Modularization of Industrial Service Processes

Application of the Service Modularity Function

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24th EurOMA Conference
July 1-5, 2017
Edinburgh, Scotland

Modularization of industrial service processes: application of the service modularity function

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Abstract

In this paper we examine how complex service processes can be dealt with through the lenses of modularization strategies. Through an illustrative case study of a manufacturer of industrial equipment for process industries we propose the use of the service modularity function to conceptualize and assess the service modularity of service offerings. The measured degree of modularity would allow us to sharpen our understanding of modularity in the context of industrial services, such as the role of standardization and component reuse on architecture flexibility. It would also provide a foundation for analyzing the short- and long-term impact of service innovation.

Keywords: Service modularity, Industrial services, process standardization

Introduction

Recent studies suggest growing importance of modularity in services (Eissens van-der Laan, 2016; Frandsen, 2017; Brax et al., 2017; Broekhuis et al., 2017; Avlonitis and Hsuan, 2017) a topic, also becoming central for manufacturers providing industrial services (Carlborg and Kindström, 2014; Hellstrom, 2014). While service architecture has been suggested as an important research area (Ostrom et *al*. 2015) only few studies attempt to empirically measure modularity in services and relatively little is still known about dynamics of modularization of service processes. We investigate the modularity of service processes by applying the service modularity function (Voss and Hsuan, 2009) within the context of industrial services. The notion of industrial services involves services such as repair and maintenance, condition monitoring and engineering services in relation to industrial equipment. However it is only recently that modularization of processes for delivering industrial services has come on the research agenda (Carlborg and Kindström, 2014).

Modularity has been suggested as a way to reduce complexity and enable re-configurability in the design of service systems. A complex system can be decomposed into hierarchies that can be analyzed into many independent components having relatively many relations among them so that the behavior of each component depends on the behavior of others (Baldwin and Clark, 2000). Consequently product modularity has received much attention in both research and practice (Salvador, 2007). With the growing importance of industrial services, manufacturers now face a need to develop new service and offer customer solutions (Brax and Visintin, 2016). However they often face challenges based on lack of experience in new service development and methods needed for systematically designing service architectures.

Service delivery processes play a fundamental role in new service development, as the implied variability must either be reduced or accommodated by the service process design. Sampson and Frohle (2006) argue that customer input into the delivery process is the defining characteristic of services, imposing major managerial implications. An important facet of the nature of service is thus the simultaneous production and consumption, implying reduced opportunities to manage variability through inventories. This is important as a fundamental characteristic of services is the existence of the customer within the process, which creates an inherent variability not present in manufacturing processes in which the customer only receives the output from the process (Morris and Johnston, 1987).

Variability of service delivery and requirements for customization imply a need to manage the complexity of service architecture. This involves carefully specifying service offerings and standardizing industrial service processes. While such standardization enables efficiencies and reduces complexity, it is important to retain the ability to offer unique solutions when necessary. Although reference models for industrial services have recently been proposed (Gerosa and Taisch, 2008), manufacturers need to carefully craft architectures of industrial services and solutions that meet the needs of their customers without drowning in complexity.

In this paper we examine how complex service processes can be dealt with through the lenses of modularization strategies applied to service settings. We are motivated by the following research questions: 1) How can degrees of modularity be captured in the context of industrial services, and 2) What are the challenges and dilemmas associated with standardization of processes?

The paper is organized as follows. First, a literature review on service modularity and service process architectures. Next, we give a brief overview of case study as the research methodology and present the case company. Then we introduce the conceptualization and measurement of service modularity, and how service modularity function can be applied in the case company to measure the degree of service modularity. Finally, discussion and conclusion are presented.

