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A FRAMEWORK FOR ENTERPRISE-DRIVEN PRODUCT-SERVICE SYSTEMS DESIGN

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ABSTRACT
As products become service platforms, customers purchase both products and their associated services. Service attributes affect product choices, and product choices affect to service demand and profit during the products life cycle. Enterprises offering such product service systems (PSS) must co-design products and services to maximize overall profit. This paper proposes an Enterprise-driven Product-Service Systems (EPSS) design framework that integrates models of design, choice, demand, and cost into a profit optimization problem. The EPSS framework is demonstrated on a study of product and service design for tablets, e-books, and cloud services. Optimizations results quantify the trade-offs between profits from product and service dependent upon design decisions and use scenarios.

Keywords: product-service systems, optimal design, profit maximization, design for market systems

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1 INTRODUCTION

Low price tablets such as Kindle Fire HD and Nexus 7 in the U.S.A. are aggressively marketed, even though the manufacturing cost of a tablet is apparently higher than its price. Why would tablet manufacturers launch these supposedly unprofitable products? This is because customers purchase both a product *and* its associated services: They are typically required to “bundle” the manufacturer’s services (e.g., apps, e-books, movies) with its specific product. For example, if a customer purchases a Kindle Fire HD, then she would need to use Amazon “services”, such as digital books. Tablet manufacturers thereby make a profit when including the sale of paid services over a period of time.

Originally, Amazon was a service-oriented company but recently it has moved into a ‘productization’ of service: The evolution of service to include launch of an associated product, like Kindle devices for promoting the sale of books. On the other hand, Apple was originally a manufacturer focused on electronic devices but then moved to a ‘servitization’ of products by expanding its business into service such as sale of music. The convergence of the ‘servitization’ of product and the ‘productization’ of service has been addressed in the emerging research area called Product Service Systems (PSS) (Baines, et al., 2007). This convergence results in competition of the various product and service players in the marketplace. The need for a design methodology to quantify the trade-offs between profits from product and service motivates the research presented here.

Research in PSS proposes co-design methodologies considering the value of product and associated services simultaneously rather than independently. Rigorous optimization studies are still limited (Vasantha et al., 2011). Research in Design for Market Systems has studied profit maximization for enterprises for products without considering the service aspect and how it might affect design decisions (Frischknecht, et al., 2010. Lewis, et al., 2006. Michalek, et al., 2005. Michalek, et al., 2010). This paper proposes an extended modeling framework called Enterprise-driven Product Service Systems (EPSS) design. Similar to PSS, EPSS considers design of product and service together using profit maximization as the objective. We develop the EPSS framework in the case study that looks at product and service design of tablets, e-books, and cloud service. The remainder of the paper is organized as follows. Section 2 introduces the EPSS framework. In Section 3, we demonstrate the EPSS framework on the case study for an existing product and service, and for a new product and service. Sections 4 and 5 discuss results, and conclusions and limitations, respectively.

2 ENTERPRISE-DRIVEN PRODUCT SERVICE SYSTEM DESIGN

An EPSS modeling framework is developed for two design scenarios, a current PSS and a future PSS.

2.1 Optimal design of a current PSS

Design model

The modeling process starts with benchmarking competitors’ PSS concepts. Benchmarks are used to define the current PSS concept, its design attributes and associated design variables. Product, interface, and service design models are used for mapping design variables to product, interface, or service attributes, and to determine constraints on design variables. Product attributes cannot change during the product's life cycle, whereas service attributes can change over time. Interface models and interface attributes can be best understood by grouping them into three categories: design variables, constraints, and financing. Design variables are shared between the product and service design spaces. For example, data storage is a design variable shared between two spaces: Flash memory within the product, and cloud storage within the service design space. These two forms of storage share a similar function but differ in consumer preference and cost, therefore their optimal combination needs to be determined. Constraints exist between design spaces. For example, the degree of service compatibility is greatly affected by the operating system (OS): Apple’s iOS system allows its users to share content only among iOS devices that use cloud services, while in Google's Android OS the customer can share content with devices with other OSs. Financing considers how to allocate investment and cost in product and service design.

