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Development of a Framework to Customize Design Methodologies for Product Service Systems

Tuananh Tran
Department of Industrial and Systems Engineering,
Dongguk University
Seoul, Korea
meslab.org@gmail.com

Joonyoung Park
Department of Industrial and Systems Engineering,
Dongguk University
Seoul, Korea
jypark@dgu.edu

***Abstract*—This work introduces the development of a framework that allows researchers and practitioners to customize design methodologies for their own specific product service system (PSS) design problems. PSS has been researched for more than a decade but despite its economical and ecological benefits to customers, providers, the environment and the society, the adoption of PSS in industry is limited for its potential. One of the main reasons is that designing PSS is a difficult task because when designing PSS, designers have to deal with products, services, stakeholders, outsiders, etc. simultaneously. Many researchers worked on proposing new methodologies for designing PSS but the results were not sufficiently effective. In this work, the authors propose a new approach of customizing new design methodologies for PSS through the use of a framework which consists of the generation and selection processes of possible methodologies. We also include an illustrating example to demonstrate the use of this framework in actual cases.**

Keywords—PSS; Product Service System; PSS Design Methodology; PSS Development Framework

I. INTRODUCTION

A. *Product service system*

Product service system (PSS) forms a special case in servitization [1] where a company provides its customers with an offering including physical product and non-physical service. This new concept of providing PSS offering is different from selling product only which is becoming more and more difficult to compete, especially in today's scenario of economic crisis, growing environmental issues and diversified customer demands [1, 2, 3]. As mentioned in literature, the introduction of PSS can help companies to enhance competitiveness, achieve social, environmental, and economic goals, as well as attract and retain customers [4, 5, 6].

Formally, PSS is defined by many authors, including Goedkoop et al. [7] in 1999. In this work, PSS was defined as "a marketable set of products and services capable of jointly fulfilling a user's needs". This definition makes the concept of PSS close to functional economy [8] where customers pay for the "function" or the "use" of the solutions, not for the physical products.

Some researchers suggested that PSS can be considered as an integrated system consisting of products, services, and the infrastructure to deliver a solution to a customer to satisfy certain needs [1, 5].

B. *Classification of PSS*

Baines [9] combined ideas from prior works [10, 11, 12] to classify PSS into 3 types as follows:

- Product oriented PSS: Company sells a product with additional services to ensure the working condition of the product. The ownership of the product is transferred to the customer. Services such as: maintenance, repair, recycling, refilling, etc. could be classified into this type.
- Use oriented PSS: Company sells the use or availability of a product not owned by the customer. Examples of this type are product leasing or sharing.
- Result oriented PSS: Company sells a result or capability of a product not owned by the customer. For example, instead of selling paint to a customer, the company can sell the result, a painted house.

C. *Benefits of PSS and challenges for adoption of PSS in industry*

Surveys by Baines et al. [9] and Beuren et al. [5] showed the benefits of PSS to the consumer, provider, environment and society. These benefits result from the higher level of satisfaction, increased competitiveness, decreased environmental impact and materials savings. The main benefit of PSS for the company is that it pushes for continuous business improvement, quality improvement, and better company - customer relationship.

Although PSS brings plenty of benefits, it is still adopted limitedly in the industry for its potentials. The major challenges in adopting PSS were suggested by Mont [8], Baines et al. [9] and Beuren et al. [5]: first, consumers may not be enthusiastic about ownerless consumption; second, the manufacturer may be concerned with pricing, absorbing risks and shifting organization; and third, PSS design and development itself is a challenge. PSS is difficult to design because it is an integrated system consisting of products, services, and delivery infrastructure, and is strongly affected by stakeholders. Designers and developers need a suitable design methodology to deal with each design project. There are several design methodologies available in literature but none of them is

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holistic to work with a wide range of PSS problems and there is a lack of analysis and guidance of possible applications for each methodology.

This paper aims to develop a framework which enables the customization of PSS design methodologies. By using this framework, researchers and practitioners can customize various design methodologies for various PSS problems. This paper also includes an illustrating example to demonstrate how the proposed framework can be used in actual cases.

II. Literature review

A. Methodologies for designing product service systems

Many methodologies for designing PSS are presented in the literature (Baines et al. [9], Beuren et al. [5] and Vasantha et al. [1]). Some methodologies are case – specific, meaning that they are tailored for specific projects, including the ones proposed by Luiten et al. [13], Manzini and Vezzoli [10], Morelli [14], etc. These are not generic for a broad range of cases.