Literature review

Service modularity

Ensuring consistent, reliable and efficient service delivery is particularly challenging for service systems to which knowledge is essential. To achieve these objectives the processes and information systems through which services are delivered are often consciously designed. However when organizations engage in multiple services and when customers can proceed through service processes in a multiplicity of ways, complexities are added for the designers of such services (Tuunanen and Cassab, 2011). This paper explores the context of industrial services and how providers face these challenges in the design of architecture of industrial service processes. Modularity is recognized as an important design principle when addressing complexity but research on modularity within services is still emerging (de Blok et al. 2014, Voss and Hsuan, 2009).

Services are recognized as increasingly important within the global economy and have been subject to intensified academic investigation within various fields of management studies. Within operations management, the traditional manufacturing focus is broadening out to include services as an emerging theme. Although management of service operations has been on the academic agenda for more than three decades it is increasingly being recognized as an important field of inquiry of research in operations management (Apte et al., 2008; Chase and Apte, 2007).

One way to deal with complexity is through modularization strategies. A complex system can be decomposed into hierarchies that can be analyzed into many independent components having relatively many relations among them so that the behavior of each component depends on the behavior of others. With the increased need for seamless communication channels, technological innovations, such information and communication technologies (ICT), has become the enabling factors for easing the modularization process (Karmarkar and Apte, 2007; Sahaym et al., 2007) through the separation of tasks and how the tasks are traded globally (Baldwin, 2006; Ellram et al. 2008). While technology can be a way of creating sustainable competitive advantage, empirical studies demonstrate that achieving such advantages is a challenging endeavor (Lewis, 2002).

This challenges the architectural capabilities (Henderson and Clark, 1990) of firms and their ability to design process architectures possessing desired levels of modularity. Furthermore many companies are facing the challenge of designing operational capabilities that are flexible at low costs (Slack and Lewis, 2008). Literature suggests that the principles of modularity can be one important element in designing flexible architectures that captures economies of substitution (Baldwin and Clark, 2000; Langlois, 2002; Schilling, 2000). In order to realize economies of substitution, it requires knowledge sharing and the reuse of components (Garud and Kumaraswamy, 1995). This area of research has received increasing attention during the last decade (Campagnolo and Camuffo, 2010). Although modularity has traditionally been investigated from the perspectives of physical products (Schilling, 2000; Ulrich, 1995) and manufacturing processes (Tu et al., 2004), a number of recent studies are exploring modularity from service and service process architecture perspectives (Bask et al., 2011; de Blok et al., 2010, 2014; Pan et al., 2007; Sundbo 2002, Voss and Hsuan, 2009) following the growing importance of services and advancement on ICT (Chesbrough and Spohrer, 2006). The combination of new technological opportunities and increasing pressure on service delivery organizations imply that the design of service processes is an area of study which deserves attention (Hill et al., 2002). Although there is extensive research on service management primarily in service and marketing literature, in the field of operations management, the contribution is rather low (Metters and Marucheck, 2007). Methodologically, the majority of the empirical research designs tend to be quantitative with surveys from the financial service industry as instruments for data collection; papers with mathematical tools to develop new models or longitudinal studies are underdeveloped (Papastathopoulou and Hultink, 2012). Menor and Roth (2007) call for the development of psychometrically sound measurement items and scales for empirical research in new service development. The lack of psychometric measures is also evident in product modularity (Campagnolo and Camuffo, 2010; Salvador, 2007) and service modularity studies (Bask et al. 2011; Voss and Hsuan, 2009).

Service process architectures

According to Buzacott (2000) "*[t]he service design problem is to develop a system that enables customer's demand to be met in an effective way*" (p.17). This suggests that service managers have to embrace the design of complex production systems that are capable of coping with demand variability and heterogeneity caused by customer inputs

(Sampson and Frohle, 2006). Furthermore, customer presence within the service production process (Morris and Johnston, 1987) can add crucial challenges to service process designers, such as deciding on the point of coupling or decoupling between the front office and the back office (Metters and Vargas, 2000).