Choice and demand model

The customer chooses a particular bundle of product and service attributes among possible PSS alternatives. Choice modeling, as we discuss it here, consists of three steps: Gathering choice data using choice-based conjoint analysis, estimating preference coefficients using a Hierarchical Bayesian discrete choice model, and fitting a spline through the discrete choice points to obtain a continuous function, similarly to Michalek, et al. (2005). The random utility choice model used to quantify customer preference has the form $u_{ij} = v_{ij} + \varepsilon_{ij}$ where u is the utility value, v is an observable and deterministic component of the utility, ε is the unobservable random error, i is the individual user index, and j is the PSS alternative design index. Individuals choose the PSS alternative that gives them the highest utility among the alternatives. The deterministic utility v_{ij} is a linear function of discrete "levels" (values) of attributes and prices of product and service, defined as,

$$v_{ij} = \sum_{k=1}^{K} \sum_{l=1}^{L_k} \beta_{ikl} z_{jkl}, \tag{1}$$

where z_{jkl} are binary dummy variables indicating alternative j possesses attribute k at level l, and β_{ikl} are the part-worth coefficients of attribute k at level l for individual I (Green and Krieger, 1996). The Hierarchical Bayesian conjoint model consists of two levels. At the higher level, individuals' part-worths have the multivariate normal distribution with a vector of means and a matrix of covariances. At the lower level, probabilities of choosing specific alternatives are determined by a multinomial logit model. Markov Chain Monte Carlo (MCMC) is used to estimate the part-worth for each individual (Rossi et al., 2005). For continuous-valued PSS attributes, a natural cubic spline is used to interpolate β_{ikl} for the intermediate values of attributes. Lastly, the individual choice probabilities P_{ij} and market potential s are used to forecast market demand q_j:

$$q_j = \frac{1}{I} \sum_{i=1}^{I} s P_{ij} = \frac{1}{I} \sum_{i=1}^{I} s \frac{e^{v_j}}{\sum_{j' \in J} e^{v_{j'}}} . \tag{2}$$

Descriptions of choice and demand models for design decisions can be found, for example, in Michalek, et al. (2005, 2010) and Chen, et al. (2012).