Other methodologies are suitable for designing of a broad range of PSSs. Vasantha et al. [1] summarized eight methodologies in the literature that have been detailed, and applied and demonstrated with industrial examples. These methodologies can be applied in complex PSS development influenced by many factors.

B. Limitations of existing design methodologies

Vasantha et al. [1] pointed out major limitations of existing PSS design methodologies as follows:

- The differences in PSS design processes for different types of PSS (Product/Use/Result oriented) are not discussed.
- The roles and responsibilities of the stakeholders in co-designing PSS offerings are not clearly defined in the methodologies.
- The importance of the co-creation among stakeholders is only mentioned in insufficient detail for understanding the uniqueness of this process and its real-time implementation.
- Integrating products and services is discussed as a major objective. The overall processes involved in this integration are well detailed, but the intricate steps within each stage are not mentioned

One of the major problems of designing PSS is that nowadays, the shift from offering products to offering PSS is more and more popular and therefore, the number and the variety of PSS problems keep increasing. Researchers and practitioners are in need of “customizable” and “adaptive” design methodologies which can transform itself to be effectively applied in new cases of designing PSS. In order to be effectively implemented, these new methodologies should be improved to overcome the weaknesses which were pointed out above.

C. Purpose of this paper

This paper aims to develop a framework which allows researchers and practitioners to customize design methodologies for their own specific PSS problems. This framework can produce customizable and adaptive PSS design methodologies which can overcome the weaknesses of existing design methodologies when being applied to a variety of industrial cases.

The proposed framework can be modeled, and programmed to become a practical tool for researchers and practitioners to customize design methodologies effectively. This paper includes design examples to illustrate how the proposed methodology works for various types of PSSs.

III. Methodology

A. The process of designing product service systems

In our previous work [15], we proposed a design process for PSS which works for various types of PSSs and

- provides guidelines to designers in designing PSS for implementation (i.e., this methodology contains detailed design phases),
- considers the consumer co–creation (i.e., user involvement in the creation of PSS),
- approaches the design of PSS from systemic level, meaning that the PSS design process takes into account all PSS elements: products, services, stakeholders, business models and organizational structure,
- covers the whole PSS lifecycle.

This design process was constructed through the analysis of the differences in the design sequence of 3 types of PSSs, the analogy between product and service design processes, the involvement of stakeholders, the systemic approach in designing PSS and the consideration of PSS lifecycle [15]. This design is used in this work as the backbone of a PSS design methodology on which we detail design activities for each design phase. Figure 1 shows the details of this design process which consists of 7 main design phases including: *Idea development, Planning, Requirement analysis, Design and Integration, Test and Refinement, Implementation, Retirement and Recycling*. We will now call those phases as Phase 1, Phase 2, Phase 3, Phase 4, Phase 5, Phase 6 and Phase 7 of the design process.

Based on the 7-phase design process, we now propose 2 steps to customize design methodologies for PSS and then summarize the development process to form a single framework. The 2 steps are: (i) Generation of possible methodologies and (ii) Selection of optimized methodology. The following sub sections clarify these 2 steps in details.

B. Generation of possible design methodologies for PSS

In a PSS design process, the design problem in each phase can be solved with certain solutions or approaches. For example, the *Idea development* phase can be done with various approaches, such as: *Brainstorming, Customer observation, Crowdsourcing*, etc. Assuming that we have n phases from P_1

to P_n (n = 7 in this case) in the design process and the design problem in each phase can be solved with some different approaches from A_{11} to A_{nm}, we have Table I to represent the *problem – solution* relationship.

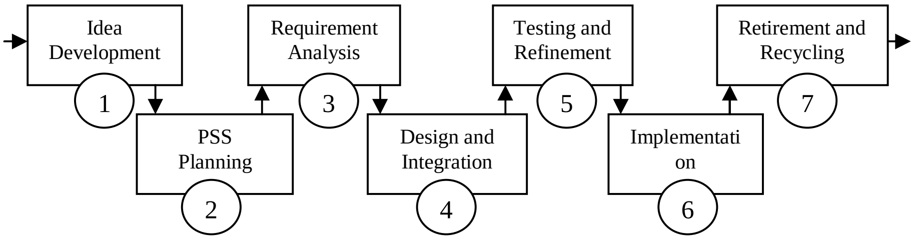

Fig. 1. The proposed PSS design process in our previous work [15].

TABLE I. THE PROBLEM – SOLUTION RELATIONSHIP WHICH REPRESENTS POSSIBLE APPROACHES FOR EACH DESIGN PHASE.

