DERIVING DESIGN PRINCIPLES FOR IMPROVING SERVICE MODULARIZATION METHODS – LESSONS LEARNT FROM A COMPLEX INTEGRATED HEALTH CARE SERVICE SYSTEM

Complete Research

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Abstract

In recent years, the principle of modularity has been increasingly applied to services as service providers seek to reduce time and cost of delivering customized service offerings. Given the intangible nature of many services, the identification of all elements and interdependencies is more challenging compared to technical systems. Uncertainty or vagueness of system composition can lead to higher efforts in system analysis and limit the quality of design decisions derived from a modularization of a service architecture. Therefore, we propose an iterative approach for the application of the Multiple Domain Matrix method for the modularization of complex service systems. By performing a detailed analysis of the service system's elements and interdependencies, we propose design principles that enhance the application of the Multiple Domain Matrix method to complex service systems in order to increase the information quality of the analysis. The design principles emphasize interdependent consistency checks and a structured dialogue between service system analysts and domain experts that refine the model of the service system underlying the modularization. We demonstrate our approach by an application to a complex service system for integrated health care service in mental health care.

Keywords: Design principles, Multiple Domain Matrix method, modularisation, quality, service

1 Introduction

For a long time, the concepts of product, process, software, and system modularity have been well established in both academic research and practice (Baldwin and Clark, 2000; Schilling, 2000; Ulrich and Tung, 1991). They refer to an approach of organizing complex products and processes efficiently (Baldwin and Clark, 1997) by decomposing complex tasks into simpler activities so they can be managed independently (Mikkola and Gassmann, 2003). Modularity permits components to be produced separately and used interchangeably in different product configurations without compromising system integrity (Mikkola and Gassmann, 2003; Baldwin and Clark, 1997). In recent years, the principle of modularity has become more and more important for services as service providers seek to reduce time and cost of delivering customized service offerings (de Blok et al., 2010; Voss and Hsuan, 2009; Meyer and DeTore, 2001). Numerous papers demonstrate the applicability of modularity to a wide range of services, such as telemedical (Peters and Leimeister, 2013), logistics (Bask et al., 2011), health care (de Blok et al., 2010), hospitality (Voss and Hsuan, 2009), and IT services (Böhmann, 2004).

From this research, a variety of conceptualizations for service modularity and modular service architecture has emerged. Additionally, a number of methods have been proposed and applied to services for designing modular service systems. A systematic review of the extant literature demonstrates that these methods are insufficient for specific requirements of service modularisation (Dörbecker et al. 2014). In other contexts, such as product development, the Design Structure Matrix method as well as its extensions to the Domain Mapping Matrix method and to the Multiple Domain Matrix method represent well established modularization methods. In recent years, numerous papers demonstrate the applicability of these matrix-based methods to the context of services (Dörbecker and Böhmann 2014). Generally, the conceptual framework of these methods is evident, but for the application to services the identification of all constituent elements and their interdependencies poses a major challenge. As services are often intangible, elements and their interdependencies have to be rendered visible and given a name. Hence, provision, analysis and quality of information play a major role. This may lead to a higher effort in the analysis of the present service system as opposed to other technical systems and the resulting modular service architecture may depend on the quality of information gathered.

To address this research gap, we propose an approach for the application of the Multiple Domain Matrix method to complex service systems. This approach follows findings from theory and experience in practice. It allows (1) a systematic decomposition of a service system into its constituent elements, (2) a check of these elements in terms of consistency, (3) a detection and analysis of their interdependencies, (4) a validation of the elements and interdependencies with experts from different domains, (5) a composition of elements of high cohesion into loosely coupled modules, and (6) an evaluation of the proposed modular service architecture. In each step, we highlight the involvement of experts from different domains. We demonstrate the application of the approach by the help of a real existing complex integrated health care system. Finally, we derive design principles from this approach that emphasize interdependent consistency checks and a structured dialogue between different experts in order to refine the model of the service system underlying the modularization.

The example for the demonstration represents a complex of several integrated sub-systems building a network for innovative mental health care solutions. The system has been launched as an innovative project in a large city in Germany several years ago and has been funded by the German government. The project connects multiple actors and organizations within mental health care and aims at providing education about mental disorders, preventing and strengthening the care and building new structures of integrated care. We aim at identifying core- and non-core modules as well as synergy potentials and benefits within this service system. This results in an integrated care concept for the present health care system that can be potentially transferred into other health care systems in different places.