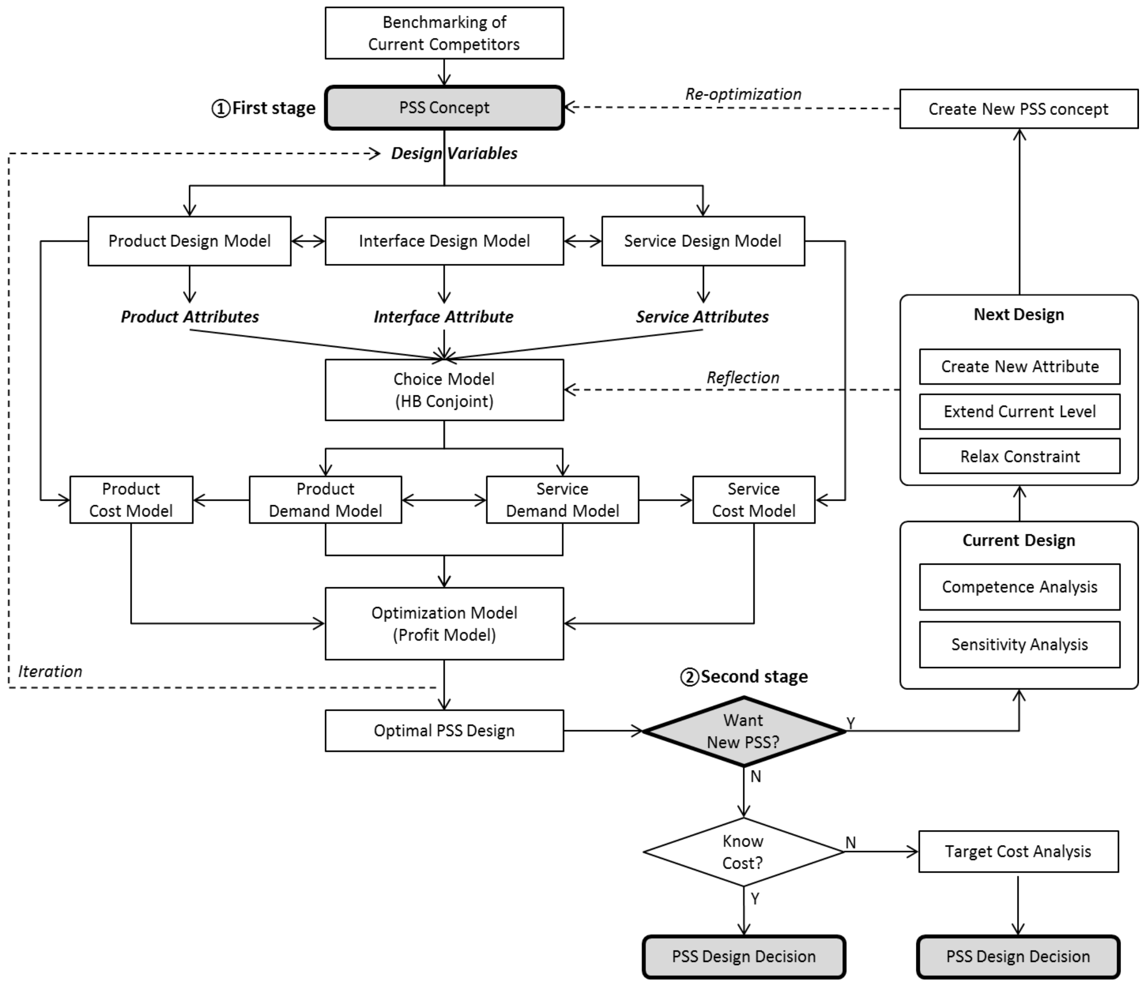

Figure 1. EPSS design framework

Optimization model
The PSS objective function is maximizing profit and the constraints pertain to various requirements, as noted earlier:

$$max_{p_p,p_s,x}\, \Pi = \Pi_p + \Pi_s = \left((p_p - c_{Vp})q_p - c_{Ip}\right) + \left((p_s - c_{Vs})q_s - c_{Is}\right) \tag{3}$$

Subject to $\mathbf{g}(\mathbf{x}) \leq 0,\ \mathbf{h}(\mathbf{x}) = 0,\ \mathbf{x}_{min} \leq \mathbf{x} \leq \mathbf{x}_{max}$,
where $q_s = \mathbf{f}(\mathbf{x}_s, q_p, t_p, f_s)$, $c = \mathbf{f}(\mathbf{x})$.

Here the $\mathbf{x}$ vector contains the PSS design variables; subscripts p and s denote product and service, respectively, and so p_p and p_s are product and service prices, q_p and q_s are product and service demands; c_v is the unit variable cost and c_i is the investment cost; t_p is the product life cycle time and f_s is the frequency of using a service. Constraints $\mathbf{g}(\mathbf{x}) \leq 0,\ \mathbf{h}(\mathbf{x}) = 0$ include product and service design constraints and business constraints, like budget and launching time, along with simple bound constraints that are usually simplifications of more elaborate requirements. Product and service demand are generally related. In the tablet example, customers who purchase a product such as an iPad then become potential customers of iBook services during the iPad's life cycle. Continuing to use the same services for a product after its intended life cycle often requires purchasing a newer version of the same product, thus creating a continuous repurchasing cycle. This has been a well-known strategy in computer-related products, although it may negatively impact customer satisfaction.

2.2 Optimal design of a new PSS

Current design
The PSS optimization model allows explicit evaluation of how sensitive is profit with respect to a variety of changes in the model. Manufacturers would not focus on attributes that do not significantly affect profit even if these attributes are of importance to customer preference. However, if certain design attributes affect profit significantly but not customer preference, manufacturers would still intensively control for these attributes when considering a new PSS design. Once favorable changes are identified, they must analyze if they have the resources (e.g., competence or technology) to effect these changes compared to the competition. This is similar to traditional QFD (Quality-Function-Deployment) studies. For example, if a company has extensive experience with service design compared to product design and they have more service content than their competitors, then this is likely to positively appeal to customers with service attributes. Usually, service price and cost are more changeable and the freedom of change is far greater with new service design than with new product design. If it is possible for a company to alter a customer’s preference structure from product-oriented to service-oriented, then the company will likely increase profit or market share compared to current PSS design.