Phase (P)	Possible approaches (A)				
P_1	A_{11}	A_{12}	A_{13}	...	A_{1m}
P_2	A_{21}	A_{22}	A_{23}	...	A_{2m}
P_3	A_{31}	A_{32}	A_{33}	...	A_{3m}
...	...	...	...	...	...
P_n	A_{n1}	A_{n2}	A_{n3}	...	A_{nm}

Each combination (or configuration) of various solutions for various phases forms a potential design methodology. Figure 2 represents these various configurations.

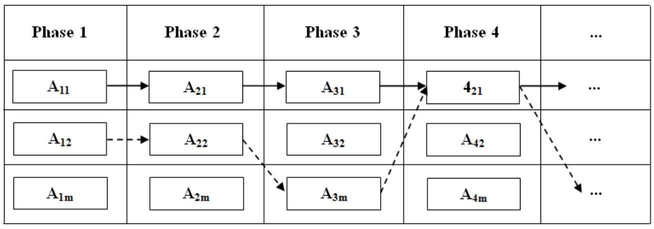

Fig. 2. Each combination of various Aijs (i ranges from 1 to n; j ranges from 1 to m) forms a potential design methodology (solid and dashed lines represent various potential methodologies).

Figure 2 shows that, there might be a large amount of potential design methodologies. If the number of potential methodologies reaches some hundreds, it will be difficult and time consuming for the users (researchers, designers, teams, or whoever use this framework) to select and customize an optimized design methodology. Thus, a filtering process must be performed in this step to eliminate infeasible or unrealistic "methodologies" so that in the end of this step, limited number of methodologies (we call this number as *N*) remain for the next *Selection and optimization* step. The decision of how large *N* is depends on the capability of the team, the time allowance, the size of the project, etc. This decision is made by the designers themselves.

At a first glance, we can eliminate obviously infeasible methodologies. To further prune methodologies, we consider 2 criteria: one criterion which stands for the compatibility of adjacent PSS design phases (*C*) and another criterion which stands for the integrity of product and service components in a certain design phase (*I*). The reason why we introduce these 2 criteria is as follows: any selected approaches must ensure (i) the ability of maintaining the design "flow", meaning that adjacent phases must be *compatible* in terms of being a continuous design process and (ii) the ability of combining product and service component smoothly as an integrated system. Since we have 7 design phases, we will have 6 compatibility factors (phase 1 – phase 2 (C_1); phase 2 – phase 3 (C_2); etc.). Also, we will have 7 integrity factors from I_1 to I_7 (Figure 3).

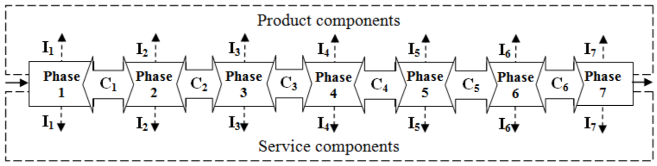

Fig. 3. Representation of compatibility (C) and integrity (I) factors when designing PSS.

Users are allowed to score potential design methodologies in terms of compatibility and integrity factors along various design phases using 1 to 5 point scale. We rank the potential design methodologies by total scores of compatibility and integrity factors as shown in Table II and Table III (assuming that we consider *k* methodologies).

TABLE II. SCORING COMPATIBILITY FACTORS FOR DIFFERENT METHODOLOGIES. CIJS ARE THE SCORES FOR CI OF MJ.

Methodology (M)	C_1	C_2	C_3	C_4	C_5	C_6
M_1	C_{11}	C_{21}	C_{31}	C_{41}	C_{51}	C_{61}
M_2	C_{12}	C_{22}	C_{32}	C_{42}	C_{52}	C_{62}
M_3	C_{13}	C_{23}	C_{33}	C_{43}	C_{53}	C_{63}
...	...	...	...	...	...	...
M_k	C_{1k}	C_{2k}	C_{3k}	C_{4k}	C_{5k}	C_{6k}

For each methodology M_j, we calculate compatibility factor as:

$$C_j = \Sigma(C_{ij}) \quad (1)$$

TABLE III. SCORING INTEGRITY FACTORS FOR DIFFERENT METHODOLOGIES. IIJS ARE THE SCORES FOR II OF MJ.