We aim at contributing to the methodological knowledge base of service engineering (Bullinger and Scheer, 2006) and follow a design-oriented research strategy (Hevner et al., 2004). The Design Science Research Process Model given by Peffers et al. (2006) is used to develop the approach. Therefore, this paper is structured as follows. We present the concept of matrix-based methods, outline their recent application to services and introduce the topic of quality in models. Next, we introduce our example and design the six-step approach. We then present the results of its demonstration. Finally, we discuss our results and derive further insights for future research.

2 Conceptual Foundations

2.1 Matrix-based methods for modularization

For a long time, the Design Structure Matrix (DSM) method as well as its extensions to the Domain Mapping Matrix (DMM) method and to the Multiple Domain Matrix (MDM) method have been well established modularization methods within the context of product development (Eppinger and Browning, 2011; Danilovic and Browning, 2007; Yassine, 2004; Sosa et al., 2003; Yassine and Braha, 2003; Browning, 2001; Steward, 1981a; Steward, 1981b; Steward, 1965).

A matrix-based method assists in structuring a system into domains, elements and their interdependencies within these domains (Steward, 1981a; Steward, 1981b). A ‘system’ is “created by entities (elements) and their interdependencies (relationships) forming a system’s structure”, whereas a ‘domain’ "represents the classification of elements which create the system" (Kortler and Lindemann, 2011, p. 2). Within product development, the elements can be the components of the product and the interdependencies can be the interfaces between these components (Eppinger and Browning, 2011). Within an organizational architecture, the elements can be people or teams within the organization and the interdependencies can be communications between the people (Eppinger and Browning, 2011).

A DSM is used to describe the interdependencies of elements within one domain. A DSM is a square nxn-matrix with n elements. The names of the elements are displayed vertically as row titles and horizontally as column titles. If there is an interdependency between element i and j, an entry is set into the matrix at position ij. Interdependencies between elements can be of binary or weighted nature. Binary interdependencies indicate whether or not a relation between two elements exists. Weighted interdependencies additionally indicate the strength of the relation. Typically, a self-reference of elements is excluded. Therefore, the diagonal is greyed out from the left upper to the right lower corner of the matrix. (Krüger and Arndt, 2013; Eppinger and Browning, 2011; Danilovic and Browning, 2007)

A DMM is used for mapping two different domains. A DMM is a non-square mxn-matrix connecting two DSMs, whereas m is the size of the first DSM and n the size of the second DSM. A MDM is used for mapping more than two domains and represents an integrated presentation of several DSMs and DMMs. A MDM is a square nxn-matrix containing n elements. The presentation of interdependencies within a DMM and MDM corresponds to a DSM. (Krüger and Arndt, 2013; Eppinger and Browning, 2011; Maurer and Lindemann, 2008; Danilovic and Browning, 2007) An exemplary illustration of a MDM relating the elements of three domains can be found in Figure 1.

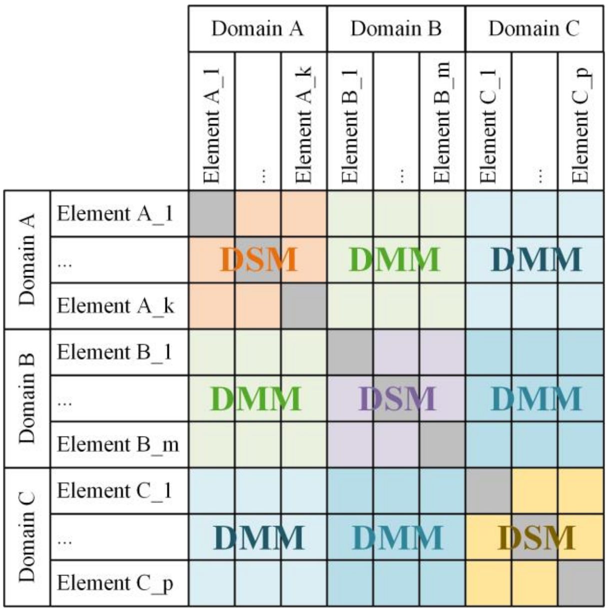

Figure 1. Exemplary illustration of a MDM for three domains (Dörbecker and Böhmann 2014)

The design of a DSM or DMM is performed in two steps: 1) Decomposition of the system into its constituent elements, and 2) identification of the interdependencies between these elements (Eppinger and Browning, 2011). The design of a DSM is followed by a partition (e.g. clustering or sequencing) that assists in the design of modules (Eppinger and Browning, 2011).