Next design
One way to generate a new PSS concept is to examine how to change the preference structure of customers. Preferences can change if new attributes or variables are added to the current PSS design. For example, suppose a company supplies free 3G service to an existing product. This will facilitate a customer’s purchase of specific contents which may increase the importance of the service contents market because the customer is now readily able to access and use other available services contents. Next, one can change constraint boundaries, for example, extend the range of attribute levels. A company may supply a larger amount of cloud storage possibly resulting in a relative decrease in the importance of flash memory. Similarly, changing service, such as OS compatibility, may make the product more appealing but reduce purchased service. Clearly, while such changes may lead to new PSS concepts, they involve tradeoffs in demand, cost, and possibly functionality.

3 CASE STUDY

We demonstrate some of the above ideas in the context of bundled product and service design of tablets, e-books, and cloud service, a highly dynamic market that exemplifies the PSS paradigm. The case study focuses on full-colored tablets with 7- to 9-inch displays. The two service contents investigated are e-books and cloud storage, because e-books are most commonly used on 7- to 9-inch tablets and cloud storage is a service gaining popularity. A survey of 177 respondents was conducted and the choice data of 151 of these respondents were retained after removing unusable data. The respondents consisted of 72% males and 28% females; 30% were 15 to 24 years of age, 49% were 25 to 34 years of age, 13% were 35 to 44 years of age, and 8% were more than 45 years of age. Also, 70% of respondents had tablet use experience. Attributes of product and service used in the conjoint survey were selected based on pre-survey questions. The same respondents were surveyed for a current PSS concept and three new PSS concepts. Amazon's Mechanical Turk (Amazon, 2012a) and Sawtooth Software (Orme, 2009) were used for the survey.

Attributes and design variables

Seven design variables and ten PSS attributes are considered, Table 1. Each design variable is mapped into exactly one PSS attribute except for the OS system which is mapped into two PSS attributes.

Table 1. Design variables and attributes

Concept	Type	Design variables	PSS attributes
Current	Product	-	Tablet price (p_p)
		Display size (x_1)	Display size (z_1)
		Weight (x_2)	Weight (z_2)
	Interface	Size of flash memory (x_3)	Flash memory (z_3)
		Size of cloud storage (x_4)	Cloud storage (z_4)
		OS system (x_5) (0:iOS, 1:Android, 2:Others)	OS usability (z_5) Service compatibility (z_6) (0:same OS devices, 1:any other OS devices)
	Service	-	E-book price (p_s)
		# of books per a month (x_6)	Lending service promotion (z_7)
New	Service	Free 3G (x_7) (0:No, 1:Yes)	Free 3G service promotion (z_8)

Design and cost model

Table 2 shows the cost and constraints utilized in this study. The tablet cost models used are adopted from previous product design research (Wang et al., 2011). Other costs considered include battery cost, integrated circuits cost (e.g., CPU), and miscellaneous costs (e.g., speakers). The constraint on LCD size and weight is derived from the regression of data for 7- to 9-inch tablets in the current market (November 2012). For the interface cost models and constraints, we assume that the cost of cloud storage is half the price of cloud storage in current prices (Amazon, 2012b). The constraint of the interface design model is that service computability is determined by the OS system of a tablet. In the service cost models, the price of an e-book includes margin, royalty fees, tax, and delivery costs. The royalty fees of an e-book comprise the majority of its price (Amazon, 2012c) and we consider only royalty fee based on the iBook's royalty rate (Mill City Press, 2012). We further assume that, when a customer borrows an e-book for free from the e-book market, the company pays 1% of the normal royalty fee to the publisher (Paul, 2011). Membership or annual fee for lending service is not considered. The product life cycle in the table is obtained from survey questions.

