more market share and attract more customers, the provider may reduce the price and launch a cost leadership strategy.

It is worth mentioning here that do not forget the trade-off based methodology along the whole COPSS design. The "COPSS design activities" in this Figure is a black box that contains three core design activities. The box proposes the PSO scenarios which will be evaluated by both customer side and provider side. And their advice and comments will be back to the box. The cycle indeed is the way of evaluating PSO scenarios and optimizing PSO scenarios.

Based on the COPSS design cycle, the requirements of "customer satisfaction assessment (A13)", "sustainability assessment (A31)" and "customer-provider satisfaction trade-off (A32)" can be addressed preliminarily. The supporting methodologies will be illustrated in chapter 4 due to their characteristic of lifecycle orientation.

5. Design framework for COPSS from 3DCE perspective

Now, almost all the basic elements have been explained except several supporting management methodologies. It's time to form the reference design framework for COPSS from 3DCE perspective. As shown in Figure 26, the framework is composed of three lanes; respectively are: 1/ the up lane for PSS measuring metrics, 2/ the center lane for PSS design key targets from 3DCE perspective and, 3/ the bottom lane for key design methodologies, models, actions etc. In this section, the key elements of the framework will be recalled in order to build a completed understanding of proposed framework.

Inspired by the 3DCE concept from product design field, we have proposed a new 3DCE design concept for PSS, which is called; similarly, Product-Service Offerings (PSOs), Value Co-Creation Processes (VCCPs) and Virtual Enterprises (VEs) 3DCE integrated design. Integrated design means the strong connections and interactions between different activities and decisions during the whole design processes. As shown in the center lane, the main driven power of new PSS solution comes from mainly two aspects; respectively are customers' requirements and the innovations pushed by the kernel network and supporter organizations. Here, Customer activity cycle analysis (Vandermerwe, 2000) and Industrial customer activity cycle analysis (Song et al, 2013) could be used in order to better understand the stakeholders' requirements. Then QFD and AHP could be used to help interpret the requirements into design specifications (Harber et al., 2018).

The activity "product-service offerings co-design" begins first. Co-design means that both providers and customers will be involved in the design activity. Sometimes the customer only plays the role of requirements input and prototypes testing during PSOs design. In this case, after analyzing the requirements, the designers will select appropriate product and service modules in the network library and make the combinations according to requirement engineering (modular design) and new PSOs function decomposition and test them with customers. Customers' requirements link to the customers' expected value and designed PSO alternatives link to the customers' perceived value. The gap between them is the customer satisfaction. Based on the customer satisfaction index approach (Johnson et al., 2001), we can conclude the satisfaction degree of different combinations.

If the customer is satisfied, designers could retain these alternatives temporarily for later design activities.

If the customer is not satisfied, the designers have to design new product or service components or launch new bids for components, in order to meet customers' needs. In this case, the customer can be deeply involved not just to provide his requirements and co-test the prototypes, but also during the ideation phase, conceptual design phase etc. The new combinations will be tested and held, otherwise, both designers and customers should go back to re-design the combinations, which will impact the PSO design loop (L1). Modularization is selected to support the PSOs design.

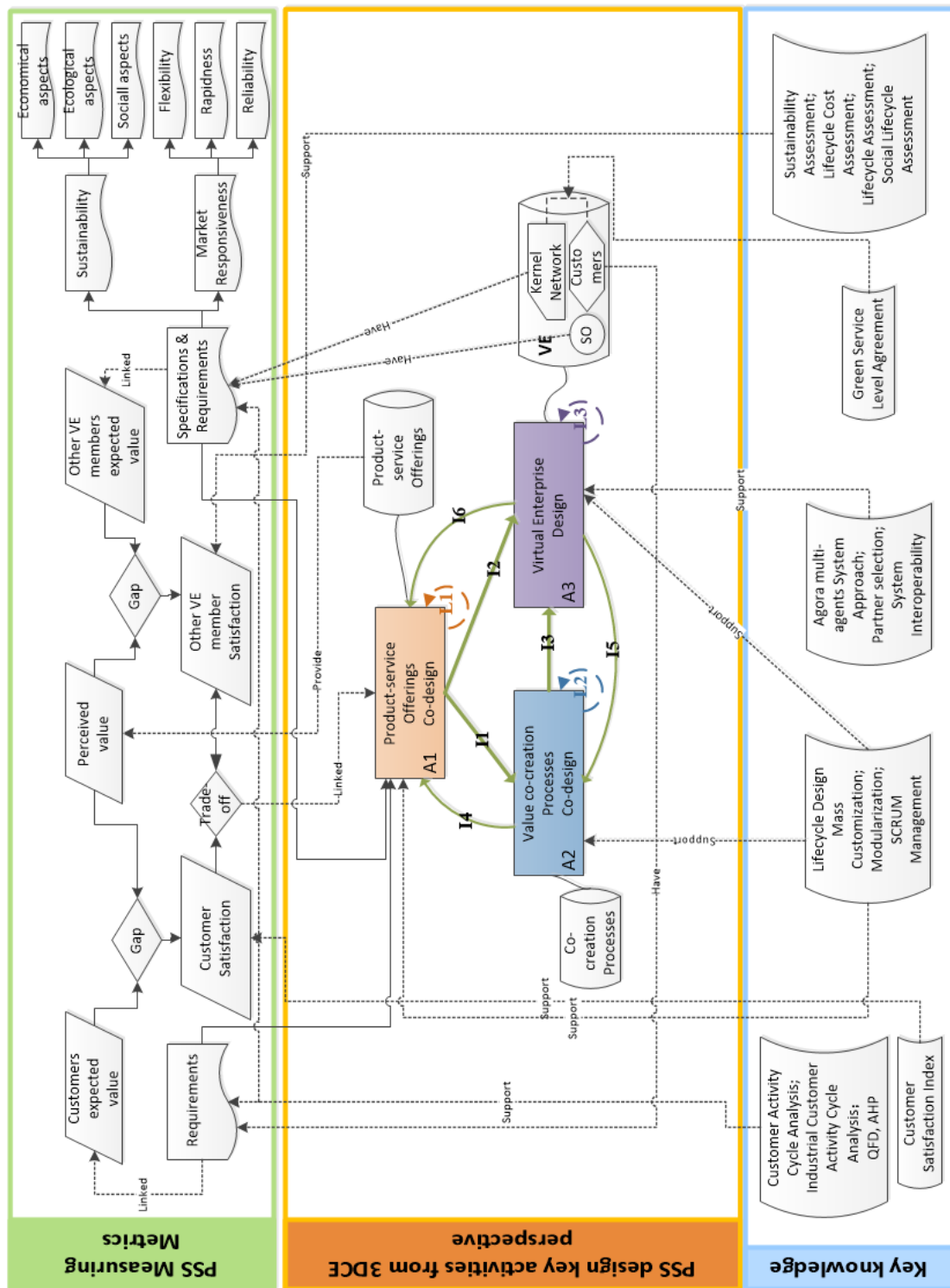


Figure 26. Reference design framework for COPSS from 3DCE perspective

Indeed, the “Value Co-Creation Processes” co-design activity follows steadily the path of PSOs co-design. VCCPs co-design begins after PSOs requirement engineering and function decomposition, and then run in parallel with PSOs co-design (I1). In the VE library, each product or service module will map at least one series of

corresponding manufacturing, production, delivery (etc.) processes. According to decomposed functions, designers could conclude necessary product and service modules, as well as the processes supporting these modules. Similar with PSOs design activity, there are also two main categories of customer involvement in the VCCPs design activity. The first one is a shallow involvement, in this way the customers just play a role as receiver or buyer and use the PSOs; the second one is called deep involvement, in this way customers maybe also act as co-producer, co-distributor, co-cycler etc. The VCCPs will also change when PSOs' requirements change, thus there could be a design loop for itself (L2). However, sometimes, according to existing PSOs alternatives, designer cannot come up with appropriated VCCP solutions; there will be a feedback from VCCPs design activity to PSOs design activity (I4). In this case, designers may need to re-do PSOs requirement engineering or re-design PSOs alternatives.

In terms of VE design, this thesis assumes that there is an existing supported network at the beginning. This network may consist of several kernel enterprises, with their partners or suppliers, and some communities of customers. According to the necessary product and service modules, as well as designed value co-creation processes, different business tasks will be distributed to different members in a virtual enterprise. Then in the first case of PSOs design, when this network is able to provide all the modules as well as the VCCP processes by itself, it is not necessary to spare more effort (costs, time, etc.) to find partners outside the network. What is necessary to do is to optimize the combination of network members (I2) to form a new VE since there may be some redundancies or overlapping modules or processes among different members. On the contrary, this VE has to launch bids to look for other stakeholders to supplement the lacking points (I2). In this case, a new VE design is necessary, including finding suitable partners, evaluating partners, creating new collaborative mechanisms, etc. Similarly with VCCPs design, different VE scenarios will also need update if the corresponding bids change; thus the VE design has a loop with itself (L3). Then sometimes, the designers cannot find out an appropriate solution for new VE design, they maybe need to go back to revise the VCCP design (I5) or PSO design (I6).

Besides, in order to make interactions and communications between different VE members more effective and efficient, interoperability technique and AGORA multi-agents system approach (Petersen et al., 2001) will be used to support designing a new VE. What's more, green service level agreements will be necessary in order to better serve the customers. This paper summarizes two main categories of providers' requirements. The first category is called sustainability requirements, which include economical, ecological and social aspects. The second category is called market responsiveness, which includes flexibility, rapidness and reliability. These requirements are described through their expected value. The gap between their perceived value (provided by designed PSOs) and their expected value represents the kernel network and supporter organizations' satisfaction. We can use sustainability assessment related techniques to evaluate their satisfaction degree. Finally, the stakeholders need to address the trade-offs, and select the optimal alternative.

Lifecycle design (LCD) and design for X (DfX) ideology should run through PSOs-VCCPs-VE design activities. In order to better and faster respond to markets, this framework also adopts Scrum management technique (Ashraf & Aftab, 2018) to control and manage the design processes.

6 Conclusion

This Chapter is the core Chapter of whole thesis, in which the key 3DCE design framework has been proposed and explicated. In order to better understand where the framework comes from, this Chapter firstly identifies eight requirements from three categories for the framework: A11-customer requirement analysis, A12-deeper customer involvements, A13-customer satisfaction assessment, A21-PSOs-VCCPs-VE integrated design, A22-design for X, A31-sustainability assessment, and A32-customer-provider satisfaction trade-off. Secondly, to satisfy these requirements, this Chapter introduces the methodology of “Three-Dimensional Concurrent Engineering (3DCE)” and makes an introduction plan with three steps: (1) the basic understanding of 3DCE and three design activities under 3DCE design logic; (2) detailed design processes for each activity; (3) the communication and interaction logic among three design activities. Thirdly, the Chapter comes to the integration of changes coming from involved stakeholders to help supplement the performance evaluation and optimization. Finally, the integrated design framework for COPSS based on 3DCE approach comes out.

In this chapter, two requirements “PSOs-VCCPs-VE integrated design (A21)”, “customer requirements analysis (A11)” and “Customer-Provider Satisfaction Trade-off (A32)” have been satisfied; “customer satisfaction assessment (A13)” and “Sustainability Assessment (A31)” have been mentioned preliminarily, and need to be completed in chapter 4.

However, several points haven't been addressed in this Chapter and need to be discussed in Chapter 4: (1) due to VE's integration into PSS lifecycle, traditional lifecycle is not enough to modelling the PSS lifecycle in VE context, thus a new stakeholder-driven PSS-VE lifecycle is necessary for design teams to manage COPSS lifecycle; (2) we just design a VE and know which companies and organizations will collaborate in the network; however, we still don't know how they can work in an effective and efficient way. Hence, this thesis introduces the multi-agent system concept into PSS supporting network design, and proposes new AGORA framework for VE modelling in order to support cooperative network (VE) creation and operation. (3) In order to achieve the target of high-quality in short lead time, agility management methodology is adopted in the thesis; however, how to achieve the agility management still a problem; (4) customer satisfaction assessment and sustainability assessment in provider's side will be addressed.

Chapter 4. Supported Management Frameworks and Methodologies

1 Introduction

In Chapter 3, we proposed an integrated sustainable 3DCE design framework for Customer-Oriented PSS (COPSS). According to this framework, we are able to come up with an integrated PSS solution which is dedicated to design PSOs, VCCPs and VE together as a whole. Especially, mass customization, particularly modularity, is adopted to design PSOs and VCCPs. What's more, in the last Chapter, we have also developed different design processes for the three key design activities and also introduced corresponding techniques and knowledge. However, as shown in the blue box on the right side in Figure 14 and the proposed framework, there are still four problems which have not been addressed in Chapter 3.

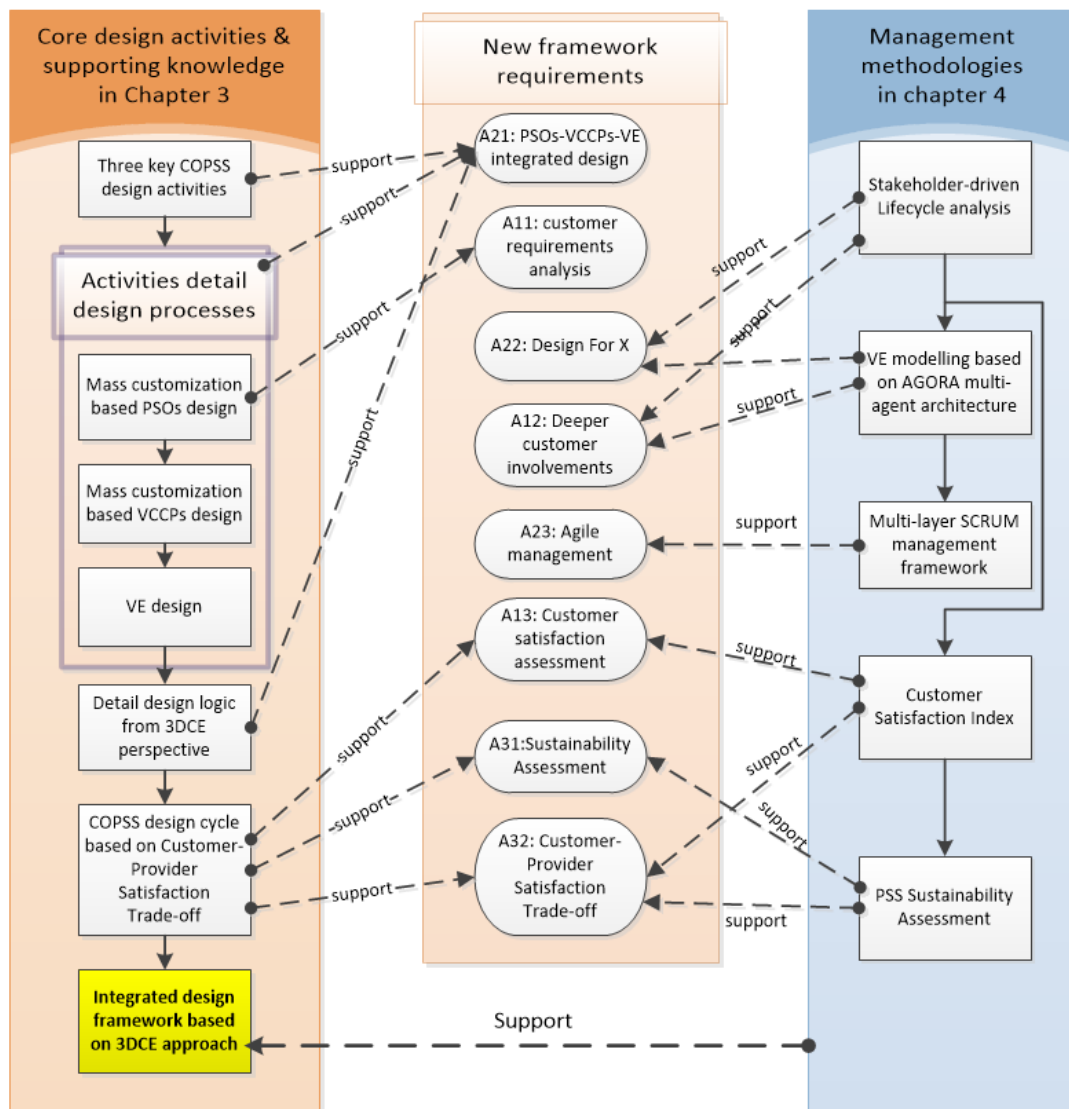


Figure 14 holistic design logic

First, this thesis emphasizes the importance of stakeholders, i.e. both providers and customers, in a product service system. According to our literature review, see Guan et al. (2017), majority of existing lifecycle models only focus on products and services and few attach importance to stakeholders. Hence, it is necessary and significant to propose a stakeholder-driven lifecycle models in order to help stakeholders to define their own roles and responsibilities in the different PSS life phases. This can be useful for designers to reduce system complexity and uncertainty and can help them to avoid unpredictable risks all along PSS lifecycle. Furthermore, lifecycle modelling is also able to support “design for X”, which is significant to promote solution quality. Besides, lifecycle modelling will also establish a foundation for sustainability assessment, which is a lifecycle oriented methodology.

Second, in Chapter 3, the main work was to fulfill the “PSOs-VCCPs-VE integrated design”; however, how do the VE members collaborate to support VCCPs? This Chapter introduces the multi-agent system, particularly AGORA architecture, to provide the cooperative and collaborative mechanism among the different VE members; further on, based on **stakeholder-driven COPSS lifecycle model** and **AGORA architecture**, the requirements of “**Design for X (A22)**” and “**Deeper customer involvements (A12)**” could be satisfied.

Third, the framework is dedicated to come up with the best solution in a short lead time with high quality. Under this situation, agile management is adopted to Figure out this problem. This Chapter introduces the agile management methodologies from the software design field into the PSS field, to expect to come up with the solutions for the **agile management (A23)** of COPSS design.

Fourth, the COPSS advocates win-win solutions for both providers and customers. In order to address this target, the 3DCE design framework here includes the assessment for both customers’ satisfaction and providers’ during design processes, as shown in the design processes in Chapter 3. Assessment of different scenarios can help designers and practitioners’ decision-making and optimize the solutions of COPSS. Thus, on the one hand, to satisfy customers, the framework tries to answer the requirements of high cost performance, short lead time, safety and reliability, environmental aspects etc.; and on the other hand, to satisfy providers (providers here are the floorboard of kernel network and supporter organizations), the framework tries to answer the economic, social and environmental requirements. Designers and companies should make trade-offs between the two sides according to companies’ strategies, in order to come up with win-win solutions for each side. In this way, the requirements of “**Customer Satisfaction Assessment (A13)**” and “**Sustainability Assessment (A31)**” could be satisfied.

2. Reference stakeholder-driven PSS-VE lifecycle models

This section is the further work based on Guan et al. (2017) where an exhaustive

literature review for existing PSS lifecycle models and VE lifecycle model was done to define PSS life phases and VE life phases. Finally, two cases of reference PSS-VE lifecycle models were proposed according to a three steps method. As mentioned previously, most of the existing PSS lifecycle models only focus on products and services lifecycles independently, or on the interactions between them and ignore “stakeholders”, or “players” in a PSS.

Due to PSS’s multi-organizations context, Virtual Enterprise (VE) is becoming a common organizational means when adopting PSS solutions. Hence, it is necessary to raise a comprehensive PSS lifecycle model in which all PSS elements are considered: product, service, stakeholder, and VE lifecycle.

Accordingly, an updated version of the “reference stakeholder-driven PSS lifecycle models in VE context” comes out here called “stakeholder-driven PSS lifecycle models in VE context”, as schematized in Figure 29 and 30. To do so, a “stakeholder-driven lifecycle modelling method” with four key steps are briefly described hereafter to help designers to come up with their own “stakeholder-driven PSS-VE lifecycle”, as briefly described hereafter and further detailed in the next subsections (see Figure 27).

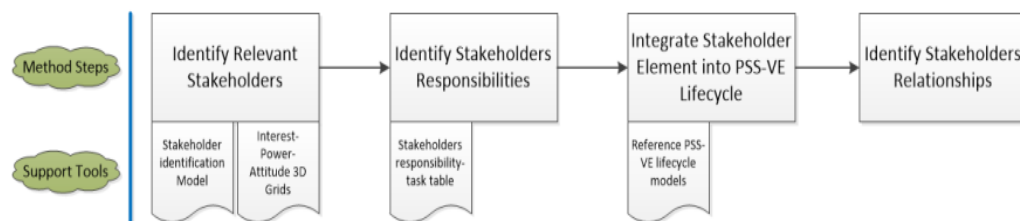


Figure 27 stakeholder-driven lifecycle modelling method

Step 1: Identify relevant stakeholders. This is the first and pivotal step in which all the most relevant stakeholders are identified in accordance with the new PSS to design. To achieve this target, this thesis provides a relatively comprehensive “reference PSS stakeholder identification model”, in which all the stakeholders are presented so that designers can choose among them. An “interest-power-attitude 3D grids model” can be used to help identify which stakeholder is the more relevant, (Webster & Simon, 2006).

Step 2: Identify stakeholders’ responsibilities. Once all the relevant stakeholders are identified, the next step is to identify their responsibilities. All along the PSS life phases, each stakeholder is responsible for performing some tasks according to the requirements. In this step, a “stakeholder responsibility-task Table” is needed to clarify the necessary tasks to perform and the different stakeholders’ responsibilities.

Step 3: Integrate stakeholders and their responsibilities into PSS-VE lifecycle. A PSS is by essence a system rather than a combination of tangible products and intangible services. Thus it is significant to think about the lifecycle from a system perspective where the system has its own organizational structure and the relationships between its constitutive elements are considered. This step integrates stakeholder element in addition to products and services into PSS-VE lifecycle. Later

this section will expound how to achieve PSS-VE lifecycles. In this step, stakeholder element and lifecycle phases will be exhibited in horizontal axis and vertical axis respectively. This will be shown in Figure 31. The tasks identified for each stakeholder will be displayed in appropriate place according to the PSS life phases.

Step 4: Identify stakeholders' relationships. Stakeholder relationships identification coming from the list of tasks identified in the third step. Process flow and information flow can be adopted for the relationship identification. Once this step is done, the final stakeholder-driven PSS-VE lifecycle model is achieved.

Each of steps introduced above is detailed below.

2.1. Identify relevant stakeholders

Stakeholder being the vital element in this kind of lifecycle model, the first task is to identify relevant stakeholders. Figure 28 shows all the possible stakeholders when implementing a PSS solution.

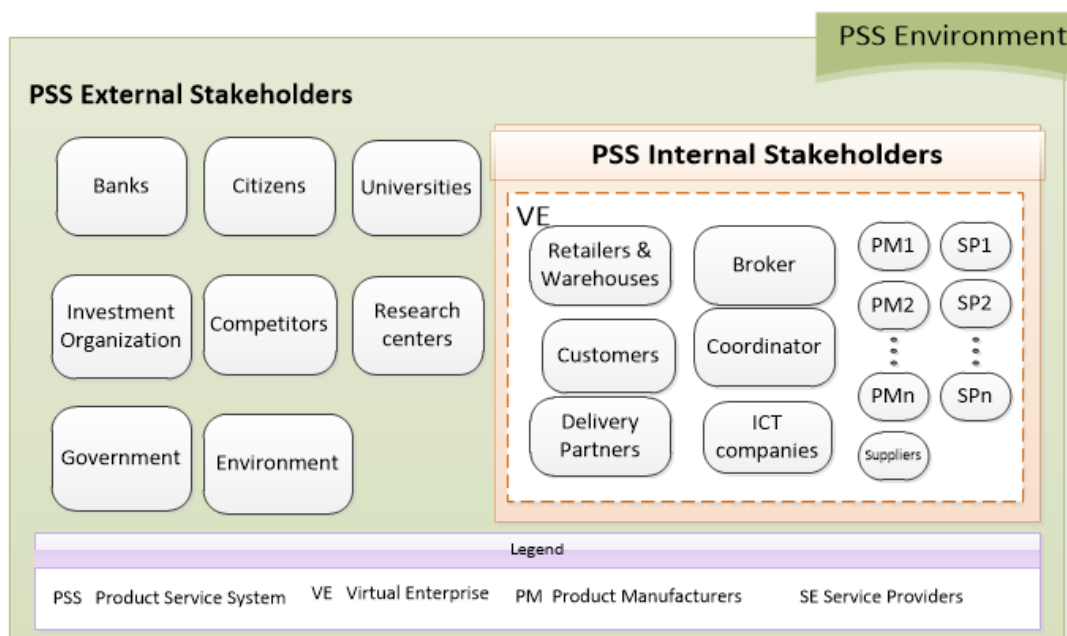


Figure 28 reference stakeholder identification model

From a system perspective, PSS consists of its own structure and environment, and PSS stakeholders are separated into internal stakeholders and external stakeholders.

In terms of **internal stakeholders** we actually consider that the PSS solution is performed by a Virtual Enterprise. **The broker** is the initiator of the VE which is responsible for creating the VE, planning its processes and searching for partners. **The coordinator** is the regulator component of VE related activities which plays VE coordination role and at the same time is responsible for the global goal. Broker and coordinator can also be providers of a part of the PSS offering: i.e. VE members. **VE member**, such as service providers or product manufacturers and their suppliers, delivery partners, retailers or warehouses will receive and fulfil tasks according to their

responsibilities and competencies. Besides, a VE also may include some ICT support companies. Beyond the VE, another key internal stakeholder in a PSS is the customer. The **customer** is a source of requirements and is also responsible for value co-creation.

External stakeholders include third party partners such as universities and research centers, banks, government, environment, competitors, citizens, etc. These third party partners have their own duties all along the PSS lifecycle. For instance, universities and research centers are responsible for some consultancy jobs, or probably jointly PSS design and development, government policies could impact on PSS spreading (a PSS supported by the government may evolve rapidly; instead it may breakdown), etc. Additionally, PSS should take environmental impacts into consideration and be sustainable. Social responsibility is another concern as the PSS offering proposed by the VE should bring the society and citizens with positive impacts.

The previous list of internal and external stakeholders is probably not exhaustive but is supposed to be sufficiently representative of the cases that may arise. Accordingly, the reference stakeholder identification model proposed in this section is a relatively comprehensive instance from all the cases.

2.2 Identify stakeholders' responsibilities

A stakeholder responsibility-task Table is needed in this step. Take customer as an example, shown in Table 14. The columns from left to right, in turn, are stakeholder, PSS lifecycle phase, responsibility and tasks. Hence each stakeholder's responsibility will be decomposed into concrete tasks in corresponding PSS lifecycle phases. This representation adopts the PSS lifecycle phases proposed by Guan et al.(2017), which includes PSS planning, PSS development, PSS production, PSS delivery & usage, PSS evolution and PSS decomposition. This Chapter provides designers a "stakeholder-driven PSS lifecycle modelling method" to help achieve their own stakeholder-driven PSS-VE lifecycle model, in which a reference stakeholder identification model is proposed to help identify relevant stakeholders in a real project. Next Chapter will elaborate an example to expound how this method work and provide readers a more unambiguous understanding.

Table 14 reference stakeholders' responsibilities-tasks Table

Stakeholder	PSS lifecycle phase	Responsibility	Tasks
Customer	PSS planning	PSS planning	<ul style="list-style-type: none"> ➤ Idea generation ➤ Idea evaluation
	PSS development	Requirement engineering	<ul style="list-style-type: none"> ➤ Requirements input
		PSS test and refinement	<ul style="list-style-type: none"> ➤ Participating in testing ➤ Giving feedbacks
	PSS delivery and usage	Receiving and utilizing offering	<ul style="list-style-type: none"> ➤ Receiving offering ➤ Utilizing offering

			<ul style="list-style-type: none"> ➤ Giving feedbacks for delivery and usage ➤ Abandon the offering
	PSS evolution	Providing new requirements	<ul style="list-style-type: none"> ➤ Giving feedbacks according to usage stage and providing new requirements

2.3 Integrate stakeholder element into PSS-VE lifecycle and identify stakeholders relationships

The reference PSS lifecycle models in Virtual Enterprise Context proposed in Guan et al. (2017) lay on a three steps method to come up with the PSS lifecycle phases in VE context: identifying PSS lifecycle phases, identifying VE lifecycle phases and finally integrating PSS lifecycle phases into VE context.

- PSS lifecycle phases consist of six stages, respectively PSS planning, PSS development, PSS production, PSS delivery and usage, PSS evolution and PSS decomposition (purple blocks in the following two Figures);
- VE lifecycle phases contain VE creation, VE operation, VE evolution and VE dissolution (green blocks).

Two cases can occur when integrating PSS lifecycle phases into VE lifecycle phases depending on who will be in charge of the main business processes in the PSS lifecycle.

In the first case, a broker could be a small or medium company with few capabilities and resources. The broker is only the initiator of the VE, so when the VE will be created, the most appropriate company of the VE for this market opportunity will be selected to be the coordinator who will have to manage all the business. In this case, the coordinator is not a broker. In the second case, if the broker is a big company with numerous capitals, resources and competencies, its role in the VE can be totally different as he can be both the broker and the coordinator in charge of the VE creation and of all the main business processes. In that case, the coordinator is a broker.

In the first case (see Figure 29), when the coordinator is not broker, the broker generates a draft idea about market opportunity and then fulfils VE initiation and VE foundation during VE creation phase. Then, during VE operation phase, the coordinator takes charge of the rest of the business. This VE targets on a new PSS as a market opportunity solution. Then PSS planning phase starts and a completed and valid PSS idea comes out through idea generation and idea evaluation, followed by PSS preparation phase, which aims at making a reasonable schedule for PSS lifecycle and also well coordinating VE members and arranging available resources. Then PSS lifecycle goes ahead phase by phase until final PSS decomposition. So far, VE operation is finished. VE evolution may occur during VE operation in some special cases. Finally, VE is also decomposed just like PSS.