2.2 Application of matrix-based methods for service modularization

Dörbecker and Böhmann (2014) identified 18 articles in an extensive literature review that apply matrix-based methods to the context of services. The analysis of the identified articles considers nine criteria in order to conclude whether a commonly used and widely accepted process for the application of matrix-based methods to services exists. The results indicate that adequate data gathering followed by an in-depth analysis of the constituent elements and their interdependencies are indispensable for the modularization. However, to the best of our knowledge, there does not exist an approach that describes in detail the steps to be undertaken to adequately prepare the data of a service system for a goal-oriented modularization. The intangible nature of many services, the degree of granularity of elements, the detection and analysis of interdependencies between elements, and the consistency and validation of the gathered data before modularization are essential for a resulting modular service architecture.

2.3 Quality in conceptual modelling

Lindland et al. (1994) propose a framework for understanding quality in the context of conceptual modelling. They argue that modelling is “essentially making statements in some language” and define three types of script quality based on the dialogue between different sets of statements: (1) Syntactic quality, (2) semantic quality, and (3) pragmatic quality, see Table 1. By ‘script’, they refer to the product obtained by applying the process of conceptual modelling. Krogstie et al. (1995) extend this framework by adding a fourth type of script quality: (4) Perceived semantic quality, see Table 1.

Type	Dialogue between	Definition
Syntactic quality	Model and language	How well does the script adhere to the rules of the grammar
Semantic quality	Model and domain	How well does the script reflect the modelled reality
Pragmatic quality	Model and user interpretation	How well is the script understood by its users
Perceived semantic quality	User interpretation and domain knowledge	Dialogue between the information that users think the script contains (user interpretation) and the information that users think the script should contain, based upon their knowledge of the problem domain (domain knowledge)

Table 1. Framework for understanding quality in conceptual modelling (Lindland et al., 1994; Krogstie et al., 1995)

3 Design Context: An integrated health care service system

The example at hand constitutes a real existing integrated health care system. This system is a real life innovative project which was launched in a large German city several years ago and has been funded by the German government. The aims of the system are diverse, but all of them seek to improve the prevention and treatment of mental health disorders. The system which contains a very heterogeneous network of different actors (hospitals, independent doctors, self-help organizations, peer-mentors, nurses, etc.) is directed at educating and building awareness of mental health, preventing across different areas of disease, improving diagnosis and therapy choice, strengthening the patients and their families as well as building more effective structures of integrated care. The complexity of the integrated mental health care arises from the nature of mental disorders, which are often accompanied by other illnesses and require a treatment by multiple actors and organizations. The example at hand is aimed at building diverse cooperation and communication bridges in order to facilitate the integration of multiple care systems and actors in one complex network.

The example consists of ten sub-projects that deal either with particular diseases (depression, bulimia etc.) or with mental health in general. Each sub-project is an example of a complex integrated system which comprises the cooperation of multiple actors and combination of diverse resources. This implies a number of tangible and intangible elements needed for assuring the overall system performance. For example, one sub-project provides improved diagnostics and care for young patients suffering from psychosis (Härter et al., 2012). As part of an integrated care concept, the project aims to further early diagnosis and treatment of psychosis. To this end, the sub-project integrates and orchestrates the care process from diagnostics to treatment across all involved hospitals and outpatient caregivers (Härter et al., 2012). In addition to traditional outpatient care by psychiatrists and psychotherapists, the university hospital developed the capability to provide acute outpatient care through hospital specialists, enabling a substantial reduction in the period of hospitalization (Härter et al., 2012; Lambert et al., 2011).

The data of the example was collected between January and March 2013. The aim was to determine all elements which were created or adopted for each of the ten sub-projects in order to enable their functioning and facilitate their effectiveness. Therefore, extensive and structured manual-based interviews of internal project team members of all ten sub-projects were conducted by external project team consultants. Additionally, external project team consultants examined documents, such as project reports, intranet articles and data tables that were provided by internal project team members.

4 Design & Development: Application of MDM method to services

Generally the conceptual framework of the MDM method is evident, but for the application to services the identification of all constituent elements and their interdependencies poses a major challenge. As services are often intangible, elements and their interdependencies have to be rendered visible and given a name. Hence, provision, analysis and quality of information play a major role. This may lead to a higher effort in the analysis of the present service system as opposed to other technical systems, and the resulting modular service architecture may depend on the quality of the gathered data.