Table 2. costs and constraints

Type	Cost model	Constraint
Product	$c_{LCD} = c_{0,LCD} q_p^{b_1} x_1^{b_2}$ ($c_{0,LCD}$ = 50($), b_1 = -0.1032, b_2 = 0.7965) c_{3G} = 19 ($) c_{others} = 115($)	$x_2 = b_1 + b_2 x_1$ (b_1 = -329.42, b_2 = -94.432)
Interface	$c_{memory} = c_{0,flash} x_3$ ($c_{0,flash}$ is 4($/GB)) $c_{cloud} = c_{0,storage} x_4$ ($c_{0,storage}$ = 0.25($/GB))	$if\ x_5 = 0, z_6 = 0, otherwise, z_6 = 1$
Service	$c_{royalty} = c_{rate,royalty} p_s$ ($c_{0,royalty}$ = 0.7) $c_{lending} = c_{rate,lending} c_{royalty} x_6 t_p$ ($c_{rate,lending}$ = 0.01, t_p = 44.5(months))	

Choice, demand, and optimization model

Table 3 describes choice-based conjoint survey based on PSS attributes and levels. The levels in Table 3 are based on existing competitors' attribute levels, which means they represent actual choice situations within the current market. An example of an actual choice is the cost of the same e-book that varies in price from one company to another. For example, Gilbert (2012) noted that "Obama's America" cost $9.00 on Amazon, $12.99 on iBook, and $16.17 on Barnes & Noble. It should be noted that 200GB of cloud storage, the lending service of three books per month, and free 3G service were used only in the survey for the three new PSS concepts. The preference splines are obtained using the choice model described in Section 2. Specifically, we used every tenth draw from the last 50,000 (total was 100,000) draws of MCMC to obtain preference coefficients. Market analysts predict the total sale of tablets in 2013 to be 172.4 million, and 7- to 9-inch tablets will control 34% of the tablet market in 2013 (Alexander, 2012. Mainelli, et al., 2012). Therefore, the projected market size for 7- to 9-inch tablets is assumed to be 58.5 million. Profit is calculated based on the above assumptions.

Table 3. PSS attributes and levels

Type	Attribute		Level			
Product	Price	Tablet price	$199	$369	$529	
	Hardware	Display size	7"	7.9"	8.9"	
		Weight	308g	395g	567g	
Interface	Storage	Flash memory	16GB	32GB	64GB	
		Cloud storage	5GB	25GB	50GB	200GB **(PSS 3&4)**
	Operating system (OS)	OS usability	iOS	Android	Others	
		Service compatibility	Same OS devices	Any other OS devices		
Service	Price	E-book price	$9.99	$12.99	$16.17	
	Service promotion	Lending service	None	One book a month	Three books a month **(PSS 3&4)**	
New Attribute **(PSS 2&4)**	Service promotion	Free 3G service	None	Free 3G		

Current and next design

Table 4 shows how PSS attribute changes affect profit. Flash memory affects profit more than the other product attributes while lending service affects profit more than the other service attributes. A company emphasizing service design compared to product design would try to reduce flash memory's impact on profit and that of cloud storage; or promote lending service.

Table 4. Attribute changes affecting profit.

Attribute	Flash memory	Tablet price	OS usability	Lending service	Display size	Cloud storage	Service compatibility	E-book price	Weight
Profit (Max – Min)	2,378M	503M	434M	164M	131M	109M	61M	40M	20M
Utility (Max – Min)	0.808	2.153	0.649	0.234	0.25	0.197	0.073	0.028	0.024

Table 5 summarizes the difference between the current and possible new PSS designs for three scenarios. The scenarios have both new attributes and extended ranges of attributes.

Table 5. New PSS concepts

Concept scenario		Description
Current	PSS 1	Have the same attributes and levels as competitors
New	PSS 2	Provide free 3G service for e-book service and cloud service
	PSS 3	Provide larger cloud storage and more lending service than competitors
	PSS 4	Combine PSS 2 and PSS 3

4 RESULTS AND DISCUSSION

4.1 Optimal PSS design

Figure 2 and Table 6 compare four optimal PSS designs that maximize overall profit (PSS 1-4) and one optimal PSS design that maximizes product profit (PSS 0). The left side of the Figure 2 shows that it is generally important to consider product and service profit together. Using the EPSS shows that the product profit for the optimal PSS 1 is negative, but when service profit is taken into consideration then overall profit is greater than PSS 0. According to the model then, a tablet with a price of $199 in the current US market is the correct strategy. The right side of Figure 2 shows that the total profit of PSS 2 is higher than that of PSS 1, but PSS 2 has a target cost for free 3G whereas PSS 1 does not. If the real cost for 3G service is higher than this target cost, then PSS 2 will be less successful than PSS 1. In reality, the price of a black-and-white Kindle e-reader with free 3G costs $60 more than the same Kindle without 3G, which means the target cost of $32.10 is reasonable. This figure also shows that PSS 3 is the most profitable design concept among the four. Lastly, the figure shows that PSS 4, composed of the combined characteristics of PSS 2 and PSS 3, will actually make less profit than PSS 3 alone. This means that bundling several new PSSs will not guarantee a greater profit for the company than would one new PSS.

