Stakeholder Engagement in Early Stage Product-Service System Development for Healthcare Informatics

Man Hang Yip, University of Cambridge
Robert Phaal, University of Cambridge
David R. Probert, University of Cambridge

Abstract: This article presents the findings from four case studies on stakeholder engagement in new healthcare information and communication technology (ICT) product-service system (PSS) development. The degree of connectivity between the new healthcare ICT PSS and its intended operating environment has emerged to be an important contextual factor that may impact decisions concerning stakeholder engagement in the early stage development process. The four propositions of stakeholder identification and engagement in the development process, put forward in this article, provide important directions for future work in exploring the implications of PSS characterization in early-stage new healthcare PSS development process.

Keywords: Product-Service System, PSS, New Product Development, New Service Development, Stakeholder Engagement, PSS Characterization, Early Stage, ICT, Healthcare

EMJ Focus Areas: Building Engineering Management Actionable Knowledge, New Product Development, Technology Management

An aging population is demanding more intensive medical treatments. Patients and clinicians are expecting more from increasingly complex healthcare services (PR Newswire, 2012). In 2011, the total amount private and government spent on healthcare in Organization for Economic Cooperation and Development (OECD) countries was U.S. $5 billion. This accounted for 18% of the U.S. and 9% of other OECD countries' gross domestic products (GDP); however, healthcare funding has been reducing. From 2009 to 2011, 70% of OECD countries had already lowered their GDP percentage-spend on healthcare (OECD.stat, 2013a; OECD.stat, 2013b; OECDiLibrary, 2013). The continual pressure to contain healthcare costs has driven hospitals to invest not only in new medical technologies, but also efficient healthcare services (PR Newswire, 2012).

Against a backdrop of increasing demand for better health or care related product-service systems (PSS), this research study explores how contextual factors influence the role of stakeholders in early stage PSS development from the perspective of manufacturers in the healthcare industry, and what implications PSS characterization has on the early-stage new healthcare PSS development process. This supports future theory building around contextual factors, stakeholder engagement, and PSS development operational and commercial effectiveness.

In this research, PSS is defined as a commercial offering, consisting of a collection of products and/or services that fulfill a customer's needs (Goedkoop, van Halen, te Riele, & Rommens, 1999). Stakeholder engagement is defined as the process of acquiring information from parties who have an interest in, or are potentially impacted by, the new PSS (Freeman, 1984; Kohli & Jaworski, 1990). Early stage is defined as the process steps taken after the manufacturer has set the new product/service strategy, but before commencing the new product/service development tasks.

This article discusses findings from four case studies on stakeholder engagement in new healthcare information and communication technology (ICT) PSS. A literature review of product-service systems, new PSS development, and stakeholders' involvement in new development is first presented, followed by a summary of the literature gaps and an overview of the methodology. The background of the cases is then presented, followed by a discussion of the findings, leading to conclusions.

Product-Service Systems

The distinction that products are tangible and services are intangible has been commonly used since the 1960s (Yip, Phaal, & Probert, 2012a). For this research, the definitions adopted for product and service are: a product displays the characteristics of independent existence and can be stocked without losing its identity (Hill, 1999); a service is something that cannot be stored and cannot be independent from the interactions between the producer and the consumer (Hill, 1999; Levitt, 1972). This definition does not rely on tangibility as the demarcation of product and service, and, therefore, does not confuse a digital (intangible) product, such as software, as a service.

The idea of customers buying bundled offerings consisting of products and services was proposed and applied by researchers in the field of marketing, service marketing, and management in the 1970s and 1980s (Bell, 1986). Levitt (1972) proposed the concept of product as "a tool to solve their [customers'] problems" (p. 50) and that service is an integral part of what is sold (Levitt, 1980). According to Baines et al. (2007), the formal definition of PSS was first given by Goedkoop et al. (1999): PSS, or product service combination, is a "marketable set of products and services capable of jointly fulfilling a user's need" (p. 3). This was not dissimilar from the earlier idea of Levitt: a "customer-satisfying entirety" (p. 85) or a "bundle of differentiating value satisfactions" (p. 87) that comprises layers of products and services (Levitt, 1980). Recognizing one school of thought behind PSS is to promote sustainability, Baines et al. (2007) proposed that a PSS offers "the opportunity to decouple economic success from material consumption" (p. 1545).

Since the PSS definition proposal by Goedkoop et al. (1999), scholars in both marketing and sustainability communities have proposed various PSS classification schemes. The three frequently-used classifications in the reviewed PSS literature (product-oriented, use-oriented, and result-oriented PSS) were first proposed by Hockerts and Weaver in 2002 (as cited in Neely, 2009), and was extended to include integration-oriented and service-oriented (Neely, 2009). Exhibit 1 compares three existing classification schemes and also comments on whether or not the examples provided by these schemes display product or service characteristics. As seen in Exhibit 1, it appears that the definitions

Research Manuscript accepted by Speical Issue Editor Daim.

of "result-oriented PSS" and the "change of system" have confused service and intangible (digital) product.

New PSS Development

Between the 1970s and 2000s, there were many proposals for new product development (NPD) and new service development (NSD) process models, and a few new PSS development process models. The stage-gate process is one of the most generic product development processes (Nepal, Yadav, & Solanki, 2011), and service blueprint (Shostack, 1984) is a frequently-cited new service development process. As observed by Maussang, Zwolinski, and Brissaud (2009), some of the design approaches for PSS are product-focused and others service-focused. Product-focused design approaches deal with the extension of product life span (Aurich, Schweitzer, & Mannweiler, 2008; Juehling, Torney, Herrmann, & Droeder, 2010). Service-focused design approaches illustrate the interactions between customers and services (Gummesson, 2007; Shostack, 1984).

Process models that have less bias towards product or service include those proposed by Kindström and Kowalkowski (2009); Maussang et al. (2009); Tan, McAloone, and Matzen (2009); and Yang, Xing, and Lee (2010). These models remain at a business strategy level, and could be applied to NPD and NSD (e.g., Kindström & Kowalkowski, 2009; Mont, 2002) or do not provide any guideline in terms of the timing of execution of each suggested activity (e.g., Yang et al., 2010). The exception is the proposal by Maussang, Zwolinski, and Brissaud, which takes a holistic approach to the design and development of both product and service elements in the PSS, and includes enough technical details required for product development.

