Collaborative Decision Support for Adaptive Digital Enterprise Architecture

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Abstract. The digitization of our society changes the way we live, work, learn, communicate, and collaborate. This disruptive change interacts with all information processes and systems that are important business enablers for the context of digitization since years. Our aim is to support flexibility and agile transformations for both business domains and related information technology and enterprise systems through adaptation and evolution of digital enterprise architectures. The present research paper investigates collaborative decision mechanisms for adaptive digital enterprise architectures by extending original architecture reference models with state of art elements for agile architectural engineering for the digitization and collaborative architectural decision support.

Keywords: Decision Support, Collaboration, Digital Enterprise Architecture, Architectural Engineering and Transformation

1 Introduction

Digitization is the collaboration of human beings and autonomous objects beyond their local context using digital technologies. Digitization further increases the importance of information, data and knowledge as fundamental concepts of our everyday activities. By exchanging information human beings and intelligent objects are able to make decisions in a broader context and with higher quality. Social networks, smart portable devices, and intelligent cars, represent only a few instances of a pervasive, information-driven vision [1] for the next wave of digital economy and better-aligned information systems. Major trends for the digitization are investigated by [2] itemizing the digitization of products and services, context-sensitive value creation, consumerization of IT, digitization of work, and the digitization of business models. The Internet of Things, Adaptive Case Management, Decision Support Systems, Mobility Systems, and Services for Big Data in Cloud Ecosystems are emerging to support intelligent user-centered and social community systems. They will shape future trends of business innovation and the next wave of information and communication technology. Biological metaphors of living and adaptable ecosystems provide the logical foundation for self-optimizing and resilient run-time environments for intelligent business services and related distributed information systems with service-oriented enterprise architectures.

The technological and business architectural impact of digitization has multiple aspects, which directly affect adaptable digital enterprise architectures and their supported systems. Smart companies are extending their capabilities continuously managing their changing Business Operating Model [3] by developing and maintaining Enterprise Architectures as the architectural part of a changing IT Governance [4]. Enterprise Architecture Management [5] and Services Computing is the approach of choice to organize, build, utilize, and distribute capabilities for the digital enterprise architectures [6], [7]. They provide flexibility and agility in business and IT systems. The development of such applications integrates Web and REST Services, Cloud Computing and Big Data management, among other frameworks and methods for the architectural semantic support.

Today's information systems span a broad range of domains including: intelligent mobility systems and services, intelligent energy support systems, smart personal health-care systems and services, intelligent transportation and logistics services, smart environmental systems and services, intelligent systems and software engineering. One of the challenges is the safe integration of mobile devices into managed enterprise architecture of both business and IT. Nowadays it is much easier to work together over large distances, which allows often an uncomplicated outsourcing of business tasks. Businesses need to adapt and have to rethink their business models to develop innovative business models according to employees' current skills and competencies.

Digitization of products and services requires the close alignment of business models and digital technologies for creative digital strategies and solutions, as well as for their digital transformation. Unfortunately, the current state of art and practice of enterprise architecture lacks an integral understanding and support of collaborative decisions in the process of architectural adaptation and enterprise transformation. Our main motivation and the current presented work is to extend previous approaches of quiet static enterprise architecture to fit for flexible and adaptive digitization of new products and services and by introducing suitable mechanisms for collaborative architectural engineering and decision support with adaptive case management for agile changing business models, information systems and their digital enterprise architecture. We report about our work in progress research to provide a unified collaborative decision framework for adaptable digital enterprise architecture models from relevant information resources of digital products and services and their digital transformation.

Our current research paper is investigating the following questions:

RQ1: What is the blueprint of extended digital enterprise architecture for the digital transformation with mechanisms of adaptation and adaptive case management?

RQ2: How can processes of architectural engineering and transformation be supported collaboratively?

RQ3: How can collaborative decision support mechanisms be specifically designed by introducing decision-making metamodels for digital enterprise architecture?

The following Section 2 describes our research platform for digital enterprise architecture, which was extended by concepts from adaptive case management, architectural adaptation mechanisms and a specific model integration method. Section 3 presents our collaborative architectural engineering and transformation approach and links it with specific decisional and prediction mechanisms. In Section 4 we focus on collaborative decision techniques and present a decisional metamodel for digital enterprise architectures. Finally, we summarize in Section 5 our research findings, our ongoing work in academic and practical environments and our future research plans.