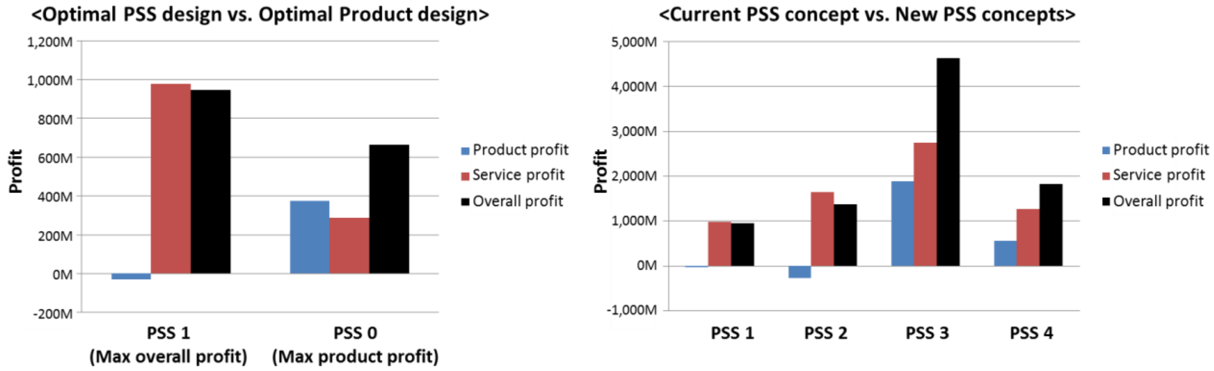

Figure 2. Profit of optimal PSS designs

Table 6. Optimal results

i) Profit, market share, and cost

Objective		Profit			M/S	Cost per person		
		Product	Service	Total		Product	Service	Target
Max product profit	PSS 0	375M	289M	664M	4.2%	$210.1	$316.6	
Max overall profit	PSS 1	-31M	978M	947M	13.1%	$203.1	$334.9	
	PSS 2	-266M	1,641M	1,375M	22.8%	$218.9	$339.5	$32.1
	PSS 3	1,886M	2,744M	4,630M	48.9%	$195.9	$366.6	
	PSS 4	554M	1,271M	1,825M	26.8%	$208.6	$381.5	$55.9

ii) Optimal PSS variables

	Product attribute			Interface attribute		Service attribute		
	Price	Display	Weight	OS/Compatibility	Flash/Cloud	Price	Lending	Free 3G
PSS 0	$363	9”	520g	Android/any OS devices	8GB/38GB	$9.78	3books/3M	
PSS 1	$199	9”	520g	Android/any OS devices	8GB/32GB	$10.41	3books/3M	
PSS 2	$199	9”	520g	Android/any OS devices	8GB/50GB	$10.41	3books/3M	Free 3G
PSS 3	$262	9”	520g	Android/any OS devices	8GB/136GB	$10.41	8books/3M	
PSS 4	$244	7”	331g	Android/any OS devices	8GB/200GB	$10.41	7books/3M	Free 3G

4.2 Tradeoff between product and service

Figure 3 shows that, when the primary product and service variables of PSS 3 change, then product, service, and overall profit also change. The upper portion of Figure 3 shows that flash memory increase tends to decrease product profit due to flash memory cost, but increase service profit because of increased demand. Similarly, cloud storage increase tends to increase product profit, but service profit initially increases and then decreases after a certain point. The shape of the total profit surface is similar to that of the product profit surface rather than the service profit surface which means that storage affects product profit more than service profit.