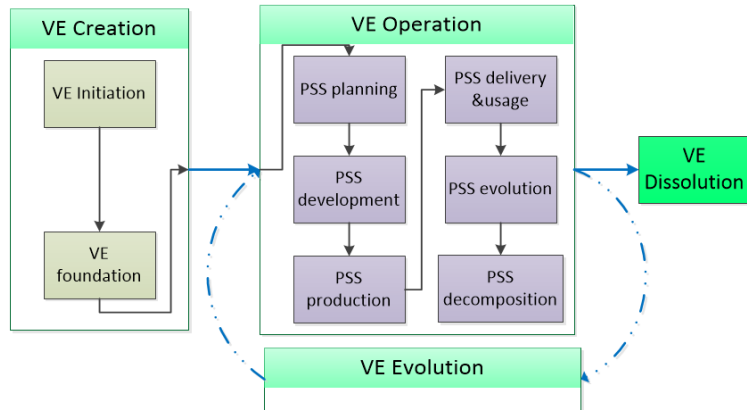


Figure 29 PSS lifecycle phases in VE context-coordinator is not a broker.

In the second case (see Figure 30), when the coordinator is a broker, the broker as a big company is able to come up with a PSS solution by himself. What he needs is to supplement his lacking capabilities when creating the VE. The most prominent distinction compared with the first case is that indeed the broker in this case will start with idea generation and idea evaluation during PSS planning phase and then VE creation phase will occur during PSS preparation phase. The PSS preparation phase in this case contains three sub-phases: VE initiation, VE foundation, and PSS scheduling & Resources arrangement. The VE operation phase will start from last PSS preparation sub-phase. The rest of the phases of the PSS lifecycle and VE lifecycle are the same than in the first case.

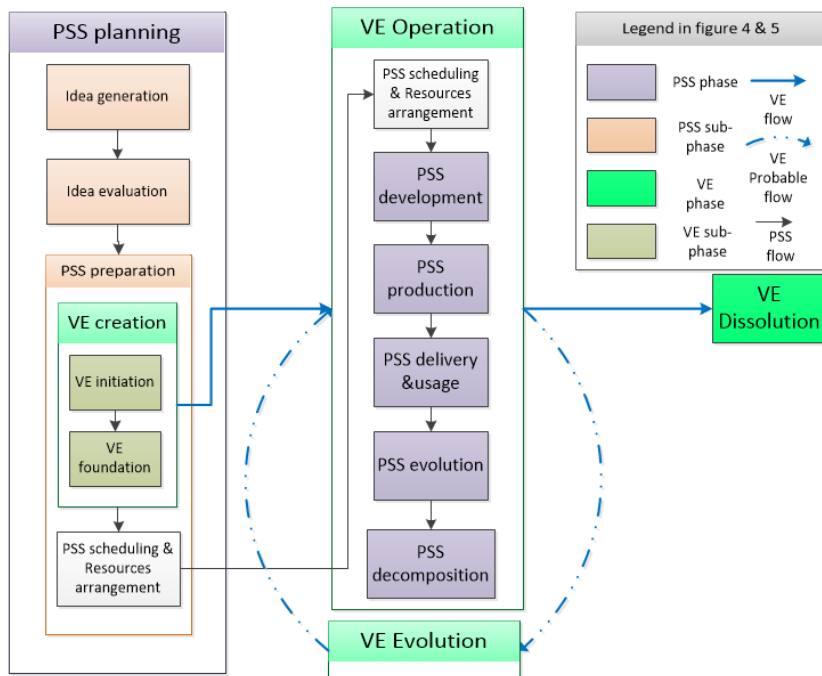


Figure 30 PSS lifecycle phases in VE context- coordinator is a broker

2.4 Illustration of the Reference stakeholder-driven PSS-VE lifecycle model when the coordinator is the broker

This section will develop the second case to provide an unambiguous understanding of the stakeholder-driven PSS-VE lifecycle model by using a study case.

The following Table 15 displays the stakeholders' responsibilities and tasks.

Table 15 reference stakeholders' responsibilities-tasks Table

Stakeholder	PSS lifecycle stage	Responsibility	Tasks
Broker	-----	VE creation	<ul style="list-style-type: none"> ➤ Rough idea of market opportunity ➤ Initiate VE & select VE members ➤ Deal with constitution & start up
Coordinator	PSS planning	PSS planning	<ul style="list-style-type: none"> ➤ Idea generation ➤ Idea evaluation ➤ Schedule PSS & resource arrangement
	PSS development	Distributing business processes	<ul style="list-style-type: none"> ➤ Requirements input from customers ➤ Distributing processes for VE members ➤ Building communication channels between VE members ➤ Requirement and specification design
		Service design	<ul style="list-style-type: none"> ➤ Process design ➤ Process prototypes ➤ Process validation ➤ Offering identification & analysis ➤ Combination of products functions and services functions
		PSS testing and refinement	<ul style="list-style-type: none"> ➤ Test and optimization of each combination option ➤ Valid PSS
	PSS production	Service implementation	<ul style="list-style-type: none"> ➤ Service implementation
	PSS delivery and usage	PSS delivery and usage	<ul style="list-style-type: none"> ➤ Combination of finished products and implemented services ➤ PSS delivery ➤ Monitoring the delivery and usage ➤ Maintenance
	PSS evolution	PSS evolution	<ul style="list-style-type: none"> ➤ New loop from development stage to usage stage
	PSS decomposition	PSS decomposition	
Customer	PSS planning	PSS planning	<ul style="list-style-type: none"> ➤ Idea generation ➤ Idea evaluation
	PSS development	Requirement engineering	<ul style="list-style-type: none"> ➤ Requirements input
		PSS test and refinement	<ul style="list-style-type: none"> ➤ Participating in testing ➤ Giving feedbacks
	PSS delivery and usage	Receiving and utilizing offerings	<ul style="list-style-type: none"> ➤ Receiving offering ➤ Utilizing offering ➤ Giving feedbacks for delivery and

			usage ➤ Abandon the offering
	PSS evolution	Providing new requirements	➤ Giving feedbacks according to usage stage and providing new requirements
Service enterprise	PSS development	Service requirement engineering	➤ Requirement engineering
		Service design	➤ Process design ➤ Process prototypes ➤ Process validation ➤ Offering identification & analysis
	PSS production	Service implementation	➤ Service implementation
Product enterprise	PSS development	Product requirement engineering	➤ Requirement engineering
		Product design	➤ Definition ➤ Translation ➤ Implementation ➤ Assessment
	PSS production	Product production	➤ Product production
Universities / Research centers	Whole PSS lifecycle	consultancy	➤ Idea generation ➤ Idea evaluation ➤ Knowledge and techniques supports for PSS preparation , etc.
Delivery partner/ Retailers/ Warehouses	PSS delivery	Delivering offerings to customers	➤ Transportation support ➤ Delivery service ➤ Store offerings ➤ Sell offerings.
IT companies	Whole PSS lifecycle	ICT infrastructure support	➤ ICT infrastructure support

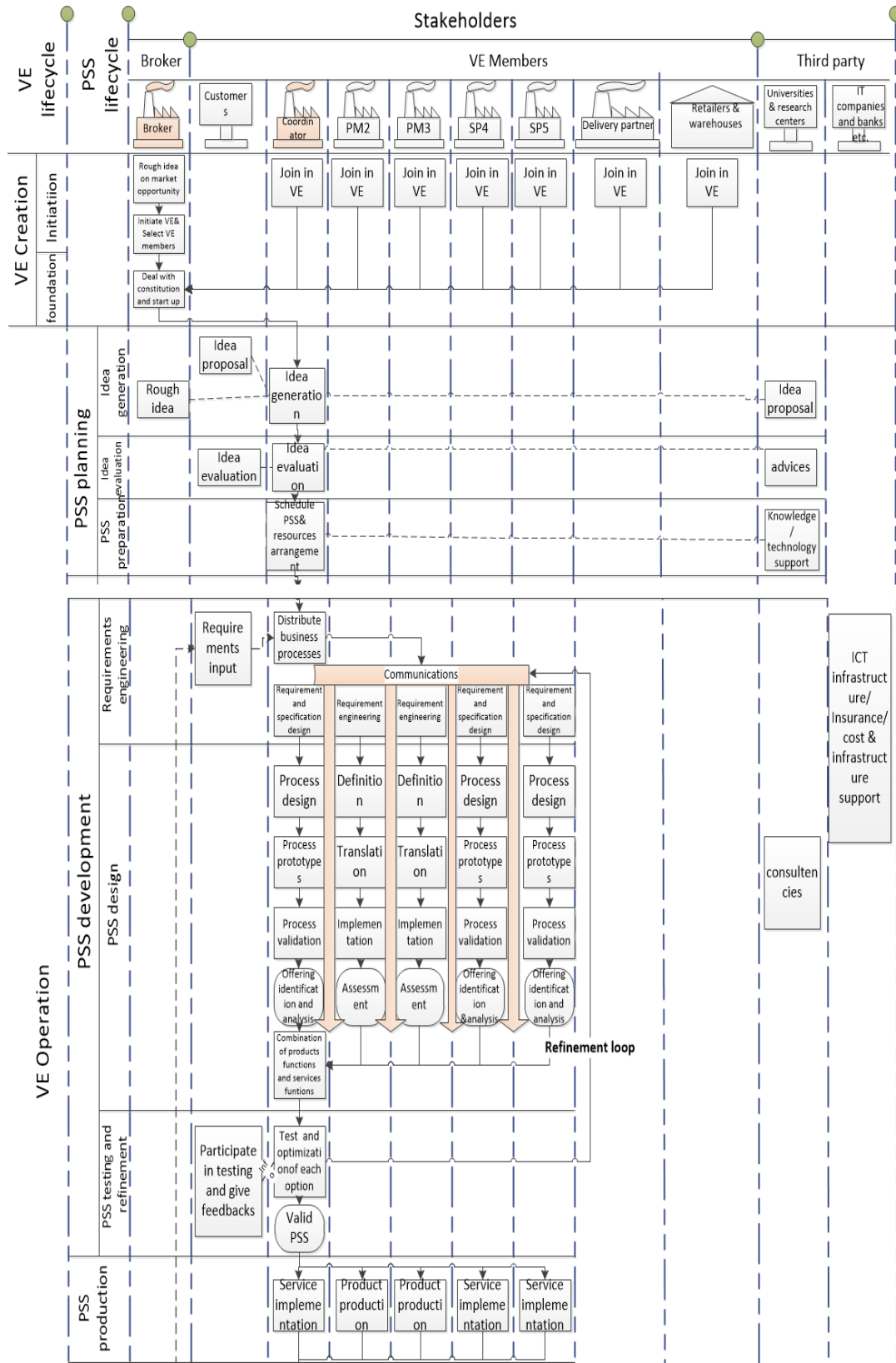
To achieve the coordinator-centered PSS-VE lifecycle model, the first step is to identify the relevant stakeholders. In this case, we assume that the relevant stakeholders consist of twelve categories among which: internal stakeholders including broker, coordinator (also a service enterprise), customer , two product enterprises, another two service enterprises, several delivery partners, retailers and warehouses; and external stakeholders such as universities, research centers, and ICT companies.

The second step is to identify their responsibilities and corresponding tasks. In this case, the broker is responsible for the VE creation and the coordinator is responsible for all the core businesses all along the PSS life phases.

- Customer is the value co-creator, participating in all the PSS life phases;
- Service providers are mainly responsible for relative services development and implementation;
- Product manufacturers, similarly, are mainly responsible for relative products development and production;
- Universities/ research centers are responsible for consultancies all along PSS life phases;
- Delivery partners/ retailers/ warehouses are responsible for PSS offerings delivery, storing and selling;

➤ ICT companies are responsible for the ICT infrastructure support.

Table 15 expounds more detailed responsibilities of each stakeholder all along PSS life phases, as well as the corresponding tasks.



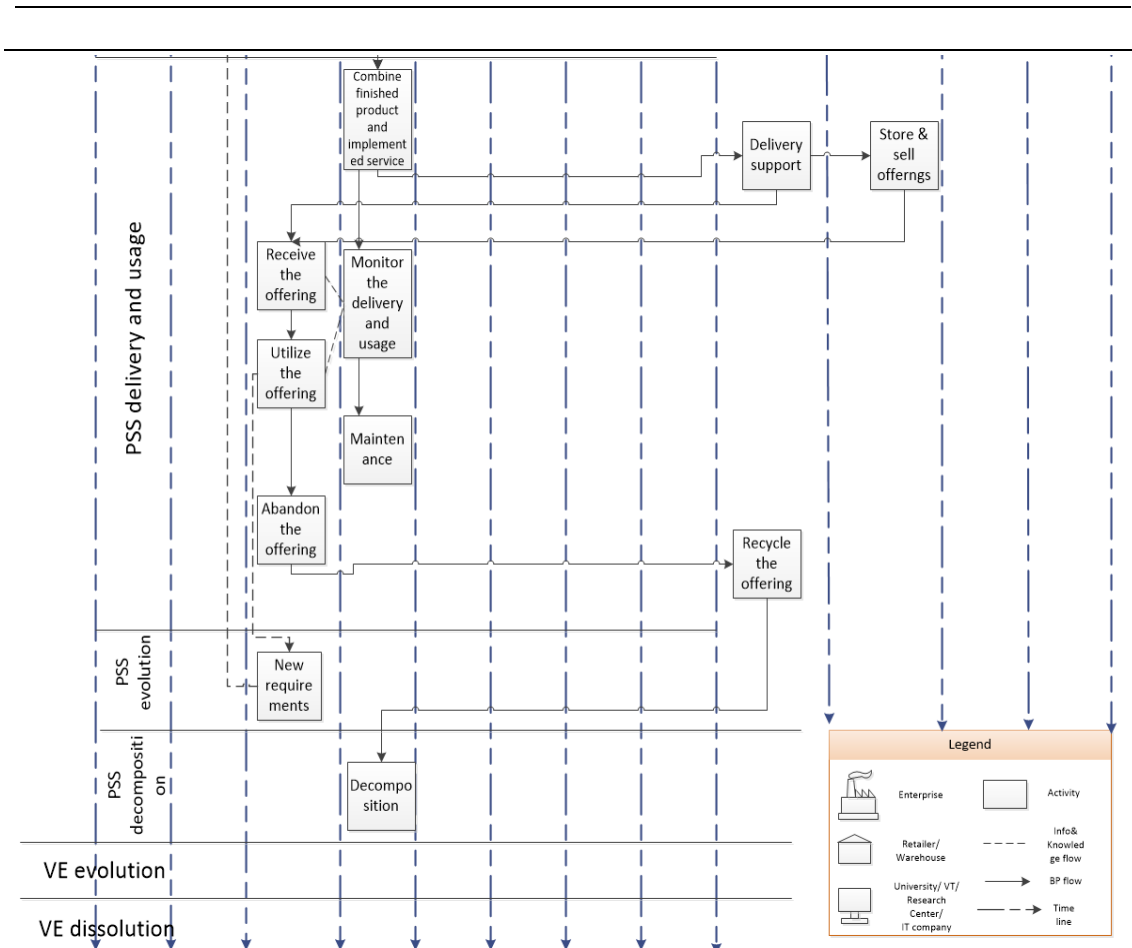


Figure 31 broker-centered stakeholder-driven PSS-VE lifecycle model

Step3 and step4 actually could proceed simultaneously after identifying all the stakeholders and their responsibilities. Figure 31 shows the broker-centered stakeholder-driven PSS-VE lifecycle model. According to the Figure, there are three main columns: VE lifecycle, PSS lifecycle and Stakeholders. Since this is the first case of “PSS lifecycle models in VE context” proposed by Guan et al. (2017), the VE lifecycle consist of four phases: VE creation, VE operation, VE evolution and VE decomposition. Particularly, all the PSS lifecycle phases proceed in VE operation phase (shown in left two columns). Before integrating stakeholder element into PSS-VE lifecycle, all the stakeholders will be displayed in the “stakeholders” column firstly. There is a “legend” displaying all the elements in the model. The arrow line represents the business process flow, the dash line represents information and knowledge flow, and the double dot dash line represents the time line. So this Figure can be read in a top-down way. The green point at the top of Figure 31 is the start point for each stakeholder’s activity.

Broker obtains a rough idea on market opportunity and then tries to create the VE. Accordingly, he seeks for partners in the cluster and finally selects the most appropriate ones. Once these companies reach an agreement, they can join the VE and the VE foundation is fulfilled. A discussion will be engaged among them to select the most appropriate company to be the coordinator and to be in charge of almost all the core businesses.

Then VE lifecycle steps into VE operation phase while the PSS lifecycle begins. The coordinator leads this VE to start the PSS planning phase, from PSS idea generation to idea evaluation to PSS scheduling & resources arrangement. Through this phase, customers, VT, universities and research centers are involved to provide information, knowledge and/or advices. Once the PSS idea is validated, the PSS development phase can start. Requirements coming from customers and from the market are analyzed by the coordinator, and a general requirement specification is generated and sent to the service providers and product manufacturers. What is worth mentioning here is that from the standpoint of reducing waste and achieving sustainability, the first and basic principle is to realize the functionality (coming from customers' requirements) in a most profitable (with less expenses and efforts) and environmental way. So in the design phase, the objective of designers is to find an optimal way of combining "product functions and service functions" rather than just combining "product components and service components". That's why here product manufacturers adopt the design processes from value engineering theory (Ferguson et al., 1968), while service providers adopts SService Engineering Methodology (Pezzotta et al., 2014).

During PSS development phase, due to the fact that customers' requirements will possibly update leading to the PSS solution requirements updating, it is necessary to build communication channels between different product and service providers to guarantee requirements synchronization and functions compatibility. When all the function components are produced, the coordinator will combine them to come up with several PSS offerings. These offerings will be then tested.

Additionally, there is also a refinement loop for optimizing developed PSS offerings. Later the valid PSS offerings components will be produced or implemented by these VE members and combined. The final offerings will be distributed and delivered by delivery partners, retailers and warehouses and finally received by customers for utilization. During this phase, information and feedbacks derived from customers' will be collected by coordinator's monitoring system, which will be used for later PSS evolution. Once the usage contract expires, the customer maybe abandon the offering and delivery partner will help recycle the offerings and the PSS lifecycle go to decomposition phase. All along the lifecycle, universities and research centers will possibly provide any kind of help in each phase; while the IT companies will help set up and maintain the ICT infrastructure.

In this case, the PSS decomposition also occurs in the VE operation phase. We assume that the VE is stable once it is created. The rest part is for VE evolution and VE dissolution.

This section lays a foundation for Chapter 4. PSS-VE lifecycle modelling in this thesis is not only useful for designers to reduce system complexity and uncertainty, and to help them to prepare for unpredictable risks along lifecycle, but also prepares for satisfying the proposed framework's requirements due to their nature of lifecycle orientation.

For instance, "Design for X (A22)" refers to design for manufacturing, design for production, design for delivery, design for use etc. Constraints coming from these phases need to be considered; besides, "customer involvement (A12)" also could happen in each phase of PSS-VE lifecycle; "customer satisfaction (A13)" refers to the interactions and communications quality and efficiency between customers and providers in some phases along PSS-VE lifecycle; "Sustainability Assessment (A31)" must consider all the value in each process along lifecycle.

3. Modelling Virtual Enterprise (VE) using AGORA Multi-Agent System (MAS)

According to our literature review, few authors have attached importance to the design of supporting network in the PSS field. This thesis elects agent-based approach to bridge this gap. Agent-based approach has been widely used in software engineering field since last century; and later several researchers introduced this approach into cooperative network modelling, particularly for VE modelling, such as Petersen et al. (2001), Rao & Petersen (2003). In this section, multi-agent system, especially AGORA multi-agent system which is dedicated to solve the cooperative network problem in PSS field is adopted. This section will firstly briefly introduce several concepts about AGORA framework in order to achieve a general understanding about agent-based fundamental knowledge, and then will introduce how to use AGORA framework to model VE in order to support VE design.

3.1 Fundamental knowledge about AGORA multi-agent system

Agent, Multi-Agent System (MAS)

Different definitions of agent can be found in the literature. Wang et al. (1999) defined an agent as a piece of autonomous software created by and acting on behalf of a user (or some other agent). Matskin (1999) supplemented more characteristics to an agent as an autonomous, proactive, social and reactive system as well as able to represent user-delegated goals and tasks. Petersen et al. (2001) followed the definition that an agent can be defined as a hardware or software-based computer system that is autonomous, reacts to changes in its environment in a timely fashion, is proactive by

taking initiative and by exhibiting goal-oriented behaviour and has social ability to interact and communicate with other artificial and human agents. More recently, Dorri et al. (2018) have reviewed the notion of multi-agent system and regard an agent as an entity that is placed in an environment and senses different parameters that are used to make a decision based on his goal. The entity performs the necessary action in the environment based on this decision. Despite of the evolution of the concept, each agent should consist of four elements: entity, environment, parameters and action (Dorri et al., 2018):

- Entity refers to the type of agent, which evolves from a piece of autonomous agent (Wang et al., 1999) to software or hardware (Petersen et al., 2001) to software, hardware or a combination of both, for instance, a robot (Dorri et al., 2018).
- Environment refers to the place where the agent is located.
- Parameters refer to different types of data that an agent can sense from the environment.
- Action: each agent can perform an action that results in some changes in the environment.

Moreover, agent is acknowledged to be autonomous, proactive, social and reactive which makes agent-based system carry on the same property. The agent-based architecture shows outstanding advantages in simplicity and flexibility and particularly useful in modelling and providing support to cooperative activities (communication, negotiation, coordination and collaboration) (Wang et al., 1999). An agent-based approach show more advantages also because it is a constructive approach for work in an open environment, which is much similar to the human's way of doing things in a real world, therefore having a rational model of behaviour and having motivations to be fulfilled by implementing goals (Matskin, 1999). Multi-Agent System (MAS), as a loosely-coupled network of problem solvers, is regarded as a good way to solve a given problem (Wang et al., 1999). Dorri et al. (2018) indicated due to MAS' salient features of efficiency, low cost, flexibility and reliability, that MAS can be an effective solution to solve complex tasks. A MAS show more advantages in following five aspects during modelling cooperative network (Wang et al., 1999):

- Decentralization: being able to break down a complex system into a set of decentralized, cooperative subsystems;
- Reuse of previous components/ subsystems: building a new and possibly larger system by interconnection and interoperation of existing (sub) systems, even though they are highly heterogeneous;
- Cooperative work support: being able to better model and support the spectrum of interactions in cooperative work;
- Flexibility: being able to cope with the characteristics features of a distributed environment;
- Simplicity: being able to offer conceptual clarity and simplicity in modelling and design.

AGORA multi-agent framework

Before introducing the AGORA multi-agent framework, it's necessary to introduce the basic elements of a multi-agent framework. There are mainly four elements in a multi-agent system: AGORAs, agents, workspaces, and repositories (Wang et al., 1999).

AGORAs

An AGORA is a word which is defined as a public open space used for assemblies and markets in Oxford Dictionary. It is also the abbreviation of AGent Oriented Resource mAnagement (AGORA) (Basit and Matskin, 2010). In the context of multi-agent architecture, an AGORA is both a place where agents can meet and establish a common context for cooperative work and a place where they can get support for a particular cooperative activity (Matskin et. al., 1998; Matskin, 1999). An AGORA is also a place where software agents meet and interact, but can also be a market place where agents “trade” information and service (Wang et al., 1999). An AGORA can also be a facilitator in a multi-agent system, which acts as an intermediary between the agent sending the request (requester) and the agent providing the service (requestee) (Dorrie et al., 2018). From multi-agent point of view, AGORA follows a metaphor of a marketplace which provides support for conducting collaborative agent activities. An AGORA consists of four main components as depicted in Figure 32, respectively: AGORA node, AGORA services, AGORA Managers and Registered agents (Dorri et al., 2018).

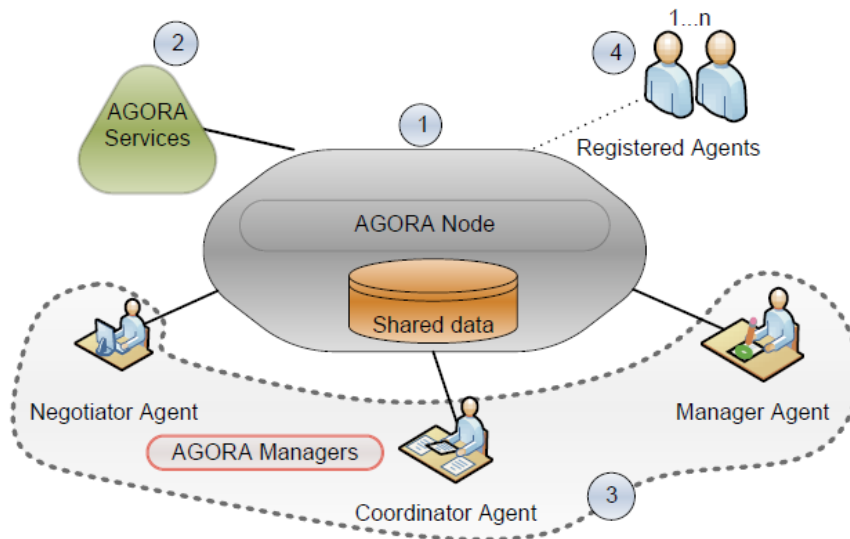


Figure 32 a simple AGORA node

- AGORA node contains all the critical data of the AGORA. The data is shared among all the AGORA managers. All AGORA managers and services are initialized at the start-up of AGORA node.
- AGORA is able to provide an arbitrary number of services which are different according to managers. These AGORA services can be: access to information

sources and tools. For instance, when an agent registers in an AGORA, it may need a certain information source, such as a document in order to conduct the work. A specialized service agent can obtain the document for the agent.

- AGORA managers are those agents that are responsible for providing management related services. There are mainly three categories: manager agent, coordinator agent and negotiator agent. Manager agent is responsible for overall operations related to AGORA management, including registration and un-registration of other AGORAs and agents, maintaining all the critical data in node, and providing access to AGORA services; coordinator agent implements logic which insures the smooth flow of collaborative activities; negotiator agent implements the logic of conflict resolution for all supported activities of AGORA.
- Registered agents are external agents willing to use functionalities provided by AGORA. Registered agents could communicate with AGORA manager by message passing based on Agent Communication Language (ACL), and consume services provided by AGORA.

Agent

The whole VCCPs are carried out by groups of people, using tools, such as work tools, process tools, and communication tools. Each participant can create a set of agents to assist oneself in some particular aspects (Wang et al., 1999). There are mainly three categories of agents: System agents, local agents and interaction agents:

- **System agents:** This covers default agents for the administration of the multi-agent architecture, such as creation and deletion of AGORAs. Each AGORA may have several agents registered, and each agent may be registered in several AGORAs. Thus, the management of the AGORAs is not the role of any of the participating agent but the role of system agents. The system agent functionality described above is a minimum of features the multi-agent architectures need. In some cases more specific system agents are needed: (1) monitoring agents: to monitor events in and out of the workspaces as well as the AGORAs and to collect relevant measurement according to predefined metrics; (2) repository agents: a repository agent can provide intelligent help both for human and software agents to find specific information in repositories.
- **Local agents:** To assist in work within local workspaces. These agents act as personal secretaries dealing with local process matters. It should be possible to create local agents for several purposes, but here we will only present two examples of subclasses of local agents:
 - (1) Work agents: to assist in normal production activities, such as software development and testing;
 - (2) Process agents: to model the facilities and tools of defining, planning, scheduling and enacting process models, both local and shared.
- **Interaction agents:** To help participants in their cooperative work. Such agents can also be viewed as shared process agents. Such agents include:
 - (1) Communication agents: to support a spectrum of more high-level

communication facilities. Communication between agents takes place in AGORAs, while communication between agents and humans takes place in workspaces. Communication agent can be used as a simple information carrier between users, and further, more as a complex software problem solver that interacts with various agents and information sources in order to complete its mission;

(2) Negotiation agents: by definition, negotiation is the process of joint decision making where the negotiating agents verbalize their (possibly contradictory) demands and the move towards an agreement. Many kinds of negotiations occur in a multi-agent system. For example, two concurrent developers modifying same software modules need to negotiate about how to schedule their work and merge their results;

(3) Coordination agents: to support, for example, a project manager issuing a work-order that involves a group of developers; or a higher-level manager being called in to mediate negotiation agents and reach an agreement; etc.;

(4) Mediation agents: in a complex, real-life domain, negotiation and coordination are not easy to carry out purely by algorithms. Third part mediation is often necessary. Mediation agents help negotiating agents to reach an agreement. In doing so, mediation agents may consult the Experience Base (EB), act according to company policies or ask a project manager (human) for help to make decisions.

Workspace (WS)

A workspace is a place where human and agents access files and tools. In addition, interaction between users and agents takes place in workspace. One important requirement for a workspace is that data is accessible in a format possible for tools and humans to interpret. A workspace can store all kinds of data which incorporate process data as well as process models. Agents can access data in the workspace either directly or indirectly through tools. It is also possible to have private works spaces as well as shared workspaces. More advanced workspaces provide hierarchical levels of workspaces. There sharing of data is not only limited to humans, but are also shared among agents.

Repositories

A repository represents an information server that in the simplest form only provide services for storing and retrieving persistent data. A more advanced repository will provide services for data modelling and agent offerings services for searching through data, comparing data, computing data, etc. Repositories can be accessed either by tools or by agents. The architecture allows repositories to exist locally directly related to a workspace, called local repository, or shared among several workspaces, called distributed repository. Local repositories are mostly accessed directly by tools running in the workspace, while distributed repositories are supported through AGORA and repository specific agents. Such agents can provide intelligent services for storing and retrieval of data to/from repositories.

According to the introduction of system components, the following Figure 33 exhibits the AGORA multi-agent system components decomposition hierarchy.