2 Digital Enterprise Architecture

Enterprise Architecture Management (EAM) [8], [9], [10] defines today with frameworks, standards [11], [12], tools and practical expertise a quite large set of different views and perspectives. We argue in this paper that a new refocused digital enterprise architecture approach should support digitization of products and services, and should be both holistic [5] and [12] and easily adaptable [13] to support the digital transformation with new business models and technologies like social software, big data, services & cloud computing, mobility platforms and systems, security systems, and semantics support. We are evolving the first versions of ESARC–Enterprise Services Architecture Reference Cube [5], [12] (Fig. 1).

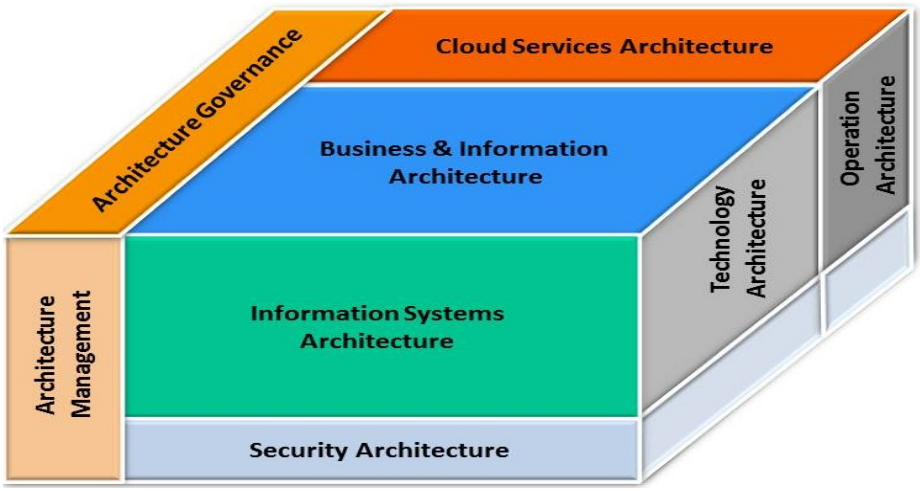

Fig. 1. Enterprise Services Architecture Reference Cube

In this paper we extend our service-oriented enterprise architecture reference model for the context of managed adaptive cases and decisions [14], [15], which are supported by case services of a collaborative case framework [14] within an adaptive case management environment [16]. Additionally we have tailored our architectural metamodel integration approach [17] to support digital enterprise architectures for digital transformations [6] and the integration of Internet of Things [7] architectures.

ESARC – Enterprise Services Architecture Reference Cube [5], [12] is an architectural reference model for an extended view on evolved digital enterprise architectures. ESARC is more specific than existing architectural standards of EAM – Enterprise Architecture Management [11] and [12] and extends these architectural standards for digital enterprise architectures with services and cloud computing. ESARC provides a holistic classification model with eight integral architectural domains. These architectural domains cover specific architectural viewpoint descriptions [18] and [19] in accordance to orthogonal dimensions of both architectural layers and architectural aspects [12], [9], and [20]. ESARC abstracts from a concrete business scenario or technologies, but it is applicable for concrete architectural instantiations to support digital transformations. The Open Group Architecture Framework [11] provides the basic blueprint and structure for our extended service-oriented enterprise architecture domains of ESARC [5], [13] having: Architecture Governance, Architecture Management, Business and Information Architecture, Information Systems Architecture, Technology Architecture, Operation Architecture, and Cloud Services Architecture. ESARC provides a coherent aid for examination, comparison, classification, quality evaluation and optimization.

We developed an architectural evolution approach to integrate and adapt most valuable parts of existing EA frameworks and metamodels from theory and practice [17]. Additionally to handling architectural structures for dynamically extending core metamodels we see a chance to integrate decentralized mini-metamodels, models and data of architectural descriptions coming from small devices and new decentralized architectural elements, which traditionally are not covert by enterprise architecture environments. The focused model integration approach is based on special correlation matrixes to identify similarities between analyzed model elements from different provenience and integrate them according their most valuable contribution for an integrated model. According to [21] we are building the conceptualization of EA in 4 steps – from stakeholders' needs, to the concerns of stakeholders, then the extraction of stakeholder relevant concepts, and last but not least the definition of relationships for new tailored architectural metamodels.