A fundamental characteristic of services is the existence of the customer within the process creating an inherent variability not present in manufacturing processes in which the customer only receives the output from the process (Morris and Johnston, 1987), meaning that customer presence is essential. Sampson and Frohle (2006) argue that customer input into the delivery process is the defining characteristic of services, which imposes major managerial implications. An important facet of the nature of service is thus the simultaneous production and consumption, implying reduced opportunities to manage variability through inventories. Consequently the service delivery process plays a fundamental role in new service development, as the implied variability must either be reduced or accommodated by the service process design. Furthermore Tsikriktsis and Heineke (2004) find that process variation significantly impact customer satisfaction implying that consistency in service delivery is critical to performance. This is particularly difficult as service processes are often not long sequences of standardized activities, but rather mobilizations of processes in service encounters. Developing and managing services and service delivery processes pose challenges for management to identify appropriate structural compositions to handle the service process demand.

Following Simon (1962), we conceptualize architectures as hierarchical systems following his notion that hierarchy "*is one of the central structural schemes that the architect of complexity uses… In hierarchic systems, we can distinguish between the interactions among subsystems, on the one hand, and the interactions within subsystems - i.e., among the parts of those subsystems - on the other*" (p.468-473). Architecture in this sense is consisted of a complex set of related systems, which are organized with the intent to achieve a certain outcome. Process architecture is assumed, to some extent, to be layered in order to reduce complexity. In the language of Simon, the architecture is assumed to potentially be considered a nearly decomposable system: "*as a second approximation, we may move to a theory of nearly decomposable systems, in which the interactions among the subsystems are weak, but not negligible*" (p.474). Decomposability is essentially a way to manage complexity and is tightly related to the notion of modularity (Garud et al., 2003).

A complex system can be decomposed into hierarchies that can be analyzed into many independent components having relatively many relations among them so that the behavior of each component depends on the behavior of others. Similar to product systems, service systems can also be decomposed. If we interpret a set of services as a system (just like a product system), then a service system can be broken down into different levels of complexity. Services can be conceptualized through the notion of architectures (Voss and Hsuan, 2009) in which modularization of a system can occur at various levels of decomposition with different opportunities for modularization.

Research methodology and approach

We apply a case based research methodology. Case research can be used for exploration, theory building, theory testing, and theory extension/refinement and uses contextually rich data from real-world settings to investigate a focused phenomenon. In this paper we develop the conceptual basis for empirically measuring the structural composition of the industrial service architecture in order to understand the degree of modularity embedded in the processes. Specifically we propose the application of the service modularity function to numerically and graphically investigate the composition of industrial service process architecture and to measure the degree of modularity embedded in the process architecture system.

Data collection

The study build on data collected in interaction with industrial firms as part of a wider research project focusing on servitization. The interactions include a range of workshops with service managers and seminars with senior service executives. While our thinking behind the conceptual framework presented below is informed by data from interactions with multiple service managers in different industrial firms, the framework itself is based on qualitative data from a single case company.

Case Company

The case company has been involved in activities as part of a wider project focusing on servitization in Denmark. The company provides specific industrial equipment for process industries along with advanced spare parts and consumables. The company has been essential in developing its niche market and possesses significant technical insights. As part of its delivery of equipment, industrial services have traditionally been provided, including installation and commissioning of equipment along with technical expertise for the repair, maintenance and optimization of equipment usage. In recent years the company has increasingly commercialized its services involving the development of service contracts along with the provision of industrial services on commercial terms.

The drive towards commercializing services have implied a need for professionalizing services which have involved developing standard services and frameworks for communicating service offerings. In other words, there have been an increasing attention to organizing the service offerings and delivery processes. In effect the firm has developed industrial service architecture, involving both a configuration of clearly defined service offerings, generic process modules through which services are delivered along with an application landscape to support this. Figure 1 illustrates the framework for industrial service architecture of the company.