Thus, we propose an approach consisting of six steps: (1) Data collection, (2) consistency check, (3) transformation, (4) validation, (5) modularization, and (6) evaluation. This approach allows a detailed analysis of an existing complex service system and assists in designing a modular service architecture. The approach is iterative: From each step of the approach, a returning to the first step of the approach is possible and desired if incompletion or errors are detected during analysis. This assists in a gradual refinement of the elements and their interdependencies of a service system, continuously increases data quality and herewith influences the resulting modular service architecture. The MDM method is used as a tool for data and information transport from one step to another. The result of the approach is a proposition for an evaluated modular service architecture based on consistent and validated elements and interdependencies. In addition, we highlight the involvement of experts from three different domains within each step, see Table 2. We chose these experts from diverse internal and external domains in order to perform a reliable multi-faceted analysis of the present service system.

Expert	Domain	Definition
Internal project team member	Sub-project of service system of interest	Internal experts from ten sub-projects that are project employees or project managers (medical staff and doctors)
External project team consultant	All sub-projects of service system and whole service system of interest	External experts that analyse and observe the operational functioning and strategic development of sub-projects from the external point of view
External system developer	All sub-projects of service system and whole service system of interest	External experts that evaluate the analysis of external project team consultants by using analytics independent from the project knowledge

Table 2. Experts from different domains

4.1 First step: Domain Specification and Data collection

In a first step, the domain specification is required for the MDM method. Table 3 represents both types of elements that were identified during data analysis, defines them in terms of service systems and gives examples from the present service system.

Type	Definition	Examples
Process	Activities that help to deliver a specific service (Tokar and Böhmann 2013; Böhmann et al. 2012)	Training, process evaluation, team meeting, etc.
Resource	Knowledge, skills or other sources needed to enact the service (Tokar and Böhmann 2013; Böhmann et al. 2012)	Information material, questionnaire, cooperation agreement, etc.

Table 3. Definition of service system elements and examples

Afterwards, data of the service system of interest is collected. The aim is to determine all elements which were created or adopted for each of the ten sub-projects in order to enable their functioning and to facilitate their effectiveness. Therefore, extensive and structured interviews of internal project team members of all ten sub-projects performed by external project team consultants were conducted. Additionally, external project team consultants examined project reports, intranet articles and data tables that were provided by internal project team members. The interviews allowed gathering information on the most important elements that are crucial for project existence or are essential for building an integrated care system. According to the taxonomy presented in Table 4, each identified element is described by six different attributes. In the subsequent steps, these attributes are used for analysis of interdependencies between the elements and combination of the elements of high cohesion into modules. The final result of the first step is one list of processes and resources for each sub-project.

Attribute	Definition	Values (examples)
Number	Continuous number	[1001,…,10999]
Sub-project	Number of sub-project	[1,2,3,4,5,6,7,8,9,10]
Element	Descriptive name	Poster, information leaflet, etc.
Developer	Actors that develop and refine an element	Project team, research group, etc.
User	Actors that apply an element to a target group	Staff, general practitioner, etc.
Target group	Audience that uses an element	Interested parties, patients, etc.

Table 4. Taxonomy of elements

This first step has a specific role within the whole approach as a returning from every other step to this first step is always possible and desired. In case of incompletion or errors in elements or their interdependencies, we explicitly decided to always return to the first step because each change in elements and their interdependencies should be consequently followed by a full analysis in terms of consistency, interdependencies, and validation. Only in so doing, system complexity can be adequately handled and data quality can be continuously increased.

4.2 Second step: Consistency check

A check of all elements in terms of consistency is conducted. On the one hand, each element is checked separately (element check). On the other hand, each element is checked in relation to each other element (cross-element check). The degree of consistency between elements directly influences the analysis of the interdependencies between these elements in the following step: The more consistent elements are, the easier similarities and differences of elements can be detected. Each consistency check is based on the taxonomy displayed in Table 4. This second step is restricted to external system developers and is supported by external project team consultants. For this technical part of the analysis, the involvement of internal project team members is not required. The final result of the second step is one list of consistent elements for each sub-project.

4.3 Third step: Transformation

The interdependencies between the elements are determined. This step is the most important step within the whole approach as it highly influences the resulting modular service architecture. According to the interdependencies which are chosen during the modularization process in the fifth step, different modular service architectures can result. Additionally, this step is challenging as the identification of interdependencies in service systems can be more complex than in technical systems. As services are often intangible, the interdependencies of the elements have to be rendered visible and given a name.

First, we define an interdependency named "operational interdependency" that describes the operative connectedness of two elements, which can be associated with each other in terms of their usage, content or actors associated with these elements, see Table 5. Additionally, we analyse the link between the elements by examining whether they are associated with same actors: Developers, users, and target groups, see Table 5. These three interdependencies provide objective information at the level of actor cooperation by creating or using the elements in an integrated setting. The "operational interdependency" tells how this cooperation is perceived by the actors within each setting. This plural set of interdependencies especially enables the detection of additional elements within the service system of interest. Each of the four interdependencies can be strong (2), weak (1), or non-existent (0), see Table 5. Due to simplification reasons, we assume symmetric interdependencies, i.e., if element A is interdependent with element B, element B is identically interdependent with element A.

