KNOWLEDGE SHARING APPROACHES IN METHOD DEVELOPMENT

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ABSTRACT

Product-Service Systems (PSS) or, life-cycle offerings, is a challenge for knowledge sharing within manufacturing industry due to an integration of intangible (tacit) and tangible (explicit) domains. One consequence is that the engineers have to make sense of abstract customer information in early development. For this, they need knowledge sharing support. Method developers are employees that are responsible for in-house development of such support. There are similarities in their contemporary work practices and some aspects of the development of life-cycle offerings. The aim in this paper is to draw from the method developers' experiences in managing acquisition of user information for the purpose to contribute to knowledge sharing in early development. We have found that the problem-setting approach applied by the method developers could help the identification, analysis and application of user needs, thus also could be applied to identify metrics/characteristics for intangibles.

Keywords: Knowledge Enabled Engineering, Product-Service Systems, PSS, Knowledge Based Tools

1 INTRODUCTION

In recent time, Product-Service Systems (PSS), i.e., a special kind of service proposition [1], is an ongoing movement in manufacturing businesses. The main business argument for moving towards PSS, for both customers and providers, are increased customer value, a long term improved return on investment, and a more stable cash flow management [2]. Developing a PSS offer implies though that the firm need to have a life-cycle view and be able to manage the development of both tangibles (i.e., product characteristics) and intangibles (i.e., service characteristics) in a coordinated or integrated development process [2]. A product's impact during its life-cycle is highly dependent on decisions made during early development [3].

The focus on "user value" throughout the life period of the offer changes the firm's innovation strategy and also the design process [4]. The focus on utilization rather than standalone products, increase the importance of understanding what is essential for the customer/user in early development, i.e., it becomes important for product developers to understand the customer's need in order to meet their expectations [5]. Further, since life-cycle development takes a longer time horizon into account, and insist on support to explore and evaluate many more design alternatives, e.g., standalone, leasing or total offer, the development becomes more intertwined compared to stand alone products. These kinds of integrated offerings and subsequently their development processes are expected to be produced in a network of actors, which will add design dimensions such as social and cultural [6].

Although there are many possibilities and benefits by a change of business plan, there are also difficulties. One difficulty is to capture and formalize experience-based, or tacit knowledge, e.g., user needs, engineering know-how, lessons learned. Another is to share and make use of such a knowledge base to benefit the development of life-cycle offers. Simulation and modeling tools such as Computer Aided Engineering (CAE), Computer Aided Design (CAD) and Knowledge Based Engineering (KBE) are successfully used in product development today. But, for example, being able to simulate life-cycle characteristics for early decision making whether to go for a total offer or not is a key for the future [5].

A changed business plan and development of integrated life-cycle offers opens up traditional boundaries within manufacturing firms. Typically, acquisition of user information is a marketing responsibility, and the core skills of engineers are to find out how to realize what is specified. The acquisition of user information for technical product development, naturally focus on generating requirements for a particular product, e.g., what kind of product features that is required, while integrated life-cycle offers focus on a more value driven approach, e.g., what kind of functionality or performance that is needed. An engineer thus finds that the inputs to the development of life-cycle offers have radically shifted in its nature, i.e. from concise and product-focused to abstract and functionality-focused. This radical shift makes it possible to argue that the engineers must not only possess problem solving skills, but also problem definition skills [7].

To cope with these fuzzy front-end activities engineers have to be equipped with supportive tools and practices. Mature and large organizations commonly have staff that is responsible for purchase of computer support, but in high-tech focused organizations there are often people that develop in-house support for engineers. These people, here called method developers, apply technology pull approach in some cases, and a technology push in others. Technology refers here to applications, computer support and expert systems. Technology pull is used to describe a situation when an internal client is asking for a specific type of solution; cf. the method developer gets a specification and has to solve the problem. Technology push is used to describe a situation when the method developer identifies a need within the organization; cf. the method developer has to define the problem and find user needs before solving it. Applying the framework of life-cycle integration, *the intent in this paper is to account for the method developers' experiences in managing these two approaches for the purpose to contribute to a discussion about knowledge based tools for PSS in early development.*

2 METHOD

In general, the research project of which this study is part of builds upon an action research approach [8]. Briefly, an action research approach means that the researchers should be close to the industrial context and have an open access to the practices. Within the project there is one industrial PhD student, located on site, and one academic PhD student, i.e., two of the authors of this paper. The case for this paper is found within the manufacturing company affiliated to the research project.

