MAPPING STAKEHOLDER ENGAGEMENT NEEDS IN EARLY-STAGE SYSTEM DEVELOPMENT PROCESS

Yip, Man Hang

Institute for Manufacturing, University of Cambridge

ABSTRACT

Companies design, develop, and market new systems of products and services, through the process of translating beneficiaries' needs into design specifications, where beneficiaries are those who generate value when using the new product or experiencing the new service enabled by the product. Successful new systems of products and services attract potential beneficiaries. This study explores how to identify the stakeholder engagement requirements of a new system at its early stage of development.

The study proposes a procedure and a tool - a new visual representation called the stakeholder-value map - to show the system development team how stakeholders are to interact with the system's key elements, and hence inform the timing of stakeholder involvement, for realising the value proposition of the new system. A working theoretical construct is also emerged from the study: for a new system to have a higher chance of market adoption, one can first visualise the 'route' of value-creation, from the lowest value-level product/service elements to the highest value-level service elements; then, identify the requirements for stakeholder engagement in the new system development.

Keywords: Product-Service Systems (PSS), Visualisation, Design process, Stakeholder, Value-in-use

Contact:
Yip, Man Hang
University of Cambridge
United Kingdom
mhy29@cam.ac.uk

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1 INTRODUCTION

New product and service development is risky. Companies that pay early attention to the risk could significantly reduce cost and time to market (Goffin and Mitchell, 2005). With an increasing number of companies designing functional total care products (Alonso-Rasgado *et al.*, 2004) that no longer ends at the exchange of product ownership but also cares about the utility of the systems comprising product and service elements (Sakao and McAloone, 2011), the product-service system (PSS) development process has become more complex to manage – more components, interdependencies, diversity, and variabilities (Zou *et al.*, 2018). If a development team can visualise the complexity of the system at the early stage of the development process using a set of models, the team could be in a better position to manage the development. This study explores the usage of a standard set of diagrammatic representations to show the key configuration parts of a new system, how these key elements associate with stakeholders, and how these stakeholders and elements need to interact to create the intended value proposition. The aim of the study is to refine the proposed tool that can be used by practitioners. The attractiveness of exploring the usage of visual representations for early-stage system development is that using diagrams has the advantage of making the invisible relationships apparent (Kazmierczak, 2001), improving perception of system relationships (Logan *et al.*, 2018), preventing cognitive inertia, and mobilising actions (Kerr and Phaal, 2017).

The remaining of the paper is as follows. Section 2 is a literature review. Section 3 summaries the approach of the study. Section 4 presents the case studies, and Section 5 is the concluding discussion.

2 LITERATURE REVIEW

2.1 System

The concept of system comes from general system theory and its central position is that "the whole is more than the sum of its parts" (von Bertalanffy, 1950, p. 142). A system is defined as "a complex of interacting elements", where "interaction means that the elements stand in a certain relation, R, …their behaviour in R is different from their behaviour in another relation, R′" (von Bertalanffy, 1950, p. 143).

2.2 Product, service, and product-service system

The definition of product and service in this study does not rely on the tangibility of the object, as this demarcation had created confusion with the advancement of digital technology (Yip *et al.*, 2019). The distinction used to separate service from product is its ability to be stocked up: while a product can be stocked up independently without losing its identity over time, a service cannot and requires the presence of both producer and consumer (Hill, 1999). The overall offering can be referred to as a product-service system (PSS). One of the earliest definitions of PSS is "a marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.*, 1999, p. 18). The definition of PSS has then evolved, and the description of PSS is found to be numerous, diverse and at times conflicting (Rizvi and Chew, 2018). In this study, the term system is used when referring to PSS defined as per Goedkoop et al. (1999). It is like the term 'solution' or 'offering' generally used in industry.

2.3 Stakeholder identification in new system development process

Stakeholders in new system development process can be defined as groups or individuals who can affect or are affected by the new system (Freeman, 1984). For system development, there are proposals to identify stakeholders using the concept of direct and indirect product and service stakeholders (Rondini *et al.*, 2015) and along the life cycle of a product (Bertoni *et al.*, 2016; Pigosso and Mcaloone, 2016). There is also proposal to adopt model base system engineering (MBSE) to identify system stakeholders (Boggero *et al.*, 2021).