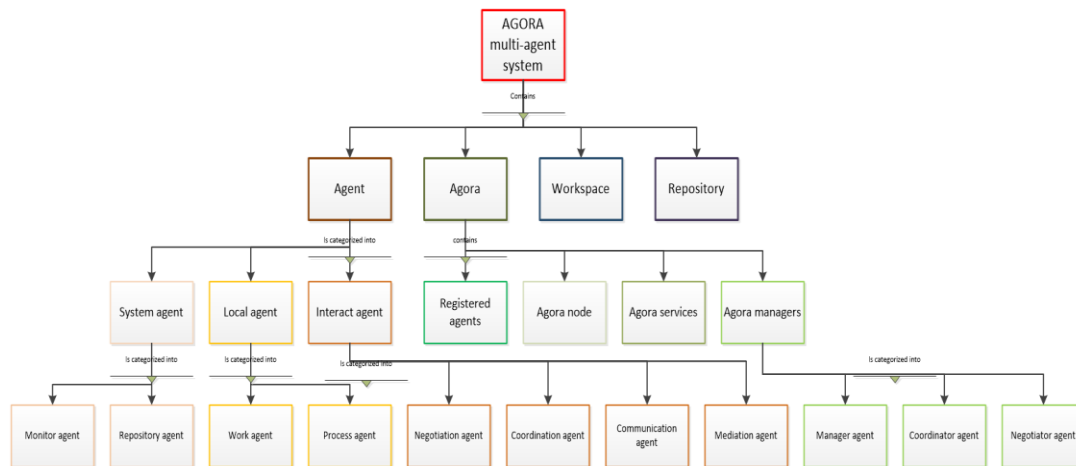


Figure 33 AGORA multi-agent framework components decomposition

3.2 VE modelling using AGORA multi-agent system

This section is dedicated to make simple examples of VE modelling using AGORA multi-agent system in order to show the basic regulations and ways of modelling. According to the VE design processes developed in Chapter 3, here we select three typical activities: requirements engineering, partner selection, VE implementation. Here, we start from requirements engineering:

During the requirements engineering, a requirement AGORA could be built. According to Figure 34, there are three main categories of roles during requirement phase, respectively: customers, broker, and other enterprises that are interested in this opportunity and intend to integrate the collaboration. These roles have their own workspaces, in order to fulfil the requirement engineering activity; all the potential involved stakeholders need create new negotiation agents and join into the requirement AGORA. These agents register at an AGORA by submitting their names and addresses, their interests, competencies, goals and any other relevant information. After registration, these parties are able to specify the customers' needs and their own requirements as well as the operational requirements for a new VE. Based on continuous negotiations, these parties will come up with an agreement about the necessary requirements. Indeed, there is also a huge need for information searching and exchanging during the whole lifecycle of VE, hence it is necessary to build a service agent, which is used to stored variety of information among different partners. In here, the concept of Experience Base (EB) is adopted. The Experience Base (EB) indeed is one typical category of shared repository, which holds information about previous completed projects and offerings and previous updates/ releases of current offerings, such as: the project profiles, evolution patterns, performance metrics, and process models (Wang et al, 1999). All the departments can access into EB and store experience files in it. What's more, the information in EB actually keeps updating, which will be used for future activities.

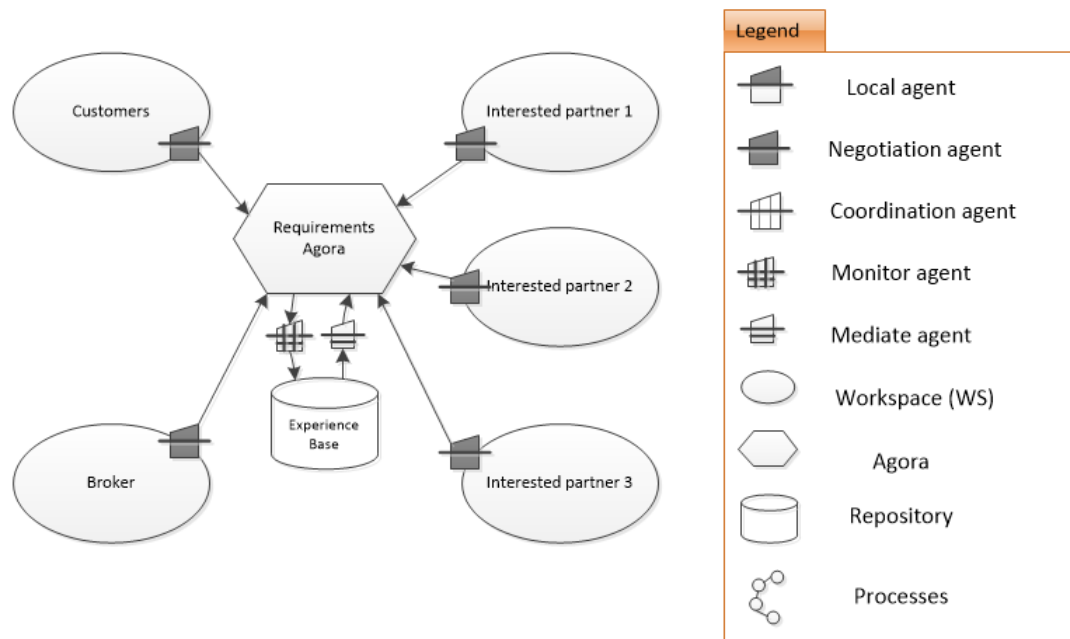


Figure 34 the requirement AGORA

In terms of partner selection, as shown in Figure 35, a broker may create “partner selection AGORAs” between different interested partners. They will negotiate according to selection criteria. If an interested partner is selected finally, there will be an agreement contract between the broker and the interested partner. This Figure also shows the flexibility of the AGORA framework. The registration process can be customized depending on the application area. A new AGORA can be created from an existing AGORA and agents can register at any time and at several AGORAs at the same time (Petersen et al., 2001). In the partner selection activity, if some problems need to be discussed or some activities need to be coordinated between different interested partners, it is possible to create a coordination AGORA between them to deal with them. What’s more, when customers and broker need to negotiate about the contracts, they may also create an agreement AGORA. This thesis adopts “service level agreement” to formulate the contracts and regulations between them. Service level agreement may have different definitions in different contexts (Jin et al., 2002; Fawaz et al., 2004; Kowalczyk et al., 2007; Klimova et al., 2015). However, usually a service level agreement is able to describe an agreement between service provider and service consumers which defines mutual understandings and expectations of a service. A service level agreement may consist of ten aspects (Jin et al., 2002):

1. Purpose - describes the reasons behind the creation of the SLA;
2. Parties - describes the parties involved in the SLA and their respective roles (provider and consumer);
3. Validity period - defines the period of time that the SLA will cover. This is delimited by start time and end time of the term;
4. Scope - defines the services covered in the agreement;
5. Restrictions - defines the necessary steps to be taken in order for the requested service levels to be provided;

6. Service level objectives: the levels of service that both the users and the service providers agree on, and usually include a set of service level indicators, like availability, performance and reliability. Each aspect of the service level, such as availability, will have a target level to achieve;
7. Penalties - spells out what happens in case the service provider under-performs and is unable to meet the objectives in the SLA. If the agreement is with an external service provider, the option of terminating the contract in light of unacceptable service levels should be built in;
8. Optional services - provides for any services that are not normally required by the user, but might be required as an exception;
9. Exclusions - specifies what is not covered by the SLA;
10. Administration - describes the processes created in the SLA to meet and measure its objectives and defines organizational responsibility for overseeing each of those processes.

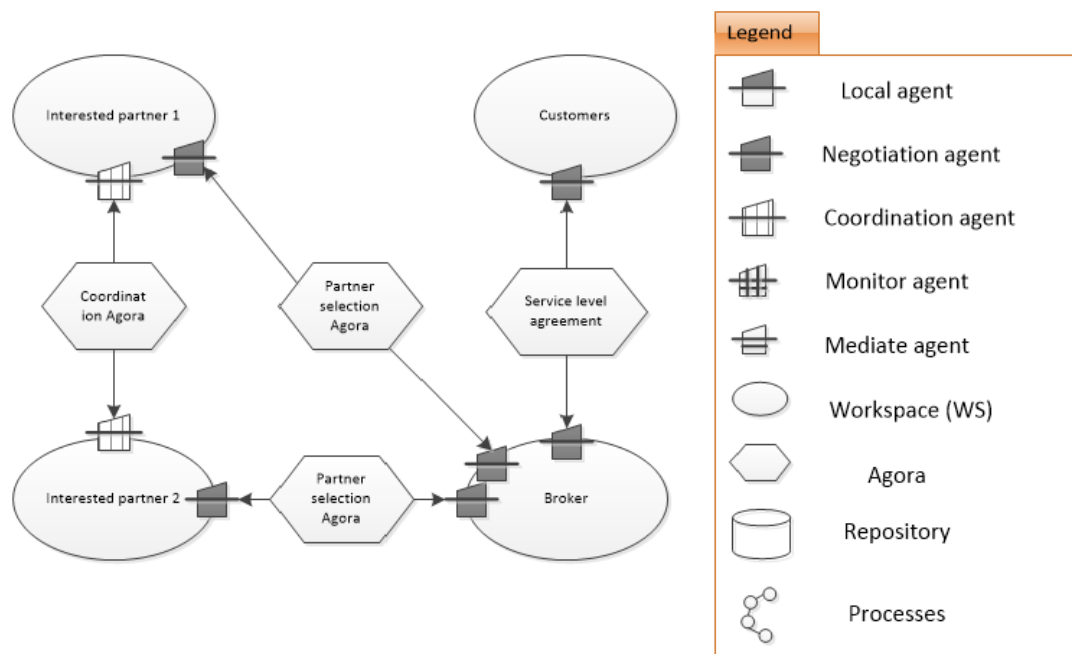


Figure 35 Cooperative work during Partner Selection

After requirements phase and partner selection phase, the broker, the customers and other interested partners are ready to create the VE, hence we come to the implementation phase. In this phase, an Implementation AGORA is to be created firstly, as well as the Experience Base (EB), so that the broker/coordinator, customers and the potential partners are able to access the EB and query and utilize the information in it. According to Camarinha-Matos & Afsarmanesh (1999) and Guan et al. (2017), during VE creation phase, resources allocation & rearrangement and infrastructure reconfiguration also need to be fulfilled. Hence a series of negotiation and coordination activities have to be launched in order to come up with the agreements among the different interested partners. As shown in Figure 36, a cooperation AGORA is created between potential partner 1 and broker, the same with

potential partner 2, etc. Based on the cooperation AGORA, coordination agents and negotiation agents are built in the broker/coordinator workspace as well as potential partners. The broker/coordinator could send out a proposal to all the potential partners and receiving offers which can be handled by a coordination agent having a Contract Net Protocol (Davis and Smith, 1988), in it. The coordination agent assumes the role of a manager and announces the required work to be done to the potential contractors. Juneja et al. (2015) describe how the Contract Net Protocol works in detail, as shown in Figure 37: The manager communicates a cfp (call for proposal), communication act to other agents in the group describing the task and constraints, if any. Agents listening to the cfp are potential contractors and few of them may opt to send in the propose communication act showing their willingness to do the task while few others may refuse to accept this cfp. The manager agent analyses all j responses and may choose $l=j-k$ proposal while reject $k \leq j$ proposals. In both cases, manager is required to send the relevant communicative act (reject or accept, as applicable) to the contractor agents. The l number of chosen agents may include none of the agents, few agents or all of the contractors. Finally, the contractors handling the task shall inform the status to manager using inform (inform-done and inform-result) or failure communicative acts. Thanks to the protocol, communications between different agents become more convenient. Additionally, the coordination AGORA also could be created between different interested partners, in order to deal with the coordination activities between them. One of them could be regarded as a manager while the other one could be seen as a contractor. They can also communicate by utilizing the protocol.

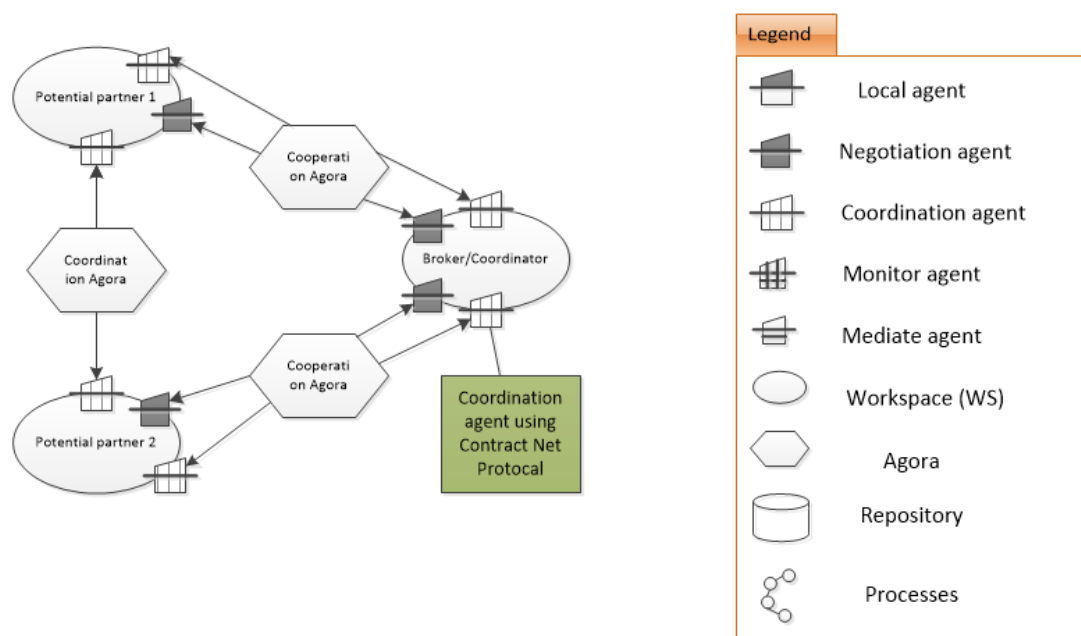


Figure 36 Cooperative work during implementation phase

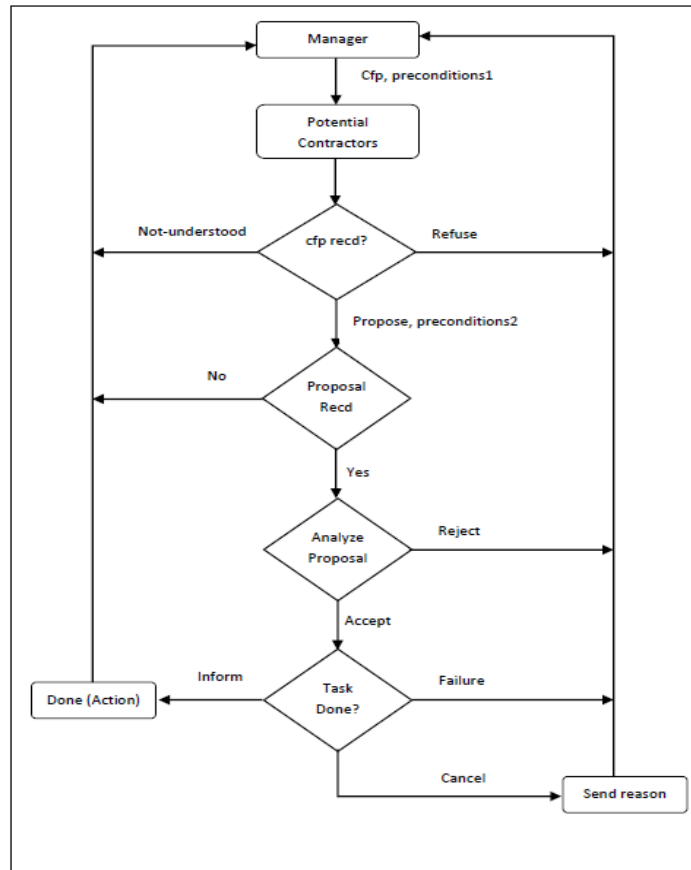


Figure 37 Contract Net Protocol (Juneja et al., 2015)

The AGORA multi-agent architecture supplements the VE design process introduced in Chapter 3 to provide an efficient way of collaboration among different VE members. From now on, all the interactions and communications in VE will be based on AGORA architecture, including design activities among different life phases and departments, customer involvement in PSS-VE lifecycle, and design activities controlled by agile management.

3.3 Design for X and Customer Involvement

PSS-VE lifecycle modelling enables designers and practitioners to consider all the stakeholders' roles, responsibilities, resources, knowledge etc. all along the PSS-VE lifecycle in the early stage of PSS design, which also settles a solid foundation for "Design for eXcellence (DfX)". Design for X is also one of the key requirements of the integrated sustainable 3DCE COPSS design framework presented in Chapter 3. DfX research emphasizes the consideration of all design goals and related constraints in the early design stage. By considering all goals and constraints

early, companies can produce better offerings. Furthermore, the offerings will enter the marketplace earlier because an inherently simpler offering is designed correctly the first time without the introduction of problems, delays and changes of orders (Osorio et al., 2014). X not only means excellence but also represents different goals and different life stages. Basically, designers should consider the constraints coming from manufacturing, production, testing, delivery, recycling and so on; hence, DfX may contain design for manufacturing, design for assembly, design for production, design for testing, design for delivery, design for recycling and so on. Moreover, as variety of goals, such as environmental aspects, quality, safety, reliability etc., should be considered in the early design stages, design for X may also include design for environment, design for quality, design for safety and reliability.

Design for X technique shows huge potentials and competitive advantages. For instance, Osorio et al. (2014) indicated Design for Disassembly (DSD), Design for Recyclability (DFR) and Design for Lifecycle (DFL) allow the designers to plan ahead for product re-processing after its useful life. Design for the Environment (DFE) focuses on environmental, safety and health related issues and thus can help to reduce the indirect cost of a product. Design for Quality (DFQ), Design for Maintainability (DFM) and Design for Reliability (DFR) can also be ensured by the design and process controls rather than by an expensive testing, diagnostics and re-work.

In this thesis, we have developed the concept of COPSS that focuses more on customers' experience and value than traditional provider-driven/ technology-driven PSS. In Chapter 2, we have identified one of the most important distinctions of COPSS rather than PSS-customer involvement. We emphasize that the customers in modern COPSS solutions should be active and involved in the solution design and development and even be co-ideator, co-designer, co-producer, co-manufacturer, co-tester, co-distributor, co-consumer etc.

In order to figure out the abovementioned issues, we propose to use the above-mentioned AGORA multi-agent architecture to support the 3DCE COPSS design framework addressing the three aspects of COPSS design: (1) basic design processes of PSOs and VCCPs design, (2) design for X during design processes and (3) customer involvement during design processes.

This section will introduce the "Virtual Department" concept in VE context. This concept extends the boundaries of traditional physical departments in one company as in VE context, majority of businesses processes are fulfilled based on cooperative work which need more than one company's department. Each virtual department consists in human beings, as well as their corresponding resources. For instance, the production department may consist of several production departments from different companies; therefore, there are several local agents in it, which means that the production processes may be distributed to several cooperative companies. We use the term "workspace" to model different "virtual departments" based on distinctive feature of responsibility for different business processes. In workspaces, local agents, repositories, negotiation agents, coordination agents are integrated to deal with different problems. In Figure 38, five main virtual departments are exhibited;

respectively are marketing department, design & development department, production department, delivery department, and usage & maintenance department. Indeed, the above-mentioned workspaces also can represent different life phases of the COPSS lifecycle, from marketing, to design to usage, which designers should consider in the early design phase in order to fulfill Design for X goals. It's worth mentioning that we set an individual workspace for customers, because we also consider customers as a virtual department, since customers are involved in each phase of the COPSS lifecycle.

AGORA architecture's prominent advantages could be shown under this condition. The Figure just gives an example of how to model. In real cases, the departments or concerned life phases will not be limited to those in this Figure. However, designers could add whatever they think necessary into the Figure, including both workspaces and AGORAs. Besides, in this Figure, we just identify some key relationships among different workspaces and AGORAs only to show how to use these elements to model design processes based on AGORA multi-agent architecture.

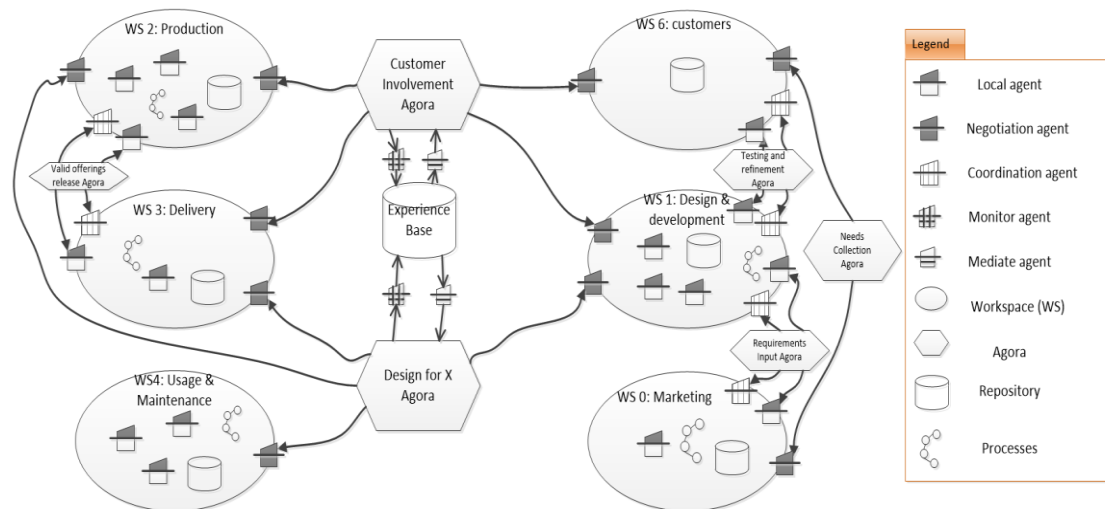


Figure 38 modelling COPSS design using AGORA multi-agent architecture

Figure reading starts from right to left. Requirements always come first. Based on “needs collection AGORA”, marketing department is able to contact with customers, and negotiate with customers so that they can obtain the requirements from them. These requirements will be later transferred to design and development department through “requirements input AGORA”, negotiation agents and coordination agents will be necessary here for agents to cooperate with each other. After obtaining the requirements from the marketing department, the design and development department will fulfill “PSOs functions decomposition” (one of PSOs design processes developed in Chapter 3). In accordance with the decomposed functions, designers will try to find corresponding products and services modules from Experience Base so that they can combine them to propose suitable solutions for PSOs offering scenarios. The Experience Base indeed is one typical category of shared repository, which holds information about previous completed projects and

offerings and previous updates/ releases of current offerings, such as: the project profiles, evolution patterns, performance metrics, and process models. All the departments can access into EB and store experience files in it. The Figure shows two typical ways of using EB. We use mediator agent to draw previous experiences from the EB in mediating difficult negotiations. We also need monitor agents to keep track of the happenings in workspaces and AGORAs to collect and analyze data, and to store them into EB. During the design phase, both PSOs and VCCPs should be designed and developed. Thus, on one side, for PSOs design, designers should consider the constraints from later life phases, such as production phase, delivery and usage phase; hence it is necessary to set up a “design for X” AGORA, according which different departments are able to negotiate with each other using their negotiation agents; on the other side, for VCCPs design, designers should collect the processes from the other departments, and rearrange them and put forward effective and efficient combination of VCCPs; hence, a “design for X” AGORA is also necessary.

In terms of customer involvement, we set up a “customer involvement AGORA”. Based on the AGORA, customers are able to communicate with different departments in different COPSS life phases, so that they could provide their thoughts, experiences, knowledge, and advices etc. with designers, in order to help designer improve their solutions. Especially, due to the flexibility characteristic of AGORA architecture, players on this platform can set up whatever AGORA they want to fulfill specified target or Figure out specified problem. In this case, customers and designers also set up a “testing and refinement AGORA” in which they will coordinate and negotiate with each other in order to test and refine the prototypes; therefore improving the PSOs’ quality based on customers’ experience and feedbacks. In this way, AGORA architecture also helps fulfill the goal of “Design for Quality”.

Additionally, it is worth mentioning that the architecture indeed could be decomposed in lower levels since the VE itself essentially is a system of systems. The workspaces listed in the Figure 38 not only describe different work groups but also different core activities in different lifecycle phases. These core activities could be decomposed into more detailed tasks in lower levels; therefore these workspaces could also be decomposed into more sub-workspaces. This will be deeply developed in the next section.

4. Agile management using Scrum and XP

4.1 Brief introduction to agile methodologies

Agile methodologies stems from the beginning of 21th century in software design field. Agile-denoting “the quality of being agile; readiness for motion, nimbleness, activity, dexterity in motion”- software development methods are attempting to offer once again an answer to the eager business community asking for lighter weight along with faster and nimbler software development processes (Abrahamsson et al., 2017). Agile methods can be seen as an outgrowth of rapid prototyping and rapid development experience as well as the resurgence of a philosophy that programming is

a craft rather than an industrial process (Boehm, 2008). Agile methods have been introduced in the PSS field in recent years. Stare (2014) indicated that “despite the growing popularity of agile project management in the field of IT projects, it has not yet been established in other types of projects (engineering, research & development, organization of events)”. This statement can be also applied to PSS design and management field. Only few relevant articles have been found on the search engines, such as “Google Scholar”, “Research Gate” and “Science Direct”. Typically, Minguez et al. (2012) proposed reference architecture based on service-oriented architecture (SOA) to support coordination and definition of goals in heterogeneous supply chains. Since the SOA is able to provide rapid reconfiguration of business processes, rapid integration of services and goal definition through service level agreements. The agile PSS network consists of three building blocks: goal definition and conflict resolution, PSS network performance, and PSS network configuration. Freitag et al. (2018) proposed an “agile product-service design approach”, which closes the gaps between the development of new PSSs and market launch. This approach was applied to real use cases of two companies in furniture industry. Tran et Park (2015) have proposed a strategic prototyping framework for PSSs using co-creation approach. This framework pays more attention to customer value as well as customer involvement. Six steps help designers design and make evolve PSS prototypes: demonstration, participation, refinement and analysis, visualization, evaluation and modification. This framework is essentially a way of iteration of prototyping and evaluation. Similarly, Asmar et al. (2018) also developed a framework for agile development of innovative PSSs, which consists of PLAN, BUILD, MEASURE and LEARN four stages. When summarizing the common characteristics among the three articles, it is not difficult to find that the core thought of agile design is the loop of prototyping and measuring. Prototyping is a series of processes, from which product service offerings will be designed and developed; these prototypes will be launched on the market and be measured by customers. Feedbacks from customers and market will be used for the second generation. This iteration will be lasted until the final prototypes satisfy both customers’ and providers’ requirements.

Pathak and Saha (2013) reviewed some existing articles and made a comparison between traditional approaches and agile approaches which is able to bring us a general understanding of agile methodologies (see Table 16).

Table 16 how agile is different from traditional approaches from authors

Traditional approaches	Agile approaches
Deliberate and formal, linear ordering of steps, rule-driven	Emergent, iterative and exploratory, beyond formal rules
Optimization is the goal	Adaption, flexibility, responsiveness is the goal
In this type the environment is taken as stable and predictable	In this type the environment is taken as turbulent and difficult to predict
Sequential and synchronous process	Concurrent and asynchronous process
It is work centered process because people will	It is people centered process, as the same team is

change according to different phases.	developing throughout
Project lifecycle is guided by tasks or activities	Project lifecycle is guided by product features.
Documentation is substantial.	Documentation is minimal
Developers do waiting until the architecture is ready	The whole team is working at the same time on the same iteration. Good coordination between team members
Too slow to provide fixes to user.	Provide quick responds to user feedback
Change requirements is difficult in later stages of the project	Can respond to customer requests and changes easier
More time is spent on design so the product will be more maintainable. The “what ifs” arise earlier	There is no time for the what ifs
No communication within the team, novices stay in their rooms and try to understand things	High level of communication and interaction, reading groups, meetings
Restricted access to architecture	The whole team influences and understands the architecture. Everybody will be able to do a design presentation
Documents and review meetings are needed to solve an issue	5 minutes discussion may solve the problem
Everything is up front, everything is big before you start	The focus is on whether customer requirements are met in the current iteration
Normal releases take 18 months	After 10 months the first release was out

According to this comparison, the most distinctive characteristic and advantage of agile approaches is the response time. An agile methodology is able to respond to customers-whatever existing requirements or changes-in a very short lead time. At the same time, agile approaches are also dedicated to satisfy customers’ needs since customers’ requirements must be met in a current iteration. Agile approaches change the way of doing things as a project is divided into several sprints. Each sprint is to be done in a short time. Another key point for agile approaches is concurrent and synchronous processes since developers are distributed into different groups and responsible for different work, so that the project could be processed concurrently at the same time. Due to the abovementioned advantages, this thesis introduces the concept of agility into COPSS design. In this way, companies adopting the design framework proposed here could also be able to quickly respond to customers.

Several articles have launched the literature review for existing agile methodologies (Dingsøy et al., 2012; Pathak and Saha, 2013, Abrahamsson et al., 2017; Ashraf & Aftab 2017). According to their review, the acknowledged agile methodologies mainly include eXtreme Programming (XP), Scrum, Crystal family of methodologies, Feature Driven Development (FDD), Rational Unified Process (RUP), Dynamic System Development (DSD), Adaptive Software Development (ASD), Open Source Software development (OSS), etc. Among these methodologies, the most

widely used and recognized ones are eXtreme Programming (XP) and Scrum (Anwer et al., 2017). This is also one important reason for my thesis to adopt them as the main agile management methodologies.

From the viewpoint of project management, Scrum is able to manage large projects since PSS design -particularly in the context of VE- is sometimes a bigger project than common software design. Anwer et al. (2017) have indicated that Scrum is suitable for all size of projects. Alqudah & Razali (2016) have made a literature review for agile methods in large software development in which they indicated that Scrum can be used for large software design projects. They called the Scrum in large software development context “LeSS”, which means “Large-Scale SCRUM”. Larman & Vodde (2013) describe basic LeSS as a method that is applied to a median implementation covering approximately “70 people on one product and for LeSS huge thousands of people one product at 5 sites with about 15 million source code”. There are three strong points for Scrum use in project development and management: transparency, inspection and adaption, which are also critical features in PSS design.