The research project aims to support PSS development teams to innovate by studying knowledge strategies, and from those results propose tools or methods to increase heterogeneous collaboration. One focus for the project is life-cycle knowledge modeling; another is collaborative innovation work practice.

In particular, the study here is inspired from a pre-study in which three main challenges were identified. First, it was found that the implementation of a radical innovation approach into life-cycle offers is necessary, but not clear. Second, the increased degree of intangible aspects will challenge the development of knowledge based tools. Third, explicit knowledge is typically managed in both product development and in development of support tools, but how can tacit knowledge be managed?

The empirical data for this study is collected by performing semi-structured interviews, questionnaires and by scanning internal company documents. The questionnaire was sent to seven product developers that are users of different knowledge based tools. The questions focused on how, where and with whom they shared knowledge, as well as what tools they used to achieve this, and was focused on the personal point of view of the respondents. The questions in the individual semi-structured interviews, which were performed with three engineers, i.e. method developers, were based on the topic to find out about their practices. For example, the respondents were asked to describe the rationale, steps and procedures for developing supporting tools, and also they were asked to describe how they got access to organizational and individual knowledge. The semi-structured interview provided a broader span of data. Also, they allowed the researchers to follow a planned theme, and the respondents to freely formulate their answers, or to diverge deeper into areas of particular interest [9]. The semi-structured interviews complemented the surveys, and provided themes to emerge. The interviews started with an open-ended request, e.g., “tell me about your work”; from this story follow up questions was posed. The follow up questions were built upon words/terms/concepts coming from the respondents. Thereby, the respondents choose the terminology. By applying this approach, the researcher can encourage the respondent to go deeper into the area, and to some extent potential biases by the researcher are avoided [9].

The interviews were recorded and partly transcribed. The researchers first performed the analysis individually and after that they continued the process in a group. The description of the industrial practices comes from this initial analysis.

3 A LIFE-CYCLE PERSPECTIVE ON TOTAL OFFERS

A total offer spans over a long time period compared to standalone goods [5]. If the goods has a longer life time than typical products, the total offer time horizon also expands. A jet engine has, today, a life time of over 30 years. So, if developed as a total offer, technologically advanced equipment is guaranteed during the life time [5]. A total offer for a jet engine is a long term commitment. Thus, the capability to model properties throughout a longer life-cycle is a necessity. A general view on a product life-cycle timeline is exemplified in Figure 1. This is a traditional product view focusing on the products (goods, tangibles) stages of life.

