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# Examining dimensionality and interdependencies in the design of service innovation

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Abstract

Service innovation is increasingly recognized as the design of multidimensional and complex systems. Accordingly, there is a need for comprehensive and validated conceptualizations, as well as an enhanced understanding of the interdependencies between the dimensions making up the service. Promising in this respect is the potential of applying complex systems theory in the form of the NK-model, based on an evolutionary interpretation of innovation. In this analytical structure, new offerings are interpreted as emerging from adaptive search processes. Which strategy is appropriate for modifying a certain service is argued to depend on characteristics of the design space a firm is facing. By demonstrating the applicability of the NK-model in the context of intangible products, we aim to advance the multidimensional approach to service innovation. We explore the dimensionality and interdependencies of 13 qualitatively studied service innovations by mapping each of them on one single multidimensional conceptualization. Whereas some cases support the claim that services are associated with ill-defined design spaces, we argue that familiarity with common elements, and archetypical modifications therein, might provide valuable guidance to service innovators. Furthermore, the observed dimensionality points at intermediate degrees of interdependency and ways to use modularity for dealing with this. Jelcodes:O31,-

## 1. Introduction

Service innovation is increasingly recognized as the design of multidimensional and complex systems (Gallouj & Weinstein, 1997; Windrum & Garcia-Goñi, 2008; Den Hertog et al., 2000; Roth & Menor, 2003; Maglio & Spohrer, 2008). The emergent understanding that there is a need for all-encompassing notions led scholars to describe the last five years of service innovation research as the 'multidimensional phase' (Carlborg et al., 2013). Whereas some authors seem to take an ontological perspective when referring to the multidimensional nature of service innovation (Gago & Rubalcaba, 2007; Gallouj & Djellal, 2010; Rubalcaba et al., 2012), others merely stress the analytical benefits of applying a multidimensional approach to (renewal in) intangible offerings (e.g. Trigo, 2013; Janssen et al., 2014). In either case, however, the current lack of theoretical and empirical examination of multidimensionality leaves several prominent research issues unaddressed.

To start with, only few scholars attempted to capture the dimensionality of services in a single conceptualization (Salunke et al., 2011; Bryson et al., 2012; Droege et al., 2009). A multifaceted appreciation of service innovation should go beyond simple and frequently criticized distinctions like process versus product innovation (Djellal & Gallouj, 2001) or technological versus organizational renewal (Drejer, 2004), but avoid losing its focus due to unlimited broadening (Carlborg et al., 2013; Stauss, 2005). When equipped with comprehensive and sufficiently illustrated concepts, the multidimensional approach to services is expected to provide a fruitful basis for comparative analysis (Janssen et al., 2014).

Secondly, and more importantly, little is known about the complex interactions between the various dimensions making up a service offering (Carlborg et al., 2013; Briscoe et al., 2012; Chae, 2012b; Maglio et al., 2009; Van Riel et al., 2013). In several instances, scholars presumed the existence of such interdependencies (Den Hertog et al., 2010; Gallouj & Weinstein, 1997; Agarwal & Selen, 2011). For instance, Windrum & Garcia-Goñi (2008) and De Vries (2006) discuss how a change in one type of service characteristics (e.g. user preferences or producer competences) might induce changes in other elements in turn. Similarly, Partrício et al. (2011) argue that service design requires insight in the relation between service concept, service system architecture, and service encounter. Ignorance of interaction mechanisms and the existence of complexity in the design of new services obscures the nature of service innovation as an outcome as well as a process, both of them frequently being reported as ill-understood (Gallouj & Djellal, 2010; Bryson et al., 2012).

The current paper aims to advance the multidimensional or 'systemic' approach to service innovation (Carlborg et al., 2013; Rubalcaba et al., 2012). Following a synthesis perspective on innovation (Coombs & Miles, 2000; Gallouj, 1994), scholars are urged to develop integrative frameworks and methods that build on insights from a wide variety of innovation studies (Gallouj & Savona, 2009; Carlborg et al., 2013; Drejer, 2004). In this vein, we adopt an evolutionary interpretation of innovation (Nelson & Winter, 1982) in order to shed light on the dynamics within multidimensional services.

Specifically, we rely on complexity theory in the form of the NK-model (Kauffman, 1993). In this particular analytical structure, innovation concerns the deliberate manipulation of one or more of the elements within a multidimensional, system-like design space. Due to

the presence of interdependencies, changing one element (or dimension) influences the fitness of other elements, thereby introducing complexity in the search process. Over the years, extensive theorizing and simulation efforts revealed valuable strategic and managerial insights on how to deal with such complexity (Levinthal, 1997; Porter & Siggelkow, 2008; Frenken, 2006).

With some rare exceptions (e.g. Chae, 2012a, 2012b), NK-logic has mainly been applied to technological change. Benefitting from its potential to enrich the multidimensional approach to intangible and coproduced products prompts us to make two contributions, each of them corresponding with a core parameter of NK-models.

First of all, we address the void of empirical examinations of the dimensionality of service innovations (Salunke et al., 2011; Droege et al., 2009; Den Hertog et al., 2010). By defining service design spaces on the basis of one single multidimensional conceptualization, we map 13 qualitatively studied innovations in order to assess how many of those dimensions are typically affected. Whereas some cases support the claim that service innovation corresponds with search in design spaces that appear to be ill-defined, others demonstrate the existence of archetypical (rather than genuinely original) modifications on certain dimensions. Familiarity with design space elements and common mutations therein might be fruitful ways to reduce complexity and optimize innovation processes.

Guided by complexity theory, we then examine empirical evidence for the existence of interdependencies between the separate dimensions. In order to interpret service innovation as an act of adaptive search (Chae, 2012a), it is essential to have an empirically grounded impression of the extent to which changes in various elements affect each other. Rather than presenting services as an aggregation of elements to be optimized independently, we use our case evidence for showing that most changes do induce several related changes in turn. Some cases, however, exemplify how the complexity-reducing notion of modularity can be interpreted in a multidimensional conception of services (Pekkarinen & Ulkuniemi, 2008; Rahikka et al., 2011; Carlborg et al., 2013).

Applying complex systems methodology to services, as demonstrated in our case analysis, provides several implications for future research.