Stakeholders' Involvement in New Development

In this research, Freeman's stakeholder definition is adopted: a stakeholder is defined as any group or individual who can affect or is affected by the new PSS (Freeman, 1984). Stakeholder identification frameworks and proposals of stakeholder definitions and classifications (Bryson, 2003; Freeman, 1984; Mitchell, Agle, & Wood, 1997) are found mainly in management, economics, and policy literature. There are also proposed stakeholder attributes in order for organizations to evaluate the

Exhibit 1. A Comparison of PSS Classifications

Goedkoop et al. 1999	Neely, 2009	Mont, 2002	Examples in literature	Example displays product or service characteristics according to Shostack, 1977 and Hill, 1999
Product-Service (Ps) – services are connected to products	Product-oriented – products plus product-related-services; ownership of tangible product transferred to customer	Point of sales	Personal assistance in shops	Service
		Maintenance	Installation service	Service
		Revalorization	Product recycling service	Service
	Integration-oriented – products plus downstream services; ownership of tangible product transferred to customer		Asset utilization advisory service	Service
Service-product (Sp) – service provider hands products to customer	Result-oriented – replaces the product with a service	Result-oriented	Credit card (replaces cash)	Credit card – product Lending & borrowing money – service, simplified by the use of credit card
Service-product (Sp) – service provider adds product as a production aid	Use-oriented – service delivers through a tangible product; often ownership of tangible product retained	Use-oriented	ATM	ATM – product Cash withdrawal at ATM - service
Product-Service (PS) – products and services are developed in combination	Service-oriented – a coupled product and value added service; ownership of tangible product transferred to customer	Combinations (Combination of products and services)	Intelligent vehicle health management	Intelligent vehicle health management system is software (a product), and it exists independently. However, the provider could offer proactive maintenance (a service) that needs producer and consumer to interact.
Change of system – a new system that substitutes a whole system	Result-oriented PSS – replaces the product with a service	Result-oriented; Substitutions (Products substituted by services)	Electronic money Voicemail	Voicemail and electronic money do not require producer and consumer to be present at the same time. Their identities are preserved over time. They are intangible products.
	Use-oriented		Lease of equipment	Service
	Integration-oriented PSS		Consulting service	Service

strength of stakeholder's interests or concerns. These attributes include power, legitimacy, urgency, interest, influence, resistance, and feedback among multiple stakeholders (Bryson, 2003; Kipley & Lewis, 2008; Mitchell et al., 1997; Williams & Lewis, 2008).

Stakeholder theories may not have discussed how a stakeholder affects new product development, but scholars with a market-orientation have proposed models on how to process market information for new product development (Driessen & Hillebrand, 2013). One proposal viewed market-orientation as three processes: intelligence generation, intelligence dissemination, and responsiveness (Kohli & Jaworski, 1990). Another proposal viewed market-orientation as a business culture with three behavioral components: customer-orientation, competitor-orientation, and inter-functional coordination (Narver & Slater, 1990).

The literature reviewed that related to customer and lead user involvement in NPD/NSD showed that, in some studies, engaging lead users in NPD/NSD impacted new product/service positively (Oliveira & von Hippel, 2011; von Hippel, 1976); however, one study showed that no sales or competitive advantage resulted from customer involvement in NSD (Carbonell, Rodiguez-Escudero, & Pujari, 2009). A wider, multiple stakeholder view, or the criticism of the lack of such a view (Wind & Mahajan, 1987), was also investigated in studies of marketing and new product development activities. Toolkits to enable user innovation have also been proposed (Steiner, Piller, & Tarman, 2011).

The different stakeholders studied cover both internal and external stakeholders: internally – the managers of marketing, manufacturing, and research and development (R&D) departments (Kahn, 2001), and frontline employees (Talke & Hultink, 2010); externally – the customers, suppliers, dealers, competitors, additional firms such as public or legal institutions (O'Sullivan, 2006; Talke & Hultink, 2010), and external research organizations (Smirnova, Podmetina, Vaatanen, & Kouchtch, 2009). The findings of the reviewed studies were mostly case specific. For internal stakeholders, one study found that, from a business culture perspective (Narver & Slater, 1990), market-orientation was only relevant for marketing managers and not manufacturing or R&D managers (Kahn, 2001). For external stakeholders, involvement of an external research organization in NPD had positive impact (Smirnova et al., 2009), involvement of suppliers in NPD was important (O'Sullivan, 2006), and different stakeholder groups required different market launch strategies for better NPD diffusion (Talke & Hultink, 2010).

Specific to the healthcare industry, one study emphasized the importance of considering multiple stakeholders' interests, and resolving and communicating conflicts during each stage of the NSD (Smith, Fischbacher, & Wilson, 2007). Another study on the adoption of ICT innovation by healthcare professionals found that the alignment of stakeholders' objectives was important, as new ICT would likely be disrupting core processes within the hospital (Bower, Reid, Barry, & Ibbotson, 2000). A positive impact on patient satisfaction resulting from the adoption of a new healthcare ICT product by non-academic hospitals was also identified in another study (Queenan, Angst, & Devaraj, 2011). In summary, while there have been different studies on the impact of stakeholder in NPD/NSD, the timing of stakeholder engagement in the new development seems to be under-researched.

Literature Gaps

In essence, three literature gaps are highlighted here. First, the confusion between product and service may hamper the applicability of existing PSS classification schemes to the understanding of the new, to-be-developed, PSS. Second, with few exceptions, the current new PSS development processes are either biased toward product or service, or at a business strategy level, and lack the details required for technical development. Third, the timing of stakeholder engagement in the new PSS process is an area that needs to be further researched. Drawing from these literature gaps, there is a need to systematically identify stakeholders and to characterize PSS for new PSS development, and to subsequently explore how stakeholder engagement in new PSS varies with different PSS characteristics.

Methodology

This research explores three identified literature gaps in new development process models and stakeholder theories for new product/service development. The intention is to contribute novel perspectives to theoretical frameworks in new PSS development and stakeholder identification. A case research approach is chosen for this exploratory study because it allows for rich knowledge of interactions to be obtained when the boundary of the phenomenon of interest is unclear (Yin, 1994). In this instance, the unclear boundary concerns the role of stakeholders in the development process, the PSS to be developed, and the contextual factors in the PSS' operating environment. Building theory from cases also has the strength of a higher probability of generating a novel theory that is more likely to be testable and empirically valid (Eisenhardt, 1989); therefore, a multiple-case/single unit of analysis design (Yin, 1994) is selected, with the unit of analysis being a new product/service/PSS under development.