Methodology (M)	I_1	I_2	I_3	I_4	I_5	I_6	I_7
M_1	I_{11}	I_{21}	I_{31}	I_{41}	I_{51}	I_{61}	I_{71}
M_2	I_{12}	I_{22}	I_{32}	I_{42}	I_{52}	I_{62}	I_{72}
M_3	I_{13}	I_{23}	I_{33}	I_{43}	I_{53}	I_{63}	I_{73}
...	...	...	...	...	...	...	...
M_k	I_{1k}	I_{2k}	I_{3k}	I_{4k}	I_{5k}	I_{6k}	I_{7k}

For each methodology M_j, we calculate integrity factor as:

$$I_j = \Sigma(I_{ij}) \tag{2}$$

The users then keep *N* methodologies which show highest *C* and *I* factors for the next selection and optimization step.

C. Selection of optimized design methodology

After step 1, *N* design methodologies remain for selection process in step 2. In this step, we assume that the users have a specific PSS problem and want to select the most suitable methodology from N methodologies that remain. The selection is done through comparing N methodologies along various design criteria considering the characteristics of the PSS design problem (i.e the users' interests). In reference to Baines [9], Vasantha [1], Cavalieri [16] and according to the needs that PSS practitioners (i.e. designers and developers) might be interested in, we use the following groups of criteria. Each group of criteria may contain several criteria. The total number of criteria is 29. Details are provided below [15].

Holistic approach: This group contains criteria that show how holistic the design methodology is. If a design methodology is holistic, it can be used to deal with various types of PSSs. This group of criteria includes:

- usability for product oriented PSS
- usability for use oriented PSS
- usability for result oriented PSS

Practical approach: This group contains criteria that show how practical the design methodology is. If a design methodology is practical, it can provide a step by step design process which can help designing PSS effectively. This group of criteria includes:

- availability of process flow
- availability of design activities through the flow
- availability of design checkpoints
- availability of product – service integration details

Co-creative approach: This group contains criteria that show how "collaborative" the design methodology is. If a design methodology is co-creative, it can promote user involvement during the design process and thus enhance the outcome. This group of criteria includes:

- specification of stakeholders' roles and capabilities
- detail of where to take into account user involvement

Systemic approach: This group contains criteria that show how systemic the design methodology is. If a design methodology is systemic, it can cover all PSS elements in the design process. This group of criteria includes:

- coverage of business model
- coverage of organizational structure
- coverage of delivery channel
- coverage of product and service
- coverage of stakeholder's presence

Lifecycle approach: This group contains criteria that show how design methodology covers the lifecycle of a PSS from the very first idea to the retirement. This group of criteria includes:

- coverage of idea development
- coverage of PSS planning
- coverage of requirement analysis
- coverage of concept development
- coverage of design and integration
- coverage of testing and refinement
- coverage of implementation and support
- coverage of retirement and recycling
- coverage of feedback loops
- coverage of sustainable design

Evaluable approach: This group contains criteria that show the evaluable the design methodology is. If a design methodology is evaluable, it can produce predictable and assessable outcome. This group of criteria includes:

- availability of algorithms for evaluation
- availability of testing and evaluation results with a case
- presence of well structured design process

Computer-aided approach: This group contains criteria that show the support of computer tools for the design process. If a design methodology is supported by a computer tool, it can accelerate the work of designers and developers. This group of criteria includes:

- availability of computer tool to assist design process

Proved approach: This group contains criteria that show the design methodology is proved to be applicable in real case. If the result of a design methodology is proved, it can give designers and developers confidence to use. This group of criteria includes:

- availability of successful cases

Comparison scheme

To compare design methodologies, we collect the total scores that each methodology earns for each group of criteria.

The scoring rules are as follows: If a criterion is not supported in a design methodology, we give a score of "0". If a criterion is supported in a design methodology, we give a score of "1". The final score that a methodology earns for a group of criteria is the total sum of scores that it earns for criteria in that group. Scoring results can be shown in a table as Table IV.

Each PSS design project has its own characteristics and thus, designers and developers might have different priority of different design criteria. This part discusses about how to select the most appropriate design methodology for their PSS problem. To do this, we hereby use Decision Matrix, a tool that is used to describe a multi-criteria decision analysis (MCDA) problem. The steps of the design methodology selection are detailed as follows:

Selection process

- Prepare a list of PSS design methodologies
- Prepare a list of design criteria of interest (for the PSS problem)
- Prioritize each design criterion with an importance (i.e. weight) according to PSS problem characteristics.
- Calculate total score of each methodology for each criterion and final score of each methodology for all criteria (considering importance of each criterion).
- Specify the highest scored design methodology.

TABLE IV. SCORES ALONG VARIOUS CRITERIA FOR DIFFERENT METHODOLOGIES.