## 2. Background: Applying complex systems theory to services

### 2.1 Innovation as search in multidimensional design spaces

Innovation denotes an endogenous process through which the business activities performed in an economic system change continuously (Nelson & Winter, 1982; Witt, 2008). Due to ever-changing circumstances, organizations are required to adapt their daily business, so-called routines, in order to deliver products that better fit altered market conditions. A firms' dynamic capabilities are regarded as the behavioral antecedents responsible for reactive or even proactive transformation of its lower-order routines and their resulting outputs (Teece et al., 1997). The pursuit of new combinations of routines is essentially a process of creativity and experimentation, in which firms have only limited knowledge about how successful a new configuration will be.

Evolutionary economics and corresponding management literature offer several theories and tools aiming to improve our understanding of how organizational forms and combinations of resources come about. Stemming from complex systems theory, Kauffman's NK-model (1993, 1995) sheds light on search process within multidimensional, interactive design spaces. This concept concerns the hypothetical collection of resource combinations a firm could possibly explore. Each of the configurations within the design space is associated with a fitness-value, representing to what extent it is appreciated by the market. Besides being induced by exogenous changes, better configurations can emerge from a firms own efforts to deliberately manipulate the elements (i.e. dimensions) within the design space it explores (Axelrod and Cohen, 2000). The presence of dependencies between systemic elements makes innovation a complex process.

The formal NK-model to represent the dynamics of combinatorial search processes centers around two properties (Kauffman, 1993). N, to start with, denotes the number of elements that can be manipulated when developing or improving a product. In the example of automobiles, for instance, firms have the option to modify elements such as the energy sources, car fuel, and vehicle type (Alkemade et al., 2009). The various ways in which each separate element can be changed is captured by the concept of 'alleles'. For a car's vehicle type, the basis alleles include internal combustion engine (ICEV), hybrid-ICEV and fuel cell vehicles (Alkemade et al., 2009). The collection of all alleles belonging to all elements of a system corresponds with the entire design space of that product.

The second property of NK-models, K, refers to the degree of interdependencies between the system elements. If changes in different elements of a system do not affect each other's fitness at all (K = 0), optimizing a design is relatively straightforward. Because each mutation can be evaluated independently, a search journey is ultimately bound to reach the global optimum or 'peak' in a fitness landscape. The power of NK-logic, however, lays in its ability to model interactions between various attributes of an organization or product. Due to the presence of interdependencies, a single mutation within a product might increase the fitness of a particular element while reducing the fitness of others. On average, an apparent improvement (in one element) could thus turn out to result in an overall fitness reduction. The degree of interdependence in a system is at its maximum when a change in one element affects all other elements (K = N-1). When searching in the rugged fitness landscape associated with such a high level of dependencies, firms might perceive difficulties of enhancing the fitness of their products (Levinthal, 1997). Because of the far-stretching consequences of every mutation they introduce, it is hard to predict whether a jump in the fitness landscape results in any improvement at all (Beinhocker, 2006).

### 2.2 Strategic insights from NK-logic

Complex systems theory in the form of NK-models has been used for studying interdependencies in contexts like organizational level change, corporate strategy, transitions and innovation (Levinthal, 1997; Frenken, 2006). Supported by simulations of actors exploring fitness landscapes, Porter and Siggelkow (2008) argue that the dynamics described by the model provide a basis for defining how competitive advantage emerges. Assuming that experimentation is costly, firms face the challenge of balancing their innovation investments with the benefits of discovering strong combinations of resources. Uncertainty about

interdependencies might motivate firms to engage in 'local search' or 'hill-climbing'; the manipulation of one element at the time. By experimenting with resource configurations just requiring a single change, firms in a given market will eventually converge on an optimum within the fitness landscape. Some firms might imitate the identified peak, whereas those firms occupying worse local optima are likely to disappear from the market in question. The only way to outperform competitors is to discover even better combination of activities, which requires firms to change several elements simultaneously.

In absence of accurate insights in which impacts certain mutations have on other elements, the success of a radically new resource combination can only be gauged by engaging in resource-consuming experiments. Whenever a firm does manage to find a better optimum by radically changing its activity configuration, other firms are likely to experience severe difficulties when trying to imitate. Due to the contextuality within activity systems, however, imitators are required to align a wide range of interactive activities. Failing to align all activities, for instance as a result of lacking information, might lead investments to backfire (Porter and Siggelkow, 2008). Thus, although interdependencies make the innovation process more complex, they also prevent competitors from imitating successful configurations.

The innovation strategy in which firms combine secure short walks with risky long jumps is known as adaptive search (Levinthal, 1997). Simulation studies relying on NK-models resulted in a plethora of strategic insights with respect to interdependencies within combinatorial search processes (Levinthal, 1997; Frenken, 2006). Essentially, the suitability of a specific search strategy is found to depend highly on the characteristics of a fitness landscape and the population exploring it.

### 2.3 Multidimensional design of service innovation

In a recent contribution, Chae (2012a) demonstrates how new solution development could be interpreted as adaptive (i.e. evolutionary) search. Exploration and exploitation are argued to correspond with distinct search strategies. Translating Chae's highly conceptual perspective into empirically verifiable statements and practical tools for service innovation requires an appropriate conceptualization of how service design spaces could be represented.

Generally, services are associated with ill-defined design spaces (Nelson, 2003; Frenken, 2006). Due to service characteristics like intangibility, heterogeneity, perishability and coproduction (Parasuraman et al. 1985), it is relatively hard to get a grip on all (promising) mutations that could be introduced when altering the design of a service (Toivonen & Tuominen, 2009). Of crucial importance here is the notion that in services, design options tend to be fluid rather than discrete: product boundaries are characterized as blurred or fuzzy (Gallouj & Savona, 2009). One explanation lays in the fact that most services are not offered as a set of clearly defined products one can comprehensively list in a catalogue: firms might perceive difficulties when trying to formulate their propositions into distinctive concepts (Goldstein et al., 2002). Absence of a clear understanding of what really makes an offering limits possibilities to improve aspects of it. Related to this are findings that new service forms can often be explored ad hoc (Toivonen & Tuominen, 2009; Drejer, 2004) and in coproduction with customers (Hauknes, 1998; Den Hertog, 2000; Maglio & Spohrer, 2008). Firms often have to invest relatively few resources in order to extend their product

portfolios with an intangible offering directly inspired on the needs of a major client. The fact that clients play an important role in developing new ways of value creation blurs the process of generating mutations on the one hand, with obtaining (a priori) feedback from the selection environment on the other hand. In these circumstances, firms are found to perceive difficulties when assessing the extent to which the explored proposition is also attractive for other customers. Addressing the needs of a unique customer thus makes service innovation highly contextual (Chae, 2012b), which adds to the lack of transparency with respect to directions that might be viable for altering the design of services.