In this study, a four-level stakeholder identification framework for new system development that contains 32 internal and external stakeholder groups (Yip and Juhola, 2014) is adopted. This framework has been found useful by companies to systemically identify stakeholders during system development (Yip *et al.*, 2019). The four different levels of stakeholders are: (1) those in the **environment** where the new system is to be used in; (2) those involved in the operations of the new **system/offering**; (3) those who are to manage and operate the **product** portion of the new system; and (4) those who are **delivering or receiving the services** of the new system.

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There are tools and methods that assist companies to translate and prioritise stakeholders' needs into the design specifications. These tools and methods include Kansei engineering (Nagamachi, 1995), quality function deployment (QFD) (Akao, 1990), Analytic Hierarchy Process (AHP) and its generalised form called the Analytic Network Process (ANP) (Saaty, 1983, 2008), the Kano model (Sauerwein *et al.*, 1996), and their hybrids (Geng *et al.*, 2011; Hartono *et al.*, 2013; Tontini, 2007). Among the reviewed models and tools, QFD-based tools appear to be the most robust in supporting the incorporation of stakeholder interests into the design. It correlates customer needs with technical requirements and can be extended to correlate environmental needs with quality requirements (Ramani *et al.*, 2010).

In the reviewed literature, the engagement of the identified stakeholders in the new system development process is often discussed in two ways. First, stakeholders are implied to be engaged in the design specification generation step, when companies elicit, capture, and translate stakeholder needs as technical and quality requirements. Second, design methodology literature has proposed various degrees of involving users, such as lead-user involvement (von Hippel, 1976) and Living Lab (Dell'Era and Landoni, 2014). In this study, the timing of how to engage stakeholders according to their potential interactions and interests on the different configuration parts of a new system is explored, to improve the success in generating value-in-use - a concept to be presented in the next sub-section.

2.4 Value-in-use, Service-Dominant logic, and the role of Actor

The concept of value-in-use stems from service-dominant (S-D) logic (Vargo and Lusch, 2004) and is closely related to the concept of manufacturers' role in cocreating value with customers (Kowalkowski, 2011). The role of producer-consumer in an exchange of product/service for value has been extended in S-D logic to a broader term of actor-actor exchange to recognise the exchange among institutions. In S-D logic, the proposition is that value is always cocreated with the beneficiary coordinated through institutional arrangements. Value is uniquely determined by its beneficiary (axiom 2, 4 and 5 of the S-D logic) (Vargo and Lusch, 2016) and is context dependent (Vargo and Lusch, 2008). The S-D logic view of service ecosystem is close to the concept of actor networks in actor-network theory (ANT) (Vargo and Lusch, 2016). Actor-network theory (ANT) suggests that "society, organisations, agents and machines are all effects generated in patterned networks of diverse (not simply human) materials" (Law, 1992). In this study, stakeholders can be understood as actors in ANT, that would include human stakeholders (e.g. engineers, potential service beneficiaries), institutional stakeholders (e.g. government departments, charity), tools and technologies (e.g. machines, programming codes), and other living organisms (e.g. animals, plants). The views of value and actor network in this study are adopted from S-D logic and ANT. This study explores the interrelationships between stakeholders and system configuration parts, and how these interactions may impact the system's value-in-use proposition. How much value a target beneficiary perceived influences the beneficiary's decision to adopt the new system.

2.5 Diagrammatic representation

Diagrammatic representation is a type of external representation, where external representations are defined as knowledge and structures in the environment that allow human-being to interact with and can be two- or three-dimensional (de Vries, 2012; Zhang, 1997). The systematic usage of models, where a model is "a simplified version of a concept, phenomenon, relationship, structure of a system" (Hart, 2015, p. 3), in supporting system development activities can be found in the MBSE method (Rashid *et al.*, 2015). MBSE has the benefits of avoiding inconsistencies in system information and promote communicability (Timperley *et al.*, 2023). The theories underpinning the usage of diagrammatic representation to support the system design process appeared to be mainly from social and cognitive sciences. For example, the interaction between human actors, non-human actors and their environment has been explored in ANT research (Latour, 2005; Law, 1992). The usage of external representations to help people solve problems has been investigated in cognitive psychology (Zhang, 1997). The use of multiple representations has been put forward to facilitate inferential reasoning and complex information management (Kirsh, 2010). The tool proposed in this study involves using an external representation to facilitate the identification of stakeholder engagement requirements.