Interdependency	Strength	Definition
Operational interdependency	2	Element A mandatorily requires element B.
	1	Element A may be supported by element B.
	0	Element A does not require element B.
Developer, user, target group	2	Element A and element B always have the same developer / user / target group.
	1	Element A and element B may have the same developer / user / target group.
	0	Element A and element B never have the same developer / user / target group.

Table 5. Definition of interdependencies between elements and their strengths

This is followed by the operationalization of the interdependencies for the specification of the MDM method to the service system at hand. This can be done by defining a 2x2-matrix that contains all four interdependencies per relation between two elements (Corsten et al., 2009), see Figure 2. For the subsequent modularization, a prioritization of the interdependencies is required. Depending on which of the four interdependencies is most prioritized, different modular service architectures can result. As we aim at identifying modules that reflect the perception of the element integration, we firstly focus on the "operational interdependency" and secondly consider its ratio to the three other interdependencies.

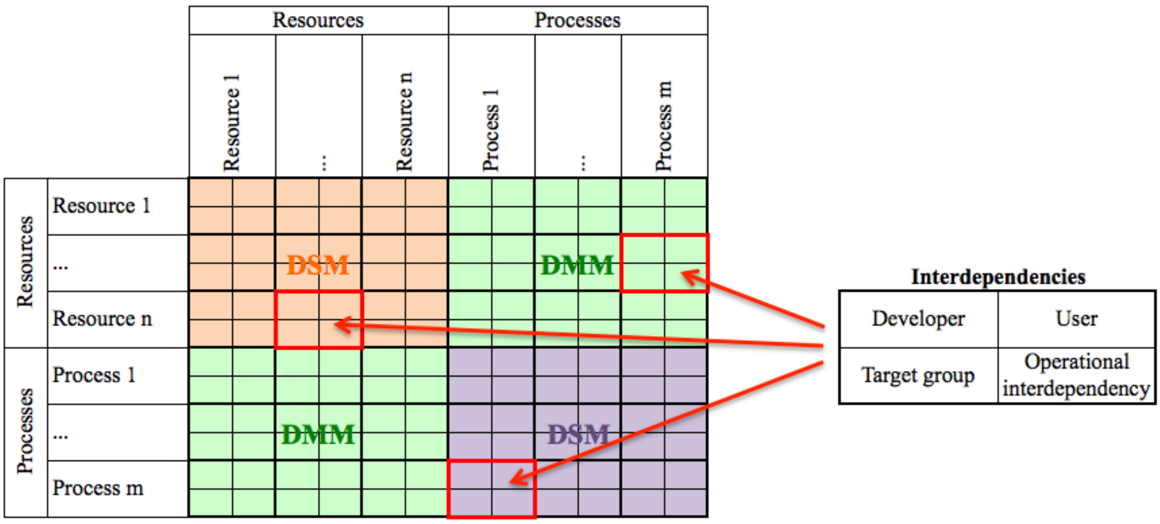

Figure 2. Structure of MDM for each sub-project

This third step is restricted to external system developers and is supported by external project team consultants. For this technical part of the analysis, the involvement of internal project team members is not required. The final result of the third step is one MDM containing consistent processes, resources, and interdependencies for each sub-project.

4.4 Fourth step: Validation

The validation of the ten different MDMs is conducted. These MDMs include all processes, resources and their interdependencies collected and analysed within the first, second, and third step of the approach. Especially the second and third steps are exclusively conducted by external project team consultants and external system developers. Therefore, the fourth step is highly important as this step represents the point of feedback from internal project team members which have a different view on the service system of interest and which may contribute to the refinement of gathered data. Extensive structured interviews and workshops are conducted. The final result of the fourth step is one MDM for each sub-project containing consistent and validated processes, resources, and interdependencies.

4.5 Fifth step: Modularization

The modularization of the ten validated MDMs is conducted. The aims of this modularization are manifold: (1) Combination of processes and resources of high cohesion into loosely coupled modules for each sub-project, (2) identification of core modules that are identically or similarly reused across different sub-projects, (3) identification of non-core modules that are only used in specific sub-projects, (4) therewith, a more efficient usage of processes and resources across different sub-projects, and (5) prospectively, a transfer of (non-) core modules into other service systems in different places.