Our research consists of a metamodel-based model extraction and integration approach [17] for digital enterprise architecture viewpoints, models, standards, frameworks and tools to support digital transformations [6] and [7]. Currently we are working on the idea of continuously integrating small EA descriptions for relevant objects of digital enterprise architecture. These EA-Mini-Descriptions consists of partial EA data and partial EA models and related metamodels. Our goal is to be able to support an integral architectural engineering and transformation process.

Adaptation drives the survival [22], [23], [24] of digital enterprise architectures [13], platforms and application ecosystems. Adapting rapidly to new technology and market contexts improves the fitness of adaptive ecosystems. Volatile technologies and markets typically drive the evolution of ecosystems. We have additionally to consider internal factors. The alignment of Architecture-Governance [3], [4] shapes resiliency, scalability and composability of components and services for distributed information systems.

3 Architectural Engineering and Transformation

Although concepts such as Business Process Management [25] introduced a customer-oriented perspective, it still contains many concepts following the ideas developed already in [26]. These are the division of larger tasks into defined, smaller tasks and the assignment of individual responsible to accomplish these tasks. Therefore it does not surprise, that a plenty of approaches such as [27], [14] tried to develop support for cooperation beyond strictly structured business processes as almost all WFMSs and most of the BPMSs, but also some groupware and case management systems. However these approaches become not as successful as expected.

One has to meet a number of challenges when supporting EA management processes. The first challenge is the lack of a pre-defined workflow. Similar to adaptive case management [28], the control-flow of EA management processes cannot be predefined in most situation. Instead the control-flow is defined "on-the-fly" during execution of the EA management process.

The second challenge is organizational integration [28]. Many early approaches addressing the support of EA management processes limited the participation of stakeholders. E.g. although classical groupware abstained from pre-defining a strict control flow, specific access rights to documents had been assigned. Thus the group of possible contributors had been limited. In this way an apriori-decision had been made deciding who may contribute and who may not. Some stakeholders were not able to contribute.

The third challenge is semantic integration [29]. Due to the involvement of a multitude of stakeholders, semantic frictions such as homonyms and synonyms create misunderstandings between the process participants. These semantic frictions may delay the EA management process or even worse, may cause deficient architectures.

Social software is based on four basic principles: social production [30], weak ties [31], collective decisions [32], and value co-creation [33]. Each of these principles support EA management processes by addressing one or more challenges, as addressed in Fig. 2.

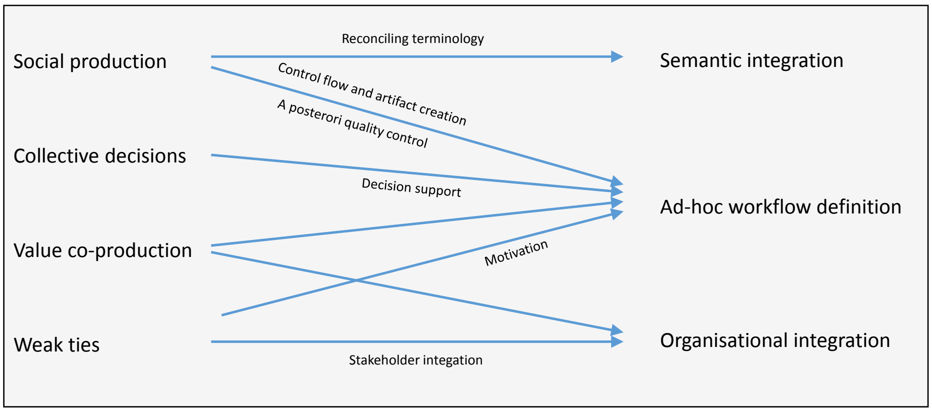

Fig. 2. Architectural Engineering and Transformation [34]

Social production [30] is the creation of artifacts without a top-down created plan but by combining the suggestions and decisions from independent contributors. By abstaining from Tayloristic top-down planning, new and innovative contributions outside the original scope can be identified and added. Due to these properties, social production matches the requirements of EA management processes. The control flow of EA management processes can be defined in an ad-hoc manner. During execution of the EA process, artifacts as architecture models can be created in a cooperative way.