3 APPROACH

This study is exploratory in nature. The intention is to propose a new procedure and a tool to identify stakeholder engagement requirements in early-stage system development through case studies. A case

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is a commercialised system and is the unit of analysis. The study follows the procedural action research approach (Maslen and Lewis, 1994; Platts, 1993). For each case, the primary data source is the analytical output of the application of an established analytical approach that characterises a system, called the System Design Characterisation (SDC) Approach (Yip *et al.*, 2016). The SDC (to be presented in the next sub-section) is chosen to gather data because it clarifies design specifications for early-stage system development through the usage of a standard set of diagrammatic representations, which fits the aim of this study. The secondary data source is publicly available information about the systems. The first case is used to build a prototype tool, and subsequent cases are to build, test, and refine this tool as per Maslen & Lewis (1994). There is no pre-determined number of cases planned, as the objective is to arrive at procedural stability. All changes to the tool are to be documented: primary change for adding or removing main steps in the procedure; secondary change for modifying the order of steps in the procedure; and tertiary change for wordings or legends clarifications.

3.1 System Design Characterisation (SDC)

SDC is developed between 2016-2019 for application in business settings (Yip *et al.*, 2016) from the research instrument PSS Characterisation Approach (PSSCA) that was stabilised in 2014. PSSCA is a five-step workshop approach that uses external representations to analyse a system for its four design characteristics. These four design characteristics have been found to be useful in clarifying design specifications (Yip, 2015). The first characteristic, the customer perceived value-level, is the value that the target beneficiaries perceive they can generate from the new system. The higher the value-level, the more desirable the system is. The second characteristic, connectivity number (Equation 1), is the number of interactions between the new and existing elements of a system or with its operating environment. This number shows the level of attention above routine design effort that the development team needs to give to the system design.

Connectivity number = 2 x number of 'new impacting existing' relationships + 1 x number of 'existing impacting new' relationships (Equation 1)

The third characteristic, the type and degree of connectivity, is related to the connectivity number, and provides more information about the nature of the relationships among the new and existing elements of a system. The relationship can be ‘independent’ when there is no relationship between the new and existing elements; ‘linked’ when there is/are new elements depend(s) on the existing element(s) to function properly; and ‘incorporated’ when there is/are new elements impact(s) the functioning of existing element(s). The last characteristic, system configuration type, represents the structure of a system in terms of how the product and service portions interact. In the original PSSCA, there were five-mirroring pairs of structural representations, which were replaced by eight molecular representations (see Figure 1) during the SDC approach development (Yip, 2022).