Within this step, an adequate method for the modularization process has to be selected and specified to the service system of interest. In our case, we decided to undertake the equivalent permutations of columns and rows manually within excel charts as the size of the present service system is relatively small. Additionally, we were interested in observing the system’s behaviour within every step of the approach, with the step of modularization among them.

The equivalent permutations of columns and rows are conducted within all ten MDMs until every MDM is a block diagonal matrix having only square matrices as main diagonal and having mainly zeros within the off-diagonal blocks. These permutations are determined by the prioritization of the interdependencies defined in Chapter 4.3. The resulting square blocks on the main diagonal finally correspond to the modules of the present service system. In other words, within the modularization step, a minimization problem is solved so that (1) the number of strong interdependencies outside the modules and (2) the number of weak interdependencies within the modules are minimized. It has to be considered that various solutions exist for this minimization problem as, for example, the desired size of the resulting modules can be freely chosen considering specifications within a sub-project. In Chapter 5, we present an extract of one proposition for a modular service architecture.

This fifth step is restricted to external system developers and is supported by external project team consultants. For this technical part of the approach, the involvement of internal project team members is not required. The final result of the fifth step is one modularized MDM for each sub-project containing consistent and validated processes, resources, and interdependencies.

4.6 Sixth step: Evaluation

The evaluation of the proposed modular service architecture is conducted. External project team consultants present a proposition for a modular service architecture to internal project team members. On the one hand, benefits and risks of a prospective implementation of the proposed architecture are discussed. On the other hand, it is discussed whether a fully implementation of all core and non-core modules or a partly implementation of selected modules is useful and possible. In this step, external system developers assist in understanding and explaining the proposed modules. The final result of the sixth step is an evaluated proposition for a fully or partly modular service architecture.

5 Results

5.1 Descriptive results of the demonstration

During our extensive analysis, we finally identified in sum 186 consistent and validated elements within ten sub-projects. A detailed distribution for each sub-project is displayed in Table 6.

Area	Sub-project	# Elements	# Processes	# Resources
Disease-unspecific health care networks	1 Awareness and education	23	11	12
	2 Interactive internet portal	22	4	18
	3 Occupational health	27	15	12
	4 General practitioner care	12	6	6
	5 Self-help and family assistance	15	9	6
Disease-specific health care networks	6 Psychosis	13	7	6
	7 Depression	33	11	22
	8 Somatoform disorders	11	5	6
	9 Anorexia and bulimia	10	3	7
	10 Alcohol in adolescence	20	10	10
	Total	186	81	105

Table 6. Structure of an integrated health care system located in Germany

In our setting, we identified 60 modules across all sub-projects. Other settings may result in other modular service architectures. The number of identified modules per sub-project as well as their minimum, maximum and average size per sub-project and across the whole project were identified, see Table 7. Within our modularization setting, every sub-project contains between four and nine different modules consisting of one to ten different elements.

		# Modules	Minimum size	Maximum size	Average size
Sub-project	1 Awareness and education	6	1	8	3,8
	2 Interactive internet portal	9	1	7	2,4
	3 Occupational health	7	2	6	3,9
	4 General practitioner care	4	2	4	3
	5 Self-help and family assistance	5	1	4	3
	6 Psychosis	5	1	4	2,6
	7 Depression	9	1	10	3,7
	8 Somatoform disorders	4	2	4	2,8
	9 Anorexia and bulimia	5	1	3	2
	10 Alcohol in adolescence	6	1	5	3,3
	Average value	6	1,3	5,5	3,1

Table 7. Number of modules, minimum, maximum, average size per sub-project

As a consequence, we named all modules within each sub-project according to their purpose. By purpose, we mean the strategic topic which is prevalent for each module and generalizes its activities and aims. Then, we identified all modules according to their purpose that appear in more than the half of the sub-projects, see Table 8. We did this in order to identify modules that are reused in the same or a similar manner for a certain purpose in different sub-projects and that therefore may have a potential for a shared provision and reuse across different sub-projects. We identified these modules as "core modules". For example, the module "Training" appears in seven sub-projects. It includes elements such as training elements for general practitioners according to the guideline on unipolar depression, special training of psychotherapists for telephone-based treatment, diverse training manuals etc. Building this module helps to determine common training elements that were developed independently throughout sub-projects. Many of them have common characteristics and could have been developed only once, changed according to disease specification and integrated in multiple sub-projects. Additionally, we identified all modules according to their purpose that appear less often in sub-projects. These modules are sub-project-specific modules and probably do not have any potential for a shared provision or reuse across different sub-projects. We identified these modules as "non-core modules", see Table 8. Such modules appear in several sub-projects, e.g., the module "Screening" which includes elements such as a screening documentation form used for health care provider rating. The results indicate that every sub-project contains between two and four core-modules that could be reused in the same or a similar manner across different sub-projects and in minimum one non-core module.