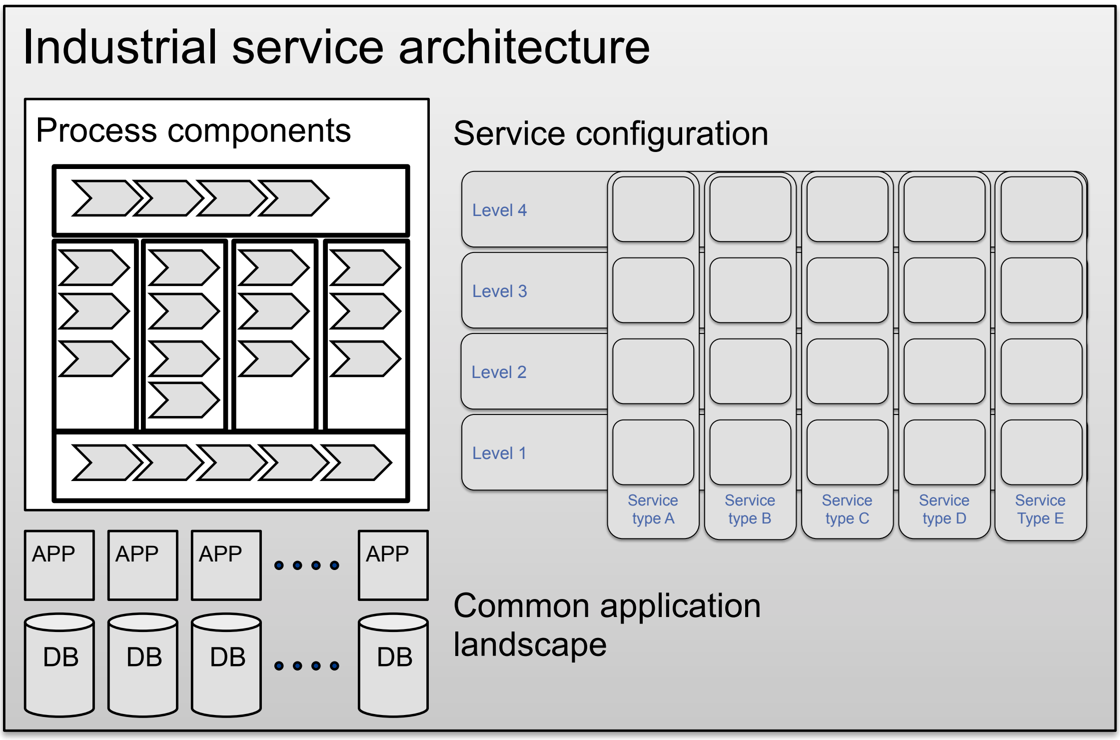

Figure 1- A framework for industrial service architecture

Conceptualization and measurement of service modularity

Product modularity has been predominantly discussed in engineering and management literature for over forty years (Salvador, 2007). Modularity is a strategy for organizing complex products and processes efficiently (Baldwin and Clark, 2000). It allows components to be produced separately and used interchangeably in different product configurations without compromising system integrity (Mikkola and Gassmann, 2003). A modular product is designed to allow for mixing and matching of components (Kogut and Bowman, 1995) to create a wide range of product varieties (Kim and Chhajed, 2000). Mirroring product modularity is the concept of service modularity, of which a service system is conceptualized as a complex system and hence can be modularized through decomposition (Voss and Hsuan, 2009). In addition to the benefits of mixing and matching of service modules to create a multiplicity of service offerings, modularity could potentially benefit service operations by allowing for faster adaption of service processes in cases of significant disturbances as well as the creation of contingency processes based on new configurations of service process modules to be executed in cases where the service system is challenged. Modularity can add new insights into the context of service processes and warrant rigorous scientific investigation. Such efforts would benefit from clear conceptualizations of service architectures and the role of modularity as well as the development of meticulous methodologies for assessing the degree of modularity in a given service process architecture.

Similar to product modularity, there is also a distinction between the nature of service process architectures, which can vary between modular and integral. Being able to operationalize such spectrum into measures can enable the creation of managerial tools to help managers to understand their systems more objectively. However, research on modularity still lacks the development of rigorous measures to further advance our understanding of modularity (Campagnolo and Camuffo, 2010). It is one of the goals of this paper to fill this gap by examining the potential for operationalizing measurements of modularity of service processes.