Healthcare ICT PSS development were targeted in this research, because (1) different ICT strategies have been employed with mixed results by the countries in the European Union and in the United States to improve the quality of care and healthcare service efficiency (Blumenthal, 2009; Chen, Kennedy, Sales, & Hofer, 2013; Christensen & Remler, 2009; Department of Health, 2012; PricewaterhouseCoopers, 2013; Queenan et al.; Ranta, 2010; Shortliffe, 2005); (2) the introduction of new healthcare ICT PSS relates to the contextual factors of organization processes and human skills (Bower et al., 2000; Queenan et al., 2011); and (3) the value of a new ICT introduction is influenced by the existing hospital infrastructure, hospital users perception, as well as patient perception (Queenan et al., 2011).

In order to prevent biasing the research findings toward prior theoretical perspectives, this research study was started as close as possible to "the ideal of no theory under consideration and no hypotheses to test" (Eisenhardt, 1989, p. 536). A conceptual framework with some potentially important variables developed from literature review (Yip, Phaal, & Probert, 2012b) was revised after 25 pilot interviews involving four cases and 13 stakeholder groups. Following a theoretical case sampling strategy (Eisenhardt, 1989), initially, cases of new healthcare ICT PSS with different proportions of product and service elements and of different degrees of "newness" were sought. As the chosen research methodology allowed data analysis to overlap with data collection, and the researchers to reflect and adjust the data collection process (Eisenhardt, 1989), upon the preliminary data analysis, more appropriate case selection criteria have emerged. The criteria used going forward are the degrees of data connectivity and process connectivity.

Four iterations of four cases per iteration were planned. The four cases discussed in this article were part of the first iteration.

Background on Case Studies

Four case studies on new PSS development for healthcare informatics have been completed. The companies involved are manufacturers who have been developing new healthcare ICT products and advisory services to improve hospital management and operations. Exhibit 2 provides more details about the cases.

The four PSS cases are different in terms of who the primary users are, the intended operating environment, and the requirements of the connectivity with the hospital's operating environment. Exhibit 3 details these various aspects.

Findings and Discussion

Stakeholders

During the case interviews, informants were asked to identify stakeholders who were involved, who should have been involved during the development process, and the timing of their involvement.

Exhibit 2. Background Information on Case Studies

	Case 1	Case 2	Case 3	Case 4
Company background	A small multinational specializing in developing health ICT software and product consulting services companies.		A medium-size Nordic-based company specializing in developing healthcare and welfare ICT products and consulting services.	A large multinational that develops, produces, and delivers medical devices and health ICT software, as well as consulting services for hospital management and operations improvement.
Purpose of the PSS	To digitalize patient test completion and result recording, help hospitals to better manage wards' workflows and have visibility of patient's status at any time.	To detect a deteriorating patient and send alerts to the right people for the right attention to be given to the patient.	To reduce the turnaround time from patient diagnosis reporting to when the report is prepared and signed.	To improve hospitals' bed management and patient discharge processes.
Commercialization status of the new PSS at the time of writing this article	Has been sold and operated in the UK.	Has been sold and operated in the UK.	Has been sold and operated in different markets including Australia and the UK.	Has been sold and operated mainly in the US.
Target outcome of the PSS	To improve patient outcome and meet the CQUIN[1] payment conditions.	To improve patient outcomes: safety and quality of care.	To improve efficiency in the hospital, the accuracy of patient records and the quality of treatment.	To reduce patient length of stay in the hospital.
Key components of the PSS	Product: 1. Database 2. Software product 3. Handheld device / computer (3rd party)	Product: 1. Database 2. Software product (rule engines) 3. Handheld device / computer (3rd party)	Product: 1. Software product 2. 3rd party software 3. Hardware accessories 4. Hardware computers	Product: 1. Software product 2. Radio frequency identification reader and tags 3. Drop boxes
	Service: 1. Patient test tracking service 2. End user training *(provided by customers)* 3. Configuration service 4. Configuration training *(could be provided by customers)* 5. Software implementation service 6. System integration service	Service: 1. Patient status tracking and warning service 2. End user training 3. Configuration service 4. Software implementation service 5. On-going support and maintenance service	Service: 1. Training 2. Implementation service 3. System integration service 4. On-going support service	Service: 1. Training 2. Planning simulation sessions 3. Implementation service 4. Change management advisory service
Roles of the informants	Informant 1[2]: Technical – product development Informant 2: Technical – product development and service development	Informant 1[2]: Technical – product development Informant 4: Commercial & Management – product & service development	Informant 5[3]: Technical & Management - Hospital's healthcare informatics manager Informant 6: Technical – product management, service development and trainer Informant 7: Commercial – business development Informant 8: Technical – solution development	Informant 9: Technical & Management – Solution development Informant 10: Technical – Advisory service development

Notes: 1. CQUIN stands for Commissioning for Quality Innovation. CQUIN payment framework is an initiative started in 2009 by the Department of Health in the UK to reward the excellence of quality of hospital operations in improving patient outcomes.

2. Informant 1 was interviewed for both Case 1 and 2.

3. All informants are employees of the manufacturers, apart from Informant 5, who works in the customer's organization that drove the co-development in Case 3 with the manufacturer. Informant 5 was interviewed in 2010 in one of the pilot interviews.

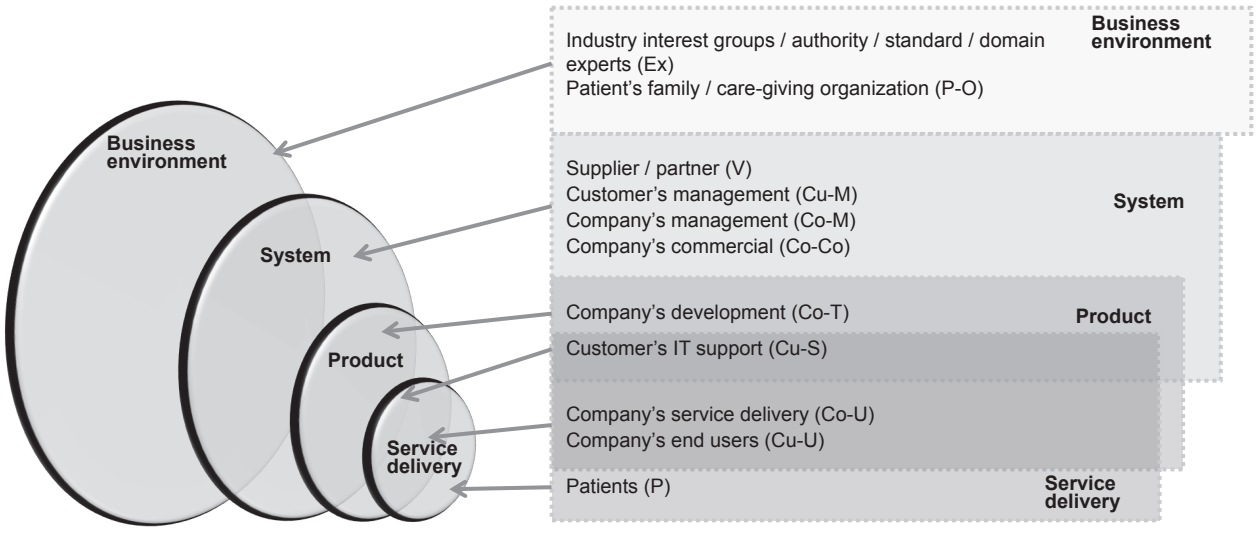
Exhibit 3. The Interaction of Each PSS with its Operating Environment