Criterion (CR)		M_1	M_2	M_3	...	M_N
Holistic	*usability for product oriented PSS*	S_{1-1}	S_{2-1}	S_{3-1}	...	S_{N-1}
	usability for use oriented PSS	S_{1-2}	S_{2-2}	S_{3-2}	...	S_{N-2}
	usability for result oriented PSS	S_{1-3}	S_{2-3}	S_{3-3}	...	S_{N-3}
	Total score	Σ_{11}	Σ_{21}	Σ_{31}	...	Σ_{N1}
Practical	*availability of process flow*	S_{1-4}	S_{2-4}	S_{3-4}	...	S_{N-4}
	availability of design activities through the flow	S_{1-5}	S_{2-5}	S_{3-5}	...	S_{N-5}
	availability of design checkpoints	S_{1-6}	S_{2-6}	S_{3-6}	...	S_{N-6}
	availability of product – service integration details	S_{1-7}	S_{2-7}	S_{3-7}	...	S_{N-7}
	Total score	Σ_{12}	Σ_{22}	Σ_{32}	...	Σ_{N2}
Co-creative	*specification of stakeholders' roles and capabilities*	S_{1-8}	S_{2-8}	S_{3-8}	...	S_{N-8}
	detail of where to take into account user involvement	S_{1-9}	S_{2-9}	S_{3-9}	...	S_{N-9}
	Total score	Σ_{13}	Σ_{23}	Σ_{33}	...	Σ_{N3}
Systemic	*coverage of business model*	S_{1-10}	S_{2-10}	S_{3-10}	...	S_{N-10}
	coverage of organizational structure	S_{1-11}	S_{2-11}	S_{3-11}	...	S_{N-11}
	coverage of delivery channel	S_{1-12}	S_{2-12}	S_{3-12}	...	S_{N-12}
	coverage of product and service	S_{1-13}	S_{2-13}	S_{3-13}	...	S_{N-13}
	coverage of stakeholder's presence	S_{1-14}	S_{2-14}	S_{3-14}	...	S_{N-14}
	Total score	Σ_{14}	Σ_{24}	Σ_{34}	...	Σ_{N4}
Lifecycle	*coverage of idea development*	S_{1-15}	S_{2-15}	S_{3-15}	...	S_{N-15}
	coverage of PSS planning	S_{1-16}	S_{2-16}	S_{3-16}	...	S_{N-16}
	coverage of requirement analysis	S_{1-17}	S_{2-17}	S_{3-17}	...	S_{N-17}
	coverage of concept development	S_{1-18}	S_{2-18}	S_{3-18}	...	S_{N-18}
	coverage of design and integration	S_{1-19}	S_{2-19}	S_{3-19}	...	S_{N-19}
	coverage of testing and refinement	S_{1-20}	S_{2-20}	S_{3-20}	...	S_{N-20}
	coverage of implementation and support	S_{1-21}	S_{2-21}	S_{3-21}	...	S_{N-21}
	coverage of retirement and recycling	S_{1-22}	S_{2-22}	S_{3-22}	...	S_{N-22}
	coverage of feedback loops	S_{1-23}	S_{2-23}	S_{3-23}	...	S_{N-23}
	coverage of sustainable design	S_{1-24}	S_{2-24}	S_{3-24}	...	S_{N-24}
	Total score	Σ_{15}	Σ_{25}	Σ_{35}	...	Σ_{N5}

Evaluable	*availability of algorithms for evaluation*	$S_{1\text{-}25}$	$S_{2\text{-}25}$	$S_{3\text{-}25}$	...	$S_{N\text{-}25}$
	availability of testing and evaluation results with a case	$S_{1\text{-}26}$	$S_{2\text{-}26}$	$S_{3\text{-}26}$	...	$S_{N\text{-}26}$
	presence of well structured design process	$S_{1\text{-}27}$	$S_{2\text{-}27}$	$S_{3\text{-}27}$	...	$S_{N\text{-}27}$
	Total score	$\mathbf{\Sigma_{16}}$	$\mathbf{\Sigma_{26}}$	$\mathbf{\Sigma_{36}}$	...	$\mathbf{\Sigma_{N6}}$
Computer aided	*availability of computer tool to assist design process*	$S_{1\text{-}28}$	$S_{2\text{-}28}$	$S_{3\text{-}28}$	...	$S_{N\text{-}28}$
	Total score	$\mathbf{\Sigma_{17}}$	$\mathbf{\Sigma_{27}}$	$\mathbf{\Sigma_{37}}$	...	$\mathbf{\Sigma_{N7}}$
Proved	*availability of successful cases*	$S_{1\text{-}29}$	$S_{2\text{-}29}$	$S_{3\text{-}29}$	...	$S_{N\text{-}29}$
	Total score	$\mathbf{\Sigma_{18}}$	$\mathbf{\Sigma_{28}}$	$\mathbf{\Sigma_{38}}$	...	$\mathbf{\Sigma_{N8}}$

Optimization process

- Consider low scored design methodologies to utilize their high performance criteria
- Try to implement that positive point into the highest scored design methodology identified above, or
- Try to implement that positive point into other design methodologies to form new methodologies and repeat from beginning.