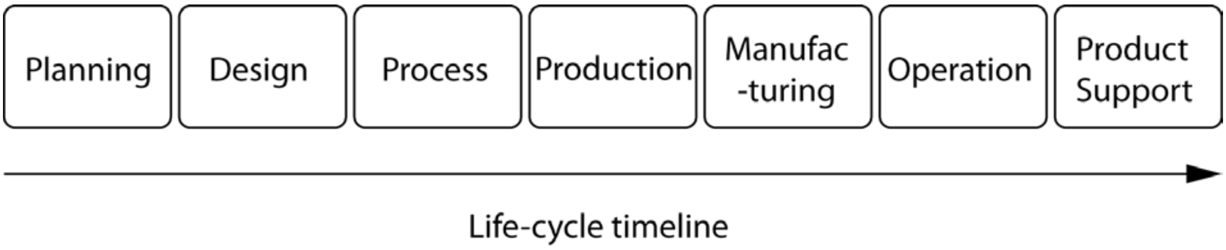

Figure 1. Product life-cycle, adapted from Prasad 1996

Starting at left in Figure 1, the product is planned. Commonly, this is a business/market responsibility including writing a specification. The specification is handed over to the engineers who have the responsibility to generate product concepts and find the technical solutions (see the design/process stages in Figure 1). At this early stage, the engineers need information for the later stages (e.g., production, manufacturing, operation and product support) to be able to find viable solutions, reduce costs and assure easy maintenance of the product. This kind of divided, yet coordinated, process is useful as a communicative tool [10], but could also separate the information and knowledge from its actors. For example, an engineer active in the design stage focus on the tangible product at hand, not on the logistic parts of it, or a service developer might not have information about the production processes.

To develop viable total offers based on a life-cycle perspective, integrated work across company borders and knowledge domains needs to be facilitated. A key in this cross-company work is sharing of metrics that indirectly or directly can be linked to customer perceived values. Examples of metrics in the production phase that describe failure or out-of norm behavior are; mean time before failure and reliability checks. In the operation, examples of metrics are: productivity, responsiveness, cost and time-to-market. And examples from the product support phase are; maintenance, upkeep and warranty costs [11]. These metrics are still valid for the product part in total offers, though the life-cycle perspective needs to be addressed differently to incorporate a service perspective. The metrics are useful for products, but, for example, operation and its metrics indicate that they are not encompassing enough to cover a life-cycle view of total offers. In particular, they are not meeting user needs of functionality. Operation in this sense is focusing on the functionality of the product, i.e., to keep it running, while a total offer aims to provide customer value by offering services. So, if extended to a life-cycle perspective, such metrics have to be linked to the performance in use and to the customers' perception of value.

A life-cycle for a total offer have to, in comparison with a traditional product view, follow the changing customer needs [12] and errors have to be prevented and supported throughout the offers life span.

4 KNOWLEDGE SHARING AND KNOWLEDGE CREATION

Engineering activities in early phases of product development deals with problem solving on different levels, managing everything from well-defined to ill-defined problems [13]; [14]. Problems that are considered well-defined are routine tasks that engineers deals with in their every day work and where the methods for solving the problem are well-known and where answers can be found easily from formulas or best practices. Ill-defined problems, on the other hand, demand more reflection from the engineer. These problems are those that may not have a well-defined problem solving method or an exact answer, such as customer preference analysis, life-cycle analysis or business model decisions.

Development focusing on new innovative products is closely related to ill-defined problems where the engineers have to find or create new knowledge [15] but also un-learn or reassess existing practices [16]. Studies on the creation of an innovation show that both creative and structured features are central for the quality of the result [15].

An important guideline for the development of PSS solutions should be that the point of departure is the functionality that the user is striving to achieve [17]. A development process for PSS benefits from a customer/user point of view, and if aiming for innovative solutions the starting point should be solution free. Hence, the input for the process should focus on customer/user needs and not settle the problem in these early stages. When there is no "problem" to solve, one must consider a process of definition, or problem-setting [18]. Such process deals with the boundaries of the problem context and in what direction the situation needs to be changed, unlike a process for problem-solving where the context is known at the beginning. For the development of PSS both processes are important, but especially the problem-setting process could be a challenge for engineers [7]. A large extent of the company's knowledge base consists of the knowledge of individuals in the organization, which to some extent is difficult to codify and store [19]. This individual knowledge is commonly categorized as tacit or explicit, where tacit knowledge can be described as know-how acquired through experience that is hard to communicate to others whilst explicit knowledge is possible to codify and communicate [20]. Sharing of both tacit and explicit knowledge is important for a company although converted to an organizational level by different means [21]. The knowledge of an individual can also be described as a profile consisting of both depth and breadth, so-called T-shaped persons [16][22]. The specific area of expertise that the individual posses make up the depth that is needed in order to accomplish for example, a specific design task, but besides that the individual also posses elementary knowledge about, for example, other disciplines and the organization, i.e. the breadth. Edeholt [16] describes in his thesis how a designer, with broad knowledge in many disciplines, interplay with a specialist, with deep knowledge in one discipline, to develop a new product. For the sake of a good solution, that takes both persons interests into consideration, the specialist must deepen the skills of the designer within the same area, as the designer must expand the specialist skills.