The multidimensional approach to service innovation, which we aim to advance, provides an excellent basis for representing the design space wherein interactive mutations can take place (Janssen et al., 2014). Over the years, various authors (Gallouj & Windrum, 2009; Windrum & Garcia-Goñi, 2008; Maglio & Spohrer, 2008) have been propagating an evolutionary approach to service innovation by providing frameworks in which services are regarded as combinations of different elements such as, for instance, provider and user resources, or tangible and intangible elements needed for the actual service solution (Miles, 1993; Maglio et al., 2009). When it comes to designing new or improving existent services, innovation can happen in any of the elements of the service in question (Ahuja & Katila, 2004; Zolnowski et al., 2013).

Noteworthy in this regard is the conceptual framework by Den Hertog et al. (2010), which is one of the few attempts to capture distinctive features of services in a single conceptualization valid for service innovation in general (Salunke et al., 2011). The framework consists of six dimensions, reflecting novelty regarding the service concept, customer interaction, business partner, value system, organizational delivery system, and technological delivery system. Changes in one of these dimensions are expected to prompt other changes in turn (Den Hertog, 2000; Den Hertog et al., 2010; Agarwal & Selen, 2011; D'Alvano & Hidalgo, 2011).

Adhering to universally valid dimensions, allowing for adequate descriptions of services (and changes therein), might be of great help for understanding the cluttered design spaces service innovators are generally confronted with (Gallouj & Toivonen, 2012). Being abstract yet well-defined and discriminant notions, the dimensions in the conceptualization by Den Hertog et al. (2010) can essentially be regarded as the boundaries (i.e. elements) of service design spaces. Each of the six dimensions covers a distinct type of changes; the alleles. Actual innovation efforts, accordingly, relate to specific routines reflected by a given dimension, rather than that innovation occurs at the level of dimensions themselves.

Defining design spaces on the basis of a multidimensional conceptualization of services points at questions hardly addressed so far. For instance, few studies examined whether service innovations might demonstrate change in just a single dimension (cf. local search) or always cover multiple up to all dimensions; whether there is any evidence (and explanation) for the emergence of specific combinations of dimensions (cf. the patterns hypothesized by Den Hertog, 2010); and most importantly: how the presumed interdependencies between dimensions affect processes concerning the actual design and implementation of a new solution (Carlborg et al., 2013; Chae, 2012b).

Due to the scarce availability of empirical examinations of frameworks like the one by Den Hertog et al. (2010), it remains unclear to what extent complex systems theory provides meaningful answers to questions regarding the design of multidimensional service innovations. Exploration of the explanatory potential of NK-logic requires empirical evidence of a rare kind, even for the broader innovation literature, stemming from qualitative research on the "middle ground between individual case studies and large-sample research" (Porter and Sikkelkow, 2008).

In the next sections, we first assess to what extent the multidimensional conceptualizations by Den Hertog et al. (2010) is able to capture distinctive features of novelty. Mapping various service innovations in a six-dimensional design space provides a so far unavailable impression of the dimensionality of innovations (Droege et al., 2009). Secondly, we examine interdependencies observed at the level of dimensions. Results are explored by interpreting services as emerging from adaptive search processes in a multidimensional, interactive system.

## 3. An empirical exploration of the systemic nature of service innovation

### 3.1 Research methodology

The objective of our empirical research steps is to use a single multidimensional framework for 'mapping' various service innovations. Although the mapping can be done just by relying on documented data, we reckon that an initial (exploratory) mapping demands deeper insights. In order to grasp the actual changes that constitute a renewed service offering, we perform several case studies on the level of concrete service innovations or service innovation projects. A critical validation of a multidimensional conceptualization requires a multi-industry approach, in which service innovations from various sectors are represented.

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INSERT TABLE 1

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In the context of a two year research program on open service innovation in the Netherlands, over a dozen case studies have been performed between beginning 2010 and February 2012. Besides involving collaborative research effort, cases were required to include some extent of novelty in order to count as an innovation. Table 1 reports a short description of thirteen innovations, studied in 9 firms of different sizes. For privacy reasons, the names of those firms are not included. Following a case study protocol developed at the start of our research project, we conducted between 5 and 10 semi-structured interviews per firm, each conversation lasting on average 75 minutes. In virtually all cases, triangulation of our data was enabled by (often publicly available) documents, such as newspaper articles, business journals, websites, flyers, manuals, and scientific publications. Besides establishing the novelty of the service being studied, these sources sometimes provided additional insights in how they came about.

In the post-visit stage, transcripts of the recorded interviews were made and non-relevant data was cancelled out (Bryman & Bell, 2007). This first interpretative round resulted in summaries that aimed to reduce the material to its relevant core. For verification purposes, those summaries were returned to interviewees, generating at maximum some minor adaptations. Subsequently, the texts in the transcripts were coded on the basis of the topic they were related to (following Miles and Huberman, 1994; Kvale 1996). The coded texts then allowed for a comprehensive case analysis, including the data retrieved from all interviewees and external sources.

After completion of a case, narratives of about twenty pages were returned to participating firms. In several occasions, the delivery of the narrative was supported by a presentation. Finally, all cases were discussed in a seminar where all of the participating firms were represented. All in all, the various communication activities provided the participants with ample opportunity for giving feedback.