	Case 1	Case 2	Case 3	Case 4
Primary users	Nurses	Nurses and Doctors	Doctors	Bed Managers
Intended PSS operating environment	Hospital – wards; part of the nursing operations.	Hospital – wards; part of the acute patient care operations.	Hospital - radiology department or outpatient; part of the radiology imaging operations.	Hospital – wards, operating rooms (basically where there are beds); part of the bed management operations.
Required data connectivity of the new PSS with the existing information systems in the operating environment	The software product is required to interface with various existing information systems in the hospital.	The software product is developed as a standalone product and is not required to link with any other systems in the hospital.	The software product is required to connect to other systems in the hospital in terms of data exchange and also to be incorporated into the user-interface of an existing software application.	The software product is developed to have data connectivity with other information systems in the hospital.
Required changes to the existing procedures in the operating environment as a result of the new PSS	The workflows of the nursing operations remain the same. The only difference introduced by this new PSS is that the input method will be changed from pen and paper to digital entry.	The workflows of patient care operations remain the same, but the software product empowers junior nurses to alert senior consultants when attention is required for a deteriorating patient.	The workflows in the radiology department and outpatient are required to be changed for the PSS to operate as intended.	The PSS added new procedures and also changed the existing processes in the hospital's operations. The new process connected the workflows of various departments within the hospital.

Eleven stakeholder groups were identified. Considering the stakeholder groups identified, the stakeholders have different degrees of proximity to the operations of the PSS. These levels are (1) business environment, (2) system, (3) product, and (4) service delivery. Exhibit 4 shows the potential mapping between the eleven identified stakeholder groups and the four levels of proximity. Case 1 is used as an example to explain this concept.

In Case 1, nurses record patient test completions and results into the new ICT product within the PSS. The patients (P) receive the service while the nurses as the end users (Cu-U) deliver the service using the product. The company's service delivery (Co-U) trains the customer's IT support (Cu-S) on how to perform configuration on the new ICT product and ensure they are able to provide end-user training; therefore, P is associated with the service delivery level while Co-U and Cu-U are associated with both the product and service delivery levels. The company's development (Co-T) configures the ICT product to the nurses' needs, and also works with the hospital's IT support (Cu-S) to ensure the new product is adopted into the nursing operations; therefore, Cu-S is associated with the service delivery (end-user training), product (implementation), and system (PSS adoption) levels, while Co-T is associated with product (configuration) and system (integration and PSS adoption) levels. The hospital's management (Cu-M), company's management (Co-M), and company's commercial groups (Co-Co) have an overall interest in the operations of the PSS, and so they are associated with the

Exhibit 4. The Levels of Stakeholders Emerging from the Case Studies



system level. Authority and domain experts (Ex) are associated with the business environment level, as their influence is not only limited to this particular PSS, but also to other PSSs within the ICT sector of the healthcare industry.

Based on the above findings, proposition 1 was developed:

> ***Proposition 1:*** *A framework could guide practitioners to systematically identify stakeholders for the new PSS development process. The framework would consist of four levels: business environment, system, product, and service delivery.*

Connectivity with Operating Environment

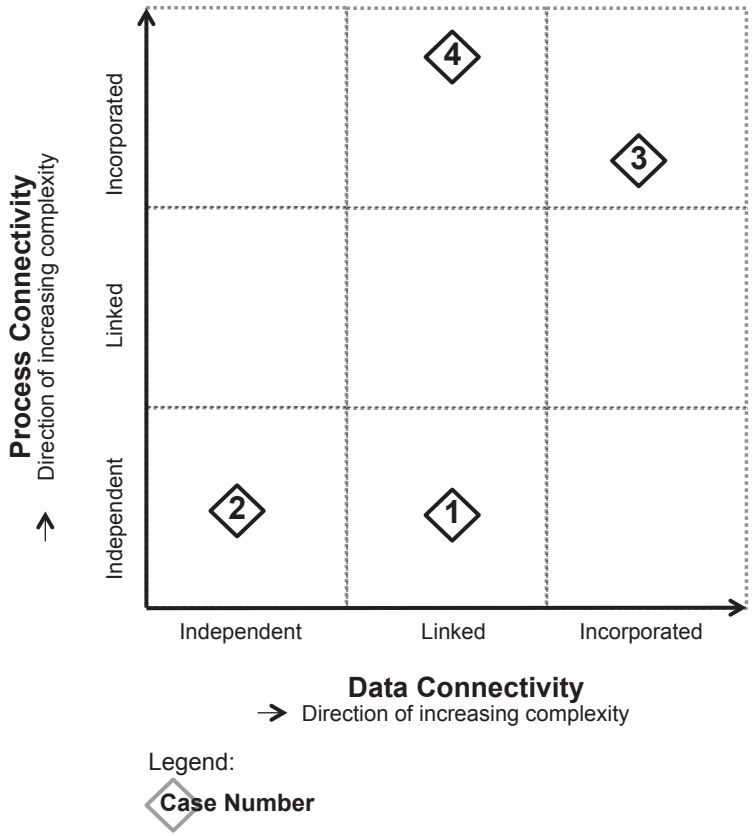
As seen previously in Exhibit 3, the PSS in each case has different requirements in terms of how it is to interact with its intended operating environment. Two aspects of connectivity have been identified from the case interviews: (1) the required data connectivity of the new PSS with the existing information systems in the operating environment, and (2) the required changes to the existing procedures in the operating environment as a result of the introduction of the new PSS. These aspects are named here "data connectivity" and "process connectivity," respectively. Exhibit 5 compares the PSS in the four case studies in terms of how each connects with its intended operating environment.