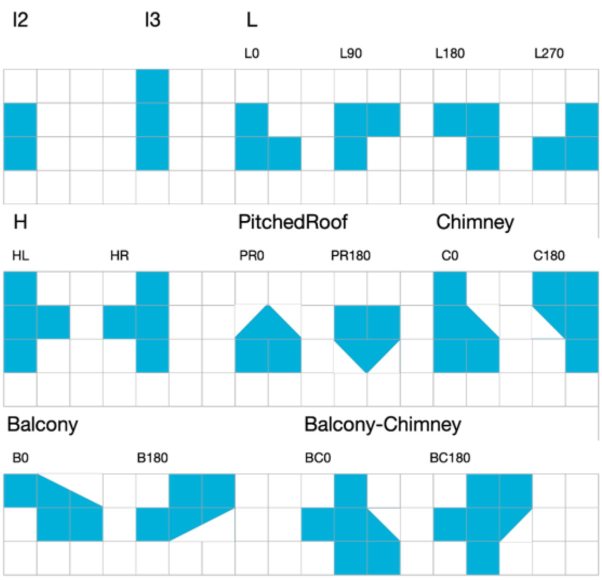

Figure 1. Eight novel molecular representations for system configuration types

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The SDC steps are: (1) stakeholder identification; (2) element identification; (3) decomposition; and (4) representation. This is followed by the new step that was emerged from the first case study, called stakeholder-value mapping. Step 1 is where the company participants choose the stakeholders of the new system using the stakeholder identification table from Yip and Juhola (2014). Step 2 is where the researcher guides the company participants to think from a functional perspective to identify the key elements of the system. An element can be a component or a sub-system. All identified elements are marked whether they are existing or to be developed (new). The elements that are viewed as important by the customers are marked. Step 3 is the systematic layout of the identified elements, based on their interdependencies, from the highest to the lowest customer perceived value-level. The output is a water-fall-like decomposition diagram, with arrows showing the different types of interactions between the elements. Step 4 is to build mini-representations from the elements with 'incorporated' (black arrows) and 'linked' interactions (white arrows) in the decomposition diagram and place them along the customer perceived value-level. Each mini-representation would be one of the eight molecular representation (Figure 1). Step 5 is the new step, where the stakeholders identified are mapped with their affiliated mini-representations, and opportunities to better engage stakeholders in the development process are identified. Step 3-5 can be done by the researcher and discuss with the company participants afterwards.

4 CASE STUDIES

Two cases are presented in this paper. Both case studies, conducted in 2020, belonged to the same company in the polymers industry. The commercialised systems were for the medical market, with an embedded innovative polymer. The same informant participated in both cases remotely due to COVID19 restrictions. Case A was a new fraction fixation surgery that enabled patients to have faster facture recovery. Case B was a dental prosthetics that improved dental patients' on-going experience.

4.1 Case A

The informant told the researcher that the benefits of “faster fracture recovery” did not reach the potential beneficiaries (patients) until later years, despite the benefits were presented to surgeons in medical conferences. On the company website, there was an abundance of information aimed at healthcare professionals, which included cost reduction, better intraoperative efficiency, and improved post-operative patient recovery progress. There was one patient testimonial video and a fact sheet for potential patients. The fact sheet has eight benefits listed, with five about patients’ experience, and three about the new material and the specific requirements of medical procedures.

4.1.1 Findings

For stakeholder identification, at the environment level, the informant identified all six groups as stakeholders where two were important. At the system/offering level, the informant identified 10 out of the 12 stakeholders, with three being important. At the product level, the informant identified only two out of eight stakeholders, and both were important. At the service delivery level, the informant identified four out of six stakeholders with two being important. For element identification, six service and seven product elements were identified. Three elements, all services, were identified as important to customers. There were three new service and four new product elements. The decomposition step identified the highest perceived-value level is level 5, and the element is "faster fracture recovery" service that interacts directly with the target beneficiary - a patient with bone fracture. This system configuration was represented by seven molecular diagrams (Figure 2).

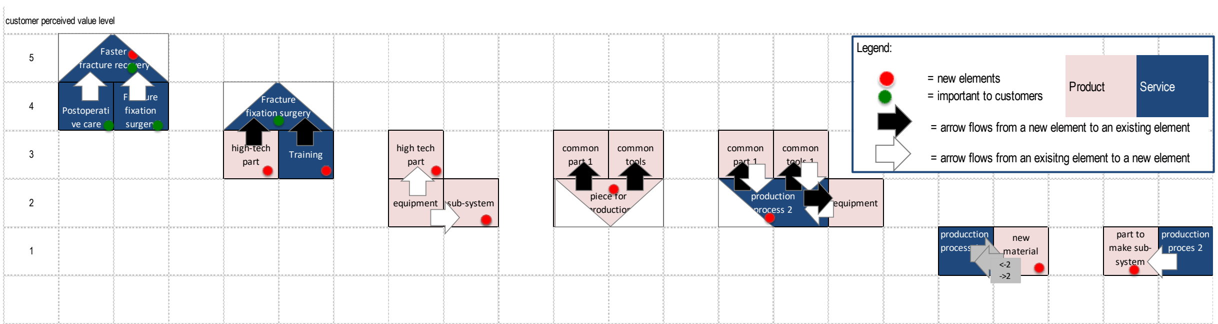

Figure 2. Representation diagram of Case A (elements anonymised)

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Using connectivity number (Equation 1) as an indicator of system complexity, the most complex inter-level interactions of this system was between value-level 2 and 3 with a connectivity number of 15, and the most complex intra-level interactions was in level 1 with a connectivity number of five. The key technology that enabled "faster fracture recovery" was embedded in the **new material** that was used to make the new products and the **new production process** in level 1 and level 2 respectively.