### 3.2 Mapping the dimensions of 13 service innovations

At the outset, the thirteen cases we studied are highly different in their nature. Mapping them on discrete dimensions allows us to verify whether the selected conceptualization (Den Hertog et al., 2010) is able to cover accurately those characteristics indicating what is novel about an innovation. In the table below, the shading indicates to what extent a dimension of the innovative service-product reflects differences with respect to services the focal firm was providing earlier. Thereby, the performed mapping provides a qualitative indication of where we can find routines that are different from the ones deployed before the innovation was introduced. In this light, we discuss the changes leading to a score on each particular dimension.

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INSERT TABLE 2

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Introduction of a new service concept denotes the delivery of a solution or experience the firm didn't provide before. The best examples of a new proposition offered to (new or existing) customers are the Taxi service for travellers who are now able to book their pre- and post-flight transportation in addition to the flight itself, and the Franchise-formula developed by the health care provider. Generally, whenever modification of the new service concepts is taking place, the observed types of modifications are highly different from each other. In other cases, however, the core of an existing service remains largely intact while it is especially the other dimensions that are being manipulated.[1]

Typical for various cases of new forms of customer interaction, is that these are enabled through digital platforms (notably the Online communities, the Taxi services and the Digital payment system). Other cases that can be characterized by changes on this dimension demonstrate an altered task allocation. Whereas customers are awarded more influence and

[1] For instance, in case of the Online communities for elderly people, the core of the service is still the provision of insurances, just like the Real time navigation services are still about traffic innovation, be it more accurate and recent.

involvement in the Joint concept development case, the Asset management model (and to a lesser extent: the Valet parking) is based on taking over tasks from the client firm.

The recently introduced dimension of 'new business partner' turns out to be the dimension most frequently affected. Obviously, this is inherent to the criteria guiding the selection of cases. Important to note, however, is that the focus was on jointly developed projects; whether the resulting service was delivered through a partnership constellation was not a requirement. The case of Trained secondees, for instance, only involves a limited level of collaborative innovation efforts, although the service itself relies entirely on the complementary activities by both parties involved. Moreover, not all the studied services are delivered through collaboration with third parties. The Asset management model relies on a new type of partnership, established between just the engineering agency and its client[2]. This difference is expressed through a high score on the dimension of 'new client interaction'. If we look at which roles the external parties play, it becomes clear that they are relatively often related to the technology constituting the innovation. Especially in case of the insurance agency, the airline company and the bank, there is some correlation between the presence of a partner and the importance of technology[3].

Characteristic for changes on the '*new business model'* dimension is that they often denote an altered cost structure. The models deployed in the online communities and real time navigation concern registrations for a service. Especially in the latter case, continuous payments mark a clear shift with the usually more incidental purchase of navigation hard- or software (i.e. map updates). Also the Asset management model and the Health care franchise involve a business model innovation with respect to the payment structure. Instead of getting paid per hour, the engineering agency fulfils a risk-taking role in which she is rewarded for saving maintenance costs and increasing asset quality. Similarly, the hospital engages in contractual agreements with franchise-takers, charging them an annual fee for enjoying superior practices.

With respect to 'new delivery systems*'*, the technological component appears not to be as central in our cases as suggested by the original 4D-model (Den Hertog, 2000). The cases in the domain of HRM services, health care, and exhibitions demonstrate various elements of novelty, without technology being one of them. In these instances, especially new forms of organizationally delivery systems are found to be prominent. Thus, whereas renewals in the technological system might co-occur with the presence of new partners, it might be a substitution for renewal in internal competences, skills and culture. This only holds when the technology is a relatively independent element of the service: whenever it concerns a website operated by the focal firm, for instance, changes in digital competences are likely to be required as well.

[2] In the initial phase of this partnership, the asset owner (an industry site or local government) and the engineering agency jointly invest about a year time in developing a long-term maintenance plan. During the actual fulfilment, the engineering agency carries all the financial risks for meeting the targets set out. Instead of charging on an hourly basis, the engineering agency is supported to save costs and increase asset quality. By providing full transparency to the client, mutual trust is created, which is why perceive to engage in a partnership rather than in a supplier-relation. From the engineering agencies side, this form of management requires skills and competences not present before.

[3] Also in case of the manufacturer of navigation devices, the external partner brings in technological expertise. In this case, however, the correlation is less clear because the focal firm itself is to a large extent responsible for renewal of the technological delivery system.

### 3.3 Exploring the service design space

As discussed earlier, the design space for services is commonly regarded as ill-defined (Frenken, 2006). Indeed, amongst those cases that did manage to attach a clear label to a discrete innovation we find especially the innovations in which technology had a prominent role (e.g.: the Digital payment system and the Real time navigation), whereas within innovations relying on a higher level of intangibility there was much less understanding of how the innovation could be defined. In the cases of Joint concept development, renewed Asset management model or Trained secondees, for instance, the innovations were relatively hard to distinguish from other activities in the provider's service constellation. Moreover, in this last case, the mutation (introduced to fulfil the needs of a particular customer) was hardly recognized as an actual innovation. As a result, the focal firm experienced severe problems with scaling the new service to new clients.

Having a very limited understanding of where innovation could occur might hamper the development of effective innovation procedures (favouring innovation by trial-and-error) or have a creativity-inhibiting up to paralyzing effect on firms wishing to improve their output (Zolnowski et al., 2013; Gallouj & Toivonen, 2012; Patrício et al., 2011; Ruiz Moreno et al., 2011; Oke, 2007). When the number of possible mutations appears to be extremely high and firms face client-specific design spaces, how does one decide which paths to explore?

Our exploration of the elements constituting a service design space appears to provide grounds for describing where innovation is taking place if it is not solely the final offering (Droege et al., 2009). Although the cases of Team Training and the Digital payment system might both seem pre-dominantly process-innovations (from the perspective of the focal firm), the findings summarized in table 2 indicate they are essentially different from each other. Even without affecting the service concept both cases concern a unique combination of service characteristics, reflecting the idiosyncratic ways in which the respective firms are realizing innovative improvements. Also for other cases, the provided analysis demonstrates how distinctive features of various service innovations are captured relatively well by the dimensions of the framework we deployed (Den Hertog et al., 2010). This observation provides valuable qualitative evidence that those six abstract 'pillars' for characterizing services can be used to represent the elements within the design space associated with new service development.