- Transparency means that every aspect of process that affects the result should be visible to all members involved in product development.
- Inspection means to keep eye on process to detect any unacceptable deviation.
- Adaptation helps in adjusting the process in case of any unacceptable deviation (Anwer et al., 2017).

From the viewpoint of customer orientation, eXtreme Programming is the only method that emphasizes the significance of customers in development processes. Although this methodology is still not a customer-centered design methodology (Sohaib & Khan, 2010), at least we could extract the customer-oriented features from XP which has the positive use for reference. Sohaib & Khan (2010) have made a literature on agile methodologies from the perspective of user-centered design and have suggested several approaches combining user-centered design and agile methods:

- iterative development throughout the project,
- multidisciplinary team to ensure complete expertise,
- collaboration between customers, product managers, business analysts, developers, will maximize overall team efficiency for usable product,
- unit testing + user acceptance testing + usability testing throughout the process,
- integration of user stories with scenario based design.

Since SCRUM methodology will be adopted in the rest of the thesis as the core agile management methodology, it is necessary to give details on its four components, respectively are Scrum team and roles, Scrum events, Scrum artifacts and rules. Afterward XP will be detailed to identify some usable features to enhance the Scrum methodology. Detail information will be shown in Appendix I.

4.2 Multi-layer SCRUM Management Framework based on AGORA Architecture

Existing design frameworks in PSS field usually focus on the integrated design of products and services, as well as on the supporting processes. However, few of them spend effort on the supporting network design. This is the key motivation for our research work. Hence, from the beginning of this thesis, we adopt the concept of Collaborative Networked Organization (CNO), particularly one of the most popular manifestations called Virtual Enterprise (VE) in Chapter 1; and then we have introduced the concept of 3DCE rather than traditional concurrent engineering only for product and process, and propose an integrated design framework which involves PSOs, VCCPs and VE together as a whole in Chapter 3. In Chapter 4, in order to support the VE design and management, AGORA architecture is chosen so that the VE could be modelled in a flexible and effective way. However, a question remains that is how can VE operate more flexibly and effectively and be able to respond to customers with reliable offerings in a short lead time? Agile management methodology provides the possibility for VE to support COPSS design. Hence, after introducing the Scrum and XP methodologies, this section propose “a multi-layer Scrum management framework based on the AGORA architecture” to Figure out this problem. This framework is based on the Holonic organization referenced by Dorri et al. (2018) in their review of the literature on agent organization.

In holonic organization, as shown in Figure 39, agents are organized in multiple groups which are known as holons based on particular features, e.g. heterogeneity or sensing ability of agents in holon. Holons are then layered in multiple layers. The agents can communicate with other agents in the same holon or in other holons in the same layers. Thus, in holonic organization an agent can be member of more than one holon in the same layer. For upper layer communications, a head agent is used which selected among the most resource available agents in the holon. This organization is suited for MAS when each supper-agent (a member of a holon in upper layer) requires sub-agents (lower layer holon members) to solve a particular task collaboratively. Each sub-agent may also have the same requirement.

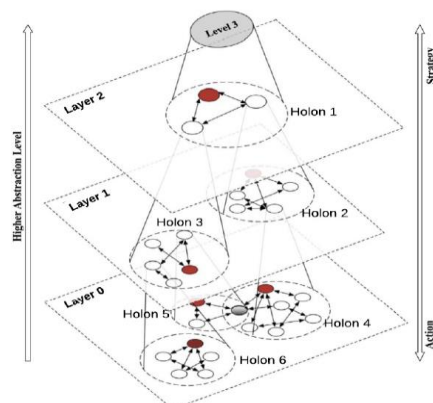


Figure 39 Multi-Agent System in Holonic organization

Hence, the multi-layer Scrum management framework is proposed, as shown in Figure 40. There are three levels displayed in the Figure: strategic level, tactical level and operational level.

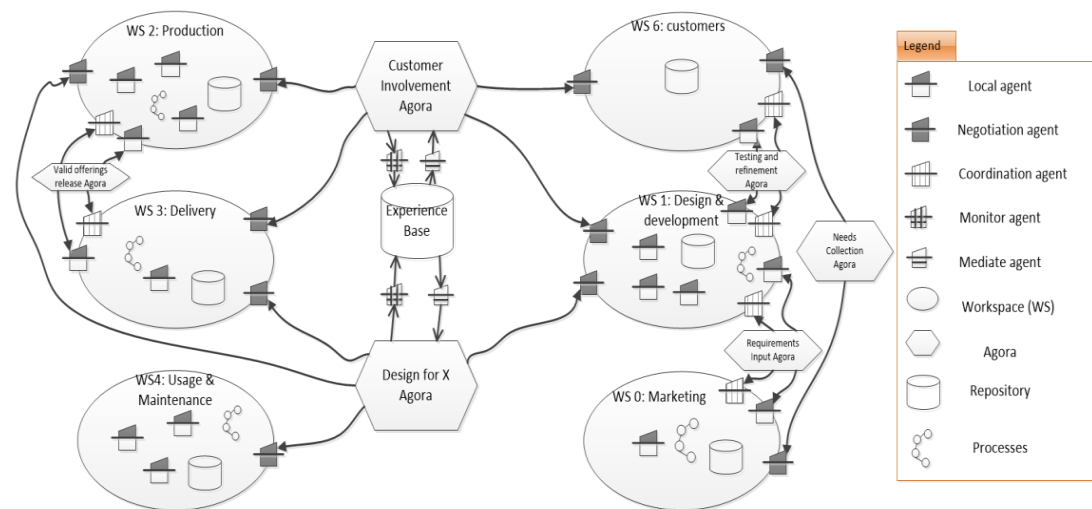


Figure 38 modelling COPSS design using AGORA multi-agent architecture

At the **strategic level**, key activities as well as their supporter organizations can be defined. Three questions has to find answer: “What kind of tasks need to be fulfilled”, “Which organizations will involve in these tasks (e.g., which design groups, which departments, which companies, which customer communities, etc.),” and “How do these organizations fulfill these tasks (e.g., with what knowledge, with how much resources, based on which processes, etc.)”.

Hence, the main work of the Scrum team at the strategic level is task allocation and supervision for all involved organizations. Taking the Figure 38 as an example, the workspaces represent both different lifecycle phases and several key VCCPs along COPSS lifecycle. In this case, if we regard the VCCPs implementation as a key task, then the Product Backlog may consist of production, delivery, usage & maintenance, remanufacturing, recycling, disposal etc. Accordingly, there will be six groups of organizations involving in the VCCPs implementation. Therefore, a Scrum team with 9 members will be set up, including a Product Owner (maybe a designer of VCCPs), a Scrum Master and the Team (including 7 persons from six different groups and a representative of customer community). Their work conforms to Scrum methodology so that the work at the strategic level could be more effective and efficient.

At the **tactical level**, the Team members from the different groups and customer community will go back to their own workspace on tactical level. Here, they will play the role of Product Owner and will distribute the tasks allocated from the strategic level. They are also the lead agents that are responsible for communicating with the strategic level. For example, workspace 2 (WS2) is Production workspace in Figure 38. In Figure 40, the production workspace is decomposed at the tactical level. As explained, during the three key activities design, each PSO scenario is a combination of a variety of product modules, service process modules and interface modules; each module is realized by a corresponding process; and each process is supported by a

corresponding organization. “Corresponding” means an optimal candidate of processes or organizations to realize the same module. Under this logic, producing an offering, which is composed of a variety of product, service and interface modules, will need a series of processes that may be supported by different organizations. In this way, as shown in the production workspace at the tactical level, the lead agent, also playing the role of product owner, in this workspace will define the product backlog so that he can decompose the production task into subtasks to the sub-workspaces. In this Figure, we assume that the offering needs three main processes; these three processes will be regarded as new workspaces under the production workspace; new lead agents will be selected from these sub-workspaces as new product owners on next level. These lead agents will constitute a Scrum team in production workspace in order to manage the work allocation and organization collaboration. What’s worth mentioning here, is that in the VE context, these processes may be realized by different organizations. This Figure gives an example that there are three organizations here; respectively Enterprise 1 (represented by an azure circle, who has three sub-processes and one of them involves in workspace I and two of them involve in workspace II), Supporter organization 1 (represented by a purple circle) and Customer group 1 (represented by a mazarine circle).

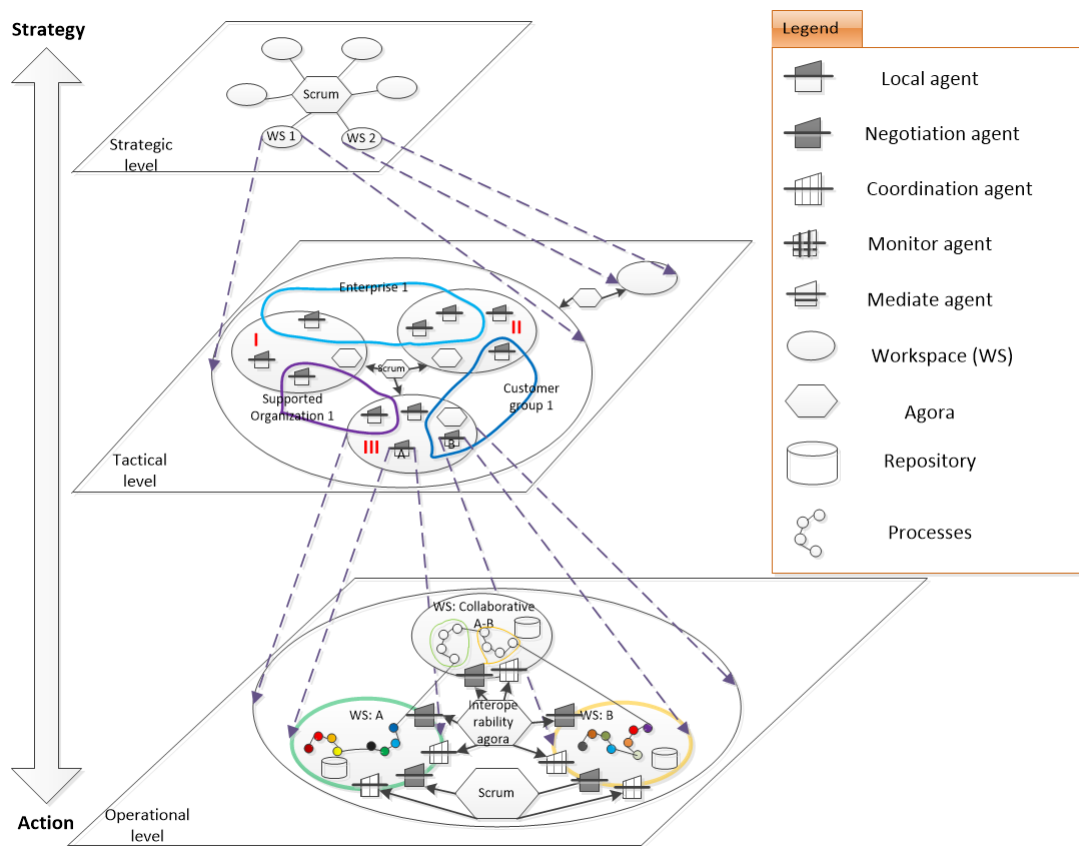


Figure 40 a multi-layer Scrum management framework based on AGORA architecture

When the work is distributed into sub-processes, we can go at the **operational level**. Taking workspace III as an example, local agent A and local agent B represent two different processes provided by two different organizations. At the operational

level, local agent A becomes a new workspace A that consists in a series of small activity agents, negotiation agents, coordination agents, etc. This is same with local agent B as well as other agents displayed in the workspace III at the tactical level. In order to manage their work progressing, a new Scrum team at this operational level is necessary. The product owner is lead agent in workspace III at the tactical level. What's more, at this level, the processes interoperability could be realized through an "Interoperability AGORA". In order to better perform the collaborative processes, a new workspace called "collaborative workspace" may be set up, in which the processes from different organizations could be integrated in a refined mechanism under new collaborative context.

Throughout these three levels, the work could be decomposed in a clear logic from the design phase to the implementation phase. Time control is significant in the Scrum management. Different Scrum events, in this way, can help supervise the progressing of project. The proposed Figure here only shows a general and macro way of thinking using agile management methodology during COPSS design and implementation. Designers could develop more precise Scrum-AGORA-based framework according to real cases.

Based on Stakeholder-driven lifecycle model, AGORA multi-agent architecture and Multi-layer SCRUM Management framework, requirements of A22 (Design for X), A12 (Deeper customer involvement) and A23 (Agile management) can be achieved.

5. Customer Satisfaction Assessment and Sustainability Assessment

As mentioned above, this section will supplement two aspects of knowledge in order to support COPSS design cycle based on Customer-Provider Satisfaction Trade-off, shown as two yellow blocks in Figure 41.

5.1 Customer satisfaction assessment

The evaluation of customer satisfaction in order to enhance design of PSS, has captured a lot of attention in the past years. Kimita et al. (2009) have developed a "satisfaction-attribute function" and have integrated it into a four steps' procedure so that designers are able to evaluate the PSS solution scenarios in the conceptual design stage. The main drawback of this method is that the estimation is limited to a single transaction, which means that this method supposes that the customers' requirements will not change. This prerequisite conflicts with the hypothesis of the proposed framework: continuously changing requirements and iterations supported by agile

management methodology. Another typical sample is the integrated method based on Balanced Scoreboard (BSC) and Multiple Criteria Decision Making (MCDM) approaches developed by Pan and Nguyen (2015). This kind of methodologies usually depends on some decision-making methodologies. However, they usually focus on how to enhance customer satisfaction through PSS, such as providing customers with value-added offerings, creating long-term partnership with customers, promoting offerings' quality etc. They have not proposed real quantitative assessment methodologies as Kimita did. Hence, we cannot intuitively conclude which PSS scenario achieves better customer satisfaction.

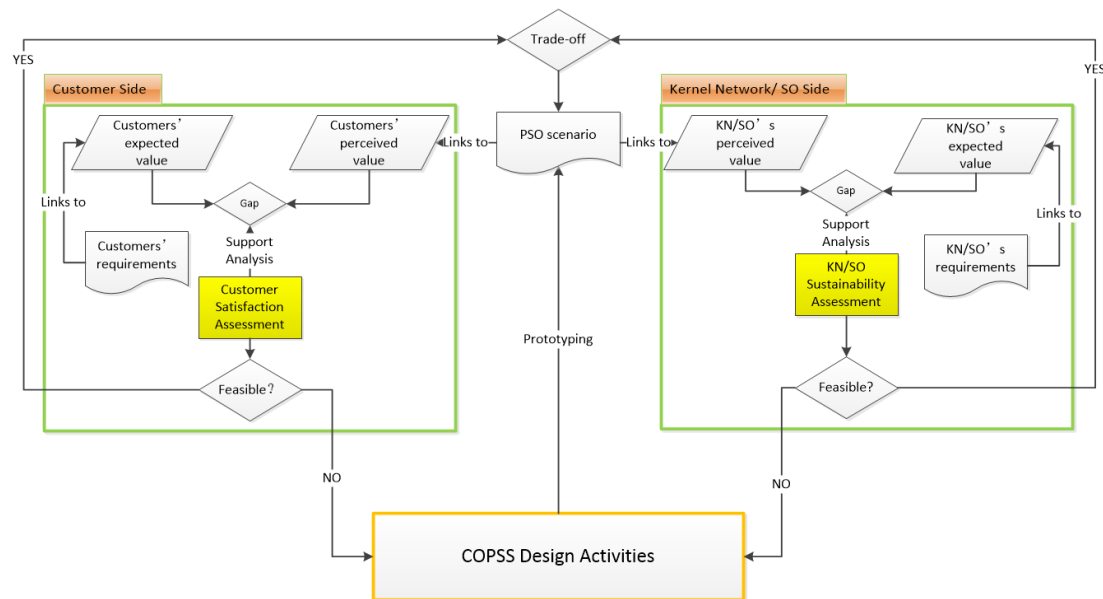


Figure 41 COPSS design cycle model based on Customer-Provider Satisfaction Trade-off

Under this context, the thesis introduces the **Customer Satisfaction Index (CSI)** from market-based performance measurement methodology. CSI is a methodology for overall customer satisfaction measurement. Comparing with the evaluation methodologies by PSS researchers, CSI shows the following advantages:

- More universal: CSI has been widely used to assess customer satisfaction in a variety of industries, such as consultancies, banking, gas industry, car industry, hotel industry, home appliance industry and so on;
- More customer-oriented: the existing methodologies usually focus on how to promote offerings qualities with designers' own imagination; however, CSI need to collect real data from customers through the whole offering lifecycle. During pre-use phase, the data mainly contains customers' expectations of offerings, image of the company, the pre-sale interactions with company's staff etc.; during usage phase, the data mainly consists of the perceived quality of the offering, the after-sale interactions with company's staff, the complaint behaviors etc.; during post-usage phase, the data mainly includes the customer loyalty and so on. Hence, the CSI indeed is a lifecycle-oriented methodology that is able to measure the feelings throughout the whole offering lifecycle;
- Quantitative and visualized: the data could be analyzed based on mathematical

methods so that designers and customers are able to know the visualized results directly.

This thesis lists three recognized CSI models:

- The earliest one is the **Swedish Customer Satisfaction Barometer (SCSB)**, which is a Sweden’s domestic products and services performance measurement, whose data was collected from 130 companies of 32 industries (Fornell, 1992). The original SCSB considered five variables including CSI antecedents-**Customer Expectations** and **Perceived Quality**, **Customer Satisfaction Index (CSI)**, and CSI consequences- **Customer Complaints** and **Customer loyalty**.
- The second one is the **American Customer Satisfaction Index (ACSI)**, whose results come from 200 companies of 34 industries (Fornell et al., 1996). In ACSI, Perceived Value was added as one of the CIS’ antecedent.
- The third one is the **European Customer Satisfaction Index (ECSI)** model, proposed by Eklöf (2000), coming from studies across four industries and 11 countries in European Union. In ESCI, a new variable was included, as shown as Figure 42. The “**Image**” variable is one of the antecedents for customer expectation, CSI and customer loyalty.

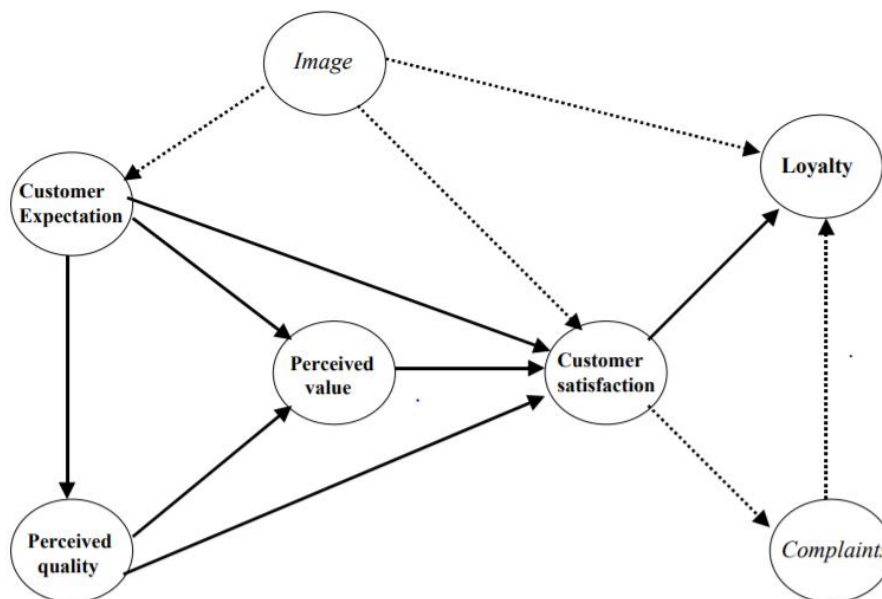


Figure 42 European Customer Satisfaction Index Model

This thesis will adopt (ESCI) due to its integrity. Based on Bayol et al. (2000) and O'loughlin & Coenders (2004), we can summarize the antecedents of customer satisfaction and the consequences of customer satisfaction as follows:

- Antecedents
 - ✧ **Customer expectations** relate to the prior anticipations of the said product in the eyes of the customer. Such expectations are the result of active company/product promotions as well as hearsay and prior experience from the product/company.

- ✧ **Perceived quality** includes two parts, product quality and service quality. Perceived product quality is the evaluation of recent consumption experience of products; perceived service quality is the evaluation of recent consumption experience of associated services, like quality guarantee, after-sale service provision, conditions of product display and assortment, documentation and descriptions and so on. Both of them are expected to affect satisfaction.
- ✧ **Perceived value** is relative to the price paid or concerns the “value for money” aspect of the customer experience. It is affected by both perceived quality and customer expectations.
- ✧ **Image** refers to brand name and the kind of associations customers get from the product/brand/company. It is expected that image will have a positive effect on customer satisfaction and loyalty.
- **Consequences**
 - ✧ **Complaints** refer to the intensity of complaints and the manner in which the company manages these complaints. It is expected that an increase in customer satisfaction should decrease in the incidence of complaints.
 - ✧ **Loyalty** is the ultimate dependent variable in the model and is seen to be a proxy measure for profitability. It is expected that better image and higher customer satisfaction should increase customer loyalty. In addition, it is expected that there is a reciprocal relationship between complaints and loyalty.

The abovementioned constructs are also called **latent variables**. In order to measure them more precisely, each latent variable will be explicated by several **manifest variables**, as shown in Table 17. All the items are scaled from 1 to 10. Scale 1 expresses a very negative point of view on the offering and scale 10 a very positive opinion. The tool Statistical Product and Service Solutions (SPSS) can be used to help fulfill the quantitative analysis.

Table 17 measurement instrument for latent variables, derived from Bayol et al. (2000)

Latent variables	Manifest variables
Image	<ul style="list-style-type: none"> ➤ It can be trusted in what is said and done; ➤ It is stable and firmly established; ➤ It has a social contribution for the society; ➤ It is concerned with customers; ➤ It is innovative and forward looking
Customer Expectations of the overall quality	<ul style="list-style-type: none"> ➤ Expectations for the overall quality of your offering provider; ➤ Expectations for your offering provider to provide products and services to meet your personal needs; ➤ How often did you expect that things could go wrong with your provider.
Perceived Quality	<ul style="list-style-type: none"> ➤ Overall perceived quality; ➤ Technical quality of the network; ➤ Customer service and personal advice offered;

	<ul style="list-style-type: none"> ➤ Quality of service you use; ➤ Range of service and products offered; ➤ Reliability and accuracy of products and service provided; ➤ Clarity and transparency of information provided.
Perceived Value	<ul style="list-style-type: none"> ➤ Given the quality of offering offered by your provider, how would you rate the fees and prices that you pay for them? ➤ Given the fees and prices that you pay for your provider, how would you rate the quality of the offering offered by your provider?
Customer Satisfaction	<ul style="list-style-type: none"> ➤ Overall satisfaction; ➤ Fulfilment of expectation; ➤ How well do you think your provider compares with your ideal provider?
Customer Complaints	<ul style="list-style-type: none"> ➤ You complained about your provider last year, how well, or poorly was your most recent complaint handled? Or ➤ You did not complaint about your provider last year. Imagine you have to complaint to your provider because of a bad quality of service or product. To what extent do you think your provider will care about your complaint?
Customer Loyalty	<ul style="list-style-type: none"> ➤ If you would need to choose a new provider how likely is it that you would choose “your current provider” again? ➤ Let us now suppose that other provider decide to lower their fees and prices, but your provider stays at the same level as today. At which level of difference (in %) would you choose another provider? ➤ If a friend or colleague asks you for advice, how likely is it that you would recommend your provider?

Based on the computation, an ECSI Causality model can be established, in which the coefficients and correlations among latent variables and manifest variables can be computed, so that we can conclude the influences of antecedents to customer satisfaction as well as the influences of customer satisfaction to customer loyalty.

5.2 Sustainability Assessment (SA)

Sustainability Assessment (SA), also called Life Cycle Sustainability Assessment (LCSA) in this thesis is a critical task, since the proposed framework should be able to provide profitability for both providers and customers, while should lead to less impact on the environment and more positive effects to society. Sustainability of a system is very hard to be assessed by the use of a single criterion because of its intrinsic multidimensionality characteristic (Doualle et al., 2015). Researchers divide sustainability assessment into three dimensions; respectively are economic dimension, environmental dimension and social dimension. Hence, a common consensus of SA can be fulfilled by three methodologies (Klöpffer & Renner, 2008; Finkbeiner et al.,

2010; Schau et al., 2012; Peruzzini & Germani, 2014; Doualle et al., 2015), as shown in Figure 43.

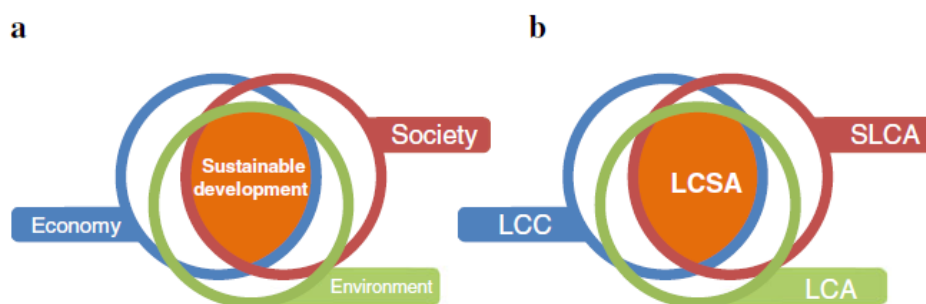


Figure 43 dimensions of sustainability and lifecycle sustainability assessment, Schau et al., 2012

$$\text{LCSA} = \text{LCA} + \text{LCC} + \text{SLCA}$$

Where

1. LCSA = Life Cycle Sustainability Assessment,
2. LCA = environmental Life Cycle Assessment,
3. LCC = environmental Life Cycle Costing and
4. SLCA = Social Life Cycle Assessment

Environmental Life Cycle Assessment (LCA) is a methodological tool used to quantitatively analyze the life cycle of product/services/activities within the context of environment impact. LCA was initially developed to compare clearly defined end product alternative and varied widely in the early years. Consequently, debates were widespread about generating more consistent approaches for conducting studies and applying impact assessment methods among other things (Dolf, 2006). The ISO 14040 and 14044 standards defined the structure of LCA methodology and its four phases: **Goal and scope of the study, Life Cycle Inventory, Life Cycle impact assessment and Interpretation** (ISO 14044, 2006a; ISO 14040, 2006b). Based on the ISO defined structure, several methods have been developed in order to Figure out specified LCA problems, such as Eco-Indicator 99 (Consultants, 2000), IMPACT 2002+ (Jolliet et al., 2003), Recipe (Zelm, 2009) and so on.

Eco-Indicator 99 method has been widely recognized and adopted to deal with a variety of LCA problems (Peruzzini & Germani; Doualle, 2015). In this method, environmental assessment relies on three comprehensive damage categories, namely **Human Health, Ecosystem Quality and Resources**. This method offers a possibility to aggregate the results into a single score, thus providing comprehensive overview of evaluation (Doualle, 2015). Five steps must be followed to ensure correct application of Eco-Indicator (Consultants, 2000):

1. **Establish the purpose of the Eco-Indicator calculation:** describe the product or product component that is being analyzed; define whether an analysis of one specific product is being carried out or a comparison between several products; define the level of accuracy required.
2. **Define the life cycle:** draw up a schematic overview of the product's lifecycle, paying equal attention to production, use and waste processing.
3. **Quantify materials and processes:** determine a function unit; quantify all

-
- relevant processes from the process tree; make assumptions for any missing data.
4. **Fill in the form:** note the materials and processes on the form and enter the amounts; find the relevant Eco-Indicator values and enter these; calculate the scores multiplying the amounts by the indicator values; and the subsidiary results together.
 5. **Interpret the results:** combine (provisional) conclusion with the results; check the effect of assumptions and uncertainties; amend conclusions (if appropriate); check whether the purpose of the calculation has been met.

Environmental Life Cycle Costing (LCC) is another critical dimension in sustainability assessment. In terms of economical dimension, providers expect more profitability from providing new PSS offerings while customers also hope to enjoy high-quality services with appropriate purchasing or renting cost. Hunkeler et al. (2008) defined environmental LCC as “an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (e.g., supplier, manufacturer, user or consumer, or EoL actor) with complementary inclusion of externalities that are anticipated to be internalized in the decision-relevant future. Environmental LCC has to be accompanied by a life cycle assessment and is a consistent pillar of sustainability.” According to the definition, similar with LCA, we should also keep life cycle thinking and stakeholders’ responsibilities in mind when fulfilling LCC. The four-phase structure proposed by ISO 14040 is also recommended when dealing with LCC (Swarr et al., 2011). Generally, LCC is divided into five phases: material processing, manufacturing, distribution, use and disposal cost (Doualle, 2015). This will be refined in some other cases, for instance, Schau et al. (2012) divided LCC into four life cycle phases: production phase, use-phase, remanufacturing phase and end of life. Production phase consists of raw material extraction, material processing and manufacturing; remanufacturing consists of new spare parts raw material extraction, new spare parts material processing, manufacturing and non-usable parts material recycling.

Social Life Cycle Assessment (SCLA) assesses the social impacts on workers, local communities, the consumers, the society and all other value chain actors affected by the production and consumption of products under consideration (UNEP, 2008). UNEP defined SLCA as a “technique that aims to assess the social and socio-economic aspects of product and their potential positive and negative impacts along their lifecycle”. This methodology framework provided in the guidelines closely follows the LCA methodology, as described in ISO 14044 (2006). Indeed, the social dimension has been receiving little attention for decades comparing with the previous two dimensions (Chou et al., 2014; Doualle et al., 2015). That’s also one of the reasons why the social dimension is still the most difficult dimension to be assessed. SLCA follows the same four main iterative steps as those used in LCA and LCC.