4.1.2 The emergence of the stakeholder-value map

There were three to four levels between these new products and processes in level 1 and level 2 to the highest level 5 that interacted with the beneficiaries. To surface the value of the new system to the target beneficiaries, the technical details at the lower levels would need to be visible to them. This observation matched the anecdote from the informant. To understand stakeholder engagement needs, the stakeholders identified were mapped to the elements in the representation diagram, and the value-level of each element was mapped to its stakeholders. This resulted in the stakeholder-value map (Figure 3).

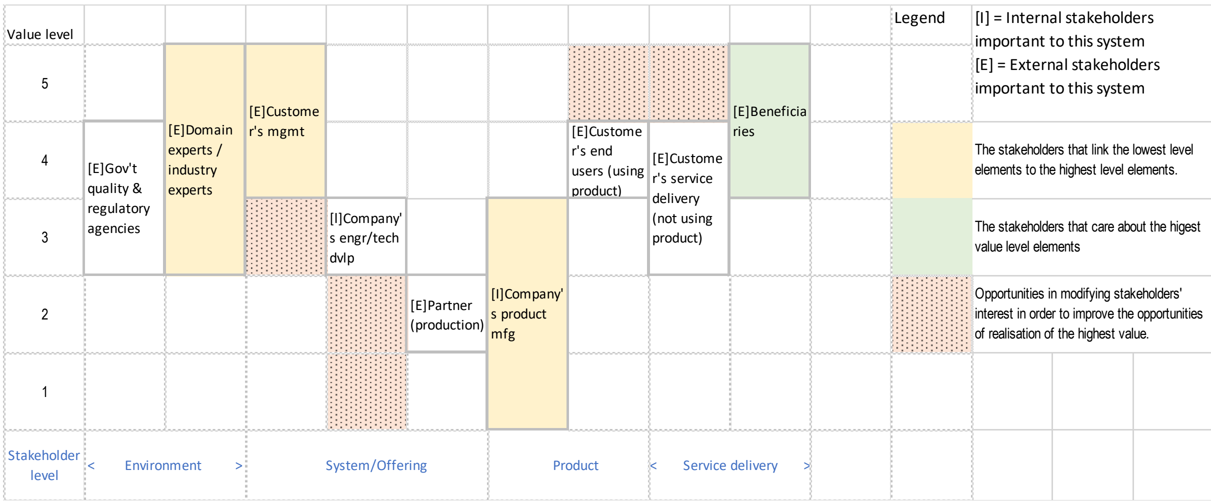

Figure 3. Stakeholder-value map for Case A

The stakeholders that link the elements at lowest to the highest value-level are coloured in beige, to show the 'route' of value-creation. Figure 3 shows that the only 'route' from value-level 1 to value-level 5 was to be through the internal stakeholder "company's product manufacturing" and the external stakeholder "domain experts / industry experts". Additionally, only "company's product manufacturing" participated in the value proposition creation between the most complex interactions between level 2 and level 3. To avoid "company's product manufacturing" from becoming a bottleneck in communicating the value of the innovation at the lower-level elements, the "company's engineering / technical development" could consider extending their interest in the development of the elements at level 1 and level 2. Similarly, to avoid "domain experts / industry experts" from becoming a bottleneck in representing the important information at level 1 to 3 in the development process to the "beneficiaries", "customer's management", "customer's end users (using product)" and "customer's service delivery (not using product)" could extend their interests to interact with level 3 and 5 elements.

4.2 Case B

The informant told the researcher that from market survey, the major issue with existing dental prosthetics implants was the discomfort experienced by patients. Videos on the company websites provided the information that 90% of patients with the company's new dental prosthetics implant had reported an improvement in chewing and in-mouth feeling. The company website targeted healthcare professionals. There were no patient testimonial nor explicit mentioning of benefits to potential patients.