As seen in Exhibit 5, Case 4 not only required the software product to be integrated with other healthcare information systems in the hospitals (linked), but also the new process for bed management was required to be embedded into the hospital's operating procedures (incorporated). Case 3 required backend data connectivity to other information systems in the hospitals and user-interface integration with another software application, in order to enable the users to have a "seamless" transition from an existing healthcare information system to the new software product (incorporated). The new PSS in Case 3 also required the users and other hospital stakeholders to change their ways of working. Although it might not be as large-scale as that required in Case 4 (impact on the departmental level's workflows versus impact on the whole hospital operations), the new process introduced by Case 3 had to be embedded in the existing radiology and outpatient workflows (incorporated).

The PSS in Case 1 and 2 had no process connectivity requirements with their operating environment (independent). Neither of these PSSs required changes to the existing operating procedures. Both software products in Case 1 and 2 replaced paper-based methods; however, Case 1 required backend data connectivity with another healthcare information system in the hospital (linked), which was lower than the data connectivity required by the PSS in Case 3 and 4. Case 2 was developed as a standalone PSS that did not require data connectivity with other healthcare information systems and, therefore, was "independent" in the data connectivity aspect. Comparing the differences among the four cases in terms of the types of connectivity and the degree of connectivity, Proposition 2 and 3 emerged:

> ***Proposition 2:*** *The type of connectivity between an ICT PSS and its operating environment can be separated into that resulting from data interactions and that related to process interactions. Data connectivity is the level of data communications between the new PSS and the other systems in the environment. Process connectivity reflects the degree of linkage between and the assimilation of the new processes necessitated by the new PSS with existing processes.*

Exhibit 5. PSS Connectivity with Its Operating Environment (Source: Authors)



Proposition 3: *Data and process connectivity can be characterized in terms of three categories: independent, linked, and incorporated. A new PSS that is not going to have any connectivity with the existing systems in the operating environment is "independent." If a new PSS is to interface with the existing systems, it is "linked." If a new PSS is to become part of the existing systems, it is "incorporated."*

Stakeholder Involvement in New PSS Development

A new PSS development process framework was used to guide the discussion with informants on stakeholders' involvement in the early stage of the development process. This proposed process framework was created as a result of a literature review and pilot interviews conducted in the previous year (Yip et al., 2012b), and was refined based on the four case studies. The resulting process can be seen on the far left-hand column of Exhibit 6. Some of

Exhibit 6. Stakeholder Involvement in Early-Stage New PSS Development Process - Comparing the Four Cases

Stakeholders Identified (Short-form label)			Industry interest groups / authority / standard / domain experts	Patient's family & other care-giving organization	Supplier or partner to the company to develop the PSS	Customer's management	Company's management	Company's commercial	Company's development	Customer's informatics (IT support)	Company's service delivery	Customer's end users	Patients
			(Ex)	(P-O)	(V)	(Cu-M)	(Co-M)	(Co-Co)	(Co-T)	(Cu-S)	(Co-U)	(Cu-U)	(P)
Early stage development - main process step	**Case number & Process/Data Connectivity**	Process ↑ Data →	*For each main process step, the stakeholder groups that were involved or should have been involved according to the informants from each case study are marked with "X" below*										
(1) Generate ideas	Case 1					X				X		X	
	Case 2		X			X	X						
	Case 3				X	X	X	X	X	X		X	
	Case 4					X			X		X	X	
(2) Assess problem	Case 1								X			X	
	Case 2		X				X			X			
	Case 3					X	X	X	X	X		X	
	Case 4					X		X	X		X	X	
(3) Identify stakeholders	Case 1					X				X		X	
	Case 2		X				X					X	
	Case 3						X	X	X	X		X*	
	Case 4					X		X	X		X		
(4) Generate concepts	Case 1								X			X	
	Case 2		X				X					X	
	Case 3						X	X	X	X		X	
	Case 4					X		X	X			X	
(5) Select concepts	Case 1									X		X	
	Case 2		X				X					X	
	Case 3					X	X	X	X	X		X*	
	Case 4					X		X	X		X	X	
(6) Generate and test prototype	Case 1									X		X	
	Case 2		X				X		X			X	
	Case 3				X		X		X	X		X	
	Case 4			X		X		X	X		X	X	X

Note: *For Case 3, it was mentioned by the informants that Cu-S was representing the interest of users during the development process. Therefore, Cu-U is added here even though they were not explicitly mentioned.

the steps may overlap and there can be feedback loops within the process.