The lower portion of Figure 3 shows e-book price has little effect on product or service profit. This is because customers typically only consider the price of the tablet itself when they purchase the tablet. This suggests that a firm should decrease tablet price and thus increase product sales. These customers would then have no choice but to purchase e-books from this service provider, which are slightly more expensive than competitors, if the operating system is not compatible with other service providers. This result can be supported by the presence of an implicit discount rate. Most customers tend to be much more sensitive to immediate cost than future cost. Customers are willing to reduce current payment and spread total payment over the long term, even if the total payment increases. Most customers do not use a mathematical criterion for decision making like net present value (NPV), or they simply do not have the ability to pay the full amount at purchase time. The result of EPSS optimization shows how a decision maker can use this customer behavior for product and service design. The shape of the total profit surface is similar to that of the service profit surface rather than the product profit surface. This means that e-book price affects service profit more than product profit —in contrast with storage.

Figure 4 shows the relationship between total profit and utility of PSS 3 with regards to different combinations of cloud storage and flash memory. Red denotes high profit whereas blue denotes low profit. The white line denotes the total amount of storage, which is the same regardless of the combination between cloud storage and flash memory. The amount of storage for maximum profit is 144 GB (i.e., 8GB of flash memory, 136 GB of cloud storage). Profit changes significantly when various combinations of flash memory and cloud storage are considered, but utility varies minutely when such combinations are considered. This means that if decision makers change the combinations of flash memory and cloud storage, then they are able to make more profit by sacrificing little utility. This is because customer preferences typically are not sensitive to the combination of flash memory and cloud storage which means they perceive both attributes as one attribute or the sum of storage. Therefore, when a product and service share an attribute that is valued similarly among both, then decision makers need to consider a service-oriented strategy rather than a product-oriented strategy.