5 THE INDUSTRIAL CASE

In the following the empirical data is used to describe the company visions, knowledge sharing and the method developers work.

The manufacturing company in this study acts in a business-to-business context within the aerospace industry. They act as a business partner in a globally extended enterprise, and thus have to possess the ability to act both independently and together with partners in the development of products. In this business-to-business setting the company operates both as a supplier and as a partner. In recent years the company was among the pioneers in moving towards a change of business model where the focus is on provision of functionality. In the beginning, the company named those PSS offerings as total care products to indicate that this was different compared to the usual business of selling standalone goods.

Taking part in the development of aero engines often implies sharing of risks and revenues where each project has many partners on different levels of the supply chain and runs for several months. Typically, in this industry, new engine programs are initiated by a larger original equipment manufacturer (OEM) that at a system level set the design parameters for the engines. The system level parameters are governing the development of components in the engine and cause a finite constraint to what is possible to do for the suppliers. In this framed setting the room for innovation is limited due to the specification given, the high safety aspects in the aero business, but also because of the position in the organization [23]. Difficulties can occur when what first appear to be minor changes in the product requirements on a system level lead to changes in the entire concept, affecting the time plan and technical solution of each partner's engine component differently.

Besides the above stated limitations, the company also has to compete against other companies by delivering components in time, with a high quality and to a low cost [24]. Even though the possibilities for innovations are limited, it is still a necessity and therefore desirable even in the product development phase. A recognized desirable quality is the ability to quickly develop concepts in early phases of product development that to some extent can represent the direction and show the options that are available and thus create a basis for further decisions. Though they are not yet fully implemented in the development process, these options can at present be represented for production

methods, material selection, and so forth and are made available through KBE-applications, expert know-how, and earlier project documentation [25].
In recent years, different add-on services have been more important for the company and are recognized as a possibility to deliver more value to the customer. Service development, at the company, is generally something that is done in a separate process after the product requirements are set and subsequently not affecting the design parameters of the tangible product. As a step towards a life-cycle perspective the company wishes to integrate service aspects in early development and planning.

5.1 Knowledge sharing activities at the company

The progress of application development and the implementation of the result are to a large extent depending on the communication with the intended users and their work process needs. As a heuristic rule, the method developers make an effort to put themselves in the user position for the purpose to make the tool as intuitive as possible. Furthermore there is a need to ask for advice from experts, e.g. process owners, since the developer does not have all the necessary knowledge about the area that the application is developed for.
The method developer runs into many different issues regarding applications, i.e. how to identify valid knowledge, how to capture and formalize the knowledge, how to implement the tool, what training the user must have in order to use the tool, how to educate the user, which type of traceability is needed for the execution of the input/output, down to what level of detail and scalability aspects. During development when faced with technical problems, the method developers seek help from the closest available colleague within the group. However to gain deeper understanding within a topic the method developer stresses the importance of individual learning by doing, for their own reflection and creation of new knowledge. Re-occurring meetings, documented guidelines and instructions found on collaborative repositories such as team sites or network disk drives support the knowledge sharing activity within the group.
In general, sharing of tacit and experience-based knowledge at the company is closely linked to the project and group activities, where verbal communication is a common way. The importance of team members and colleagues to ask for guidance or help was significant for the company. Email and chat conversations are mentioned by respondents as one mean for contacting people in the organization before talking to them face-to-face. The use of project portals, team portals and chat software allow both horizontal and vertical transition of information such as written text, pictures, presentations, CAD models, etcetera and make it possible for a more dispersed team or project organization.
Information sharing in larger groups or with the whole organization is mainly done in a formal way through reports, such as written instructions, lessons learned documents, documents for standards, best practice documents, or design practice documents, etcetera. Formal documents are vital for some information, and to some levels of detail, as it is uploaded to servers where employees can search and keep organized, to various level of satisfaction. Finding specific information on these servers is perceived as time consuming and is seldom fully accomplished by the engineers since it is easier to ask a colleague or a former team member.