4.2.1 Findings

For stakeholder identification, at the environment level, the informant identified all six groups as stakeholders, and two as important. At the system/offering level, the informant identified 11 out of the

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12 stakeholders, with five being important. At the product level, the informant identified only three out of eight stakeholders, and two were important. At the service delivery level, the informant identified three out of six stakeholders with two being important. For element identification, seven service and two product elements were identified, of which two service elements were identified as important to customers. There were four new service and one new product elements identified. The highest customer perceived value-level was 5, where the "new experience of dental prosthetics" directly interacts with the potential beneficiary - a potential patient that needs dental prosthetics. The system configuration was represented by six mini-diagrams (Figure 4). Using connectivity number (Equation 1) as an indicator of system complexity, the most complex inter-level interactions was between value-level 3 and 4 with a connectivity number of eight, and the most complex intra-level interactions was in level 2 with a connectivity number of two. The service element "on-going dental check-up" were found in two mini-representations, one spanning from level 3 to level 4 and the other from level 4 to level 5 (directly supporting the system's value proposition of "new experience of dental prosthetics"). This element was with a connectivity number of seven, the most complex element in this system.

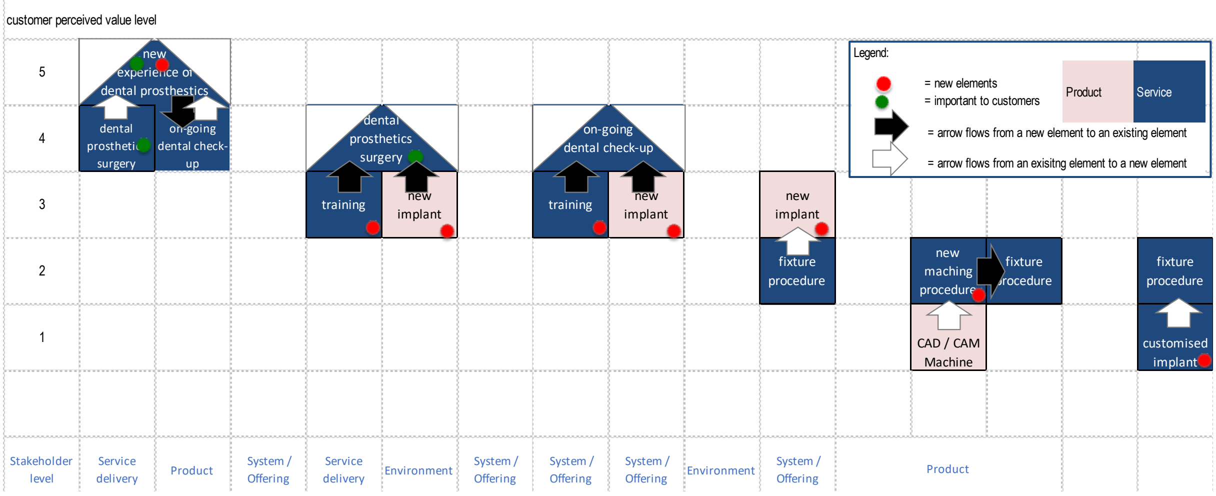

Figure 4. Representation diagram of Case B (elements anonymised)

4.2.2 First application of the stakeholder-value mapping step

Following the procedure that was emerged from Case A, the stakeholders identified as important to the system were mapped to the elements they were interested in or impacted by. The procedure that was emerged from Case A was applied directly to Case B, and no modifications of the procedure was needed. Figure 5 shows Case B's stakeholder-value map. There is only one 'route' of value creation, highlighted in beige, through "company's product manufacturing" and "domain experts / industry experts". The interests of these two stakeholders do not overlap, which may be a risk to surface the innovative customised implant and machining procedure at level 1 and 2 to the targeted "beneficiaries".