Table V shows how the selection process is done with an example. In this example, we assume that there is a designer (Designer A) who would like to select an appropriate design methodology from 2 methodologies for his PSS problem. Upon reviewing his own PSS problem, he assigns the importance of aspects differently as shown in Table V.

TABLE V. SCORES ALONG VARIOUS CRITERIA FOR DIFFERENT METHODOLOGIES WITH REGARDS OF DIFFERENT PRIORITY LEVELS FOR DIFFERENT CRITERIA.

Criteria	**Methodology**	**Methodology 1**		**Methodology 2**	
	Importance	Score	Weighted Score	Score	Weighted Score
Holistic	PR_1%	$\mathbf{\Sigma_{11}}$	PR_1* $\mathbf{\Sigma_{11}}$	$\mathbf{\Sigma_{21}}$	PR_1* $\mathbf{\Sigma_{21}}$
Practical	PR_2%	$\mathbf{\Sigma_{12}}$	PR_2* $\mathbf{\Sigma_{12}}$	$\mathbf{\Sigma_{22}}$	PR_2* $\mathbf{\Sigma_{22}}$
Co-creative	PR_3%	$\mathbf{\Sigma_{13}}$	PR_3* $\mathbf{\Sigma_{13}}$	$\mathbf{\Sigma_{23}}$	PR_3* $\mathbf{\Sigma_{23}}$
Systemic	PR_4%	$\mathbf{\Sigma_{14}}$	PR_4* $\mathbf{\Sigma_{14}}$	$\mathbf{\Sigma_{24}}$	PR_4* $\mathbf{\Sigma_{24}}$
Lifecycle	PR_5%	$\mathbf{\Sigma_{15}}$	PR_5* $\mathbf{\Sigma_{15}}$	$\mathbf{\Sigma_{25}}$	PR_5* $\mathbf{\Sigma_{25}}$
Evaluable	PR_6%	$\mathbf{\Sigma_{16}}$	PR_6* $\mathbf{\Sigma_{16}}$	$\mathbf{\Sigma_{26}}$	PR_6* $\mathbf{\Sigma_{26}}$
Computer aided	PR_7%	$\mathbf{\Sigma_{17}}$	PR_7* $\mathbf{\Sigma_{17}}$	$\mathbf{\Sigma_{27}}$	PR_7* $\mathbf{\Sigma_{27}}$
Proved	PR_8%	$\mathbf{\Sigma_{18}}$	PR_8* $\mathbf{\Sigma_{18}}$	$\mathbf{\Sigma_{28}}$	PR_8* $\mathbf{\Sigma_{28}}$
Final score		$\mathbf{\Sigma}(PR_i * \Sigma_{1i})$		$\mathbf{\Sigma}(PR_i * \Sigma_{2i})$	

Among the methodologies, the one with highest final score will be chosen. If there is any part of the low scored methodologies that can be utilized to improve the chosen methodology, users can try to implement.

D. The framework to customize PSS design methodology

The framework which allows the customization of PSS design methodology through a process described in Section 3.2 and 3.3 can be illustrated in Figure 4. This is our proposed framework in this paper.

IV. ILLUSTRATING EXAMPLE

A. Application of the framework to a case

In this section we will take one example to show how the framework can be applied to an actual case. We assume that company X has a PSS problem and the designers in the team have some approaches at hand for design phases as shown in Table VI.

After pruning, the design team comes up with a short list of below methodologies:

- M_1 = *{Brainstorm; Planning; Agent based modeling; Functional Analysis; FMEA; ServQual; Recycling}*
- M_2 = *{Crowdsourcing; Planning; Agent based modeling; Functional Analysis; FMEA; ServQual; Recycling}*
- M_3 = *{Idea development; Planning; Agent based modeling; Functional Analysis; FMEA; ServQual; Recycling}*
- M_4 = *{Crowdsourcing; Planning; QFD; Functional Analysis; FMEA; ServQual; Recycling}*
- M_5 = *{Crowdsourcing; Planning; AHP; Functional Analysis; FMEA; ServQual; Recycling}*
- M_6 = *{Brainstorming; Planning; Agent based modeling; Functional Analysis; Role play; ServQual; Recycling}*
- M_7 = *{Brainstorming; Planning; QFD; Functional Analysis; Role play; ServQual; Recycling}*

The scores for C and I factors for these 7 methodologies are calculated and shown in Table VII and Table VIII.