5.2 Method development activities

The company in this study develops components for jet engines; this is a line of business where safety is of utmost concern. In turn, this makes it necessary to certify the technologies, the processes, the production and the utilization of the product. Computer supported tools play a significant role in this context, since they inherently have the ability to enable people to store, retrieve and disseminate information. They also provide traceability of the performed activities and the ability to transfer product and process information upfront in the development process. Here knowledge based tools are used to decrease risk by planning, simulating and visualizing potential solutions before creating physical prototypes. These tools must be in line with verified company knowledge, based on explicitly defined governing processes, design practices, method descriptions and standards as well as from discussion with officially appointed product- and process developers within the organization.
The development of knowledge-based tools, here referred to as method development, is mainly pursued as a need based activity at the company. The need based approach can be seen as technology pull development and in this case a typical scenario are:

- A project leader in a product development project locates an activity that is recognized as possible to improve or automated in order to speed up the process. The project leader contacts the method developer.
- A method developer gather user data about the specific task and seeks an understanding of the user need, i.e. what is the purpose of the task, what steps are required, where are the bottlenecks etcetera.
- The method developer capture and formalize knowledge contained inside the process in an iterative application development mode through source code development and frequent testing of functionality together with the user.

These steps are comparable to the KBE life-cycle [26], namely the steps identify, justify, capture and formalize. After having developed the application, the developer has an extended responsibility to package and activate it together with the IT-department in the production environment. Typically this implies making the application available for users as a service through an application suite extending the functionality of the CAD environment. The acceptance and success of the application depends to a large extent on how well it fits in the established development process, the usability aspects and the engagement from the user. Therefore, understanding the user needs is of utmost importance.
In addition to a technology pull development mode, the method developer can also work in a technology push development mode. Typically this implies locating an activity that could be improved or supported, seeking acceptance within the organization and developing an application for implementation in the company process. In this case, where there can be little or no user data to exploit beforehand as a basis for further development, the demands on the developer are different. Here, the development only follows the governing processes, verified by the company, where documented instructions describe how to conduct the activities. The process documentation is nevertheless not defined for every activity or at every level, which implies that the method developer often must solve problems as they emerge, either as an individual or in a team. In general, the steps performed for a technology push situation are:

- Gather information about purpose of the activity
- Describe how the process works today, elaborates on future process
- Begin prototyping, sketch on paper, rapidly create application mock-ups
- Functionality development, continuous testing and dialogue with experts and users
- When faced with technical or application problems, seeks help from colleagues with similar roles
- Final testing, documentation, packaging and preparation for launch
- Launch through help of IT-department
- Teach users - mainly hands-on at his/her computer
- Provide support and maintenance throughout the application life-cycle
- Evaluate of application

Important for the method developers’ comprehension of the task/problem is to have an overall picture and to be able to gain insight into the problem, talk and discuss with other colleagues and experiment and test.

6 DISCUSSING KNOWLEDGE BASED TOOLS FOR PSS

Here, it is discussed that service aspects and a life-cycle perspective should be integrated into early development of total offers. The initial engineering activities extend to not only solve the design problem, but also to settle the design problem. Problem-setting is of utmost importance for the provision of functionality and added value to the customer. The incorporation of a total offer life-cycle perspective, including several intangible aspects, is a challenge for manufacturing companies, but particularly for engineers. Contemporary engineering practices are supported by tools to aid problem-solving, but implementations of tools to aid problem-setting is limited. Generally, the focus for engineers have for a long time been to solve technical problems and thus manage knowledge related to that product, e.g. explicit, measurable, and tangible information. By the extension of business models into PSS and life-cycle offers, the engineers are now faced with the need to manage knowledge related to customers, their objectives, needs and perception of value, e.g., tacit, contextual, and intangible knowledge. This new situation is commonly not part of the engineers’ knowledge domains; rather they are accustomed to solving the problem from interpreting a list of requirements. However, some engineers have experiences in managing both explicit knowledge and experience based knowledge, simultaneously identifying and fulfilling user needs. At the company in this study, the method developers posses such skills and some issues can be discussed to contribute to the development of supportive knowledge based tools for life-cycle offerings.