There are a number of contributions that address the challenge of measuring the degree of modularity within a system, predominantly with products as the unit of analysis (Campagnolo and Camuffo, 2010). Fixson (2005), for instance, take the function-component allocation matrix and characterizations of interfaces as point of departure to develop a method for assessing product architecture. He suggests that these two dimensions form the basis for product architecture maps, which offer graphical representations of product architectures. A number of methods has been developed to measure different aspects of product modularity, such as commonality sharing within physical product architectures (Fixson and Park, 2008; Holtta-Otto and de Weck, 2007; Mikkola, 2006; Mikkola and Gassmann, 2003; Thevenot et al., 2007) as well as within manufacturing processes (Tu et al., 2004). Less attention has been devoted to measures developed and applied within service contexts (Voss and Hsuan, 2009). This suggests that designers and managers of service processes are presented with limited conceptualizations and measures addressing the issue of modularity. This brings forward potential areas for research in the field of service modularity, such as finding methods to analyze how service process architectures can be decomposed to allow for systematic analysis of service process modularity, and how the elements of the process architecture be conceptualized to build measures that can help in designing and control the complexities of service processes.

In order to operationalize the contextual elements of industrial service process system and to measure the degree of service modularity embedded in the company's service system, we apply the service modularity function (SMF) proposed by Voss and Hsuan (2009). SMF takes the system perspective on decomposition and assumes that the system is comprised of two types of services: standard and unique. Standard services are routinized and common in multi-site services such as those in fast food and retail industries. Unique services, on the other hand, are service elements that are difficult to be copied by the competitors in the short term, such as with the expertise knowledge of consulting firms. However, service firms (especially the multi-site, multi-service firms) should also consider to what extent the unique service elements can be reused across services families. SMF is a mathematical function (Equation 1) that measures the degree of modularity deriving from unique services and degree to which the unique modules can be reused across a variety of services. It has the following variables: number of unique service components (*u*), total number of service components (*N*), and the reuse factor of the unique service component (*f*). SMF can be interpreted as follows. The degree of service modularity varies exponentially with respect to the total number of services (N), the number of unique services (u), and the number of services families the unique services can be reused for. A system that has no unique service (that is, comprised only of generic or standard service elements) would be a perfect modular system, hence a SMF value of 1.0.

$$SMF(u) = e^{-u^2/2Nf} \qquad \text{Equation 1}$$

The SMF has been applied in the context of financial services (Frandsen and Hsuan, 2010), cruise services (Voss and Hsuan, 2009), and third party logistics services (Prockl and Hsuan, 2016).

In order to apply the SMF for processes, we have to follow these steps:

1. Define the boundaries of the process/service system
2. Decompose the system into different levels and types of services. Figure 2 shows the conceptualization of industrial service offerings and the different levels of decomposition.