Based on an unified structure for Sustainability Assessment, as well as the

service design context, this thesis adopts the Sustainability Assessment methodology proposed by Peruzzini & Germani (2014). The proposed method can be summarized in the following steps, as shown in Figure 44:

1. Definition of an integrated product-service lifecycle able to support and manage all the activities related to product design and development, service ideation and implementation, system infrastructure design and creation, product-service delivery, until PSS disposal. Lifecycle modelling considers the product as well as the technological infrastructure and the services.
2. Identification of the sustainability objectives and requirements for each lifecycle phase. Three main aspects have been considered: environment, economics and social wellbeing.
3. Definition of a set of Sustainability Indicators (SIs) able to measure the impacts of the lifecycle stages on the selected aspects of sustainability. In particular, authors considered that the relevant impacts arise from the end of the design stages until the system end-of-life and defined some SIs for environmental impacts ENs (EN1–ENn), for economic impacts ECs (EC1–ECn) and for social impacts SCs (SC1–SCn), shown in Figure 45.
4. Definition of reliable measuring techniques to assess method SIs. According to LCD approaches, LCA, LCCA and SLCA are chosen: LCA focuses on the impact on environmental resources and ecosystem and is adopted for measuring ENs indicators; LCCA estimates the total costs by considering all the actors involved and allows measuring ECs indicators; SLCA estimates the impact on human resources and human health and is used for measuring SCs indicators.
5. Measurement of the sustainability impacts by SIs. Impacts are separately measured for each relevant stage and any design solution as well as EE scenario. The scenario depends on the companies involved into the EE, the user typologies, profiles and behaviors, as well as the considered lifetime to carry out targeted analyses. The SIs measurement allows quantifying the achievement of the defined objectives.
6. Calculation of the global SA of product-services by combining the selected techniques and normalizing the single indexes to have a sustainability global assessment (SA), resulting from the addition of SIs; additionally, the normalization procedure is shown in Figure 46. Detail calculation algorithm will be shown in the case study, in next chapter.

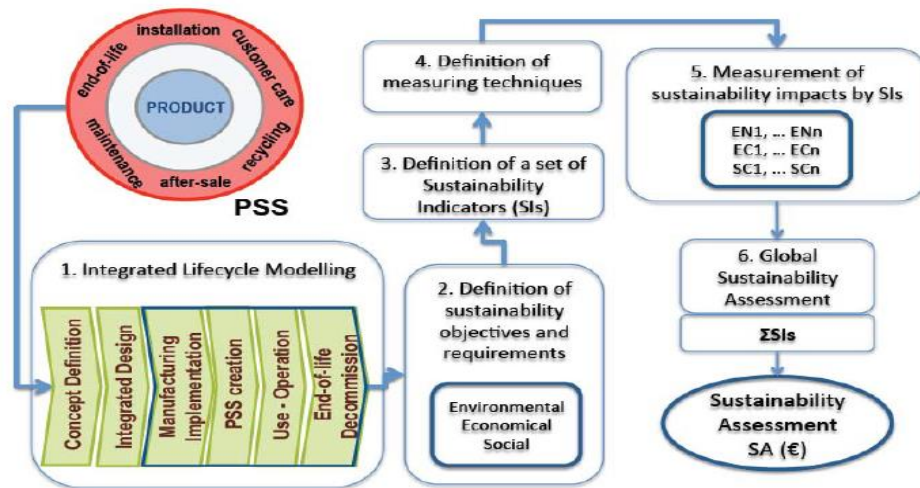


Figure 44 methodology for PSS SA, Peruzzini & Germani (2014)

Sustainability Objectives	SIs	Description	Measuring techniques
Low impact on the ecosystem	EN1	Impact on the Ecosystem Quality	LCA (EI-99 pt)
Low resource consumption/emissions	EN2	Consumption of Resources	LCA (EI-99 pt)
Low cost of resources	EC1	Cost of raw materials	LCCA (euro)
Low cost of material use	EC2	Cost of material use	LCCA (euro)
Low cost of transformation/transport	EC3	Cost of transformation processes and transport	LCCA (euro)
Low impact on human health	SC1	Reduction of human health	SLCA (QALYs*)
Low impact on human living conditions	SC2	Reduction of human living conditions	SLCA (QALYs*)

Note: *Quality adjusted life years

Figure 45 the integrated lifecycle for PSS and related SIs, Peruzzini & Germani (2014)

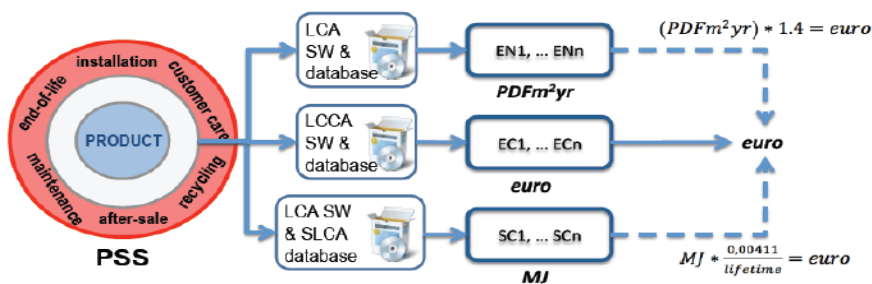


Figure 46 Normalization procedure, Peruzzini & Germani (2014)

The general supporting methodologies of customer satisfaction assessment and sustainability assessment have been introduced. Hence, Requirement A13 and Requirement A31 have been satisfied. According to the results from the quantitative analysis, together with providers' strategies, the designers are able to optimize the scenarios based on COPSS design cycle. So far, the requirement of A32 (Customer-Provider Satisfaction Trade-off) has been fully Figured out

6 Conclusion

This Chapter supplements the lacking management methodologies in the proposed framework in Chapter 3. At the beginning of Chapter 3, we have defined eight requirements organized in three categories for to support the proposed framework. In order to satisfy these requirements, Chapter 3 has expounded three key design activities: PSOs design VCCPs design and VE design, as well as the detailed 3DCE logic among the three activities. In addition, in order to optimize the design solutions, a COPSS design cycle based on Customer-Provider Satisfaction Trade-off is proposed. Therefore, the requirements of A11 and A21 have been satisfied; A13, A31, and A32 have been partially referred because of their lifecycle oriented characteristic.

So far, the completed framework has been expounded. In next Chapter, a case study will be launched to explain how to use this framework.

Chapter 5 Air conditioner PSS case study

1. Introduction

In the previous Chapters, the concept of Customer-Oriented Product Service System (COPSS) is excavated; the framework to develop a COPSS solution is also proposed, as well as its supporting management methodologies. In this Chapter, an air conditioner PSS case study is developed to show how to use the framework, supporting methodologies, techniques and tools. It is necessary to mention that not all the proposed frameworks and methodologies are verified in this case as it is based on the real case of a company that has both given limitations and already applied some principles. For instance, product modularization has been addressed according to the manufacturer's own knowledge so that we do not need to redo it according our recommended methodologies; multi-layer Scrum management methodology hasn't been used because they are reluctant to change the existing organization operation modes into a new agile mode; Hence, in this case study, the PSOs-VCCPs-VE design process is based on 3DCE framework, but it is not iterative and it becomes to a waterfall design process.

In this Chapter, the AS-IS air conditioner system will be briefly introduced at first as well as the current situations, from which we can understand the necessity of servitization. Then, we will go on develop the air conditioner PSS in detail, including the customer niche, stakeholders' requirements, the offerings design, as well as supporting processes & supporter organizations, the new business models and so on.

2. AS-IS system

Z Company is a home appliance wholesaler (distributor) in the north of China. Its main businesses include selling home appliances directly to customers and distributing them its retailers. However, with the home appliance market saturation in the recent years, it becomes more and more difficult for them to sell more products and achieve their revenue objectives.

Taking the air conditioner as example, at a first strategy, Z Company was to put forward several price-off promotion strategies in summer so that more air conditioners were sold. But this strategy was not a long lasting one and in the recent two years, it did not work anymore. Despite lower prices and more promotions, the sales volume is no longer progressing; the company currently achieves less profit due to the price strategy. The sale manager mentioned that another problem leading to the current situation is the fact that buying air conditioners is low frequency consumption; more seriously, the customers are less and less loyal to the business because of variety of competitions. Accordingly, another strategy needs to be defined so that providing the customers with customer-oriented product service offerings may be one of the solutions.

With the aim of triggering a process of servitization, the company should shift its traditional product-centric strategy into a service-oriented strategy at first. Table 18

exhibits the key elements' comparison between the AS-IS system and the TO-BE one. In the AS-IS system, the company is absolutely a product-centric company; they sell products and get money from sales. Their products come from a big and famous home appliance company called A in China. A is also the manufacturer of the wholesaler's products, so that what the wholesaler sold before usually was determined by A. The wholesaler has two retailers who help to sell the products. It also has three transportation partners who will help deliver the products to users' locations. Additionally, the manufacturer's maintenance department and other two small-medium maintenance enterprises are responsible for the maintenance service. This company has no supervision on their maintenance work. Customers in this system play the only role of receiver. Their activities only include select and buy the products and use them from the wholesaler and its retailers.

Table 18 Comparison between product-centric system and service-oriented system

	AS-IS product-centric system	TO-BE COPSS
Offering	Product only	Combination of products and services
Value	Product-centric	Service-oriented
Processes	Manufacturing processes only	VCCPs
Customer	Receiver and user	Active stakeholder
Network	Producer-centric supply chain	Flattening VE

3. TO-BE COPSS design

Two main points should be changed essentially. The first one is the role of customers, i.e., the company and its manufacturer should pay more attention to their customers. At least, the air conditioner requirements should come from the customers and their feedbacks when using the products should be collected in order to improve the products' quality. The second one is the business model. Traditional selling model should be changed into a renting model. Value in exchange should shift to value in use.

When using the framework to design the COPSS, the final target is to come up with an integrated solution including appropriate PSO scenario, supporting VCCPs, as well as corresponding VE. For the purpose of the case study, due to the limitations mentioned above, we revised the existing framework and simplified it into four steps, without deeper development of VE:

- PSOs and VCCPs design,
- VE design and modelling,
- COPSS realization and visualization,
- Customer-Provider satisfaction trade-off based design optimization.

3.1 PSOs and VCCPs design

Regarding PSOs design, the first task is customer segmentation. We finally focus on those customers who are far away from home and live in renting departments in

the north of China. These customers are segmented in a group because of the following characteristics:

- They are office workers renting departments or students living in school dormitory;
- They may live in this place for a short time, several months for example;
- They are reluctant to pay for too much money for a new air-conditioner;
- They only use the air conditioners in summer not in the other three seasons;

In this case, we want to focus on this niche and provide them with an appropriate COPSS solution.

3.1.1 Requirements Engineering

Starting from the requirements engineering, two steps can be conducted: *the first one is to collect requirements from stakeholders in the system*. In this case, there is no innovation pushed by the kernel network, their only objective is to achieve more benefits from selling products. Hence, the main requirements come from the customers; kernel network's and government policies take secondary roles. Hence, in the first step, the *customer activity cycle analysis (refer to Chapter 3-2.2.2, Table 13)* is core method. The *second step* is to *interpret the requirements into Engineering Characteristics (ECs)* for later development. In order to achieve more precise results, this thesis not only adopts QFD to analyze the relative importance among different ECs, but also adopts the FAHP to optimize the results (*refer to 3-2.2.2, Table 13*).

Then a *customer activity cycle analysis (refer to 3-2.2.2, Table 13)* is done to analyze comprehensive customers' requirements, shown in Figure 47. Cycle analysis consists of three phases; respectively are "Pre-use phase", "Use phase", and "Post-use phase". In order to support the requirements analysis, we made a questionnaire that asks the customer possible requirements in each activity; therefore we finally conclude the following requirements.

- In pre-use phase, customer activity starts from their needs for cooling living environment in summer so that they need new air conditioners. Under PSS context, they will purchase an offering (combination of air conditioner and related services) from the wholesaler or retailers, they need to pay for the functions of products and services according to the contracts with wholesaler or retailers. Then the wholesaler will ask third party logistics to help deliver the air conditioners to customers' homes, accompanied by the technicians who will be responsible for the air conditioner installation and commissioning in order to prepare for customers' usage activity. Here, the *first requirement (I)* is **quick and high-quality response for customers' demands**, the delivery, installation and commissioning services should be fulfilled within three days. High-quality installation is also significant. It is very important for customers to maintain the air conditioners so that it is beneficial to extend the air conditioner lifespan; good installation is also an important factor to lower noise.
- In usage phase, the leading customers usually have the following requirements: *(II) customers want rapid cooling*, i.e., they hope the

temperature could be decreased smoothly in a short time; and they also want to *feel comfortable during cooling*. (III) These customers are always workers and students; they may work in the night, or keep the air conditioner working when sleeping, hence they need a quiet environment, i.e. *the lower noise, the better*. (IV) *An easier and practical remote-control unit is also necessary*. (V) *Lower power consumption* is also very significant. (VI) Customers want *high operation quality*; an easier explanation is that they don't want the air-conditioners break down too many times during use phase. However, in case it breaks down, the customers also want to get quick response from the wholesaler and get high-quality maintenance services. Hence another requirement is (VII) *fast and high-quality maintenance service*. Additionally, if the problem is very serious, a repair service may be necessary which is also provided by the maintenance provider. However in case some problems cannot be handled by them, the customers should have to replace the air conditioners.

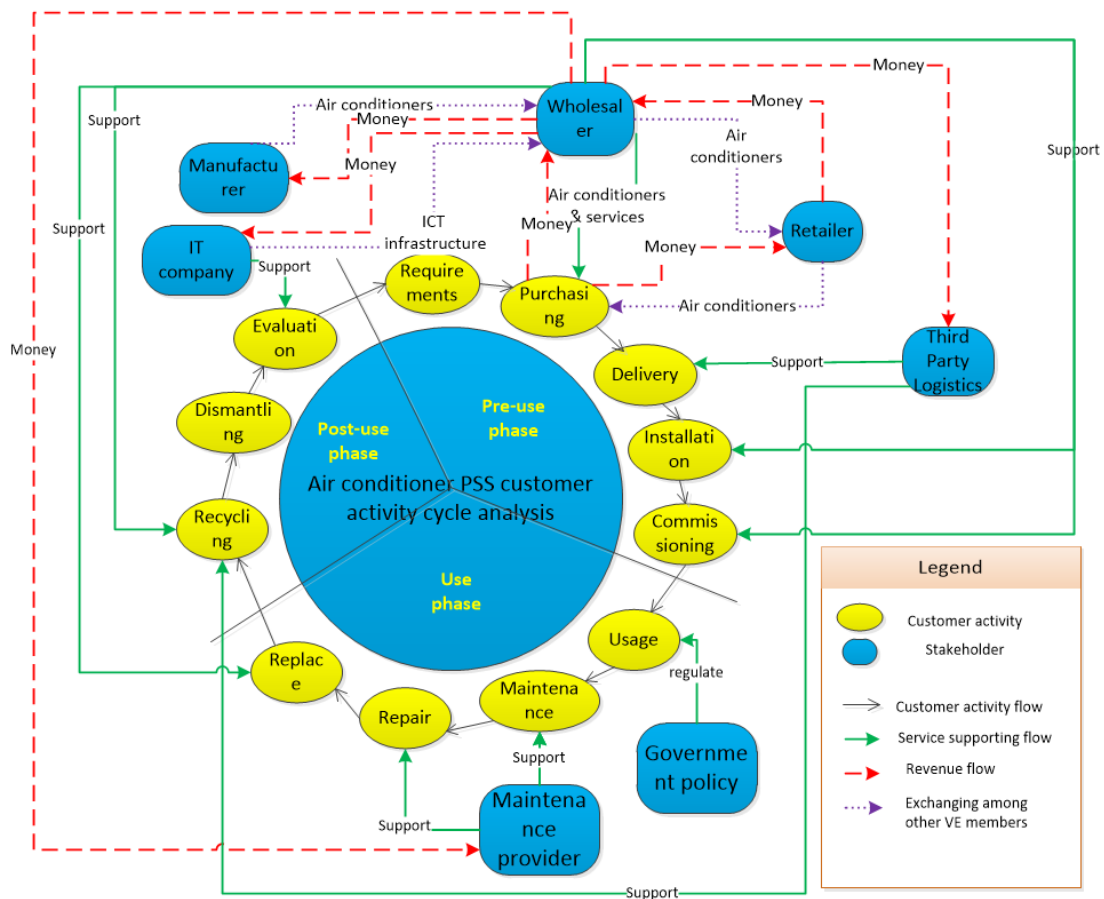


Figure 47 Customer Activity Cycle Analysis in air conditioner PSS case

- In post-use phase, in previous product-centric business model, the customers have to dispose these air conditioners by themselves, which usually waste a lot of money and leave wastes to the environment. In PSS context, the wholesaler will (VIII) **recycle** the air conditioners, and dismantle them in different ways, such as re-use for other customers, re-manufacture if some

components don not work, etc. Besides, it is better for customers to give evaluation for using the offering to help the system to improve products and services.

After analyzing the three phases, we finally obtain eight customers' requirements. It is worth mentioning that *(VIII) less environment impact* should be also integrated, particularly the emission of CO₂ and Freon, which is the requirement coming from government policy during air conditioner usage phase.

Once the customers' requirements are collected, the *second step- interpreting CRs into ECs*- can start. Based on the QFD and FAHP research approach proposed by Haber et al. (2018), the four subsequent steps can be set up:

1. Definition of the CRs and ECs;
2. Definition of the importance of ECs;
3. Implementation of the fuzzy logic and AHP;
4. Analysis of results.

1. Definition of the CRs and ECs

As mentioned above, a questionnaire in its leading customer community was launched, based on which we summarized the feedbacks and fulfilled the average calculation about the importance of each requirement. The importance assessment was carried out using the 1-to-5 Likert scale. The final results can be used for later calculation as an expert advice. After customers' advice calculation, we selected other three experts in products development field. Finally, we came up the results shown in Table 19, which exhibits each requirement's importance and its relative importance.

Table 19 List of Customer Requirements (CRs) in air conditioner case

	List of CRs		
CR code	Requirements description	Importance	Relative Importance
CR1	Rapid cooling, comfortable cooling	3.75	12.20%
CR2	Low noise	4.5	14.60%
CR3	Low power consumption	4	13.00%
CR4	Quick & high quality response after demand (Delivery, installation, commissioning)	3	9.80%
CR5	Ease of use	2.5	8.10%
CR6	High operation quality during air conditioner usage	5	16.20%
CR7	Less environmental impact	3.25	10.60%
CR8	Fast & high-quality maintenance	3	9.80%
CR9	Recycling	1.75	5.70%

Then the Engineering Characteristics (ECs) can be defined in collaboration with

the experts' advices, as shown in Table 20.

Table 20 list of Engineering Characteristics (ECs)

EC code	EC description
EC1	DC inverted frequency air-conditioner
EC2	Double eccentric rolling rotor compressor
EC3	Larger heat exchanger surface
EC4	Good quality installation and commissioning
EC5	Response (delivery, installation, maintenance) with 48 hours
EC6	Ease of use for customers
EC7	Users' training for use and care air-conditioner
EC8	Technicians' training
EC9	Product quality warranty
EC10	Utilize new refrigerants called R32 or R410A instead of R22 (Freon)
EC11	Higher energy efficiency ratio
EC12	Management and documentation of environmental and safety issues
EC13	Customer service contracts documentations
EC14	Recycling service, recycling parts and raw materials

2. Definition of the importance of ECs

In this step, the traditional QFD was applied utilizing the CRs and ECs defined earlier to determine the Absolute Importance (AI) of the ECs through Equation (1)

$$AI_j = \sum_{i=1}^{n=9} CRI_i * RS_{ij} \quad (1)$$

Where AI is the importance of a SC as a column entry "j", CRI is the importance of a CR as a row entry "i", and RS_{ij} indicates the Relationship Score (RS) between a CRI and SC_j defined earlier. The results are shown in Table 21.

3. Fuzzy logic and AHP implementation

To achieve the FAHP implementation, the first tasks is to make a pairwise comparison between two CRs. The pairwise comparison matrix is checked for consistency and afterwards normalized. From the normalized matrix, a column vector emerges representing the fuzzy importance levels which are then defuzzified as to obtain the crisp input of the HoQ (Haber et al., 2018), the detail fuzzification and defuzzification logic can be found in Ho et al. (2012). The following Table 22 displays the pairwise comparison between CRs, and Table 23 shows the results of HoQ augmented by FAHP.

Table 21 results of ECs analysis using traditional QFD

	Importance	RI	CR ranking	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14
CR1	3.75	12.20%	4	9		9						9		9			
CR2	4.5	14.60%	2	3	3		9					3					
CR3	4	13.00%	3				9					3					
CR4	3	9.80%	6				3	9			3					3	
CR5	2.5	8.10%	8				9		9	9		1			3	3	
CR6	5	16.20%	1							3		9				3	
CR7	3.25	10.60%	5									3	9	3	3		1
CR8	3	9.80%	7					9			3					3	
CR9	1.75	5.70%	9												3	3	9
		EC importance		47.25	13.5	33.75	108	54	22.5	37.5	18	116.5	29.25	50.25	22.5	45.75	19
		EC RI		7.65%	2.19%	5.47%	17.48%	8.74%	3.64%	6.07%	2.91%	18.86%	4.73%	8.13%	3.64%	7.41%	3.08%
		EC ranking		5	14	8	2	3	10	7	13	1	9	4	11	6	12

Table 22 a pairwise comparison between the CRs

	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9
CR1	(1,1,1)	A(1/4,1/3,1/2) B(1/6,1/5,1/4) C(1,1,1) D(1/4,1/3,1/2)	A(1,1,1) B(1/5,1/4,1/3) C(1/4,1/3,1/2) D(1/4,1/3,1/2)	A(2,3,4) B(1/3,1/2,1) C(3,4,5) D(3,4,5)	A(3,4,5) B(2,3,4) C(3,4,5) D(1,2,3)	A(1/5,1/4,1/3) B(1/6,1/5,1/4) C(1/4,1/3,1/2) D(1/6,1/5,1/4)	A(1,2,3) B(1,1,1) C(1,2,3) D(1/5,1/4,1/3)	A(1/3,1/2,1) B(1,2,3) C(3,4,5) D(1,1,1)	A(1,2,3) B(1,2,3) C(3,4,5) D(4,5,6)
CR2	A(2,3,4) B(4,5,6) C(1,1,1) D(2,3,4)	(1,1,1)	A(2,3,4) B(1,2,3) C(1/4,1/3,1/2) D(1,1,1)	A(3,4,5) B(5,6,7) C(1,2,3) D(2,3,4)	A(5,6,7) B(6,7,8) C(3,4,5) D(3,4,5)	A(1/3,1/2,1) B(1,1,1) C(1/4,1/3,1/2) D(1/4,1/3,1/2)	A(3,4,5) B(4,5,6) C(1,2,3) D(1/3,1/2,1)	A(1,2,3) B(5,6,7) C(3,4,5) D(2,3,4)	A(3,4,5) B(5,6,7) C(3,4,5) D(6,7,8)
CR3	A(1,1,1) B(3,4,5) C(2,3,4) D(2,3,4)	A(1/4,1/3,1/2) B(1/3,1/2,1) C(2,3,4) D(1,1,1)	(1,1,1)	A(1,2,3) B(4,5,6) C(1/3,1/2,1) D(2,3,4)	A(3,4,5) B(5,6,7) C(1,2,3) D(3,4,5)	A(1/5,1/4,1/3) B(1/3,1/2,1) C(1/6,1/5,1/4) D(1/4,1/3,1/2)	A(1,2,3) B(3,4,5) C(1/3,1/2,1) D(1/3,1/2,1)	A(1/3,1/2,1) B(4,5,6) C(1,2,3) D(2,3,4)	A(1,2,3) B(4,5,6) C(1,2,3) D(6,7,8)
CR4	A(1/3,1/2,1) B(1/3,1/2,1) C(1/3,1/2,1) D(1,1,1)	A(1/5,1/4,1/3) B(1/7,1/6,1/5) C(1/3,1/2,1) D(1/4,1/3,1/2)	A(1/3,1/2,1) B(1/6,1/5,1/4) C(1,2,3) D(1/4,1/3,1/2)	(1,1,1)	A(2,3,4) B(1,2,3) C(2,3,4) D(3,4,5)	A(1/6,1/5,1/4) B(1/7,1/6,1/5) C(1/5,1/4,1/3) D(1/6,1/5,1/4)	A(1,1,1) B(1/3,1/2,1) C(1,1,1) D(1/5,1/4,1/3)	A(1/4,1/3,1/2) B(1,1,1) C(2,3,4) D(1,1,1)	A(1,1,1) B(1,1,1) C(2,3,4) D(4,5,6)
CR5	A(1/5,1/4,1/3) B(1/4,1/3,1/2) C(1/5,1/4,1/3) D(1/3,1/2,1)	A(1/7,1/6,1/5) B(1/8,1/7,1/6) C(1/5,1/4,1/3) D(1/5,1/4,1/3)	A(1/5,1/4,1/3) B(1/7,1/6,1/5) C(1/3,1/2,1) D(1/5,1/4,1/3)	A(1/4,1/3,1/2) B(1/3,1/2,1) C(1/4,1/3,1/2) D(1/5,1/4,1/3)	(1,1,1)	A(1/8,1/7,1/6) B(1/8,1/7,1/6) C(1/7,1/6,1/5) D(1/7,1/6,1/5)	A(1/4,1/3,1/2) B(1/4,1/3,1/2) C(1/4,1/3,1/2) D(1/6,1/5,1/4)	A(1/6,1/5,1/4) B(1/3,1/2,1) C(1,1,1) D(1/3,1/2,1)	A(1/4,1/3,1/2) B(1/3,1/2,1) C(1,1,1) D(3,4,5)
CR6	A(3,4,5) B(4,5,6) C(2,3,4) D(4,5,6)	A(1,2,3) B(1,1,1) C(2,3,4) D(2,3,4)	A(3,4,5) B(1,2,3) C(4,5,6) D(2,3,4)	A(4,5,6) B(5,6,7) C(3,4,5) D(4,5,6)	A(6,7,8) B(6,7,8) C(5,6,7) D(5,6,7)	(1,1,1)	A(4,5,6) B(4,5,6) C(3,4,5) D(1,2,3)	A(2,3,4) B(5,6,7) C(5,6,7) D(4,5,6)	A(4,5,6) B(5,6,7) C(5,6,7) D(8/9/10)
CR7	A(1/3,1/2,1) B(1,1,1) C(1/3,1/2,1) D(3,4,5)	A(1/5,1/4,1/3) B(1/6,1/5,1/4) C(1/3,1/2,1) D(1,2,3)	A(1/3,1/2,1) B(1/5,1/4,1/3) C(1,2,3) D(1,2,3)	A(1,1,1) B(1,2,3) C(1,1,1) D(3,4,5)	A(2,3,4) B(2,3,4) C(2,3,4) D(4,5,6)	A(1/6,1/5,1/4) B(1/6,1/5,1/4) C(1/5,1/4,1/3) D(1/3,1/2,1)	(1,1,1)	A(1/4,1/3,1/2) B(1,2,3) C(2,3,4) D(3,4,5)	A(1,1,1) B(1,2,3) C(2,3,4) D(7,8,9)
CR8	A(1,2,3) B(1/3,1/2,1) C(1/5,1/4,1/3) D(1,1,1)	A(1/3,1/2,1) B(1/7,1/6,1/5) C(1/5,1/4,1/3) D(1/4,1/3,1/2)	A(1,2,3) B(1/6,1/5,1/4) C(1/3,1/2,1) D(1/4,1/3,1/2)	A(2,3,4) B(1,1,1) C(1/4,1/3,1/2) D(1,1,1)	A(4,5,6) B(1,2,3) C(1,1,1) D(1,2,3)	A(1/4,1/3,1/2) B(1/7,1/6,1/5) C(1/7,1/6,1/5) D(1/6,1/5,1/4)	A(2,3,4) B(1/3,1/2,1) C(1/4,1/3,1/2) D(1/5,1/4,1/3)	(1,1,1)	A(2,3,4) B(1,1,1) C(1,1,1) D(4,5,6)
CR9	A(1/3,1/2,1) B(1/3,1/2,1) C(1/5,1/4,1/3) D(1/6,1/5,1/4)	A(1/5,1/4,1/3) B(1/7,1/6,1/5) C(1/5,1/4,1/3) D(1/8,1/7,1/6)	A(1/3,1/2,1) B(1/6,1/5,1/4) C(1/3,1/2,1) D(1/8,1/7,1/6)	A(1,1,1) B(1,1,1) C(1/4,1/3,1/2) D(1/6,1/5,1/4)	A(2,3,4) B(1,2,3) C(1,1,1) D(1/5,1/4,1/3)	A(1/6,1/5,1/4) B(1/7,1/6,1/5) C(1/7,1/6,1/5) D(1/10,1/9,1/8)	A(1,1,1) B(1/3,1/2,1) C(1/4,1/3,1/2) D(1/9,1/8,1/7)	A(1/4,1/3,1/2) B(1,1,1) C(1,1,1) D(1/6,1/5,1/4)	(1,1,1)

Table 23 results of the HoQ augmented by FAHP

	Importance	RI	CR ranking	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	EC10	EC11	EC12	EC13	EC14
CR1	0.2404	8.52%	4	9		9						9					
CR2	0.7508	26.60%	2	3	3		9					3		9			
CR3	0.4979	17.64%	3				9					3					
CR4	0.0052	0.18%	6				3	9			3					3	
CR5	0	0.00%	8				9		9	9		1			3	3	
CR6	1	35.43%	1							3		9				3	
CR7	0.3070	10.88%	5									3	9	3	3		1
CR8	0.0209	0.74%	7					9			3					3	
CR9	0	0.00%	9												3	3	9
		EC importance		4.416	2.2524	2.1636	11.2539	0.2349	0	3	0.0783	15.8307	2.763	7.6782	0.921	3.0783	0.307
		EC RI		8.18%	4.17%	4.01%	20.85%	0.44%	0.00%	5.56%	0.15%	29.33%	5.12%	14.22%	1.71%	5.70%	0.57%
		EC ranking		4	8	9	2	12	14	6	13	1	7	3	10	5	11

4. Analysis of the results

Figure 48 shows the relative importance between CRs in traditional QFD method and method augmented by FAHP. According to the Figure, we can find that the variation range of traditional QFD is 10.5%, while the variation range of FAHP is 35.43%. It is clear that FAHP enables a clearer distinction of the CRs highlighting the most important requirements in a more distinct manner than traditional QFD (Haber et al., 2018). According to this Figure, we could know a reason why the customers always have lower loyalty. The CR4 represents quick & high-quality response after demand; CR5 represents ease of use; CR8 represents fast & high-quality maintenance service. However, according to the experts' advice, we finally find that these requirements which have significant effects on Customer Experience were always ignored before. Previously, the company emphasized products quality itself and were not aware of that corresponding services are also very important for customer satisfaction. Another frustrating finding is that the relative importance of recycling (CR9) is zero, the same with ease of use (CR5). This find means that previously the company did not attach importance to the customers and environment at all.