Method developers primarily performed two distinct categories of processes for the acquisition of user data. The first could be described as problem-solving process, i.e. technology pull, where the method developers obtain a list of requirements, having an existing work description and specific user data to acquire. The second could be described as a problem-setting process, i.e. technology push, where the method developers encounter a problematic situation, develop a deeper understanding of the users and frame the problem to be able to solve it. The problem-setting process moves towards areas where there are little or no established practices, and scarce user requirements. For the problem-setting processes the method developers describe the work as influenced by:

- The governing development processes
- A firm user perspective; empathizing with users
- Experimenting and prototyping; based on the user environment
- Sharing of experiences, within their occupational role and with users

For elicitation of user need, the method developer have to apply personal and experience based knowledge about the work to get access to the user perspective. In those situations where the method developer needs to create a deeper understanding of the problem, they are required to experiment and prototype to identify tacit user knowledge or get the information from expertise in the specific area. Since it is not possible for the method developers to learn everything in the specific area, they are forced to gather information from experts. In that dialog the method developer possess the deep knowledge about how to formalize the knowledge into an application but does only have basic knowledge about the expert’s area. Still it is important that both persons can discuss on the same level of understanding. For the success of the KBE-application, in this case, it is of importance that the method developer has a wide knowledge base (of the disciplines involved) so that he/she can understand and acquire knowledge from the expert’s deeper knowledge, but also in order to be able to broaden the user (i.e., experts within their discipline) perspective. By doing so, the method developer, can develop tools that support engineers in specific design tasks, for a common goal, without possessing the specific knowledge that the expert have.

PSS and the integration of intangibles into knowledge based tools implies that the method developer does not personally posses experiences about the matter, thus could have difficulties to extract information. Because of this, we argue that the interaction between users and method developers in early stages of the development of tools for life cycle offers is vital. By doing so, the development approach aligns with a problem-setting process, where method developers also can suggest appropriate tools.

Life-cycle offers as such integrates several knowledge domains and competences, thus it seems like a necessity that method developers actively participate in early support development to acquire an understanding of the different domains and interests. However, the method developer does not possess specific service related knowledge; they could by applying a problem-setting process bridge those shortcomings.

Commonly today, the use of KBE-tools is beneficial and enables elaborating different design alternatives, e.g. virtually and at low expense since no material will be used for physical prototypes. The benefits of KBE-tools are non-trivial, for example when being exposed to a change in the settled product specification. The use of KBE-tools can ease new concept generation and shorten lead-time. Still, it is so far mainly on a physical abstraction level that these tools are used and to a specific level of detail. But, for life-cycle offerings, the possibilities to explore, try out, see and evaluate different solutions before signing contracts or start product development seems even more important. For example, the company is encountered with a raised requirement and is forced to choose a more durable material that might be more difficult and more expensive to process. If seen from a different perspective, it might be advantageous to choose between increasing the product technology level, increasing the service degree, keeping the product technology level constant, or maybe even lowering it. What would be the effect of each choice? Therefore it would be desirable to be able to visualize combinations of solutions, service and products, intangibles and tangibles to support decision making at all levels in the company. Accordingly, there is a need for tools that handle physical characteristics and non-physical characteristics that could also support development for more than one physical products life span, i.e. during the total offer different solutions could fulfill the user need, see Figure 2. In contrast to the traditional product life-cycle, see Figure 1, the changed ownership opens up for the supplier to design products with a new perspective on the different phases.