Apart from allowing characterization of where novelty occurs, a validated multidimensional design space also has the potential of providing guidance in the design of service innovations (Gallouj & Toivonen, 2012; Zolnowski et al., 2013). When searching for potentially successful modifications of an existing service, or even when trying to configure an entirely new proposition, service innovators might consider a holistic set of dimensions as a 'map' that delimits the range of explorable possibilities. For instance, in the case of the Asset management model, the dimensions provide suggestions for further development of the innovation. Focusing at the previously unaffected dimensions would point at the possibility of including a new business partner (e.g. collaboration with or certification of contractors), introducing a new technological delivery system (digital monitoring), or further modification of the organizational delivery system (acquiring additional legal/financial competences).

Looking at our empirical evidence, we also observe that not all innovations are truly unprecedented mutations. Instead, some innovations demonstrate changes that can be considered archetypical for a certain dimension. When designing a new business model, for instance, 'common alleles' include the choice to make incidental deals (e.g. charging a fixed fee each time the Digital payment system or Shuttle service is used), to provide services on a registration basis (e.g. the Real time navigation, membership of the Online community for freelancers, and the Health care franchise), or to base the cost structure upon the savings a service provider realizes (in case of the Asset management model). Similarly, an archetypical mutation in case of introducing mutations to technological delivery systems is to introduce a web-based communication channel (Online communities) or to connect various databases (Taxi service). When identifying common mutations for designing an altered value system, one could think of all the possible roles a new partner could fulfil; supplying technology (e.g. Online communities, Waste conversion, Digital payment systems) or information (Real time navigation), providing complementary services (Trained secondees) or covering a part of the execution of the new service (Valet parking, Shuttle service). Typical alternatives for new forms of customer interaction, to conclude our examples, are ways to take over some of their tasks (Asset management model, Valet parking) or to let them more themselves (Taxi service, Joint concept development).

Familiarity with archetypical modifications is likely to support firms when considering which changes to introduce in which dimensions. Especially when these mutations become commonly known and get codified (Nonaka & Takeuchi, 1995) or formalized adequately (Gallouj & Weinstein, 1997), the perceived transparency of design options can be increased. Besides enhancing possibilities for innovating through recombination (following Schumpeter, 1934)[4], the demonstrated success of a particular mutation could also result in less organizational resistance to adopting it (Schilling et al., 2012).

### 3.4 Exploring the interdependencies within multidimensional service systems

Having an impression of the various ways in which a new service can be composed might contribute to a firm's perceived control when engaging in service design. To what extent a mutation in one or more of the dimensions enhances the perceived quality or fitness of a service, is yet another issue. According to NK-logic, dimensions cannot be seen in isolation from each other. Success of service innovation is argued to depend on a firms understanding of the mechanisms determining how various dimensions are affected simultaneously (Chae, 2012b). As argued before, the presumed dependencies within services (Den Hertog et al., 2010; Gallouj & Weinstein, 1997; Agarwal & Selen, 2011) introduce a level of complexity with respect to balancing changes in multiple elements at the same time. In order to examine the existence of those interdependencies, expressed by parameter K in the NK-model, we investigate to what extent the reported changes within an innovation occur independently from each other.

[4] Recombination here concerns the implementation of adaptations that are common within a given dimension; it is not about bundling service concepts themselves (cf. Den Hertog et al., 2010)

### 3.4.1 Innovations characterized by independent changes

If changes in different elements of a service system do not affect each other's fitness at all (K = 0), possibilities to evaluate each mutation independently make optimizing a design relatively straightforward.(Frenken, 2006).

Looking at our cases, it is not very probable that the conceptually distinct dimensions are also empirically uncorrelated (Janssen et al., 2014). One type of evidence for a service system with such properties would be a case where only a single dimension changed. In none of the 13 cases examined, this is observed. Although our qualitative evidence makes it unlikely that changes tend to occur independently from each other, it should be noted that our findings might be somewhat biased. First of all, innovations based on a one-dimensional change are probably less visible than those involving a multitude of changes. This reduces the chance that it is identified as innovation and selected as a case. Secondly, it might be that innovations involving changes on just a single dimension are relatively less successful (Chae, 2012b; Janssen et al., 2014). If this is true, it points at another possible reason why such innovations are not present in our sample.

An indication that even minor improvements stretch over more than one dimension, reducing the likelihood of very low K-values, is provided by the cases observed in the hospital we studied. One could argue that highly visible innovations tend to be characterized by changes in many dimensions, whereas it may be the modest innovations that involve just a single dimension (for a discussion of defining radical service innovation, see section 4.3). Interviews with directors of the examined hospital show that they regard many of their innovative efforts as part of a single transformation concerning the safety and hospitality of the environment they manage. Besides the examples discussed earlier, these efforts also contain modest interventions such as a 'Time-out' procedure which requires doctors to verify multiple times if they are about to do the correct operations. If this portfolio of very small actions would be considered as one innovation, it might be an example of a case in which various dimensions are changed without the full spectrum of changes being caused by interdependencies. However, as table 2 demonstrates, even small innovations like Team Training and Valet Parking cover a multiplicity of dimensions already.

### 3.4.2 Innovations characterized by fully interdependent changes

The opposite of a design space characterized by independent changes, is a service in which all dimensions are inherently related to each other (K= N-1). Far-stretching consequences of every mutation a firm introduces limit possibilities of ex-ante examination of its success and possibly require firms to make additional modifications.as well.

Although most of the cases studied in this paper stretch only over an intermediate number of dimensions, the changes that do occur often seem to be entirely correlated. When taking a close look at the way they evolved, it is not or hardly possible to imagine the innovation without a change on one of the dimensions that was ultimately affected. A striking example is the Asset management service. In this specific proposition, relatively unknown in the market of engineering agencies, the focal firm takes over some of her client's tasks by creating partnerships. Introducing a responsibility-based business model in which the engineering agency carries substantial risks (but is rewarded according to performance, instead on an hourly rate) is inherently connected to the creation of those partnerships. Only

through the creation of high levels of trust, the client is willing to source out even the strategic (rather than operational) planning of her asset management. Also necessarily related to these changes is the mutation in the organizational delivery system: the novel service requires so much new competences that external employees had to be attracted (for acquiring skills in project management and finance) or taken over from the client itself (for technical knowledge related to asset management). In sum, it is likely that the innovative asset management service would not be feasible or far less successful if any of the involved changes was not carried through.