Figure 48 the relative importance between CRs using traditional method and FAHP

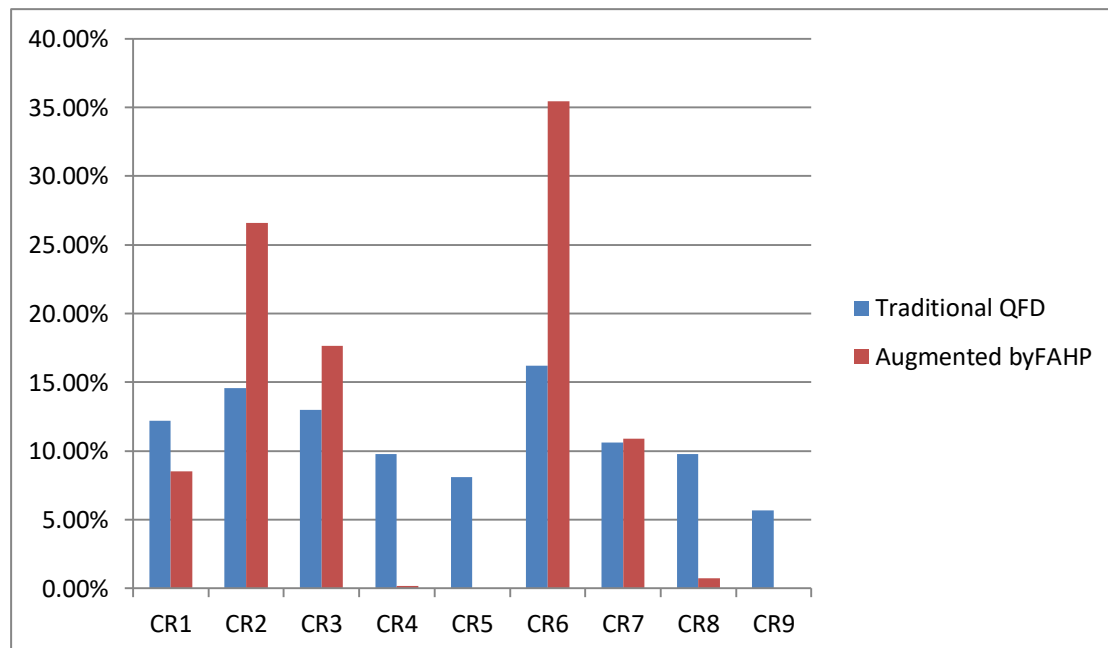


Figure 49 shows the relative importance between ECs in traditional QFD method and method augmented by FAHP. According to the Figure, the variation range of FAHP is 29.33%, while variation range of traditional QFD is 16.67%. The most highlighted EC is also about the product quality warranty, the same with CRs ranking. Table 24 shows the ranking of the CRs and SCs using traditional QFD method and method augmented by FAHP. In terms of CRs ranking, although the distinction is not so clear in traditional QFD method, the rankings are the same with the ones in FAHP. While for ECs rankings, it is the same that EC9-product quality warranty ranks the

first and EC4-good quality installation and commissioning ranks the second, since they are the guarantee of products' quality during usage phase. For the third one, in traditional method, quick and high-quality response ranks the third, while the ranking drops to 12 due to the low importance of CR4 and CR8 in FAHP method, and the third one is EC11-higher energy efficiency ratio in FAHP. Additionally, we can see that EC1, EC11 and EC13 are all important in both sides. However, the same conclusion with CRs ranking, in ECs ranking, EC6-ease of use for customers and EC14-recycling service including recycling products, parts and raw materials are also in a very lower relative importance so that they both are in a low ranking range.

Figure 49 shows the relative importance between ECs using traditional method and FAHP

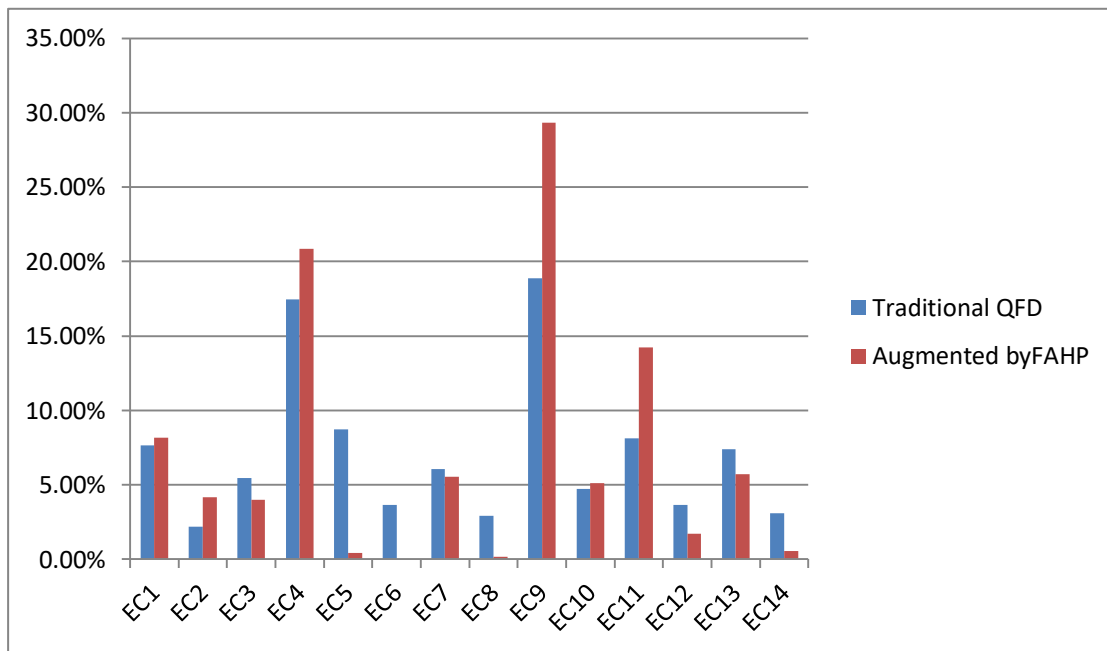


Table 24 rankings of CRs and ECs using traditional method and FAHP

Customer Requirements (CRs)			Engineering Characteristics (ECs)		
CR Code	CRs Ranking		SC Code	ECs Ranking	
	Traditional	FAHP		Traditional	FAHP
CR1	4	4	EC1	5	4
CR2	2	2	EC2	14	8
CR3	3	3	EC3	8	9
CR4	6	6	EC4	2	2
CR5	8	8	EC5	3	12
CR6	1	1	EC6	10	14
CR7	5	5	EC7	7	6
CR8	7	7	EC8	13	13
CR9	9	9	EC9	1	1
			EC10	9	7
			EC11	4	3

			EC12	11	10
			EC13	6	5
			EC14	12	11

To sum up the analysis above, it can be found that the experts still use the “old mind” to develop the offering. Their thinking keeps product-centric and they are still focusing on the quality of product itself. In this case, from the viewpoint of PSS, we are still retained the low-ranking CRs, for instance, CR4 (quick & high-quality response after demand), CR5 (Ease of use) and CR8 (fast and high-quality maintenance service) which are important to achieve good customer experience; CR9 (recycling) which is very important for addressing sustainability. In this way, some low ranking ECs are also retained, such as EC5 (response within 48 hours), EC6 (Ease of use), and EC14 (recycling service, parts, and raw materials).

3.1.2 Function decomposition and module selection

In last section, we analyzed the customer requirements based on customer activity cycle analysis and calculated the priority of the requirements based on QFD and FAHP. In this section, the requirements will be decomposed into different functions; finally these functions will be fulfilled by different products modules and service modules. The manufacturer does not want to show too much information about their basic components about the products, hence in this case study, we only have three layers based on “*PSS function decomposition logic (refer to Chapter 2-3.3.3, Figure 11)*”, shown in Figure 50.

In the first layer, nine requirements are listed. When translate the requirements into functions, there are also nice functions identified in this case, from F1 refrigeration to F9 recycling. Next, from function level to module level, in order to fulfill the refrigeration function, three main systems are necessary, respectively: heat pump system, heat exchange system and air supply equipment. Further on, the heat pump system can be divided in to three product modules. Now we conclude five product modules; respectively are *PM1-compressor, PM2-refrigerants, PM3-throttling and pressure regulating device, PM4-heat exchanger and PM5-air supply equipment*. To lower noise during usage, three modules are necessary: PM1-a good compressor, PM5-good air supply equipment and a new Service Module-*SM1-installation and commissioning service*. F3 is also related to PM4 and PM1. F4 corresponds to SM1 and SM2-delivery service, and so on.

In this Figure, we can see PM2, PM3, SM3 and SM4 are circled by red dotted line. This is because, in this case these modules are not fixed; and there are several optional modules for each one, so that there will be several offering scenarios because of different combinations of products modules and service modules. Different scenarios will be analyzed according to *customer satisfaction index (refer to Chapter4-5.1, Figure 42)* and *sustainability assessment (refer to Chapter 4-5.2)*, so that the scenarios will keep optimizing based on *Customer-Provider Satisfaction Trade-off design cycle (refer to Chapter3-4, Figure 25)*. In the following Table 25, the detailed information of optional modules is listed as well as their supporting processes and corresponding companies. It is necessary to mention here that in this

case we have not worked on the product module design due to the manufacturer is a big company who has already fulfilled it.

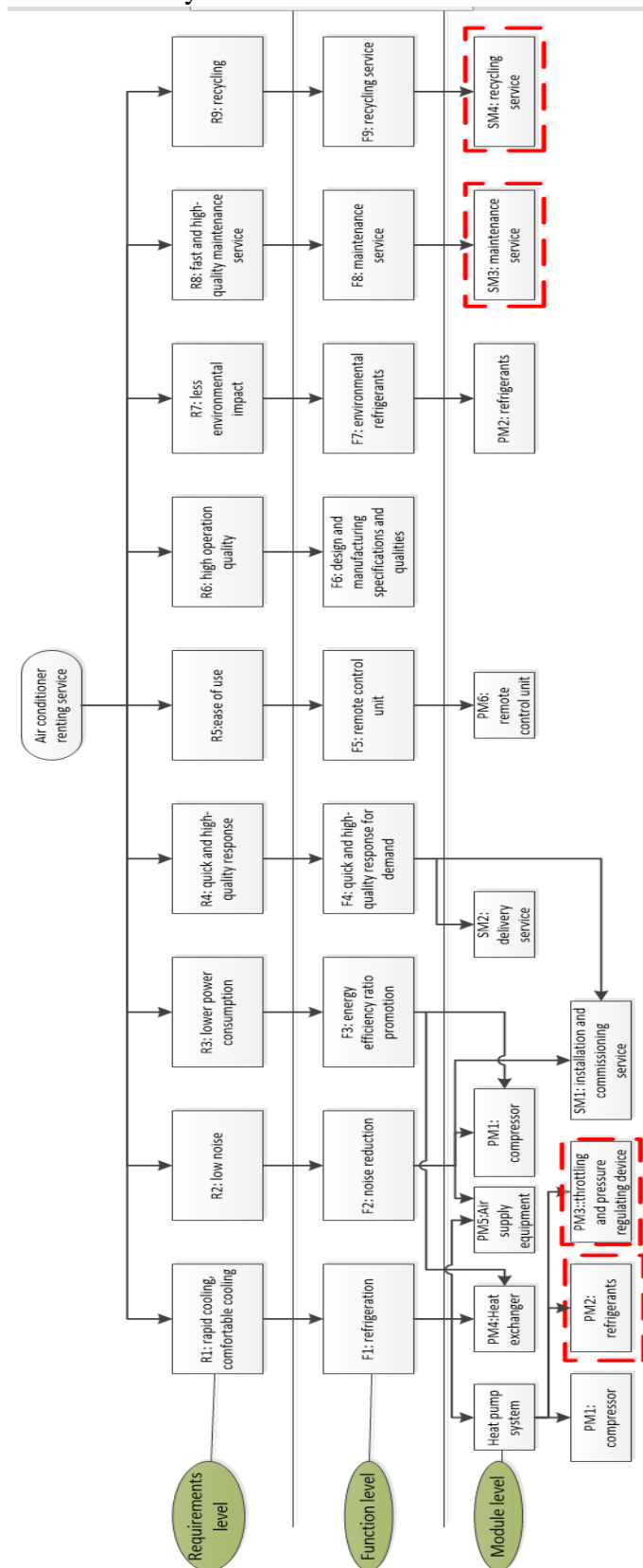


Figure 50 Air conditioner function decomposition

Table 25 detail information about optional modules

PSO modules						VCCPs	VE members
Necessary modules	Name of modules	Detail explanation of modules	Existing Fixed modules	Optional modules	New added modules comparing with previous business model	Supporting processes	Corresponding company
PM1:	Compressor	Double eccentric rolling rotor compressor	<input checked="" type="checkbox"/>			Compressor production process	Manufacturer
PM2:	Refrigerants	R410A		<input checked="" type="checkbox"/>		Refrigerants filling process	
		R32		<input checked="" type="checkbox"/>			
PM3:	Throttling and pressure regulating device	Cooling & heating air conditioner with four-way valve		<input checked="" type="checkbox"/>		Throttling and pressure regulating device production process	
		Sole cooling air conditioner without four-way valve		<input checked="" type="checkbox"/>			
PM4:	Heat exchanger	Larger surface	<input checked="" type="checkbox"/>			Heat exchanger production process	
PM5:	Air supply	Cross-flow fan	<input checked="" type="checkbox"/>			Air supply equipment	

	equipment					production process	
PM6:	remote control unit	Remote control unit	<input checked="" type="checkbox"/>			Remote control unit production process	
SM1:	Installation and commissioning service	Installation and commissioning service	<input checked="" type="checkbox"/>			Installation and commissioning service process	Wholesaler
SM2:	Delivery service	Delivery service	<input checked="" type="checkbox"/>			Delivery service process	TPL partner
SM3:	Maintenance service	Maintenance service			<input checked="" type="checkbox"/>	Maintenance service process	Manufacturer and maintenance partners
SM4:	Recycling service	Recycling service			<input checked="" type="checkbox"/>	Recycling service process	Wholesaler and TPL partner

So far, we have fulfilled the preparatory work for PSOs design and VCCPs design. The abovementioned design processes mainly include *identifying PSOs requirements; decomposing PSO functions, selecting module alternatives for PSOs design, and planning matching processes for modules for VCCPs design (refer to 2.2.2, Figure 19 and 20)*. In this case, the existing collaborative partners are able to provide all the necessary modules; accordingly, they are also able to provide supporting processes, so that the wholesaler doesn't need to launch bids outside the collaborative network to find other partners to provide them with the modules and supporting processes. The following work mainly consists of *realizing combinations of modules and reconfiguring processes (refer to Chapter3-2.2, Figure 19 and 20)*. This will be done after VE modelling and will be further developed later based on *Customer-Provider Satisfaction Trade-off design cycle (refer to Chapter3-4, Figure 25)*.

3.2 VE design and modelling

In this case, VE design indeed is limited by the wholesaler's existing partnership. Hence, after analyzing the necessary modules, the new VE is almost fixed. Table 25 has already indicated the kernel network in the new VE. In this case, *VE design is an internal optimization process*. As mentioned above, the wholesaler does not need to find partner outside the VE; however, there are businesses overlapped in the existing collaborative network. Taking the maintenance service as an example, there are three companies responsible for it- the manufacturer and other two small-medium maintenance service companies (mentioned in the AS-IS system).

3.2.1 Partner selection and VE creation

Hence, when optimizing the existing network to be a new effective and efficient VE. *Partner Selection* is necessary, so that the *AGORA multi-agent architecture* will be used here (*refer to Chapter 4-4.3.2*). Considering the company's situation that it is the wholesaler of AUX Company, part of the maintenance service must be done by AUX own maintenance department, particularly, the core components suffer some kinds of damage and break down, the repair work must be distributed to their own company. Hence, the rest is to select a better one for the low level maintenance and repair service from the other two. The Figure 51 shows the selection work.

The wholesaler is the broker in this VE, who will be charge of the selection work. Besides, coordination AGORA is also necessary among different members since communications and coordination may be necessary because the cooperation or non-cooperation will lead to many problems that must be discussed. To address the selection, a partner selection AGORA is necessary. Interested partners need to register into this AGORA at first. QFD and FAHP will be used again here in order to assess which company is more appropriate; detail algorithm can be found in Ho et al. (2012). Figure 52 lists the hierarchy metrics for the selection. This section will not explain again the calculation steps. The same selection process will also be used for TPL

partner selection. Finally, the wholesaler chooses two TPL partners and one small-medium maintenance enterprise. Hence, the final VE consists of the following three parts:

- **Kernel Network:** the wholesaler, a manufacturer, two retailers, two TPL partners, a maintenance enterprise;
- **Supporter organization:** government, IT companies and banks etc.;
- **Customers.**

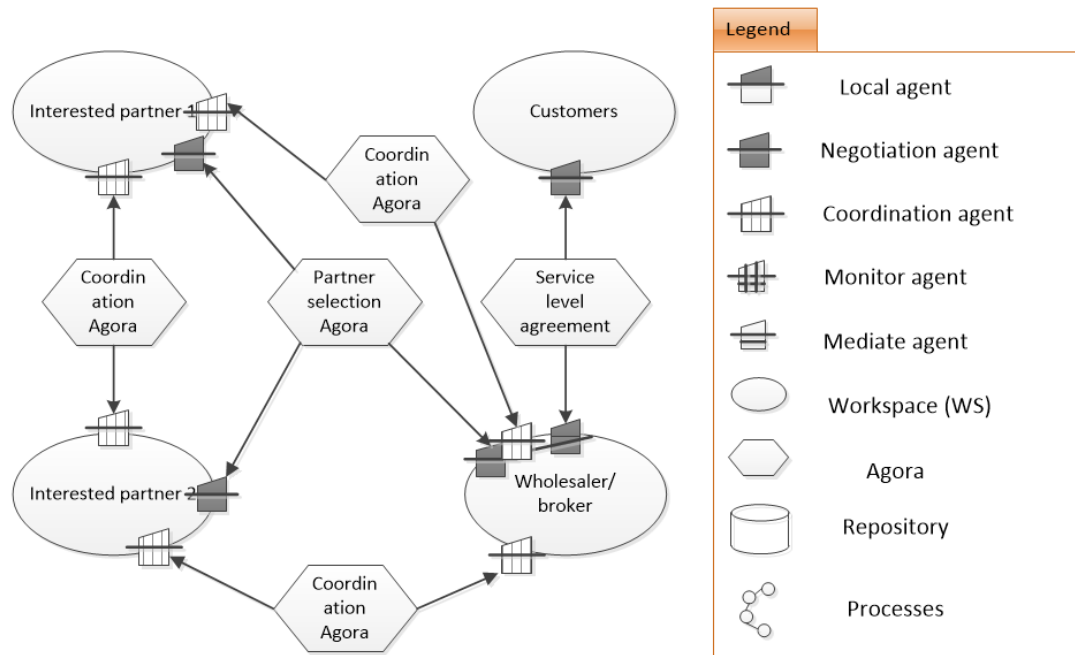


Figure 51 air conditioner maintenance service partner selection process

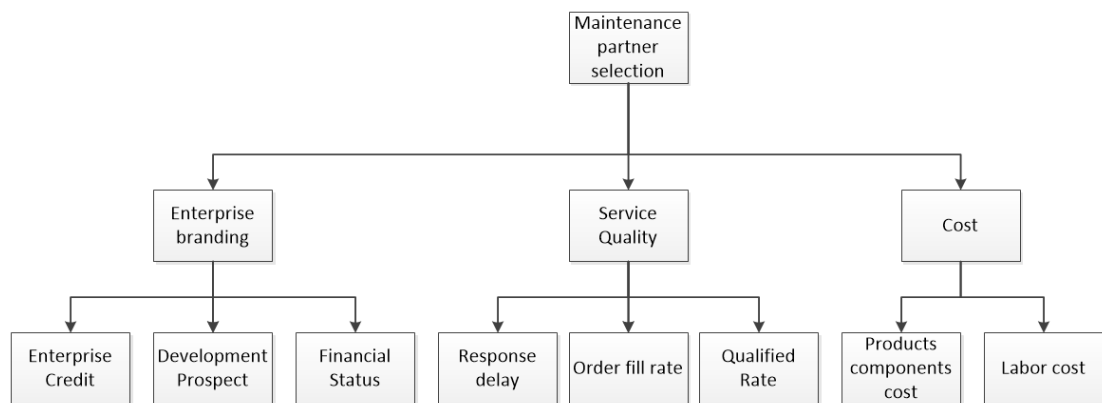
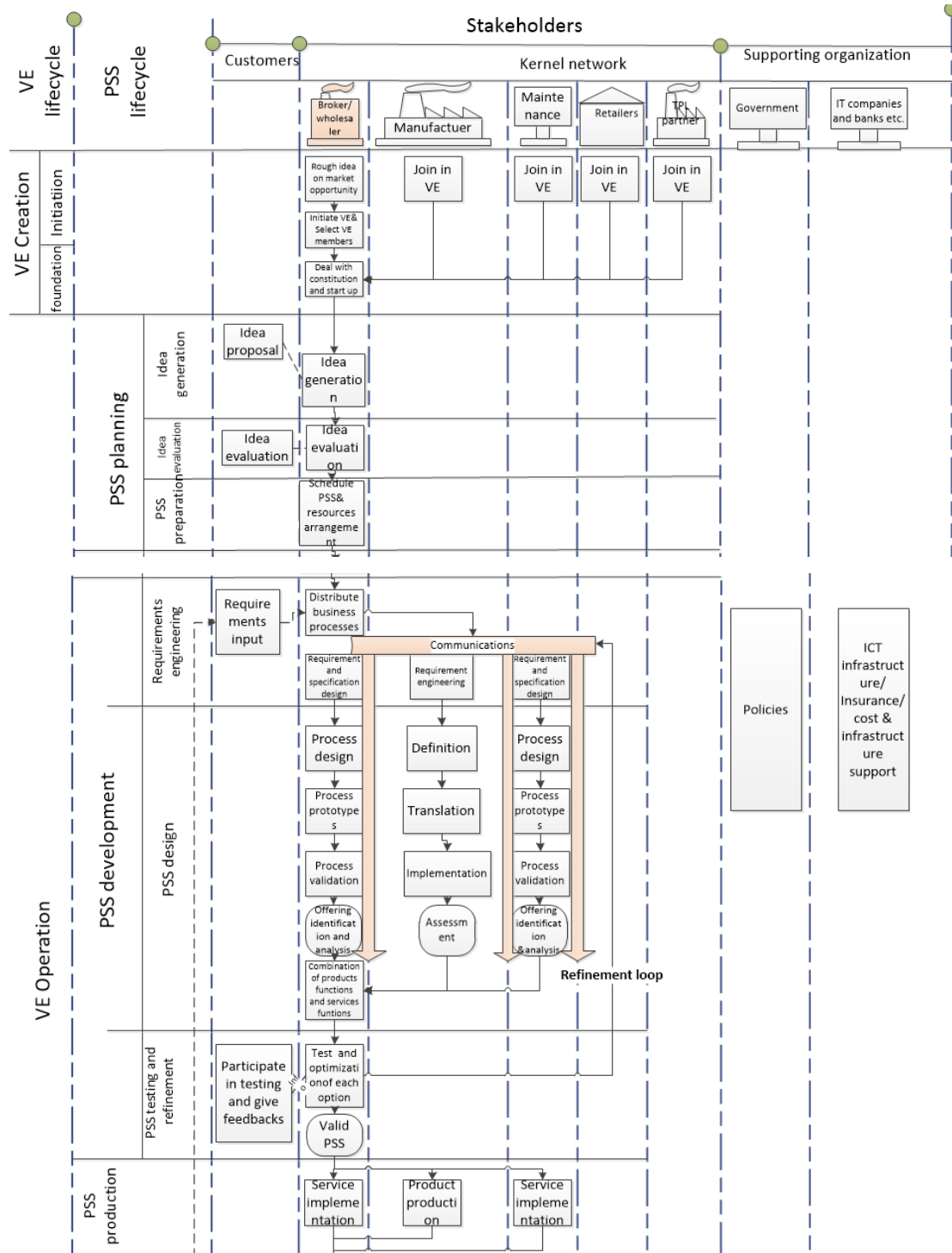


Figure 52 Selection metrics hierarchy

3.2.2 Stakeholder-driven PSS-VE lifecycle model

In last section, the stakeholders in the new VE have been confirmed. In order to guide the work flows for the stakeholders, this section proposes the stakeholder-driven PSS-VE lifecycle (Figure 53) according to the “*stakeholder-driven lifecycle modelling method*” (refer to Chapter 4-2).

This air conditioner case study belongs to the first case of PSS lifecycle phases in VE context (*refer to Chapter 4-2.3*). The wholesaler plays three roles together in this case, respectively: **broker** who is the initiator of the VE, **coordinator** who is charge of main businesses of the VE, and the **service provider** who is the main provider of air conditioner renting service. Under this condition, the PSS lifecycle phases in VE context will adopt Figure 29, in which all the PSS lifecycle phases will be contained in VE operation lifecycle, shown as left two columns in Figure 53.



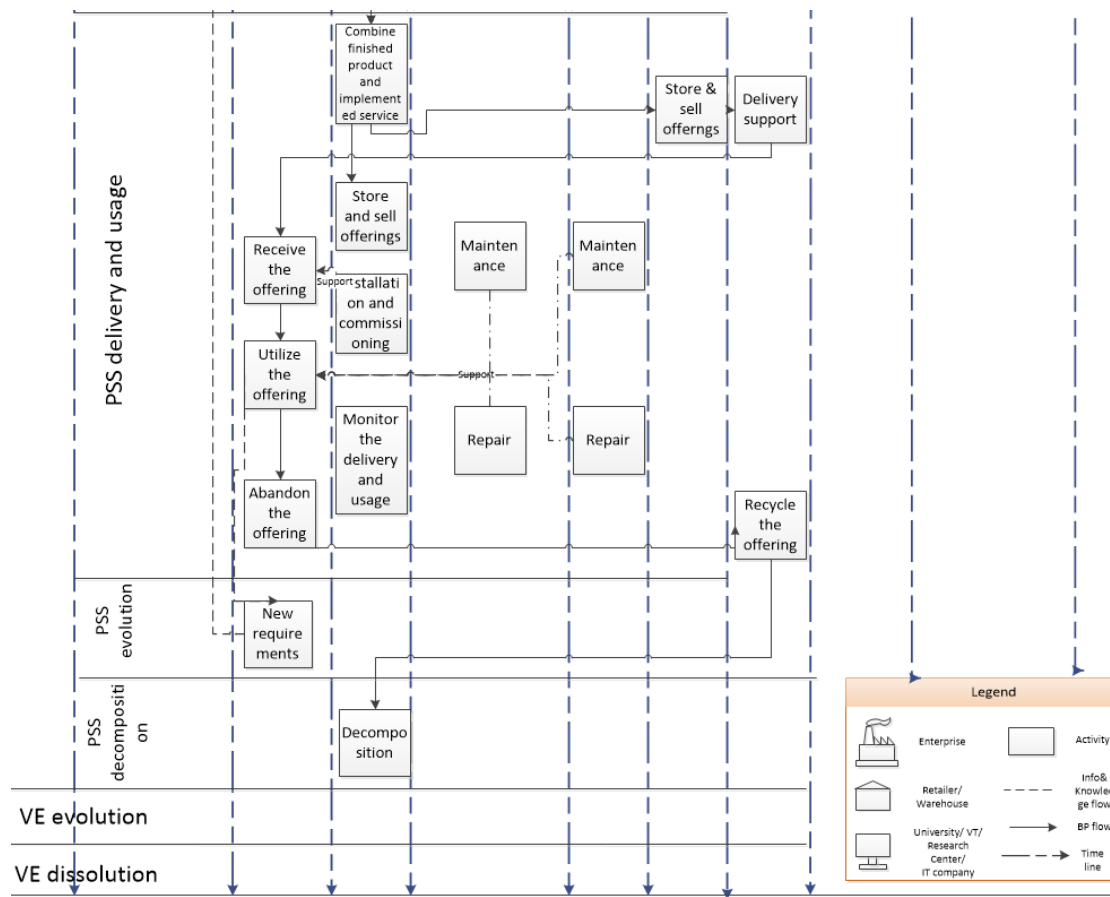


Figure 53 air conditioner case study PSS-VE lifecycle model

During **VE Creation phase**, the wholesaler has a rough idea on air conditioner renting, so that it initiates the VE as broker and select the VE members. After partner selection, these companies will join into the VE. So far, the new VE is created.

Then the **VE** is going on the **operation** phase, which consists of six main life phases; respectively are *PSS planning*, *PSS development*, *PSS production*, *PSS delivery and usage*, *PSS evolution* and *PSS decomposition*.