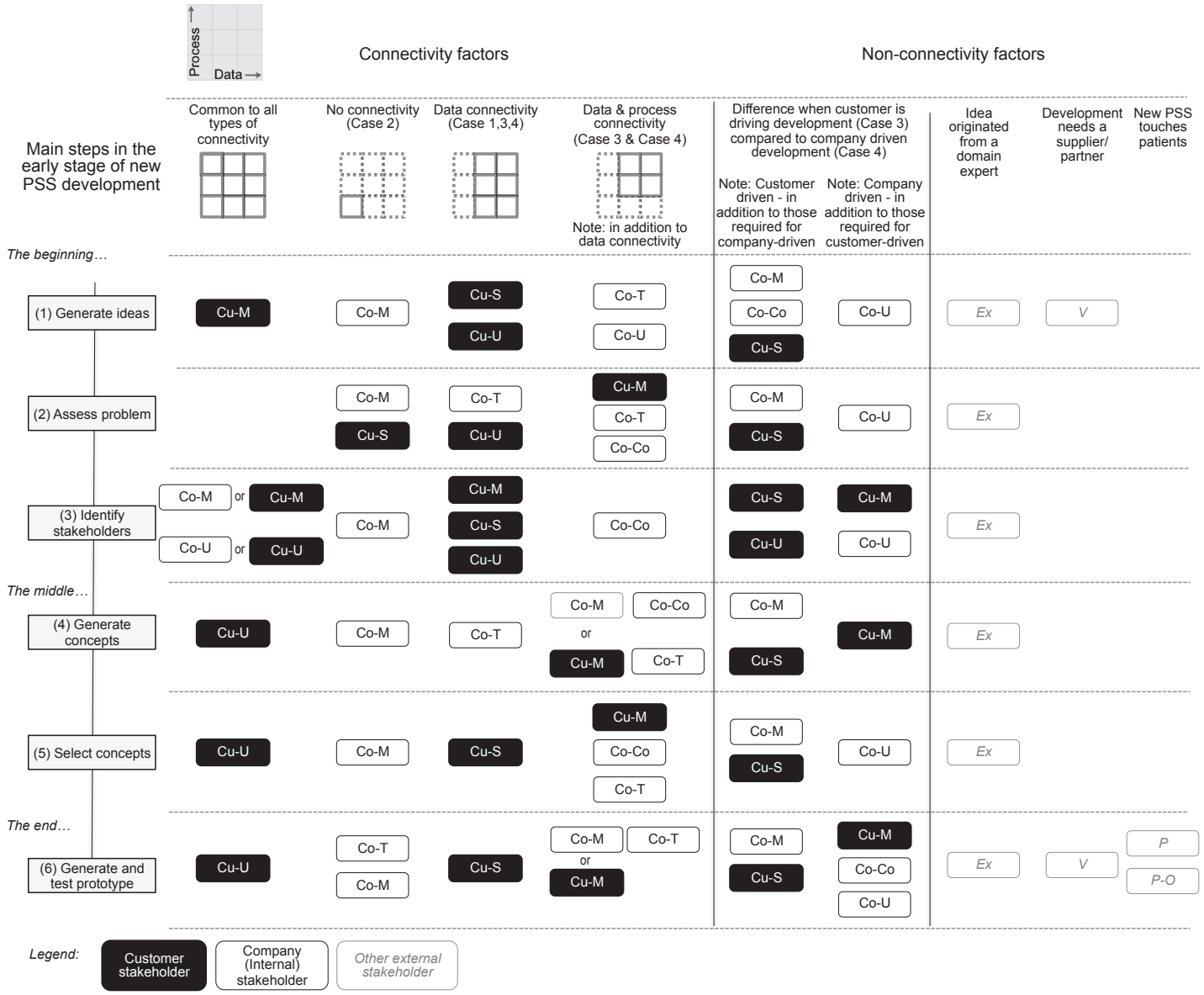
Exhibit 6 captures the informants' opinions about which stakeholder group was engaged or should have been engaged in each early-stage development process step. As the four cases have different degrees of process and data connectivity, it is possible to compare the requirements of stakeholder engagement with respect to the required level of PSS connectivity with its operating environment. This analysis is summarized in Exhibit 7.

In Exhibit 7, the analysis concerning connectivity factors shows stakeholder engagement that is common to all PSS development regardless of the level of connectivity, stakeholder engagement for PSS with no connectivity, stakeholder engagement for PSS with data connectivity, and stakeholder engagement for PSS with both data and process connectivity. Non-connectivity related factors are observed and some of these analyses are shown in Exhibit 7. For example, both Case 3 and 4 have data and process connectivity requirements with its operating environment, but the customer initiated the former and the manufacturer (the company) initiated the latter. A comparison of stakeholder engagement between the two parties driving the PSS development is made. Comparisons with respect to three other non-connectivity factors are also made as an exploration of what other contextual factors could influence stakeholder engagement in the early stage of the PSS development process. Summarizing from the interview findings, Proposition 4, which is further detailed into four sub-propositions, emerged – as illustrated in Exhibit 7.

> ***Proposition 4:*** *Stakeholder engagement in early stage development needs to be varied depending upon whether or not and to what extent the PSS has data and process connectivity with the systems in its operating environment.*

> ***Proposition 4.1:*** *Regardless of the required degree of connectivity between the PSS and its operating environment, there is a need to engage hospital management in the beginning to generate ideas, hospital end users in the middle, as well as at the end of the early stage to generate concepts, select concepts and test prototypes.*

Exhibit 7. Summary of Stakeholder Engagement Analysis Based on the Four Cases



Proposition 4.2: *For an independent PSS, there is a need to engage company management and external experts (if needed) throughout the early-stage development process. The need to engage hospital stakeholders or customer-facing internal stakeholders is lower in comparison to that of PSS with higher data and/or process connectivity.*

Proposition 4.3: *For PSS with only data connectivity requirements and no process connectivity requirements, there is a need to engage hospital informatics and hospital end users in the beginning of the early-stage development process to generate ideas, assess problems, and identify stakeholders; the company development group and hospital informatics in the middle to generate and select concepts; and hospital informatics at the end of the early stage to generate and test prototypes.*

Proposition 4.4: *For PSS with both data and process connectivity requirements, in addition to the stakeholders needed for "data connectivity only" PSS development (Proposition 4.3), four other stakeholder groups are identified to be required in the early-stage development process: company management and hospital management in the beginning to assess problems, generate and select concepts, and test prototypes; the company commercial group from assessing the problem to selecting the concepts; the company development group to work with the company commercial group and management team from the middle to the end of the early-stage development process.*

Relevance to Engineering Managers

The findings presented above are intended to support engineering managers in making decisions about stakeholder requirements in the early stage of the new product, service, or PSS development process in the healthcare ICT sector.

First, the four-level stakeholder identification framework can help engineering managers to consider which parties have an interest in the new development, and which parties are potentially impacted by the new development. The proposed stakeholder groups in the four-levels of business environment, system, product, and service delivery intend to extend the viewpoint of stakeholder from the common groups of customers and lead users, to multiple stakeholder groups that span from industry regulators to organizations supporting patients.

Second, the new product, service, or PSS to be developed can be characterized in terms of its data and process connectivity with the intended operating environment. Based on the degree of data connectivity and process connectivity, managers of the new development can have a more systematic way to understand the impact of the operating environment on the new development, and have a better awareness of which stakeholders are likely to be required during the early stage of the development process.

The propositions are guidance rather than prescription, and are useful to broaden the perspectives of engineering managers in new healthcare ICT PSS development.

Conclusions

Four case studies of new PSS development for healthcare informatics were explored, resulting in a new approach to characterize PSSs, and new understanding of stakeholder engagement requirements in the early stage of the development process. It has emerged that the degree of data and process connectivity between an ICT PSS and its intended operating environment is an important contextual factor that may impact effective stakeholder engagement in the early stage development process. By analyzing and depicting the required level of data and process connectivity between the new ICT PSS and the other systems in its future operating environment, stakeholders can be more systematically identified and more effectively engaged in the development process.

Although only limited cases specific to the healthcare ICT sector were included in this article, the propositions presented provide important directions for future work in PSS characterization and stakeholder engagement requirements in new PSS development, and encourage future theory building about contextual factors, stakeholder engagement, and PSS development effectiveness. The propositions can also serve as guiding concepts for engineering managers in the role of new product, service, or PSS development, to improve their assessment of the impacts of the intended operating environment on the new product/service/PSS, and to better identify and engage stakeholders for the early stage of the development process.