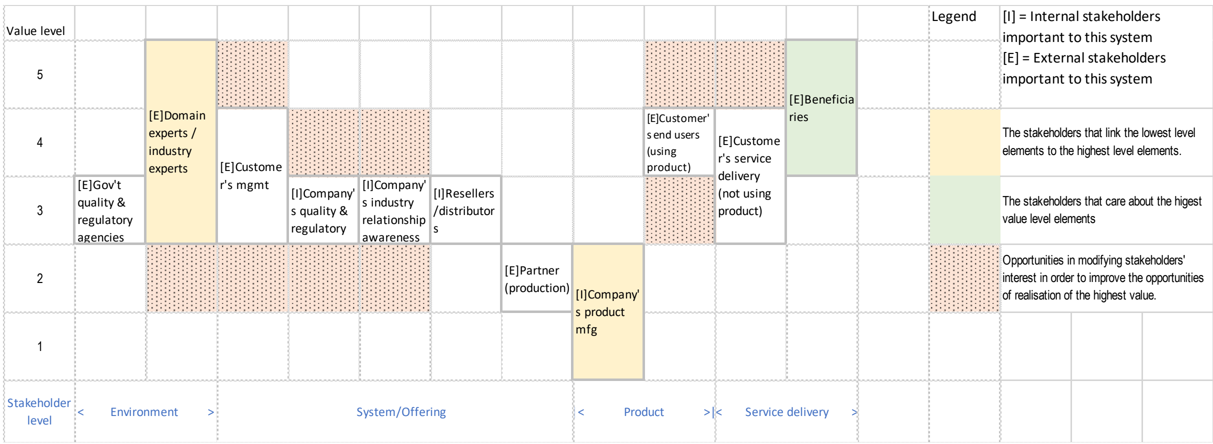

Figure 5. Stakeholder-value map for Case B

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The beneficiaries who interacted at the highest value-level of the system, level 5, could be influenced by the stakeholder at the same level, that is the “domain experts / industry experts”. The “domain experts / industry experts” impacted the creation of value proposition from level 3 to level 5. The stakeholders related to "on-going dental check-up" at level 4, namely "customer's management", "customer's end users (using product)", "customer's service delivery (not using product)", could be targeted to communicate the benefits of the new dental prosthetics and be made aware of the success of the new training for dentists to use this new implant (the elements at level 3). The most complex inter-levels relationship of this system was between level 3 and 4, but only three of the 11 important stakeholders identified had influence on elements that span across these two levels. It would be beneficial to extend the interests of level 4 stakeholders to the design of the level 3 elements, and for level 3 stakeholders to be involved in the level 4 elements design. For example, “customer’s end users (using product)” at level 4 could be involved in designing the “training” service in level 3. Another example would be for “company’s quality & regulatory” and “company’s industry relationship awareness” at level 3 to extend their interest and influence on the level 4 element design. There was no stakeholder with interests that spanned from level 1 to level 3. To strengthen the interchange of information about the level 1 to 3 design, level 3 stakeholders could extend their interest to level 2 elements, that is “domain experts / industry experts”, “customer’s management”, “company’s quality & regulatory” and “company’s industry relationship awareness.

5 CONCLUDING DISCUSSION

To summarise, this study is to explore and propose a new procedure and tool for identifying the stakeholder engagement requirements in the early stage of the new system development process. The approach of procedural action research is adopted. Two case studies documented in this paper showed the emergence of the new procedure, the stakeholder-value map, and its first successful application. The stakeholder-value map is a diagrammatic representation of stakeholders' association with key elements in a system. The stakeholder-value map appeared to be effective in both cases conducted so far in this study to help identify the needs of stakeholder engagement during the development process. This is an encouraging finding, as helping new system development team to visualise and align early-on the stakeholder engagement needs, who to engage and when to engage, may improve the chance of commercial success of the new system.

A working theoretical construct is also emerged from the study. The theoretical construct is this: for a new system to have a higher chance of market adoption, one can first visualise the ‘route’ of value-creation, from the lowest customer perceived value-level product/service elements to the highest customer perceived value-level service elements; then, identify the requirements for stakeholder engagement in the new system development. Stakeholder engagement refers to the timing of which stakeholders to engage and how to engage: to actively influence, be informed about, or to disseminate their knowledge about which product/service configuration parts of the new system.

As a next step, to finalise the tool for practitioners to identify stakeholder engagement needs, more cases from different industries are to be targeted. There are two cases that are on-going at the time of writing this paper, one in retails industry and one in education sector.

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