In the planning phase, the wholesaler and customers are the main actors; they will firstly fulfill the idea generation and idea evaluation tasks in order to come up with the appropriate solutions that customers really need. Then in the PSS preparation phase the wholesaler need schedule new PSS and rearrange the resources in the VE.

In the PSS development phase, requirements engineering is the first and critical task. Once the requirements engineering and function decomposition are done, the wholesaler can distribute the detail work or business processes to each stakeholder, so that they can obtain the requirements for their own parts. Then based on the new requirements, they will develop the distributed products or service processes. It's necessary to mention that during the design phase, the communication between the different stakeholders is significant, particularly when interfaces needed between products and service modules which are developed by different stakeholders. After, all these products and service modules will be combined to form different scenarios that

will be tested by customers and wholesaler during the PSS testing and refinement phase. If valid, a new PSS solution comes out; if not, the refinement loop is necessary.

In the PSS production phase, valid PSS solutions will be produced by the manufacturer and implemented by the service provider, so that the final offering comes out after combining the finished product and implemented service.

In the PSS delivery and usage phase, the offerings will be stored by the wholesaler and its retailers and will be sold later. Once a customer place an order, the TPL partner will deliver the products to the customer, accompanied by the staff that is responsible for the installation and commissioning service. During the usage phase, if there are some problems with the air conditioner, the customer could ask for maintenance and repair service that is supported by the manufacturer and the small-medium maintenance company. In this case, majority of users will choose to give back the products and cancel the offering contract. So the TPL partner will also support recycle the offering.

This system can **evolve** if necessary, and finally will be **decomposed** when it's not valuable.

3.3 COPSS realization and visualization

Last two sections have introduced the three air conditioner PSS design activities in order to partially explain how to use the framework and corresponding methodologies. In section 3.1, we fulfilled requirements engineering and function decomposition for PSOs and find out the corresponding processes. However, how to realize the combination of modules is remained. In this section, the *product-service blueprint* ((refer to Chapter 3-2.2.2, Table 13) (Geum and Park, 2011) is adopted to visualize the combination. Figure 54 shows the product-service blueprint with the symbolic representation, in which three areas, five lines, five activities, three related logic and six points have been listed. Further on, Table 26 explains the areas and lines, while Table 27 explains the symbols of the product-service blueprint.

Table 26 areas and lines of product-service blueprint, Geum and Park, 2011

Area		Characteristics	Line
Product area	Use area	<ul style="list-style-type: none"> • Providing the flow of product usage; • Mostly composed of customer-related activity; • Possibly including the product 	Line of use
	Management area	<ul style="list-style-type: none"> • Providing the flow of management (including maintenance) • Mostly related to the regular-basis management activities to provide the PSS; • Possibly including the product; • Mostly related to the back office area 	
Service area	Front office area	<ul style="list-style-type: none"> • Providing the flow of customer action and employee action in the area visible to the customer; • Partially related to the management are of product are, other areas of service area 	Line of invisibility

	Back office area	<ul style="list-style-type: none"> • Providing the flow of employee action in the are invisible to the customer; • Mostly related to the management area of product area, front office area of service area 	
Supporting area	Production area	<ul style="list-style-type: none"> • Providing the flow of production (including distribution among actors); • Mostly including participation of other actors 	Line of design
	Design area	<ul style="list-style-type: none"> • Providing the flow of designing the PSS; • Mostly related to the customization, customer involvement, redesign during the PSS lifecycle 	

Table 27 symbols of the product-service blueprint, Geum and Park, 2011

Type	Name	Defection	
Activity	Service-related activity	An activity which happens during service-related work	
	Product-related activity	An activity which happens during product-related work	
	Customer participation activity	An activity which customers participate in	
Point	Pont of integration	A point that products and services are integrated	
	A:add	A: if a product or service is additive to are integrated	
	S:substitute;	S; if a product or a service substitute the existing functions of product	
	M: management	M: if a product or service helps management the current function	
	Point of ownership transfer A->B	A point that the ownership is transferred from actor A to another actor B	
	Point of no transfer of ownership	Exists when the ownership is not transferred (while the product is delivered)	
	Point of actor transfer (A->B)	A point that the actor is changed from actor A to another actor B	
	Point of sustainability achieved	A point that the sustainability or environmental value is achieved	
	Point of economic value achieved		A point that the economic value is achieved
			F: if the value is achieved for the function use; P: if the value is achieved for the purchase of a product; M: if the value is achieved for the management of purchased products
	Related facility	Facilities to deliver the desired function or value	
	Decision point	A point where a decision should be made	
Fail point	A possible fail point that has a potential to be failed		

According to the introduction of Geum and Park's product-service blueprint method, we are able to go on develop our air conditioner case, as shown in Figure 55.

We will start reading this Figure from the viewpoint of designers at first. Hence, starting from the **Supporting Area, under the line of design**, as indicated in the previous sections, the wholesaler and retailer will fulfil the customer segmentation so that they could target on a niche and provide the most appropriate offerings to the customers. After requirement engineering (the customers also involve in this activity), we go to select the modules alternatives; while if lacking some modules, the VE will be bid for modules from outside or design new modules.

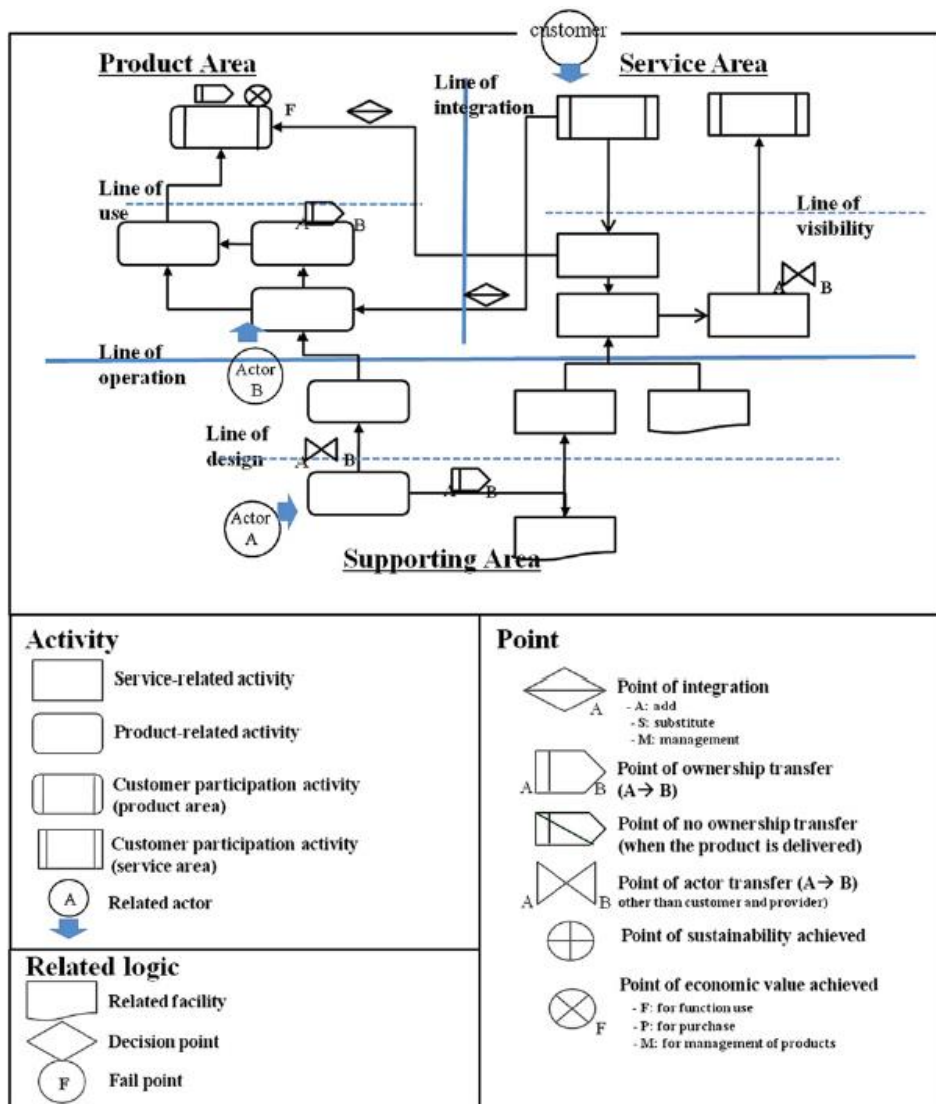


Figure 54 symbols of the product-service blueprint

Once all the necessary modules are prepared, the combination will be launched. Later, the product production task will be sent to the manufacturer, who will produce the products. Here, there is an actor transfer from wholesaler to manufacturer, i.e., from development to production. Then the manufacturer will manufacture the air conditioners, and test the products with the help of the customers, and valid manufactured air conditioners will be delivered to wholesaler and retailers' inventory. Here the ownership of the air conditioners is transferred from the manufacturer to the wholesaler and then the wholesaler will be in charge of the following businesses. What's more, the manufacturer will earn money. On the other side, service processes will be distributed to the different stakeholders, such as TPL responsible for delivery, Maintenance Company responsible for regular-basis maintenance and small problems repair, and the manufacturer will be responsible for the overhaul.

After developing and producing the PSS, we can read the Figure from the viewpoint of the customers. Hence, we start from the customers' purchasing activity

in the front office area of Service area. Customers usually have two ways of purchasing a new offering; respectively are online and offline. However, no matter which one, there is no ownership transfer before and after purchasing. Customers purchase renting services (using days) from the wholesaler and give the air conditioner back after the contracts expire. Besides, the customers need to pay for the renting services.

In the first case, customers purchase online, and the Third Party Logistics will help deliver the air conditioner to the customers' homes. The wholesaler will pay TPL Company for the delivery. In second case, the customers will purchase in the store, and will take back the air conditioner by themselves. By this way they may save some money. In both cases, the customers' demands will be sent to the back office, i.e., the staff of wholesaler or retailers will receive the orders and try to find corresponding air conditioners in the inventory (in *management area*) and will deliver it to the customers (back to *front office area*). Then the wholesaler's employees will accompany the delivery company to go to customers' homes and fulfill the installation and commissioning.

After this, the customers will start the usage phase (in **Use area of Product Area**). We used substitute integration here, which represents the traditional product is instead of a kind of renting service. During the usage phase, the air conditioner may encounter a variety of problems, leading to maintenance, repair and even overhaul. In each case, the customers take the decision (in **management area**) that asks the wholesaler for help. At the same time, this demand will be sent and handled by the ICT infrastructure (in **Supporting Area**), the aim is to come up with an appropriate time and period for employees to visit customers and help deal with the maintenance and repair. Hence, in the **back office area**, we have checked the visit time and period activity, and asked for visiting to customers' activity; after discussing with customers in **front office area**, an appointment come out. Later, the maintenance company or the manufacturer's employees will go to customers' homes for maintenance and repair. The wholesaler will pay for this activity. Hence, a management integration symbol is displayed between "working on maintenance and repair" activity and "purchased and installed air-conditioner", which means that the maintenance and repair service help to manage the air conditioner's functions. At the end of the usage phase, the customers will send the products back to the wholesaler. The recycling also needs a similar series of activities like maintenance and repair. The different thing is that recycling service is an additive service to the air conditioner renting service, therefore a add integration symbol is necessary. What's more, after recycling, the air conditioners will be delivered back to the wholesaler and retailers, so that a large amount of solid waste is reduced. Hence, the sustainability is achieved (in the **management area**).

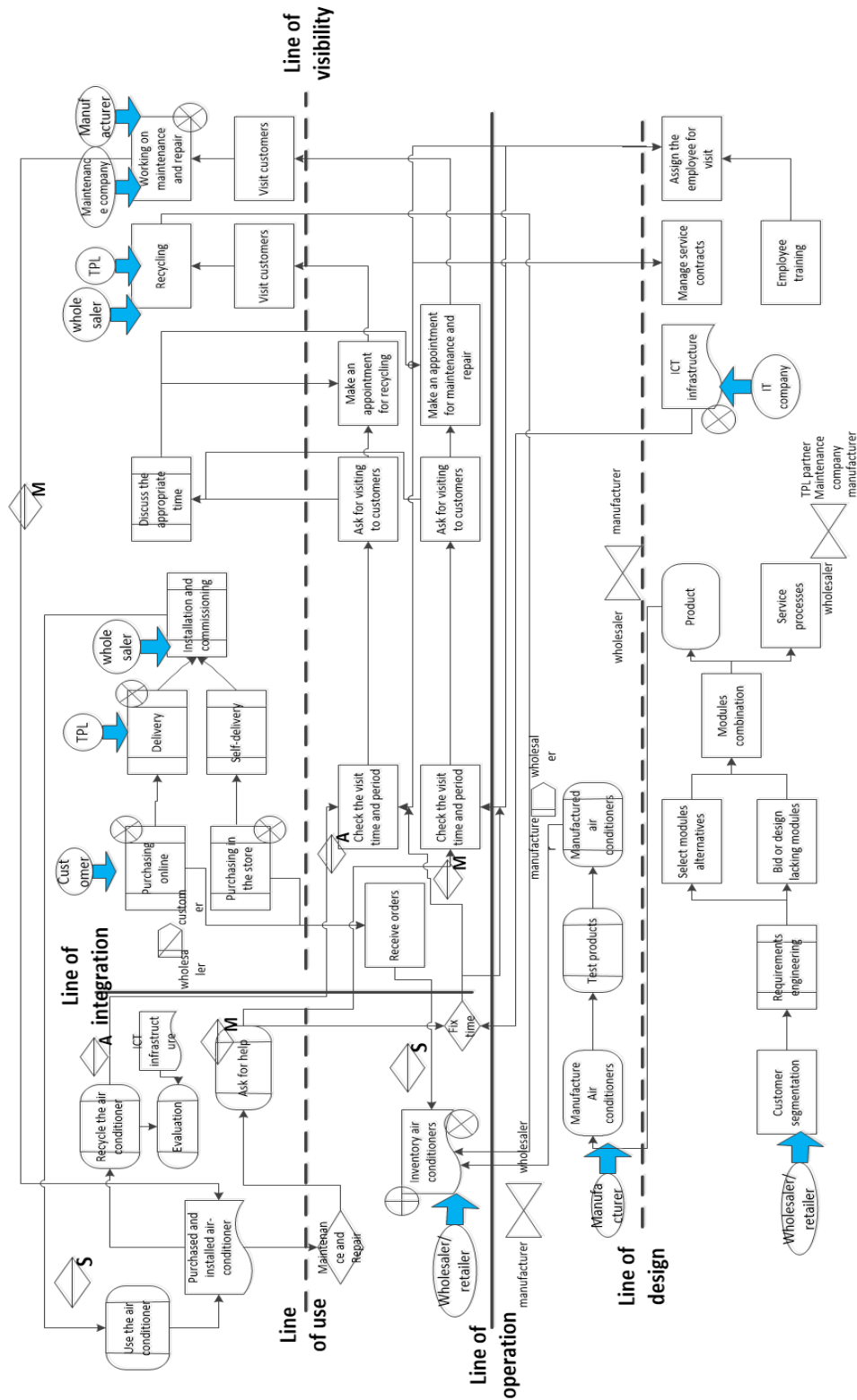


Figure 55 air conditioner renting product-service blueprint

3.4 Scenario simulation

After the above three steps, a general PSS solution is achieved. However, as

mentioned in section 3.1, Table 25; some modules are optional and thus there may be several cases for the final PSS solutions. So how to identify a better solution becomes the last problem. In the framework proposed in Chapter 3, we have given a Customer-Provider satisfaction trade-off design thinking, which means that a valuable and successful solution should be dedicated to satisfy both customer side and provider side (provider side contains the kernel network and supporter organization as mentioned above).

For the customer satisfaction, this thesis adopts the Customer Satisfaction Index as well as Partial Least Squares regression to measure customer satisfaction. However, in this case, due to time limitation, we have not obtained the final feedbacks from customers, since it took a long time from pushing the PSS innovation with the company, to data collection, to development and final production and implementation, and now they are still using the offerings. However, good news is that *“the customers who are using this kind of PSS are more satisfied than those not, at least they are very satisfied with the delivery service and installation service. The main reason is that the products ownerships now belong to us and accordingly we are responsible for the products and services. Additionally, I feel we are close,”* the sale manager said to us. So under this condition, we assume that the customers are satisfied with proposed PSS solutions, comparing with traditional product-centric offering. The rest problem is to choose a good solution for provider.

GaBi software is adopted in this thesis to help Sustainability Assessment. The environmental aspect and economical aspect are evaluated according to the software and data collected from the companies. However, it is a pity that the social aspect cannot be achieved since they are not aware of this problem; therefore there is scarcely any data to support the analysis. The following content will mainly discuss about the scenarios from the economic and environmental aspects. In this case study, three typical scenarios are analyzed in the following contents based on different modules combination in Table 25.

- **Scenario 1(AS-IS product-centric system):** PM1 (compressor) + PM2 (R410A) +PM3 (Throttling and pressure regulating device) +PM4 (Heat exchanger) + PM5 (Air supply equipment) + PM6 (remote control unit) + SM1 (installation and commissioning) + SM2 (delivery)
- **Scenario 2 (TO-BE R410A PSS solution):** PM1 (compressor) + PM2 (R410A) +PM3 (Throttling and pressure regulating device-cooling and heating) +PM4 (Heat exchanger) + PM5 (Air supply equipment) + PM6 (remote control unit) + SM1 (installation and commissioning) + SM2 (delivery) + **SM3 (Maintenance Service)** + **SM4 (Recycling service)**
- **Scenario 3 (TO-BE R32 PSS solution):** PM1 (compressor) + **PM2 (R32)** +PM3 (Throttling and pressure regulating device-**sole cooling**) +PM4 (Heat exchanger) + PM5 (Air supply equipment) + PM6 (remote control unit) + SM1 (installation and commissioning) + SM2 (delivery) + **SM3 (Maintenance Service)** + **SM4 (Recycling service)**

3.4.1 Life Cycle Assessment for environmental aspect

This thesis builds two simplified processes simulation models for Scenario 1 and Scenario 2&3. For Scenario 1, shown in Figure 56, the processes start from the production of air conditioner, which is a process box, containing the production of compressor, throttling and pressure regulating device, etc. These modules are assembled as air conditioner; and delivered to the customers. After installation and commissioning, the customers could start to use the air conditioner. During the usage phase, the air conditioner needs maintenance and repair. It's necessary to mention that the maintenance and repair service is different comparing with PSS as they are not free of charge, and the customers will pay for the real troubles that the air conditioner suffered. Finally, the customer will dispose the air conditioner, which becomes wastes at the end of use. After adding all the data for each process, it is possible to calculate the two most important indexes for LCA in AS-IS system, shown in Figure 57, 58 (results from the analysis on GaBi software). The Figure 57 lists the total CO₂ emissions during the whole air conditioner lifecycle as well as the emission situations in each process. Additionally, Figure 58 lists the environmental costs due to the emissions to air.



Figure 56 air conditioner lifecycle processes for Scenario 1

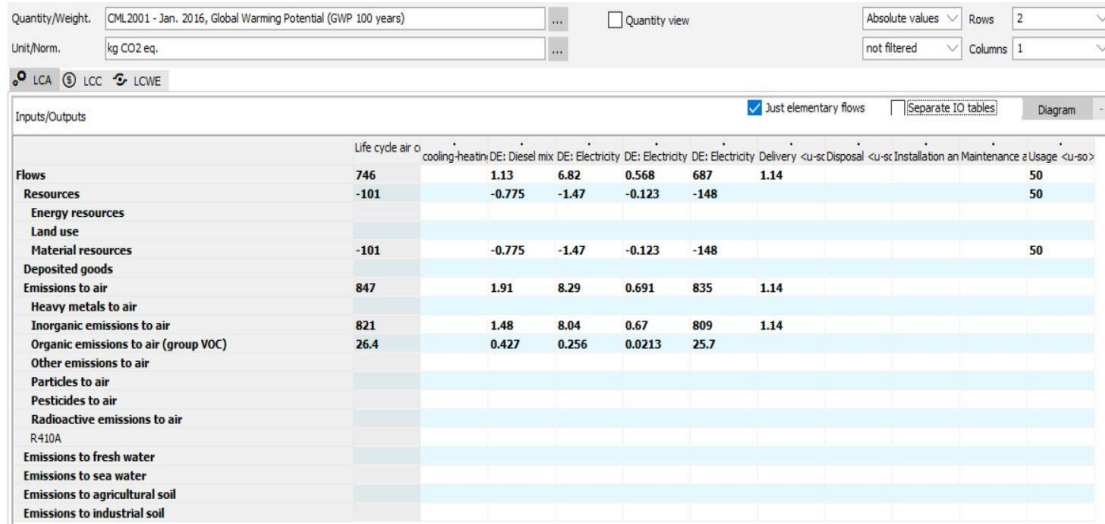


Figure 57 Global Warming Potential in AS-IS system

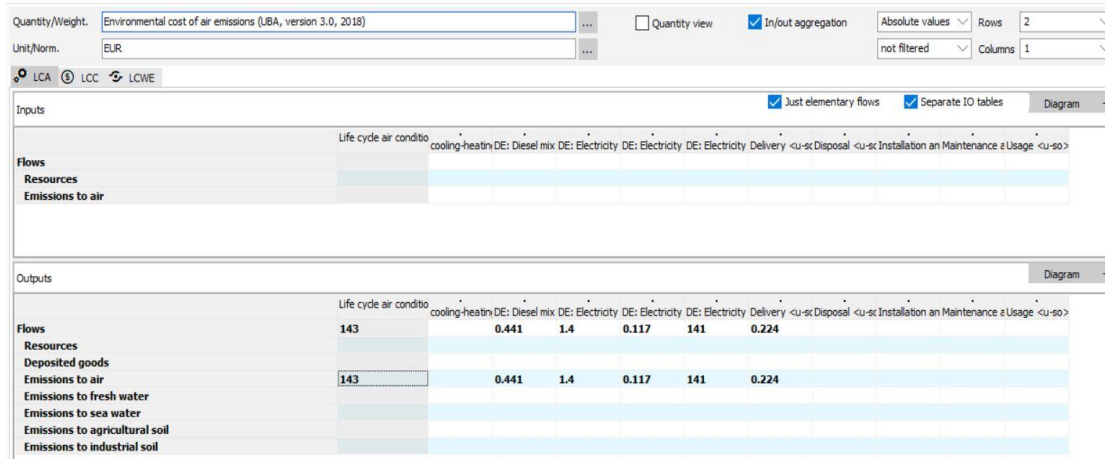


Figure 58 Environmental cost of air emission in AS-IS system

We repeat the similar processes for Scenario 2 and Scenario 3. Their processes are exhibited in Figure 59. The main differences in these two scenarios are maintenance & repair services and recycling, which haven't captured the company's attention in the AS-IS system. When comparing Figure 59 to Figure 56, we can find that the processes in Figure 59 are close-looped, which means that the products, or modules, or components etc. can be recycled and reused. The processes designed in this logic not only may save more money than the previous one but also leave much less waste to the environment.

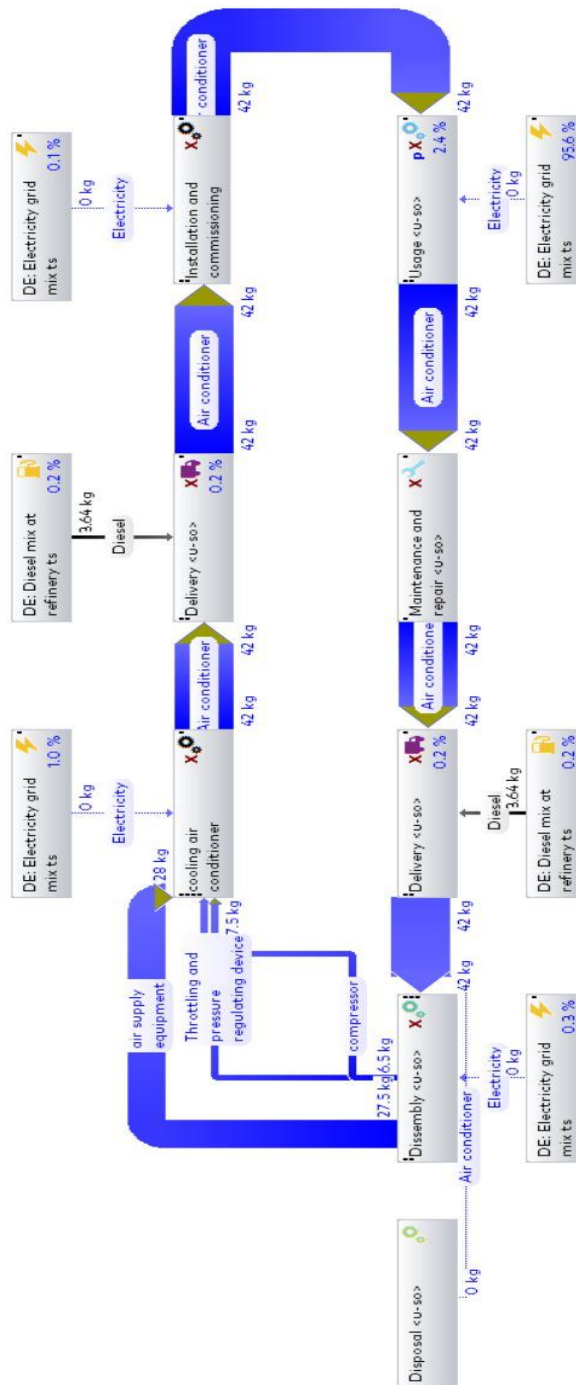


Figure 59 TO-BE PSS Processes modelling

On the other side, there are two differences between Scenario 2 and Scenario 3. The first one is that Scenario 3 finally produces sole-cooling air conditioner due to customers' requirements (as mentioned above, the customers in this niche only want to use the air conditioners for five months in summer) rather than cooling-heating air conditioner; the second one is to choose refrigerant R32 instead of R410A, mainly because R32 is more environments friendly.

After calculation, this thesis summarizes the core information, shown in Table 28. From the viewpoint of air emissions, it seems that TO-BE PSS R410A isn't much

more competitive than the AS-IS system as we preconceived. This is because the processes that lead to the air emissions are almost the same in both cases; particularly there are huge air emissions during usage phase due to the huge consumption of electricity. Additionally, because we add free recycling services in R410A case, we need one more delivery process; hence the data calculated finally is a little higher than AS-IS system. However, a big improvement is the disposal aspect that reduces to Zero or 2 kg. Zero case is because the air conditioner can be reused directly for other customers, so that there is no disposal anymore; 2 kg case is because the air conditioner can't be reused directly and need to be remanufactured; in this way, 2 kg waste is created.

The TO-BE PSS R32 takes distinct advantages over the other two. The main reason is because of the outstanding advantage of R32. Although both of them don't destroy the ozone sphere, the R410's GWP value is 2100 kg CO₂ while the value of R32A is only 675. What's more, according to tests, the air conditioner using R32 has larger Energy Efficiency Ratio so that it will cost less electricity when providing same refrigerating capacity. From the point view of LCA, we can conclude that the third scenario is better than the other two. In the next section, we will discuss the lifecycle costing and profitability in each scenario.

Table 28 comparison among different scenarios

	AS-IS system	TO-BE PSS R410A	TO-BE PSS R32
Global Warming Potential (kg. CO ₂ . Eq.)	746	751	675
Environmental cost of air emission (Euro)	145	147	134
Disposal (kg)	42.5	0 or 2	0 or 2

3.4.2 Life Cycle Costing Assessment and obtained profits

Following Figures 60, 61 62 respectively represents scenario 1, scenario 2 and scenario 3. Scenario 1 is the AS-IS product-centric system. The cost for provider mainly comes from the air conditioner production, delivery and manual work expenses. We sum them to calculate the final **provider cost** which is **1458 RMB**. On the other side, the customer should pay for the air conditioner and electricity during five months usage (9.6h/day, 30*5=150days, power 0.84kwh, 1RMB/kwh, so that the final electricity cost is 9.6*30*5*0.84*1=1210RMB), and the average maintenance cost is 40 (according to manager, the average maintenance frequency in half year is 0.4, and average cost for each maintenance is 100RMB, so that the maintenance cost is 0.4*100=40RMB). In this way, the **customer cost** is **2840RMB** (purchasing air conditioner 1590, electricity 1210, and maintenance 40), while the **providers' profits** is 1590-1458+40=**172 RMB**. Besides, the 172 RMB will be divided to the

manufacturer, the wholesaler and the maintenance company.