		Core modules				Non-core modules				
		Information	Training	Project management	Network management	Web page	Guideline	Screening	Encounter projects	Other modules
Sub-project	1 Awareness and education	+	+	-	-	+	-	-	+	2
	2 Interactive internet portal	+	+	-	+	+	-	+	-	4
	3 Occupational health	+	-	+	-	-	-	-	-	5
	4 General practitioner care	+	+	+	-	-	-	+	-	-
	5 Self-help and family assistance	+	+	+	-	-	-	-	-	2
	6 Psychosis	-	+	+	+	-	-	-	-	2
	7 Depression	+	+	+	+	-	+	-	-	4
	8 Somatoform disorders	+	-	+	+	-	-	-	-	1
	9 Anorexia and bulimia	+	-	+	+	-	+	-	+	-
	10 Alcohol in adolescence	+	+	+	+	-	-	-	-	2
	Total	9	7	8	6	2	2	2	2	22

Table 8. Core and non-core modules across all sub-projects

In a next step, we assessed the reuse effect of a shared modular service architecture. Therefore, we assumed an ideal situation: If all modules for the purposes of "information", "training", "project management", and "network management" were identical in each case and if these four modules were provided in a shared fashion, then the number of sub-project-specific modules across all sub-projects could be reduced from 60 to 30. This corresponds with a reduction rate of 50% across all sub-projects. In detail, within each sub-project, between 29% and 75% of the modules could be reduced by a centralized provision of these four core-modules, see Table 9. The total number of modules would then be reduced from 60 to 34. This corresponds with a reduction rate of 43% across all sub-projects. Finally, a reduction of modules implies a reduction of elements, i.e. processes and resources, within each sub-project. In our real situation, such a high reduction rate across all sub-projects is not to be expected as an in-depth analysis of all identified shared modules may reveal substantive differences between sub-projects that inhibit the creation of a shared module. However, the analytical approach facilitates a structured dialogue about standardization and sharing across sub-projects.

		# Modules (potential reduction rate)
Sub-project	1 Awareness and education	4 (33%)
	2 Interactive internet portal	6 (33%)
	3 Occupational health	5 (29%)
	4 General practitioner care	1 (75%)
	5 Self-help and family assistance	2 (60%)
	6 Psychosis	2 (60%)
	7 Depression	5 (44%)
	8 Somatoform disorders	1 (75%)
	9 Anorexia and bulimia	2 (60%)
	10 Alcohol in adolescence	2 (67%)
	Average value	3 (50%)

Table 9. Assessment of reuse effect of a shared modular service architecture

Then, we identified the number of modifications respectively the modification rate for the considered items (i.e. the elements, their interdependencies, the combination of the elements into modules according to their interdependencies, and the involved actors) of the present service system. Within the first data collection, we identified 184 different elements, i.e. processes and resources. After several iterations and especially within the interdependencies analysis in the third step, we finally identified 186 different elements, see Table 10. This includes removal, splitting as well as adding of further elements.

Item	Modification	Number of modifications (modification rate)
Elements	Change of definition	0 out of 2 (0%)
	Change of type	3 out of 186 (6 %)
	Change of name	39 out of 186 (21%)
	Reassignment of actors	5 out of 186 (3%)
	Reassignment of interdependencies	21 out of 186 (11%)
Interdependencies	Change of definition	1 out of 4 (25%)
	Change of name	0 out of 4 (0%)
Modules	Change of purpose	11 out of 60 (18%)
Actors	Change of definition	0 out of 3 (0%)
	Change of name	13 out of 122 (11%)

Table 10. Modifications of items during application of approach to present service system

5.2 Derivation of design principles

At last, we derived design principles from our approach that enhance the application of the MDM method to complex service systems, see Table 11. These design principles emphasize interdependent consistency checks and a structured dialogue between experts from different domains that refine the model of the service system underlying the modularization. We grouped these design principles according to the four types of script quality presented in Chapter 2.3. The numbers of the design principles correspond to their occurrence within the approach.