As already noted earlier, some other cases rely on technology enabled by the expertise of a newly involved partner (e.g. the airline company, the bank, the provider of navigation services). In essence, one could state that adapting the value system through the inclusion of a partner was not necessary when the focal firm would have had the required technological knowledge itself. The possible mutation in the value system, in this regard, could be independent from all the other mutations. On the other hand, however, we have to admit that the knowledge base of firms is always limited, which is why partner involvement might be relevant for introducing any kind of change. Especially when a desired innovation requires knowledge uncommon the sector a firm is operating in, involving partners through the development of a collaboratively produced service might be a good strategy. In those cases, whether or not to rely on the exclusive knowledge of a partner is not a choice that can be made independently of other considerations related to the envisaged innovation.

### 3.4.3 Innovations characterized by modular changes

Finally, NK-logic has been used extensively for exploring the possible benefits of modular designs in which only there are strong interdependencies within modules, but none or few between them (Frenken & Mendritzki, 2012). Despite being associated with fitness landscapes less smooth than the ones of systems without any interdependencies, modularity is likely to contribute to the probable success of search efforts (Frenken, 2006). Recognizing the importance of modularity for both service innovation and implementation, more research on this account has been urged for (Carlborg et al., 2013).

The scarce attention that has been devoted to service modularity so far mainly concerns the deployment of different independent service offerings (Zolnowski et al., 2013; Rahikka et al., 2011; Pekkarinen et al., 2008), jointly part of complex service constellations (Van Riel et al., 2013). Illustrative in this respect are the various projects as developed by the health care provider. Recall how the deployed innovations are all distinct yet part of a wider plan to increase overall hospitality and safety. Each of the studied innovations (and beyond), all of them characterized by specific changes in various dimensions, can be regarded as an individual step towards these goals. Although some dimensions do turn out to be affected by various innovations, none of these co-occurrences really concern the same mutation (in terms of the actual allele that was introduced). The fact that the new services are not directly affecting each other, making them modules of the development towards increased hospitality and safety, implies ample opportunities for acquiring feedback from customers as well as employees. As a result, unsuccessful initiatives do not endanger the entire service offering. Instead, they are distinct experiments that can be evaluated and improved or abandoned without requiring immediate management attention for other activities as well.

By interpreting service innovation as evolutionary search in multidimensional spaces, the notion of modularity can also be applied to analyse dynamics within individual services rather than interactions between various services shaping a service constellation. Modular changes, in this perspective, occur in situations in which mutation X impacts just a couple of dimensions whereas mutation Y affects another 'block' of dimensions. In presence of a modular architecture, several parts of a service can be modified without inducing changes in (the fitness of) all other elements that are required to change in order to bring about the desired innovation.

The Online communities, developed by the insurance provider and its partners, provide an excellent example of how modular design in services can be organized. The firstly introduced platform, aiming at elderly people, was merely a different channel for communication with customers. The second community, subsequently, also introduced changes in the service concept itself (resulting in extra incomes). These two innovations point at two stages, in which the second change does seem related to the first one. However, although the advisory services are delivered over a digital platform, this is not a necessary requirement. In principle there are other ways to deliver advice to community members (in written reports or through physical meetings): in this case the platform is probably just a very attractive way. The two discernible changes involved, creation of a digital community and delivering advice, both affect just a small number of dimensions. Only by combining the modular innovations or 'service units' (Carlborg et al., 2013), we arrive at an innovation that affects all dimensions to some extent.

A similar example is embodied in the Joint concept development case. The core of this innovation lies at the establishment of a commission in which the trade mart cooperates with her clients (the exhibitioners). Apart from introducing this commission, the trade mart also started deploying activities to attract more visitors to her fairs, thereby increasing her value for exhibitioners. Those activities are only partially coordinated by the commission: in theory it would have been possible that the trade mart organized everything herself. Although that would probably not have been the most effective way, it does demonstrate that the two innovations (and their dimensional changes) are not inherently connected to each other.

Our results demonstrate how complexity and modularity are relevant when analysing and managing the evolution of service constellations as well as individual services. A high number of changes, encountered in for instance the dimensions of the Online community for freelancers, might suggest that an innovation is relatively radical. In reality, however, apparent long jumps can turn out to rely on the smart combination of distinct modules.

Following a modular strategy allows firms to arrive at unique service solutions by engaging in independent experiments, each of them providing valuable feedback on the customers satisfaction and future needs. According to NK-logic, modular design is particularly able to create advantages in evolutionary search processes when interdependencies are unknown and trial-and-error is an important mode of innovation (Frenken & Mendritzki, 2012). As argued throughout this paper, both characteristics are typical for renewal of intangible and coproduced offerings. The empirical evidence we provided illustrates how modularity can be interpreted in the context of multidimensional services.

## 4. Conclusions

The purpose of this paper is to advance the multidimensional approach to service innovation (Carlborg et al., 2013). In this respect, we relied on efforts aiming at thinking of service innovation as adaptive search (Chae, 2012a). According to such an evolutionary interpretation, innovation concerns the deliberate variation of elements in a multidimensional design space (Axelrod and Cohen, 2000). We provided an empirical application of a integrative conceptualization that turns out to represent the elements of a service design space relatively well. The provided case analyses open the way for further application of insights stemming from complex systems theory.

### 4.1 Dimensionality of service innovation

First of all, empirical illustration of the conceptualization by Den Hertog et al. (2010) aims to give a qualitative impression of the dimensionality of service innovation. By pointing at communalities and differences of 13 highly distinct cases, the described applications provide guidance during the search process: which dimensions can be changed, and how (Rubalcaba et al., 2012)?