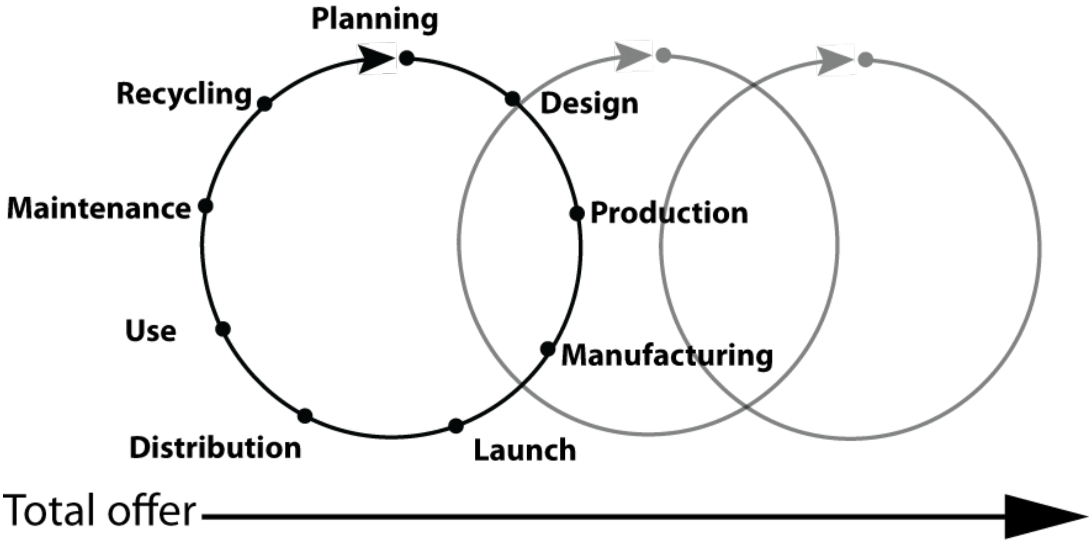

Figure 2. Total offer life-cycle

To actively and intentionally manage the development of tools for life-cycle offers, the processes for user need acquisition applied today by method developers could provide a base. But, there is a need to broaden the method developers understanding of life-cycle offers, particularly in the field of service modeling. In this respect the method developers' current type of knowledge, their current use of technologies and contact network must be expanded, this is by no means an easy task. The success of the transition is likely to depend on how different knowledge actors within a company team up, business developers, service developers, product developers and method developers. It can also be stressed that method development, at the company, is a form of in-house service development where the method developer holds important knowledge about, for example, user need acquisition, need fulfillment and implementation in a otherwise firmly technical environment.

7 CONCLUDING REMARK

In this paper, the industrial practices of method developers, i.e. those developing applications and KBE-tools to support engineers and product development, have been described. Also, a general view of knowledge sharing activities within a manufacturing company has been presented. Essentially, the study is performed from a method developers' perspective for the purpose to draw from their experiences in managing two approaches. A framework for the study has been the integration of service and product aspects into the development of life-cycle offerings. The two approaches that method developers apply are technology-push, which has similarities with a problem-setting approach, and technology-pull, which has similarities with a problem-solving approach. We have found that the problem-setting approach could help the identification, analysis and application of user needs, thus also could be applied to identify metrics/characteristics for intangibles.

Today there are numerous methods for simulating the behavior of tangible products throughout its life-cycle, but for future life-cycle offerings there is a need to extend the knowledge based tools capabilities beyond that.

For future research, we would like to highlight things that we have not considered in this study. A case studying a reversed situation could provide new insights, e.g. companies that apply method development as an integrated part of product development. Drawing from such a study, the method development could become more proactive, thus be in place beforehand to support future development tasks. This study is delimited so far as it does not go deep into the life-cycle perspective and the necessary changes to suit PSS development. What kind of changes is needed if it should encompass a changed product definition, as is the case with integrated product-service solutions. Finally, Knowledge Enabled Engineering [25] is part of our research project, thus always an interesting area calling for more research, especially the implementation of KEE in a radical innovation contexts seems utterly interesting.

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