Additional case studies for new healthcare ICT PSS with different data and process connectivity combinations and for non-ICT sectors are needed to further explore how PSS can be systematically characterized for the early stage of the new PSS development process. Other non-connectivity contextual factors, such as who initiated or originated the new development and how new the PSS is, will also need to be further explored in order to understand the influence of contextual factors on stakeholder engagement in early-stage new PSS development process.

References

Aurich, J.C., Schweitzer, E., & Mannweiler, C. (2008). Integrated design of industrial product-service systems. In M. Mitsuishi, K. Ueda, & F. Kimura (Eds.), *Manufacturing Systems and Technologies for the New Frontier* (pp. 543-546). London: Springer.

Baines, T.S., Lightfoot, H.W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M., & Wilson, H. (2007). State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *221*(10), 1543-1552. doi:10.1243/09544054JEM858

Bell, M. (1986). Some strategy implications of a matrix approach to the classification of marketing goods and services. *Journal of the Academy of Marketing Science*, *14*(1), 13-20. Retrieved from http://jam.sagepub.com/content/14/1/13.short

Blumenthal, D. (2009). Stimulating the adoption of health information technology. *New England Journal of Medicine*, *360*(15), 1477-1479. Retrieved from http://www.nejm.org/doi/full/10.1056/nejmp0901592

Bower, D.J., Reid, M., Barry, N., & Ibbotson, T. (2000). Aligning process and meaning innovating in complex healthcare delivery systems. *International Journal of Innovation Management*, *4*(3), 299-317. doi:10.1016/S1363-9196(00)00018-4

Bryson, J.M. (2003). *What to do when stakeholders matter: A guide to stakeholder identification and analysis techniques*. Retrieved from http://cep.lse.ac.uk/seminarpapers/10-02-03-bry.pdf

Carbonell, P., Rodiguez-Escudero, A.I., & Pujari, D. (2009). Customer involvement in new service development: An examination of antecedents and outcomes. *Journal of Product Innovation Management*, *26*, 536-550.

Chen, L.M., Kennedy, E.H., Sales, A., & Hofer, T.P. (2013). Use of health IT for higher-value critical care. *The New England Journal of Medicine*, *368*(7), 592-4. doi:10.1056/NEJMp1214179

Christensen, M.C., & Remler, D. (2009). Information and communications technology in U.S. health care: Why is adoption so slow and is slower better? *Journal of Health Politics, Policy and Law*, *34*(6), 1011-34. doi:10.1215/03616878-2009-034

Department of Health. (2012). *The power of information: Putting all of us in control of the health and care information we need. London*. Retrieved from https://www.gov.uk/government/publications/giving-people-control-of-the-health-and-care-information-they-need

Driessen, P.H., & Hillebrand, B. (2013). Integrating multiple stakeholder issues in new product development: An exploration. *Journal of Product Innovation Management*, *30*(2), 364-379. doi:10.1111/j.1540-5885.2012.01004.x

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532-550. Retrieved from http://www.jstor.org/stable/10.2307/258557

Freeman, R.E. (1984). *Strategic management a stakeholder approach*. Marshfield, MA: Pitman Publishing.

Goedkoop, M.J., van Halen, C.J.G., te Riele, H.R.M., & Rommens, P.J.M. (1999). *Product service systems, ecological and economic basics report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ), 1999. Economic Affairs*.

Gummesson, E. (2007). Exit services marketing - enter service marketing. *Journal of Customer Behaviour*, *6*(2), 113-141. doi:10.1362/147539207X223357

Hill, P. (1999). Tangibles, intangibles and services: A new taxonomy for the classification of output. *The Canadian Journal of Economics / Revue Canadienne d'Economique*, *32*(2), 426-446. doi:10.2307/136430

Juehling, E., Torney, M., Herrmann, C., & Droeder, K. (2010). Integration of automotive service and technology strategies. *CIRP Journal of Manufacturing Science and Technology*, *3*(2), 98-106. doi:10.1016/j.cirpj.2010.02.002

Kahn, K. (2001). Market orientation, interdepartmental integration, and product development performance. *Journal of Product Innovation Management*, *18*(5), 314–23. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1540-5885.1850314/abstract

Kipley, D., & Lewis, A.O. (2008). Examining the efficacy of the multi-rater analysis methodology as an alternative approach in determining stakeholder power, influence and resistance. *The Business Renaissance Quarterly: Enhancing the Quality of Life at Work*, *3*(4), 101-125.

Kohli, A., & Jaworski, B. (1990). Market orientation: The construct, research propositions and managerial implications. *The Journal of Marketing*, *54*(2), 1-18. Retrieved from http://www.jstor.org/stable/10.2307/1251866

Levitt, T. (1972). Production-line approach to service. *Harvard Business Review*, *50*(5), 41-52.

Levitt, T. (1980). Marketing success through differentiation–of anything. *Harvard Business Review*, *58*(1), 83-91. Retrieved from http://www.commerce.uct.ac.za/managementstudies/Courses/bus2010s/2007/Nicole Frey/Readings/Journal Articles/Classics/Marketing success through differentiation - of anything.pdf

Maussang, N., Zwolinski, P., & Brissaud, D. (2009). Product-service system design methodology: From the PSS architecture design to the products specifications. *Journal of Engineering Design*, *20*(4), 349-366. doi:10.1080/09544820903149313

Mitchell, R.K., Agle, B.R., & Wood, D.J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *The Academy of Management Review*, *22*(4), 853-886. doi:10.2307/259247

Mont, O. (2002). Clarifying the concept of product–service system. *Journal of Cleaner Production*, *10*(3), 237-245. doi:10.1016/S0959-6526(01)00039-7

Narver, J.C., & Slater, S.F. (1990). The effect of a market orientation on business profitability. *Journal of Marketing*, *54*(4), 20-35. doi:10.2307/1251757

Neely, A. (2009). Exploring the financial consequences of the servitization of manufacturing. *Operations Management Research*, *1*(2), 103-118. doi:10.1007/s12063-009-0015-5

Nepal, B., Yadav, O., & Solanki, R. (2011). Improving the NPD process by applying lean principles: A case study. *Engineering Management Journal*, *23*(1), 51-68. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Improving+the+NPD+Process+by+Applying+Lean+Principles:+A+Case+Study#0