A substantial advantage of adhering to a single conceptualization to delimit the elements of a service design space, rather than identifying useful dimensions over and over again, is that it provides a solid basis for comparative analysis (Gallouj & Toivonen, 2012; Janssen et al., 2014). From the increasingly adopted synthesis perspective to innovation (Coombs & Miles, 2000; Gallouj & Savona, 2009; Carlborg et al., 2013), there is ample interest for frameworks allowing scholars to learn from service innovation efforts in a wide variety of sectors. Whereas intangibility might make innovations hardly comparable, even within industries, representing them in a single design space gives a more comprehensive view on what an innovation exactly entails and what elements could be useful in other circumstances as well. Therefore, also managers can benefit from a common lens to look at the design of service innovations. Especially when communicating with enterprises from other sectors, absent the threat of competition, application of common dimensions opens the door to interorganizational learning. Reasoning from NK-logic, our efforts demonstrate the potential of identifying archetypical mutations such as the various ways to adapt the cost structure of the business model dimension. Analogous to cross-fertilization enabled by the observation of successful technological elements (Björkdahl, 2009), those archetypical mutations allow service innovators to base a newly designed proposition on adaptation of proven service features. Future research applying our conception of a service design space in more settings can result in an extended and more detailed view of standard ‘alleles’ and how they can be implemented.

### 4.2 Interdependencies between dimensions

The observation that most innovations involve multiple dimensions, understood as revealed interdependencies, supports the presumed existence of complexity in the search process service innovators engage in. In some instances it might be ‘technically’ possible to modify just a single dimension, but then the usability (or evolutionary fitness) of the resulting service is expected to be very weak.

Just like none of the cases is found to rely on change in just a single dimension, neither of them covers all dimensions. Without pretending to interpret the case results as if they were sound statistical data, there does seem to be some evidence that most cases stretch only over an intermediate number of dimensions. Such a finding is common for other studies of real-world examples as well (Simon, 2002). Counting major changes as entire mutations, and minor changes as half a mutation, the examined cases demonstrate on average about 3 interrelated changes. In terms of the NK-model, we can state that our cases tells us something about the degree of interdependence ($K \approx 3$) commonly associated with the respective design spaces ($N = 6$) based on the framework by Den Hertog et al. (2010). Our findings allow scholars to experiment with calibrated NK models in studies simulating how firms can benefit from different search strategies when exploring a service design space.

A fruitful but under-explored way of reducing complexity is the pursuit of modular services (Carlborg et al., 2013; Rahikka et al., 2011; Pekkarinen et al., 2008). Deploying modular services, here predominantly studied in a non-ICT context, is argued to provide strategic advantages when aiming to renew or improve services. Because the various modules involved do not have an impact on each other, corresponding with a low level of dimensions simultaneously affected by distinct innovations, search efforts can benefit from ample possibilities to engage in hill-climbing (rather than being required to make risky long jumps). Future research on this account can shed more light on how modularization within services, just like between them (Zolnowski et al., 2013), can be organized; which are ideal conditions for allowing firms to experiment with independent mutations, and is there an optimal level of modularity (Frenken & Mendritzki, 2012)?

### 4.3 Strategic implications

Interpreting service innovation as a combinatorial search process in complex multidimensional spaces has important implications for how firms can enhance their competiveness (Bryson & Taylor, 2010). Intangibility and many or ill-understood interdependencies are argued to create circumstances in which it is difficult to learn about successful configurations and interactions. As such, it hampers possibilities to replicate a service (Bowen & Ford, 2002). However, it also implies that opportunities for imitating successful configurations are limited (Porter and Siggelkow, 2008; Bryson & Taylor, 2010).

An adaptive search strategy for arriving at new service solutions relies on a combination of incremental and radical innovations (Chae, 2012a). By providing a validated conceptualization of service design space, our contributions allow scholars to examine the under-addressed success-factors related to both types of innovation (Droege et al., 2009).

Determining whether an innovation is incremental or radical, is commonly done by assessing the extent to which the offering is new to the firm, market, or world (OECD, 2005). This criterion can concern the service as such, as described by its service characteristics (Saviotti & Metcalfe, 1984), or the novelty of individual dimensions, leading authors to introduce an aggregate view to radicalness (Gallouj & Weinstein, 1997). Conceptualizing services by relying on multiple abstract but stable dimensions provides the required basis for assessing to what extent a modification is novel. Considering the very number of novel dimensions as indicative allows for development of composite indicators as explored by Janssen et al. (2014). However, the current qualitative examination of innovation

dimensionality demonstrates that developing a genuinely new 'allele' is more radical than introducing a modification that is archetypical for the affected dimension.

Next to novelty of the service proposition, radicalness can refer to the extent to which an organization has to change its current routines in order to deliver the envisaged product (Nelson & Winter, 1982). A radical innovation, from an evolutionary perspective, is an innovation that requires new routines with respect to many dimensions. Although the created service innovation might be hardly novel, it will be difficult to realize it when an organization has to transform its practices drastically. By having our cases scored from the perspective of changes in a firms design space, the observed contrast is exemplified by the case of Team training. Here, safety in a hospital is increased by providing an aviation-inspired course to the medical staff. The innovation in question involves only one major and one minor change (in the organizational delivery system and values system, respectively), but is at the same time highly original. Subjecting a medical team to a flight in a simulator, in which an altered hierarchical structure should teach the staff to overcome barriers and communicate better, is worldwide unprecedented.

Clearly, measures of radicalness in terms of novelty and organizational transformation might be at odds with each other. An evolutionary interpretation of service innovation favours the latter, in which a 'giant leap' is considered as a step in which multiple dimensions or classes of routines have to be changed simultaneously. It should be noted that the degree of interdependence within a service system is of great relevance here. Compared to a combination of modularly designed services, an innovation affecting all dimensions is more radical when the level of interdependencies is very high.

To conclude with, we stress that thinking of service innovation as an evolutionary search process could benefit from unexplored research avenues. Whereas the current study focuses on the dimensionality and interdependencies, additional research is required for more insight in the capabilities a firm should possess when engaging in combinatorial design of service innovations (Den Hertog et al., 2010; Kindstrom et al., 2012). Various authors have proposed conceptual sets of dynamic capabilities with relevance for service innovation, but quantitative studies remain scarce (Salunke et al., 2011).