Type	Design Principle	Explanation
Syntactic quality	(DP2) Identification of elements	Addresses the structured dialogue between external project team consultants and internal project team members in terms of element identification and appropriate classification
	(DP3) Taxonomy of elements	
	(DP4) Consistency of elements	
Semantic quality	(DP5) Identification of interdependencies and their strengths between elements	Addresses the structured dialogue between external system developers and external project team consultants in terms of interdependencies analysis and appropriate combination of elements to modules
	(DP6) Prioritization of interdependencies between elements	
	(DP8) Modularization of elements according to their interdependencies	
Pragmatic quality	(DP7) Validation of elements and their interdependencies	Addresses the structured dialogue between experts from all three domains in order to refine the model of the service system underlying the modularization
Perceived semantic quality	(DP1) Identification of experts	Addresses the structured dialogue between experts from all three domains in order to evaluate the resulting modular service architecture
	(DP9) Evaluation of resulting modular service architecture	

Table 11. Design principles according to the four types of script quality

6 Discussion

Within this chapter, we discuss the theoretical contributions and practical implications of the proposed approach. Regarding the theoretical contributions, we discuss the proposition of the six-step approach and the derivation of design principles for the application of the MDM method for the modularization of complex service systems. Regarding the practical implications, we discuss the identified potential transformations of the present service system in terms of reuse and the prospective transfer of core and non-core modules into other service systems in different places.

First, the steps to be undertaken during the modularization process are generally evident, namely the identification of elements and their interdependencies, the combination of these elements into loosely coupled modules, and the selection of a number of modules to design a modular service architecture. Different research works describe this procedure (Peters and Leimeister, 2013; Böhmann, 2004; and others). However, the design and demonstration of the proposed approach highlighted that these steps are much more complicated. The approach has to be specified to the present service system. This can be done by the help of a number of parameters within the approach, such as the number and type of considered elements and interdependencies, the targeted number, size and type of modules, and others. Depending on the choice of these parameters, different modular service architectures can result. However, not every resulting modular service architecture might be useful for specific purposes and/or users. Additionally, the extent of the analysis in order to identify all or even a specific number of elements and interdependencies can be unproportionally high in relation to the number of elements and interdependencies that are required afterwards. Following these observations, we now argue that the modularization process of a complex service system should start with the analysis of the targeted modular service architecture in order to derive further insights for the required number and type of elements, interdependencies and modules. Only after having accomplished this "calibration phase" and, herewith, only after having defined the goal for the overall modularization process, both the analysis of the service system in terms of elements and interdependencies and the modularization process itself can be efficiently conducted. In so doing, we additionally expect a reduction in the extent of the analysis of the service system.

Second, the application of the MDM method to complex service systems extremely depends on the quality of inputs and the validation of the recommendations of experts from different domains. Therefore, it is essential to ensure consistency of the constituent elements and their interdependencies of a service system, to make conscious design decisions and to validate all results with experts from different domains. This is represented by the design principles derived from the demonstration of the application by the help of a real existing complex service system.

Third, the demonstration of the approach led to the identification of potential transformations of the present service system in terms of reuse. In an ideal situation, four core modules could be reused across all sub-projects and herewith the number of sub-project-specific modules could be reduced by half. A reduction of the number of modules implies both a reduction of the complexity of the present service system, but also an increase of the coordination effort across sub-projects. Additionally, other benefits and risks are associated with service modularization (e.g. cost reduction, customization, faster development, standardization, and others) that should be analyzed by the help of the present service system. However, for this purpose, further detailed analyses are required.

Fourth and finally, a transfer of the identified core and non-core modules into other service systems in different places is generally possible. The proposed approach allows a specification to a variety of service systems due to its numerous parameters and is not restricted to any specific type of service system. Nevertheless, further validation and evaluation of such a transfer by the help of other real existing complex service systems is mandatorily needed.

7 Conclusion and Future Research

Following the Design Science Research Process Model given by Peffers et al. (2006), we designed a six-step approach for the application of the MDM method for the modularization of complex service systems. This approach allows for an extensive analysis of complex service systems in terms of the constituent elements and interdependencies, a composition of elements of high cohesion into loosely coupled modules, and an evaluation of the resulting modular service architecture with experts from different domains. We demonstrated its application by the help of a real existing integrated health care system. This demonstration led to the identification of potential transformations of the present service system in terms of reuse. However, this demonstration as well highlighted improvement potentials for the proposed approach in terms of efficiency and goal-orientation. In future research, the approach will be tailored according to these improvement potentials. This has to be consequently followed by another demonstration of the tailored approach within the present health care system. After having successfully accomplished this demonstration, the evaluation of the approach by the help of other types of complex service systems is required. Additionally, we derived design principles from this approach that emphasize interdependent consistency checks and a structured dialogue between experts from different domains in order to refine the model of the service system underlying the modularization.

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