O'Sullivan, A. (2006). Why tense, unstable, and diverse relations are inherent in co-designing with suppliers: An aerospace case study. *Industrial and Corporate Change*, *15*(2), 221-250. doi:10.1093/icc/dtj015

OECD.Stat. (2013). *OECD health spend (% GDP)* [Data file]. Available from http://stats.oecd.org/Index.aspx?DataSetCode=SHA

OECD.stat. (2013). *OECD health spend (Million US$)* [Data file]. Available from http://stats.oecd.org/Index.aspx?DataSetCode=SHA

OECDiLibrary. (2013). *Total expenditure on health as a percentage of gross domestic product* [Data file]. Retrieved from http://www.oecd-ilibrary.org/social-issues-migration-health/total-expenditure-on-health-2013-2_hlthxp-total-table-2013-2-en

Oliveira, P., & von Hippel, E. (2011). Users as service innovators: The case of banking services. *Research Policy*, *40*(6), 806-818. doi:10.1016/j.respol.2011.03.009

PricewaterhouseCoopers. (2013). *A review of the potential benefits from the better use of information and technology in health and social care final report* (pp. 1–60). Retrieved from https://www.gov.uk/government/publications/study-on-the-impact-of-digital-technology-in-health-and-social-care

Queenan, C.C., Angst, C.M., & Devaraj, S. (2011). Doctors' orders – if they're electronic, do they improve patient satisfaction? A complements/substitutes perspective. *Journal of Operations Management*, *29*(7-8), 639-649. doi:10.1016/j.jom.2011.03.001

Ranta, P. (2010, May). *Information and communications technology in health care*. Aalto University, Finland. Retrieved from http://epub.lib.aalto.fi/fi/ethesis/pdf/12398/hse_ethesis_12398.pdf

Shortliffe, E.H. (2005). Strategic action in health information technology: Why the obvious has taken so long. *Health Affairs (Project Hope)*, *24*(5), 1222-33. doi:10.1377/hlthaff.24.5.1222

Shostack, G.L. (1977). Breaking free from product marketing. *Journal of Marketing*, *41*(2), 73-80.

Shostack, G.L. (1984). Designing services that deliver. *Harvard Business Review*, *62*(1), 133-139.

Smirnova, M.M., Podmetina, D., Vaatanen, J., & Kouchtch, S. (2009). Key stakeholders' interaction as a factor of product innovation: The case of Russia. *International Journal of Technology Marketing*, *4*(2/3), 230-247.

Smith, A.M., Fischbacher, M., & Wilson, F.A. (2007). New service development: from panoramas to precision. *European Management Journal*, *25*(5), 370-383. doi:10.1016/j.emj.2007.06.007

Steiner, F., Ihl, C., Piller, F., & Tarman, R.T. (2011). Embedded toolkits: Identifying changing user needs during product usage. *Engineering Management Journal*, *23*(4), 3-13.

Talke, K., & Hultink, E.J. (2010). Managing diffusion barriers when launching new products. *Journal of Product Innovation Management*, *27*(4), 537-553. doi:10.1111/j.1540-5885.2010.00734.x

Tan, A., McAloone, T., & Matzen, D. (2009). Service-oriented strategies for manufacturing firms. In T. Sakao & M. Lindahl (Eds.), *Introduction to Product/Service-System Design* (pp. 197-218). London: Springer-Verlag.

The outlook for medical devices in western Europe. (2012, April 23). *PR Newswire*. Retrieved January 07, 2013, from http://www.prnewswire.com/news-releases/the-outlook-for-medical-devices-in-western-europe-148494335.html

Von Hippel, E. (1976). The dominant role of users in the scientific instrument innovation process. *Research Policy*, *5*(3), 212-239. doi:10.1016/0048-7333(76)90028-7

Williams, W., & Lewis, D. (2008). Strategic management tools and public sector management. *Public Management Review*, *10*(5), 653-671. doi:10.1080/14719030802264382

Wind, J., & Mahajan, V. (1987). Marketing hype: A new perspective for new product research and introduction. *Journal of Product Innovation Management*, *4*(1), 43-49. Retrieved from http://www.sciencedirect.com/science/article/pii/S0737678287800061

Yang, L., Xing, K., & Lee, S. (2010). A new conceptual life cycle model for result-oriented product-service system development. *2010 IEEE International Conference on Service Operations and Logistics and Informatics (SOLI)*, 23-28. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5551621

Yin, R.K. (1994). *Case study research design and methods* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Yip, M.H., Phaal, R., & Probert, D.R. (2012a). Characterizing product-service systems in the healthcare industry – an internal stakeholder perspective. *The IEEE International Conference on Industrial Engineering and Engineering Management Conference (IEEM 2012), Hong Kong*.

Yip, M.H., Phaal, R., & Probert, D.R. (2012b). Value co-creation in early stage new product-service system development. In Tossavainen, P. J., Harjula, M., & Holmlid, S. (Eds.), *Proceedings of 3rd Service Design and Innovation Conference (ServDes. 2012)* (pp. 287-298). Linkoping, Sweden: Linkoping University Electronic Press. Retrieved from http://www.ep.liu.se/ecp/067/ecp12067.pdf

About the Authors

Man Hang Yip is a part-time PhD student at the Institute for Manufacturing at the University of Cambridge. Her research interest is in early-stage new product-service system development in the healthcare industry. She works as an operations excellence expert in a healthcare equipment/software manufacturer. Yip holds a Bachelor of Engineering from the Hong Kong University of Science and Technology (HKUST), a Master of Engineering from Cornell University, Ithaca, USA, and an MBA (IT Management) from the HKUST.

Robert Phaal is a Principal Research Associate in the Engineering Department of the University of Cambridge, based in the Centre for Technology Management. He conducts research in the area of strategic technology management, with particular interests in the development and application of practical management tools in technology-intensive firms. He has a mechanical engineering background, with a PhD in computational mechanics, and industrial experience in technical consulting, contract research and software development.

David Probert is Reader in Technology Management, founding member and Head of the Centre for Technology Management within the Institute for Manufacturing at the University of Cambridge Engineering Department. This is a team of around 40 research and academic staff, with an active consortium of collaborating companies. Current research interests include technology and innovation strategy, technology management processes, technology intelligence, open innovation, industry and technology evolution, product-service systems and industrial sustainability.

Contact: Ms. Man Hang Yip, University of Cambridge, Institute for Manufacturing, Department of Engineering, 17 Charles Babbage Road, Cambridge, Cambridgeshire CB3 0FS, United Kingdom; phone: 447731688741; mhy29@cam.ac.uk