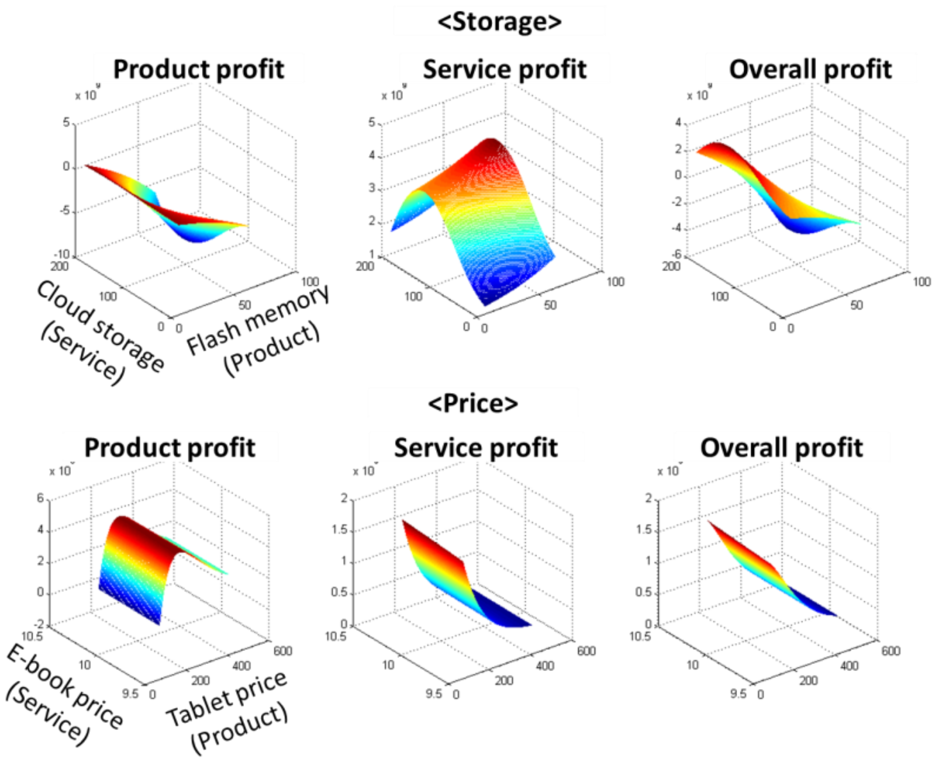

Figure 3. Product profit vs. service profit

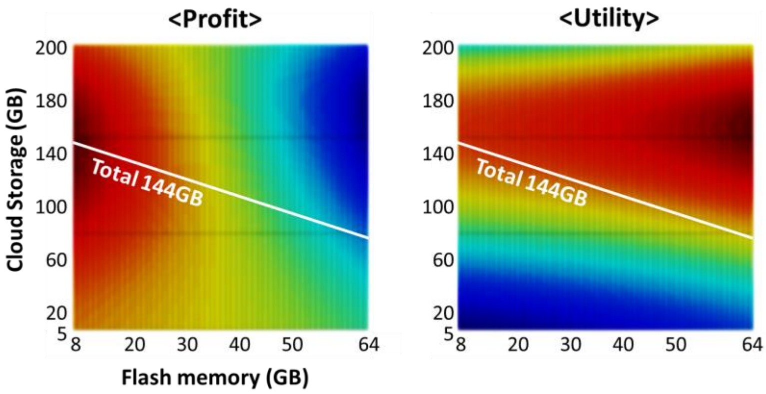

Figure 4. Profit vs. utility of storage

Customer preference

Table 7 shows the relative importance of product or service changes for different PSS from the customer's perspective.

Table 7. Relative importance across PSS concepts

		PSS 1	PSS 2		PSS 3		PSS 4	
	Attribute	Importance	Importance	Change from PSS 1	Importance	Change from PSS 1	Importance	Change from PSS 1
Product	Tablet price	49.7%	50.9%	1.3%	46.4%	-3.3%	57.2%	7.5%
	Display size	5.4%	9.2%	3.8%	5.8%	0.3%	2.4%	-3.0%
	Weight	0.5%	0.8%	0.2%	1.9%	1.4%	0.0%	-0.5%
	OS usability	15.0%	14.5%	-0.5%	11.3%	-3.7%	7.9%	-7.0%
	Flash memory	16.1%	13.1%	-3.0%	7.2%	-8.8%	9.4%	-6.7%
	Total	86.6%	88.5%	1.9%	72.6%	-14.0%	76.9%	-9.7%
Service	Cloud storage	3.9%	3.5%	-0.4%	13.9%	10.0%	11.5%	7.6%
	Service com.	1.7%	0.5%	-1.2%	0.2%	-1.5%	0.1%	-1.6%
	Book price	2.4%	3.6%	1.2%	1.4%	-1.0%	2.2%	-0.1%
	Lending	5.4%	3.9%	-1.5%	12.0%	6.6%	9.3%	3.9%
	Total	13.4%	11.5%	-1.9%	27.4%	14.0%	23.1%	9.7%

In order to compare common attributes, the new attribute of free 3G is excluded. For PSS 1, the total importance of product (86.6%) is much higher than that of service (13.4%). However, the total importance of service increases in PSS 3 and PSS 4. Since the total relative importance for the various attributes of a product or service changes little between PSS 1 and PSS 2, one may conclude that free 3G service has little effect changing customer preference. The largest relative importance for PSS 3 is storage and lending service. Extending service levels has more influence on customer preference than adding a new attribute. The importance of product price increases in PSS 4, which can mean that a customer tends to consider price more when the attributes of the PSS are complex. Overall, the results in Table 7 show that the relative importance of each attribute is not equally affected by new PSS concepts. If the degree of revision of the importance of an attribute could be analyzed then it would be possible to forecast the reconstruction of customer preferences without another conjoint survey.

5 CONCLUSION

The tablet case study illustrated the EPSS design framework and the insights that can be gained from it. The particular value gained is that such insights are quantified within the limitations of the model. Some conclusions with quantifiable results from the study are as follows. (a) The overall profit, including product and service profit, should be considered holistically when designing PSS designs. Sacrifice of product profit may increase overall profit. (b) In the product-service interface, if service attributes and product attributes are both preferred by customers then one should try to transfer the value of product to that of service as this will increase profit. (c) Quantitative analysis current PSS indicates directions for PSS designs with higher profit. (d) Current customer preferences can be changed either directly through the extension of attribute levels or indirectly through addition of new attributes.

There are important limitations to this study. Service profit is more risky than product profit because revenue is taken from a product immediately at sale while it takes a longer time for a company to receive service revenue. Next, heterogeneity with regards to patterns of service use should be considered more extensively. This study considered heterogeneity for the choice of PSS concepts, but the heterogeneity of product life cycle and frequency of using service was not considered. Finally, only exclusive channels between product and service are considered in this study. Further study will consider demand model under complex channel structures.

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