Apart from examining the role of dynamic capabilities possessed by a firm itself, scholars should devote attention to which type of mutations are typically enabled by skills and competences brought in by clients or partners (Gallouj & Weinstein, 1997). The urge to study open innovation in the context of services suggests that capabilities are only partially responsible for the results of innovation efforts (Chesbrough, 2011; Rubalcaba et al., 2012; Bryson et al., 2012). Most of our cases show that partners are not only involved as part of a newly designed value system, but contribute to developing or executing changes in other dimensions as well.

Finally, acknowledging that path dependency is commonly associated with the way firms explore design spaces and products evolve, scholars could devote attention to the question whether this is a real phenomenon in services as well. Having validated our approach across different industries, one might now want to use it for tracking mutations within the wider evolution of a single service. Could it be, that there is such a thing as service trajectories after all (Castellacci, 2008)?

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## Tables

Table 1: Description of cases

| Case nr. | Firm Size | Sector | Innovation | Description |
|---|---|---|---|---|
| **1** | Large | Insurances | Online community: elderly people | Together with two software developers, the focal firm created a community platform for elderly people. Through the platform, she facilitates discussions and communicates with customers. Thereby, it is a channel for following users and offering insurances. |
| **2** | | | Online community: freelancers | Similar to the community described above. Only differences are the variety and quality of services offered on the platform (e.g. expert advice), and that users are required to pay for membership. Besides acting as a multi-purpose channel, the platform thus generates revenues and provides additional services. |
| **3** | Large | Aviation | Waste conversion | This provider of aviation services developed an approach for converting her catering garbage into fuel, which the company in turn uses as an energy source for her catering services. This 'internal' service also leads to a green image. |
| **4** | | | Taxi service | Digital application for booking taxi trips (in addition to flight tickets) from and to the airport. Partner is involved for development of software algorithms scanning databases of taxi companies all over the world. |
| **5** | Large | Financial services | Digital payment system | This bank pioneered the domain of mobile banking by developing a mobile wallet (not normal bank account), which is linked to various applications, such as NFC-paying systems and digital ordering/paying application. |
| **6** | Medium | HRM services | Trained secondees | By joining forces with an engineering agency, this HRM service provider is able to provide her clients secondees that received relevant (on-site) training and client-specific expertise. On-site account manager generates extra leads. Offered as an integrated service. |
| **7** | Large | Navigation services | Real time navigation | Instead of selling personal navigation devices (PND's), the focal firm increasingly offers real time traffic information to registered customers paying a monthly fee. Live data is gathered by and distributed over telephone network. |
| **8** | Medium | Exhibitions | Joint concept development | Besides renting surface to exhibitioners, this trade mart now interacts with them in a commission that develops new concepts for fairs. Moreover, they jointly organize activities for attracting more visitors. |
| **9** | Large | Engineering | Asset management model | Model in which engineering agency takes over the clients tasks related to asset management. Operationalized through a contract/partnership in which the agency carries risk, but is awarded for performance. |
| **10** | Large | Health care | Team training | Training for medical staff, aimed at increasing safety by breaking communication problems due to hierarchical relations. Involves flight in simulator, in which hierarchical roles differ from normal structure. |
| **11** | | | Valet parking | Rather than asking visitors and patients to park their own car, the focal firm offers hospitality in form of valet parking. Revolutionary in Dutch health care. |
| **12** | | | Health care franchise | Various innovative practices for improving hospitality and safety are offered to other hospitals, in exchange for fulfillment of a franchise fee. |
| **13** | Medium | Logistics | Shuttle service | In order to improve capacity and efficiency of inland shipping, a Dutch port organized a shuttle service for transportation of containers. The approach is more reliable and prevents suboptimal (half-loaded) transportation moves. Actual execution of the reorganized transport is performed by the ports' clients. |

Table 2: Mapping the dimensions of service innovations

| | | Affected dimensions of service innovation | | | | | |
|---|---|---|---|---|---|---|---|
| | | New service concept | New form of customer interaction | New business partner / value system | New business model | New organizational delivery system | New technological delivery system |
| **1** | Online communities: elderly people | | Direct customer-interaction through platform | Partner developed and runs websites | Other insurances offered over platform | Provision of expertise via online communication | Online community via webbased platform |
| **2** | freelancers | Insurance provider now delivers advice to community | Direct customer-interaction and advice through platform | Partner developed and runs websites | Customers pay fee for membership | Provision of expertise via online communication | Online community via webbased platform |
| **3** | Waste conversion | | | Partners delivers conversion technology | | Focus firm embeds 'green' image in culture | New technology converges waste into energy |
| **4** | Taxi service | Aviation firm offers taxi services | Customers can book plane and taxi at same time | Partner provide algorithms for booking taxi's | One-stop-shop for door-to-door transportation | | Algorithms connect taxi databases |
| **5** | Digital payment system | | Customer can access money differently | Partners use digital wallet in new apps | Customer pay fee each time they use service | | Service relies on new soft- and hardware |
| **6** | Trained secondees | On-site training results in trained secondees | | Engineering agency trains secondees | Secondees are located at partner and its clients | Firm sends account manager to site of client | |
| **7** | Real time navigation | Still navigation services, but better (live) | | Traffic info comes from mobile network | Bundle of services, offered via registration | Firm acquired partners for tech. knowledge | Tech. for live communication with PND's |
| **8** | Joint concept development | Firm offers more than surface: also events | Marketing commission for coop. with client | External partner facilitates joint concept develop. | | Focus on collaboration, instead of selling | |
| **9** | Asset management model | Still asset management, but now as 'total solution' | Partnership with client allows transfer of responsibilities | | Revenues now % of budget and based on performance | Client-specific and management knowledge now more required | |
| **10** | Team training | | | Pilot trainer provides courses | | Medical teams collaborate more | |
| **11** | Valet parking | Service is new in sector, but does not affect core b. | Visitors no longer park car themselves | Drivers delivered by partner | | | |
| **12** | Health Care franchise | Hospital did not offer franchise | Other hospitals become client | | Revenues by franchise fee | Independent department | |
| **13** | Shuttle service | | Transport is executed by clients | Shuttle service is mainly run by freighters | Shuttle has fixed schedule with fixed tariffs | Port has to be operationally involved now | Only technology is a ship with mounted crane |

Legend: Not shaded = no change
Light shaded = minor change
Dark shaded = major change