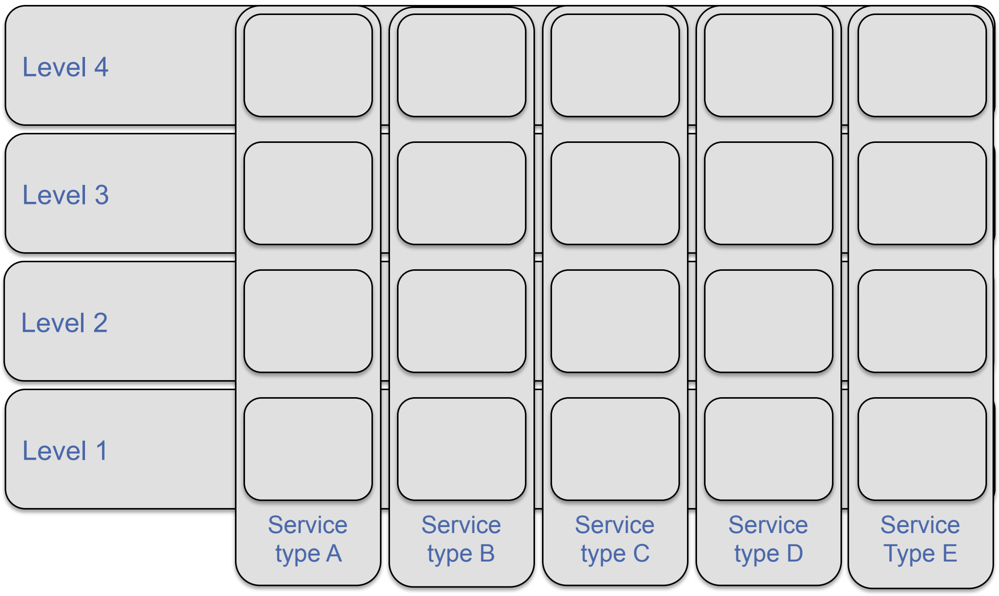

Figure 2 - Conceptualization of industrial service offerings and the different levels of decomposition

3. Identify the number of generic or standard service components for each service type: n
4. Identify the number of specialized or unique components: u
5. Determine the total number of components: N= u + n
6. Determine the number of service families to be reused: f
7. Calculate the SMF for each service type (as shown in Table 1)

Table 1 - Template for calculating SMF

	Service Types				
	A	B	C	D	E
No. of standard components, n	n_A (30)	n_B (30)	n_C (30)	n_D (30)	n_E (30)
No. of unique components, u	u_A (0)	u_B (10)	u_C (10)	u_D (15)	u_E (15)
Total no. of components, N=n+u	N_A (30)	N_A (30)	N_C (30)	N_D (30)	N_E (30)
Reusability factor, f	f_A(5)	f_A (5)	f_C (2)	f_D (2)	f_E (1)
Degree of modularity, SMF	SMF_A (1,00)	SMF_B (0,78)	SMF_C (0,54)	SMF_D (0,29)	SMF_E (0,08)

The SMF can be shown graphically as well. Doing so, we would obtain 5 different curves indicating respective levels of modularity. Service types with high number of configurations would exhibit SMF values closer to 1.0 (i.e. highly modular). Whereas, service types with high number of unique components and low levels of reusability to have lower SMF values. Table 1 provides a template for calculating SMF with illustrative examples of different characteristics of service types with resulting SMF.

Discussion and conclusion

We find that the service modularity function provides a method for capturing essential aspects of modularity. The measured degree of modularity would allow us to sharpen our understanding of modularity in the context of industrial services, such as the role of standardization and component reuse on creating architecture flexibility. It would also provide a foundation for analyzing the short- and long-term impact of service innovation.

The importance of the design of service delivery processes is recognized as crucial for the operational capabilities of service providers. The SMF is one way of conceptualizing and measuring the structural characteristics of service process architecture, hence providing additional insights for process designers working with architectural principles of standardization, reuse and platform design. It can provide designers with reference points during various stages of process design to evaluate the consequences of different design options.

The extent to which standardized services components are used as opposed to unique process service components is a crucial factor influencing the degree of modularity of a system. In the case of industrial services, the documented and tested services are available in a service repository, and can be readily applied across the different service types. Unique industrial service components, on the other hand, are those, which are new to the firm and are introduced on the basis of requirements from service types under development. They may emerge due to a lack of awareness or appreciation of the availability of standard components, and not necessarily due to heterogeneous requirements. These components can be expensive and take time to develop and their successful application is uncertain. However, they cannot be taken for granted as they are sources of competitive advantage as they can prevent imitation from the competitors. It becomes even more valuable if these unique resources can be reused across other lines of business, or that they become included in the development of new service types.

The paper seeks to contribute to the literature by extending the application of the service modularity function to the context of industrial service processes. The paper thereby contributes to the emerging literature addressing how manufacturers can apply principles of service modularity (Carlborg and Kindström, 2014) in developing industrial service architecture.

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