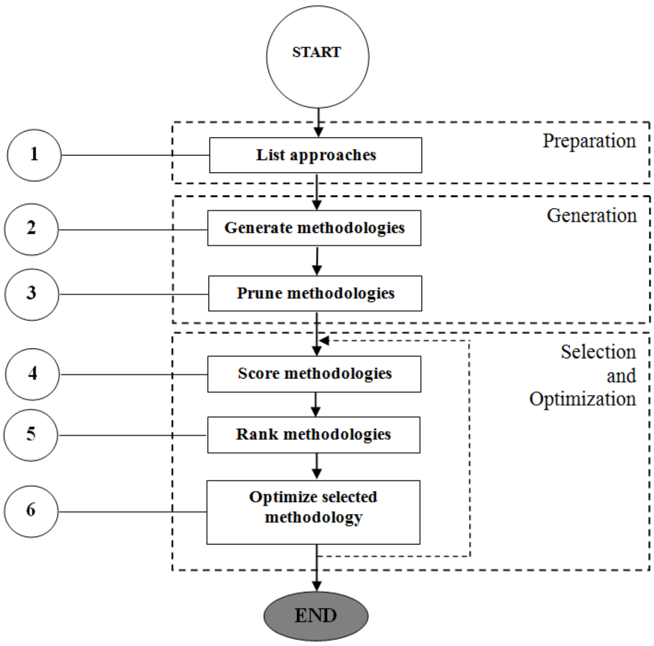

Fig. 4. Our proposed framework.

TABLE VI. POSSIBLE APPROACHES FOR DESIGN PHASES FOR COMPANY X.

Phase (P)	Possible approaches (A)				
P_1	Brainstorm	Crowdsour-cing	Idea development	-	-
P_2	Planning			-	-
P_3	Agent based modeling	QFD	AHP	-	-
P_4	Functional Analysis	-	-	-	-
P_5	FMEA	Role play	-	-	-
P_6	ServQual	-	-	-	-
P_7	Recycling	-	-	-	-

According to the scoring results which were shown on Table VII and Table VIII, the design team chooses M_1, M_6 and M_7 (highest scored methodologies for both C and I) for the selection step. Scoring for M_1, M_6 and M_7 along various criteria is done by the design team and the results are shown on Table IX.

TABLE VII. SCORING COMPATIBILITY FACTORS FOR DIFFERENT METHODOLOGIES FOR COMPANY X.

Method. (M)	C_1	C_2	C_3	C_4	C_5	C_6	ΣC
M_1	5	3	4	4	3	3	22
M_2	4	3	4	4	3	3	21
M_3	3	3	4	4	3	3	20
M_4	4	5	5	4	3	3	24
M_5	4	2	3	4	3	3	19
M_6	5	3	4	5	5	3	25
M_7	5	5	5	5	5	3	28

TABLE VIII. SCORING INTEGRITY FACTORS FOR DIFFERENT METHODOLOGIES FOR COMPANY X.

Method. (M)	I_1	I_2	I_3	I_4	I_5	I_6	I_7	ΣI
M_1	5	4	5	5	3	3	3	28
M_2	2	4	5	5	3	3	3	25
M_3	4	4	5	5	3	3	3	27
M_4	2	4	4	5	3	3	3	24
M_5	2	4	3	5	3	3	3	23
M_6	5	4	5	5	5	3	3	30
M_7	5	4	4	5	5	3	3	29

TABLE IX. SCORES ALONG VARIOUS CRITERIA FOR DIFFERENT METHODOLOGIES FOR COMPANY X.