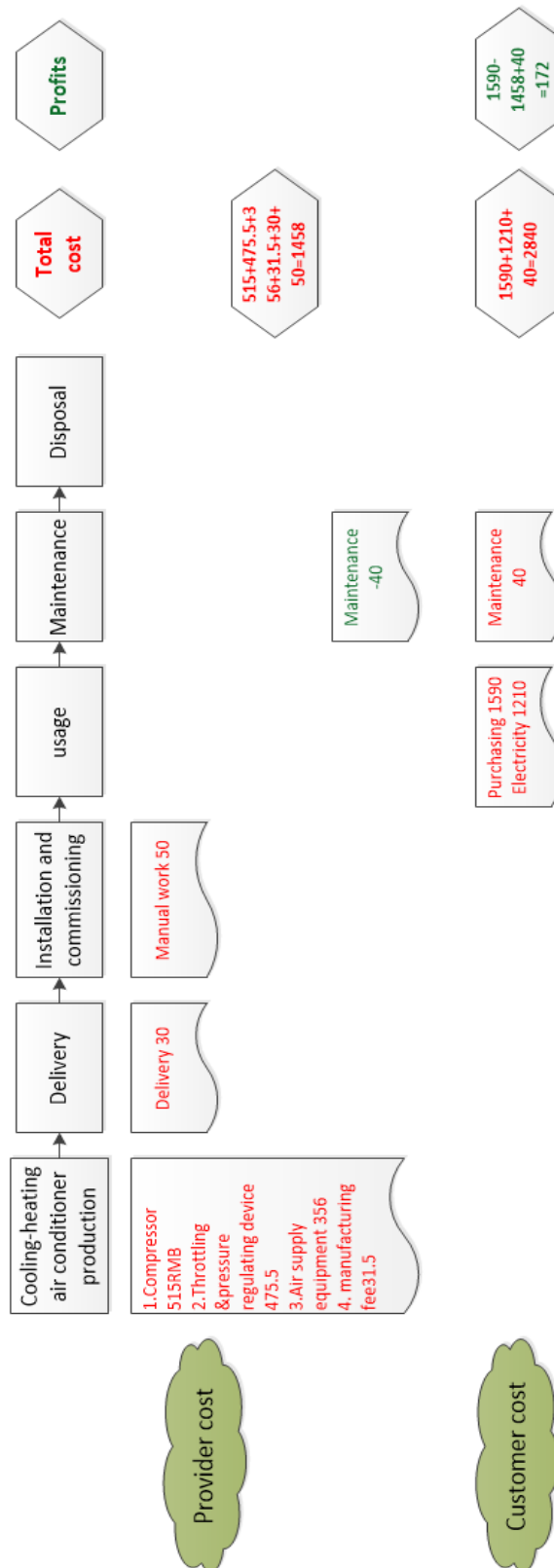


Figure 60 LCA analysis in AS-IS system

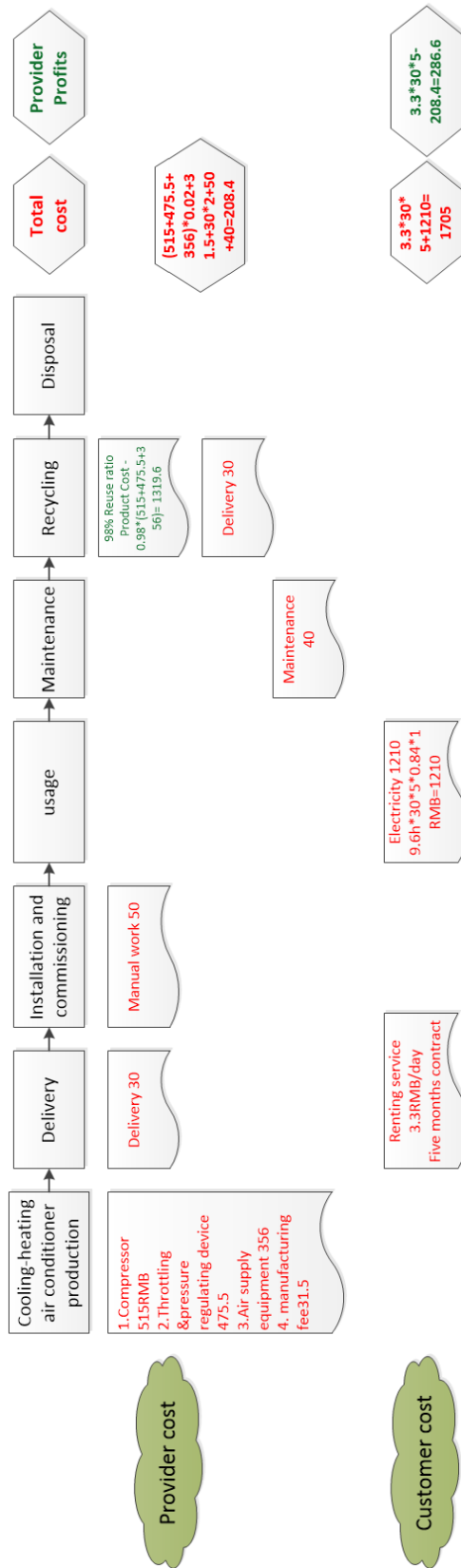


Figure 61 LCA analysis in TO-BE R410A PSS

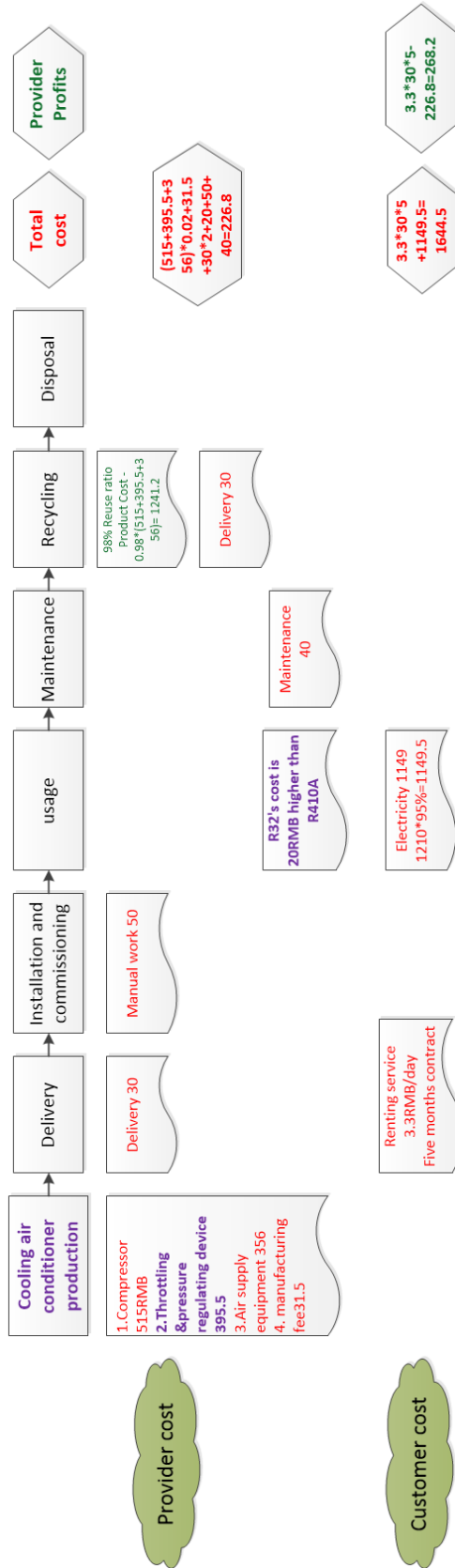


Figure 62 LCA analysis in TO-BE R32 PSS

The most distinct characteristic in the TO-BE PSS is the recycling phase. Based

on the recycling, the production cost could be reduced sharply. The average reuse ratio can reach up to 98% after five months use. Under this condition, in Scenario 2, the production cost will become $(515+475.5+356)*(1-98\%) + 31.5=58.43\text{RMB}$. Accordingly, recycling will also need delivery process, so that the provider needs to pay for it (30RMB). Another distinct characteristic is that maintenance service now is free for customers, so that the provider will pay for it (40RMB). As shown in Figures, the color of maintenance changes to green (profit) to red (cost). In this way, the final **provider cost** is $58.43+30*2+50+40=208.4\text{RMB}$. In this air conditioner PSS, “pay for product” is transformed into “pay for renting time”. In this contract, the customer will pay for 3.3RMB/day during five months usage, so that the **customer cost** is $3.3*30*5+1210$ (electricity) =**1705 RMB**, while the **providers’ profits** will be $3.3*30*5-208.4=286.6\text{RMB}$.

Scenario 3 is similar to Scenario 2 except two points. Firstly, the final product becomes cooling air conditioner which means that there is no heating function in this product, since the customers will not use the heating function in summer. Accordingly, the throttling and pressure regulating device module changes. A four-way valve is canceled so that the production cost decrease 80 RMB. Hence, the production cost becomes into $(515+395.5+356)*(1-98\%) + 31.5=56.83\text{RMB}$. Secondly, Scenario 3 uses R32 as refrigerant instead of R410A due to its environment-friendly characteristic. R32 has lower GWP than R410A although both of them will not destroy the ozone sphere. However, R32 costs more than R410A, the difference value is 20RMB. This leads to higher provider cost in Scenario 3 than Scenario 2. Hence the final **provider cost** can be calculated: $56.8+30*2+50+40+20=226.8\text{RMB}$. In this way, the **provider profits** is $3.3*30*5-226.8=268.2\text{RMB}<286.6\text{RMB}$ in Scenario 2. However, due to R32’s higher power efficiency, the customer cost could be reduced due to less electricity cost ($1210*95.1%=1150.7$, the R32’s cooling capacity is 12.6% higher than R410A, while the power consumption is also 7.9% higher than R410A, so that the overall performance of R32’ energy conservation is 4.9%). Hence, the final **customer cost** is $3.3*30*5+1150.7=1645.7\text{RMB}$.

Now we sum up the LCA and LCCA together in Table 29.

Table 29 Overall performance for three scenarios

		AS-IS system	TO-BE PSS R410A	TO-BE PSS R32
Life Cycle Assessment	Global Warming Potential (kg. CO ₂ Eq.)	746	751	675
	Environmental cost of air emission (Euro)	145	147	134
	Disposal (kg)	42.5	0 or 2	0 or 2
Life Cycle Costing	Provider cost (RMB)	1458	208.4	226.8
	Provider profits	172	286.6	268.2

Assessment	Customer cost	2840	1705	1645.7
Total cost of LCA and LCCA (Euro)		327	173	162

The current system seems really not good according to the Table. From the viewpoint of LCA, the AS-IS system shows larger GWP, larger environmental cost and quite a number of disposal; while from the viewpoint of LCCA, the AS-IS system shows larger provider cost, larger customer cost and less profits. On the contrast, the average performance of TO-BE PSS solutions is superior to the AS-IS system. In terms of Scenario 2, although little difference in environmental emission aspects, little deposited waste shows more advantage. From the viewpoint of LCCA, Scenario 2 achieves less provider cost and customer cost as well as more provider profits. In terms of Scenario 3, the performance of LCA is much better than previous one with lower GWP and environmental cost. On LCCA side, the provider cost is a little higher than that Scenario 2; accordingly the provider profit is less than that in Scenario 2. However, the customer cost also decreases due to R32's higher power efficiency.

Now it is company's strategy to choose the solution that they will provide. The As-IS system is eliminated because of its bad performance in both sustainability aspects. The provider could get more profits from Scenario 2 with more environmental impacts and higher customer cost. However, Scenario 3 will leave less environmental impacts; what's more, the provider may obtain more customers due to the lower customer cost. Indeed, the Scenario 3 cost less when integrating the total cost from both LCA and LCCA sides- 162 euros as shown in Table 29. The preferred Scenario is the third one due to the company's current strategy is to expand their renting service market, and they believe more customers will bring more profits in the future.

4. Conclusion

This Chapter launches an air conditioner case study for a traditional home appliance wholesaler. The case study is carried out based on four main steps: PSOs and VCCPs design, VE design and modelling, COPSS realization and visualization and Scenarios simulation. We use the framework and corresponding methodologies and techniques to help the company fulfill the development and implementation of air conditioner renting services.

However, this case has its own boundedness. Due to its traditional company operation modes, we can't establish the VE related knowledge on this case. For instance, the partner selection process is not totally data-driven, which still relies on the relationships between them; the Scrum management framework can't be utilized due to their reluctance to change their current work mode. However, this is also a good case study since it is very suitable for PSS design, and it's a beginning for those traditional product-centric companies to practice the PSS strategy.



General conclusion

According to the background introduction at the beginning of the thesis, we know that more and more manufacturers are trying to progress the servitization shift to satisfy the customers' requirements of more economical, more customized and more sustainable services in the current service economy. However, unfortunately, they mainly push some PSS solutions to their customers too intensely and most of the time ignores the customers' real usage requirements. Consequently, they propose a lot of useless and overlapped functions on the provided offerings, which lead to huge amount of wastes. In order to figure out this problem, this thesis proposed a concept called Customer-Oriented PSS (COPSS), and proposed an integrated design framework for COPSS from 3DCE perspective ie. considering simultaneously the design of the offering, the processes and the supporter organization, and finally launched an air conditioner service case study to explain how to use the framework.

The main results Chapter per Chapter will be briefly recalled as following:

In Chapter 1, a literature review of PSS design frameworks, methodologies, tools and techniques has been launched, which can be a solid foundation for PSS design knowledge.

In Chapter 2, there are two main contributions. **The first contribution** is the systematic literature review of COPSS. According to the analysis of this review, a clear understanding was obtained about: (1) the basic meaning of customer-oriented approach aiming at serving current and future customers with high-quality usage-driven offerings; (2) the benefits of customer-orientation that may have a positive effect on idea generation, induce a more collaborative new offering development, result in high quality products or services and increase customer acceptances; (3) five key issues for COPSS: (I) COPSS emphasizes on customer experience and customer satisfaction; (II) the customers in COPSS have more potential to reduce environmental impacts; (III) offerings provided by COPSS emphasizes on customers' requirements, as well as offerings' functions; (IV) COPSS ideology advocates customer involvement along entire PSS lifecycle; (V) Despite of new PSS design challenges coming from customer-orientation, customer-oriented design will still take more advantages over traditional product-centric method and innovation-pushed PSS. **The second one contribution** is the COPSS typology proposal. Typology is necessary because it is a guide for designers and companies to adopt, learn and utilize appropriate knowledge, skills and resources to design optimized PSS solutions for all stakeholders. This thesis proposed a "three dimensional typology toward the design of a COPSS". Three dimensions include "Value proposition dimension" answering what kind of offering the providers could provide for customers in a system, "Organization dimension" answering who are able to involve in the supporting network in order to provide variety of knowledge, capabilities and resources and "Customization degree dimension" answering to what extent they could provide customized offerings to their customers in order to satisfy customers' and their own requirements.

In Chapter 3, this thesis introduces the concept of “Three Dimensional Concurrent Engineering (3DCE)” into PSS design, and propose the core contribution of this thesis called “the integrated design framework for Customer-Oriented PSS from 3DCE perspective”, so that a final PSS solution now becomes an integrated solution consisting of Product-Service Offerings, as well as its supporting Value Co-creation Processes and supporting Virtual Enterprise rather than only a combination of products and services. In addition, to achieve a better solution conforming to the requirements and expectations of customers and providers, a concept of “customer-provider satisfaction trade-off” and a COPSS design cycle based on this trade-off were proposed, so that the designers are able to optimize the final scenarios based on their requirements. Then, in order to measure their satisfactions more precisely, the Customer Satisfaction Index and Sustainability Assessment are adopted to fulfill the quality and quantitative analysis (These two parts are illustrated in Chapter 4 for their lifecycle-oriented characteristic).

Chapter 4 supplements the management methodologies for the proposed framework in Chapter 3. **The first contribution** concerns the “stakeholder-driven PSS-VE lifecycle modelling method”. This method supports designers to identify appropriate stakeholders, as well as their responsibilities all along the PSS life phases. Accordingly, the stakeholder-driven PSS-VE lifecycle model could be proposed, which is very useful to reduce system complexity and uncertainty. **The second contribution** is dedicated to find a more effective and flexible way for network members to collaborate and cooperate. AGORA multi-agent architecture in this context is introduced. Then, to satisfy customers’ requirement in a short lead time, an agile management methodology called “SCRUM” as well as a “multi-layer SCRUM management framework based on AGORA multi-agent architecture” are proposed. Using this multi-level architecture, designers are able to decompose their tasks and processes from a strategic level to an operational level, which makes the management work more orderly and effective.

Perspectives:

This thesis proposes an advanced PSS related concept called Customer-Oriented PSS (COPSS), and makes an analysis for this concept. Further on, in order to help develop COPSS solutions, this thesis also proposes an integrated design framework for COPSS from 3DCE perspective with corresponding design methodologies, management methodologies, design techniques and tools, etc. However, there are still several points to be improved in-depth:

1. This thesis emphasizes the importance of customers and the collaborative environment among different stakeholders. However, a critical problem is how to motivate these stakeholders to involve in the collaborative environment and share their know-how, their knowledge, etc. Indeed, the knowledge, techniques and precise business processes are strategic values for a company and the fundamental reasons of a company’s survival. Here the functioning of the framework implies to share these values that could be learned/copied by a malicious company due to high-level collaborations.

Hence, research about the collaboration degree, collaboration modes and regulation is necessary.

2. Requirements engineering is still a significant point. We have chosen to use HoQ, QFD, AHP and FAHP to identify customers' requirement and interpret them into engineering characteristics and processes. An interesting point is that these requirements always come from the experts and customers; however, when a company wants to address the servitization, majority of these experts still use traditional knowledge to judge these requirements. This way of doing does not cover the new innovation requirements and even contradict them. In this case, the advice from researchers in PSS field holds the determinant position, these methods and techniques may not reasonable anymore. The case study is an example.
3. Modularity is a critical method to realize mass customization. This thesis introduces several methods to address modularity; however, whether they are more valuable or not for real companies to design their modules or refine existing modules has not been verified. Simulations could be used after modeling to compare scenarios between them, based on modules description properties.
4. The applicability of our design framework has been partially verified by a case study. However, whether it can be propagated to other cases is obviously questionable. Hence, it is necessary to apply our framework to more real projects to verify its reasonability and universality.
5. Requirements analysis, modularity design, customer satisfaction index analysis, sustainability assessment etc. need a large number of derivations and calculations. It is really difficult and inefficient to do such kind of work in real cases without the help of corresponding software tools. The development of such tool, which is an important work, could help to support the design of PSS solutions in reality.

Appendix

Scrum and XP

A lot of literatures have introduced the basic elements of Scrum (Pathak & Saha, 2013; Abrahamsson et al., 2017; Ashraf & Aftab, 2018; Darwish, 2014; Vargas et al., 2018; Anwer et al., 2017). The section will adopts the description from Anwer et al. (2017) due to its detailed explanation for new learners into software field .Table 30 displays the four components of Scrum framework (Darwish, 2014). Figure 63 shows the structure of Scrum framework. The following Scrum introduction contents are derived from Anwer et al. (2017) with some slight modifications to make it more suitable for PSS design context.

Table 30 The components of Scrum framework and their items

Scrum Component	Items or Description
Scrum Team	Scrum team includes of three roles: <ul style="list-style-type: none"> • Product Owner • Development Team • Scrum Master
Scrum Events	Scrum events include of five events: <ul style="list-style-type: none"> • Sprint • Sprint Review • Sprint Planning Meeting • Sprint Retrospective • Daily Scrum
Scrum Artifacts	Scrum artifacts include of three artifacts: <ul style="list-style-type: none"> • Product Backlog • Sprint Backlog • Increment
The Rules of Scrum	The rules of Scrum bind together the events, roles, and artifacts, governing the relationships and interaction between them.

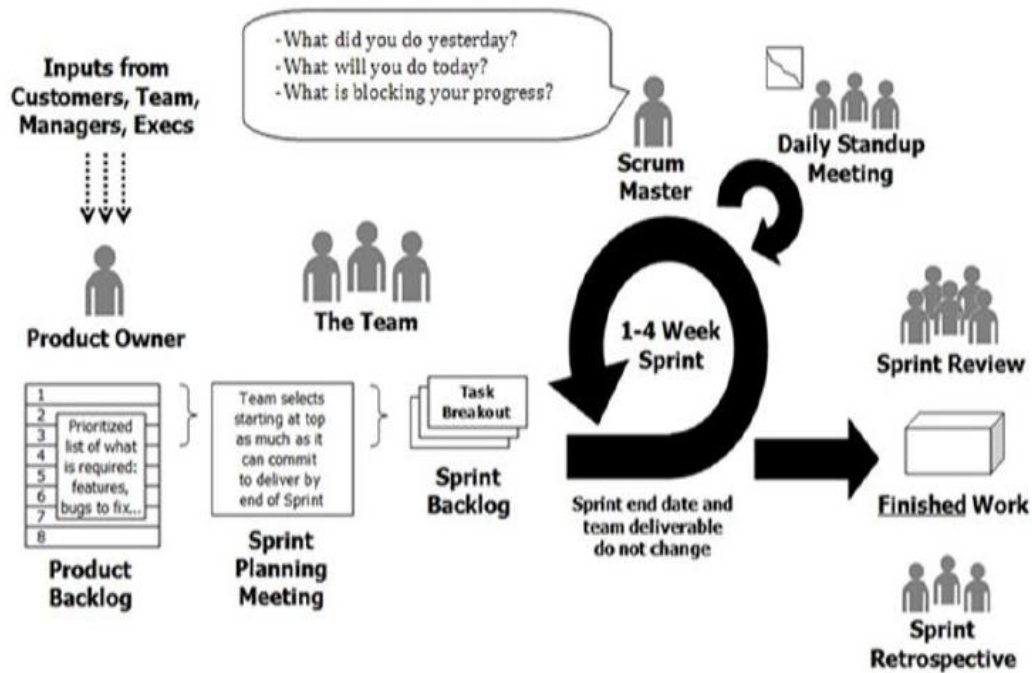


Figure 63 Scrum framework

Scrum methodology

Activities

Scrum activities can be decomposed in three phases called Pregame, Game and Postgame.

- Pregame: This phase starts by defining the vision of the project that can be unclear initially but can be refined further in later sprints. Product owner is responsible to define the vision and prepared a prioritized list of functional and nonfunctional requirements for PSOs. This prioritized list of required features is called Product Backlog. A plan that includes the time and cost estimation is also prepared in this phase with final product delivery date and number of releases in which the final product will be delivered. A high level architectural design is developed that tells how to implement the different tasks defined in the product backlog. Some other important task completed in this phase includes risk assessment, definition of development team, validation of development tools and verification of approval and funds.
- Game: This corresponds to the development phase that is performed in small iterations called sprints.
- Postgame: This corresponds to the closure phase. After having implemented the desired features during the development phase, final release occurs. A release is declared closed when all the goals defined during the pregame phase are met. In the closure phase, final integration testing is performed, user manuals and training materials are prepared for the final release.

Sprint cycles

Scrum works in sprints. A sprint is a time boxed development period ranges from one week to four weeks based on complexity and risk involved, in which a team develop the PSOs according to the product backlog. Each sprint incorporates activities like planning, development, wrapping, review and adjustment. During a sprint, scrum team works on product backlog under the guidance of a scrum master to develop the functional modules, parts, and final PSOs, that have to be delivered at the end of the sprint. Following activities are performed during each sprint:

- Sprint Planning: Each sprint starts from a sprint planning that is completed in two phases. In the first one, the product owner and scrum master review the product backlog tasks that are the most important. They decide the objectives and context of the high priority tasks which help the team members to understand the product needs clearly. As such the first phase mainly focuses on the aspect of product. The second phase focus is shifted on how to build task till the end of sprint. Team reviews the probability of task completion irrespective to product owner decision. Afterward the team commits to complete the work in a decided time period.
- Daily Scrum: Scrum team member daily conduct a 10 to 15 minutes meeting called daily scrum. This meeting helps the team members to have information about the project progress. Team members can find the cause of any speed interruption and take corrective action accordingly. In this meeting every member

tries to answer the following three questions. First two questions help to understand the project progress and last question helps to find the solution of any problem that is causing delay in the project progress.

- What did I do yesterday to achieve the sprint goal?
 - What will I do today to achieve the sprint goal?
 - Is there any hindrance in doing what I planned to do?
- **Sprint Development**: During this phase activities like design, development and testing is carried out for each tasks in the product backlog. These tasks are implemented according to the priority defined by the product owner and scrum master ?.
- **Sprint Review**: At the end of each sprint, a review of the developed product is conducted. This corresponds to the inspection and adoption phase of the product. In this review meeting, product owner judge whether the development is going according to needs. Detailed conversation among the product owner, scrum master and team members help to get feedback about the product which may change the development directions.
- **Sprint Retrospective**: Sprint retrospective corresponds to the inspection and adoption phase for the process. During this phase, the scrum master and team members discuss during a meeting what is working and what is not working in the process. They share the experience and lesson learned during sprint. This helps to decide which practices should be carried out in the next sprint and what should be changed in the next sprint. This meeting greatly helps in enhancing team knowledge and deciding what should be done in next sprint.

Scrum roles

There are three roles in scrum called product owner, scrum master and team.

- **Product Owner**: Product owner is a customer's representative who has an overall responsibility of the product. He creates and prioritizes the list of required features to be developed in the form of a product backlog. He can reposition the item in product backlog according to changing business needs. He decides the project schedule and is responsible of providing finance accordingly. He negotiates with scrum team to convey the interests of all stakeholders. The product owner is a person accountable for the profit or loss of the product. A scrum team can have only one product owner. To fulfill his duties, the product owner must have a clear understanding of business, engineering and marketing. Good communication skills are very important to deal with different stakeholders having different interests.
- **Scrum Master**: Scrum master is a team facilitator who makes sure that the team members are following the scrum practices, rules and values to gain the business value. His role is different from the one of a traditional project manager. He conducts a brief meeting with team daily, called daily scrum to watch the progress. He is responsible of protecting the team form outside intervention and provides good circumstance to work. At the end of each sprint, he conducts the scrum retrospective.

- **Team:** Scrum teams are self-organizing and consist of 3 to 9 members. In scrum team, specific roles are not assigned to members. The team can divide tasks among the members according to their interest. The entire team should have skills in designing, developing, testing or documenting the product. Each member is responsible of delivering a working product after each sprint.

Large-Scale Scrum (LeSS)

As mentioned previously the Large-Scale SCRUM (LeSS) is dedicated to large project and thus can be used in the context of COPSS design, especially in the context of VE. Hence, some Scrum contents are modified (Larman & Vodde, 2013; Alqudah & Razali, 2016), (see Figure 64).

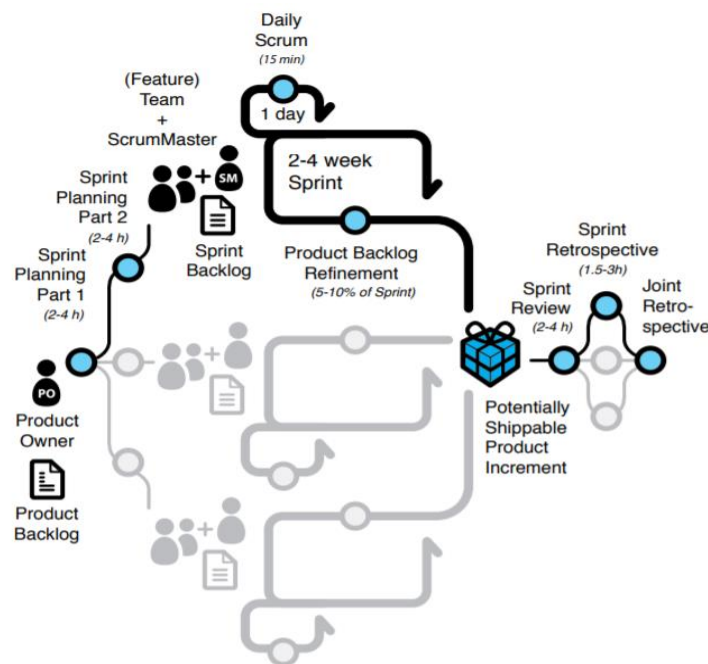


Figure 64 Large-Scale Scrum (LeSS)

- **LeSS roles:** a single Product owner is common to all teams in basic LeSS.
- **LeSS Practices:** There is a change in Sprint Planning meeting in LeSS; each of the Scrum teams is represented by two members per team plus the one overall Product Owner to decide which chunk of Product Backlog items is to work on. This is in contrast with the standard Scrum where the rest of the Scrum team participates. When a contention occurs in a backlog item, Product Owner mediates between teams. Likewise, Sprint Review changes to a single meeting for all Scrum teams. However, it is limited to two team members per each Scrum team. Three more practices were established because of these changes, namely: Inter-team coordination meeting, a Joint Light Produce Backlog Refinement and Joint Retrospective meeting.

In order to improve the information sharing and coordination, the Inter-team coordination meeting can be conducted regularly during the week by occupying various formats including an Open Space, Town Hall meeting, Multi-Team Daily

Scrum or Scrum of Scrums. While the Joint Light Product Backlog Refinement, restricted to two team representatives, has a maximum duration not to exceed 5% of the Sprint duration. The meeting aims at refining product backlog items for upcoming Sprint. In a Joint Retrospective meeting, the aim is to identify and plan improvement experiments cooperatively for the overall product or organization.

In addition to the above practices, LeSS also has alternative practice named In-Sprint Item Inspection where the teams unofficially try to find early feedback from the PO or other stakeholders on finished product Backlog items. LeSS Huge is almost similar to LeSS but it meant for huge projects which have thousands of people working on one product. In LeSS method, there is a need for area product owner, area backlog views, pre-sprint product owner team meeting, area level meeting, overall sprint review and overall sprint retrospective. So, the coordination among multiple teams will be done effectively and efficiently.

Customers involvement in XP

When summarizing the main contents of customer in XP according to Anwer et al. (2017), we can conclude that customer is a very important member of XP team who plays an active role throughout the development process. The customer is responsible for writing customers' stories, deriving functional test and verifying the test. A lifecycle of XP mainly consists of six phases: exploration phase, planning phase, iteration to release phase, productionizing phase, maintenance phase and death phase. Customer writes user stories in exploration phase as the main requirements input; customer helps test and verify the releases derived from "iteration to release phase", "productionizing phase", "maintenance phase" and "death phase". Moreover, in XP, a customer's representative is a part of the XP team and remains on-site all the time. A customer is usually a domain expert that can decide about system's desired features, answer the questions and can steer the development process. On-site presence help to reduce communication gap between developers and customers. A quick feedback remains available to developers about desired offerings (Anwer et al., 2017).

This thesis recommends to emphasize the importance of customers in Scrum due to the importance of customer orientation. Customer-oriented design shows more advantages than traditional approaches. Hence, as a widely used and recognized agile methodology, Scrum also needs to make some modification to involve customers' activities into Scrum framework.

- When mapping Scrum with XP, customer could involve in:
- Pregame phase and input requirements into product backlog;
- Game phase in a developed team and help plan the sprint backlog;
- Post game as customer could help testing and verifying each sprint in order to guarantee the quality and usability for customers, the same as other Scrum practices.

This kind of involvement is dedicated to realize the customer orientation advocated by Sohaib & Khan (2010) and the ideology in this thesis.

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