Criterion (CR)		M_1	M_6	M_7
Holistic	*usability for product oriented PSS*	1	1	1
	usability for use oriented PSS	1	1	1
	usability for result oriented PSS	1	1	1
	Total score	**3**	**3**	**3**
Practical	*availability of process flow*	1	1	1
	availability of design activities through the flow	1	1	1
	availability of design checkpoints	1	1	1
	availability of product – service integration details	1	1	1
	Total score	**4**	**4**	**4**
Co-creative	*specification of stakeholders' roles and capabilities*	1	1	0
	detail of where to take into account user involvement	1	1	0
	Total score	**1**	**1**	**0**
Systemic	*coverage of business model*	0	1	0
	coverage of organizational structure	0	1	0
	coverage of delivery channel	0	1	0
	coverage of product and service	1	1	1
	coverage of stakeholder's presence	1	1	1
	Total score	**2**	**5**	**2**
Lifecycle	*coverage of idea development*	1	1	1
	coverage of PSS planning	1	1	1
	coverage of requirement analysis	1	1	1
	coverage of concept development	1	1	1
	coverage of design and integration	1	1	1
	coverage of testing and refinement	1	1	1
	coverage of implementation and support	1	1	1
	coverage of retirement and recycling	1	1	1
	coverage of feedback loops	1	1	1
	coverage of sustainable design	1	1	1
	Total score	**10**	**10**	**10**

Evaluable	*availability of algorithms for evaluation*	0	1	0
	availability of testing and evaluation results with a case	0	0	0
	presence of well structured design process	1	1	1
	Total score	**1**	**2**	**1**
Computer aided	*availability of computer tool to assist design process*	1	0	0
	Total score	**1**	**0**	**0**
Proved	*availability of successful cases*	0	0	0
	Total score	**0**	**0**	**0**

Now, we combine this scoring result with the design problem in company X. We assume that, for company X's specific problem, criteria are prioritized with various levels as in Table X.

TABLE X. SCORES ALONG VARIOUS CRITERIA FOR DIFFERENT METHODOLOGIES WITH REGARDS OF DIFFERENT PRIORITY LEVELS FOR DIFFERENT CRITERIA FOR COMPANY X.

Criteria	**Method.**	**M_1**		**M_6**		**M_7**	
	Imp.	Score	W. Score	Score	W. Score	Score	W. Score
Holistic	0%	3	0	3	0	3	0
Practical	15%	4	0.6	4	0.6	4	0.6
Co-creative	10%	1	0.1	1	0.1	0	0
Systemic	20%	2	0.4	5	1.0	2	0.4
Lifecycle	15%	10	1.5	10	1.5	10	1.5
Evaluable	25%	1	0.25	2	0.5	1	0.25
Computer aided	10%	1	0.1	0	0	0	0
Proved	5%	0	0	0	0	0	0
Final score		**2.95**		**3.7**		**2.75**	

According to the results from Table X, M_6 gains highest final score and it is the most suitable methodology for company X's PSS problem.

B. Discussions

Through the illustrating example, our proposed framework shows that it can be adopted by researchers and designers to customize a design methodology for a specific PSS problem that arise in reality. In this section, we introduce a simple set of approaches for design phases and thus, the number of possible design methodologies is rather small. In actual use in industry, there might be much more approaches available and the number of possible design methodologies which can be generated will be much larger. But still, the process of customizing design methodology using our proposed framework is the same. In this paper, we fixed the design process of product service systems to the one proposed in our previous work [15] and because of that, there were not many differences in the scoring results of methodologies along various design criteria (as in Table IX). If the design team comes up with another design process of their own interest, the differences in scoring results can be more apparent.

The process of customizing design methodology suggested by our proposed framework ensures the ability of matching between the solution (i.e. PSS design methodology) and the PSS problem and thus, the design methodology which comes from our proposed framework can overcome the limitations of existing design methodologies in terms of effectively designing PSSs.

V. CONCLUSIONS

In this paper, we proposed a framework that allows researchers and designers to customize an optimized design methodology for a certain PSS problem. Using this framework, through 2 steps of generation and customization, a tailor made PSS design methodology which can be effectively used to design PSS can be produced. We also introduced an illustrating example to demonstrate how the proposed framework works for a certain case that occurs in real PSS design environment.

Future work might include a case study of applying this framework to real industrial PSS problem to customize and evaluate the outcome design methodology.

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BIOGRAPHY

Tuananh Tran is a Ph.D candidate who is currently working at Digital Product Lab, Department of Industrial and Systems Engineering, Dongguk University, Seoul, Korea. He received B.E in Materials Engineering from Hanoi University of Technology and M.S in Industrial and Systems Engineering from Dongguk University. His work has been published in the international journals including: Industrial & Engineering Management Systems (IEMS) and Journal of Computational Design and Engineering (JCDE). His research topics include New Product Development, Crowdsourcing and Product Service Systems.

Prof. JoonYoung Park is currently a professor at Department of Industrial and Systems Engineering, Dongguk University, Seoul Korea. He received Ph.D. from The University of Michigan. His research interests include New Product Development, Product Lifecycle Management, Crowdsourcing, Mass Customization, Product Service Systems, Rapid Prototyping and Geometric Algorithms.