Collective decisions [32] provide a new way in EA management processes to make decisions. They provide statistically better results than experts, if the decision cannot be made using scientific means and the participants decide independently. Surowiecki describes in [35] the approach of the so-called the wisdom of crowds. He argues that a decision made by several persons often leads to better results, because each person has a specific knowledge. Value-co-production [33] is also supporting the definition and execution of EA management processes by integrating contributions from the business side. By abolishing the separation between artifact producer and consumer, a better adaptation to the individual requirements can be achieved. Furthermore value co-production enhances the organizational integration.

Adaptive Case Management (ACM) [14] and [15] offers a lightweight model to support knowledge-intensive processes, which are driven by user decision-making. Knowledge processes of usually high-skilled stakeholders, like enterprise architects, require process adaptations at run-time. ACM is not dictating a predefined course of action [36] and provides the necessary information and knowledge support to be able to solve a case.

A case [15] is typically a collection of all relevant information into one place, which is handled by one or more knowledge workers during solving this case. The case is the jointly used focal point for assessing the situation, initiating activities and processes, implementing the work, and reflecting results based on a history record about what was really done. A case brings together all the necessary resources and also tracks everything that has happened into a record history, which can be mined to synthesize best practices, patterns of success, and used and extended instruments. Fundamental aspects and requirements for ACM, are mentioned in [36]:

1. The adaptation aspect of ACM consists of content, people, and reporting capabilities to be able to change the knowledge process at run-time by end-users. Additionally to the adaptation aspect a knowledge worker should be able to continuously improve his case templates.

2. The organization aspect groups policies, processes, and data. In ACM data is the dominant factor as opposed to the process-oriented view from BPM. Knowledge work requires the integration of data [36] into the execution process.

3. The case handling aspect is about collaboration, decision support, and integration of resources, events, and communication. Complex problems are typically solved collaboratively by involving individual stakeholders in respect of different necessary knowledge types and stakeholder concerns. Decision support requires transparency within a shared understanding of analyzed scenarios of enterprise

architecture by named stakeholders.

Opposed to routine work, which can be supported by business process management because of its repeatable kind, knowledge work is typically unpredictable. Knowledge workers [37], [38] are acting under uncertainty. An unpredictable process [15] does not repeat in routine patterns and emerges as the work is done. The practice of preparing for many possible courses is called agility. Differentiating seven domains of predictability [15] case management can be focused on two main types:

1. Product Case Management: Supports design-time knowledge processes with a well-known set of actions, having much variation between individual cases. It is not possible to set out a single fixed process. Knowledge workers are actively involved in deciding the course of events for a case.

2. Adaptive Case Management: Knowledge workers are involved not only in the case, and picking predefined actions, but they are constantly adapting the process and striving for innovative approaches, and may want to share and discuss process plans.

The Object Management Group (OMG) has published the Case Management Model and Notation (CMMN) [39] as a first step to support modeling for case management scenarios. In [40] was implemented a case study of a TOGAF-style process for EAM with CMMN. The upcoming standard Decision Model and Notation (DMN) of OMG [41] discern three usage models: for modeling human decision-making, for modeling requirements for automated decision-making, and for implementing automated decision-making.

DMN bridges the gap between business decision designs and their implementation by providing a common notation for decision models. The purpose of DMN is to facilitate a decision model framework, which is easily usable for decision diagrams and as a base for optionally automating decisions. Decision-making support is addressed from basically two perspectives: normal BPMN business Process Models can be expanded by defining specific decision tasks, or decision logic can be used to support individual decisions, e.g. business rules, decision tables, or executable analytic models.

DMN can additionally provide a third perspective to bridge between business process models and decision logic by introducing the Decision Requirements Diagram. Complementary to the DMN notation, which is used to model decisional relationships and concepts like Decision, Input Data, Business Logic, Application, Application Risk, etc. DMN introduces an expression language to represent decision tables, decision rules, and function invocations. Today we are exploring the suitable usage and close link of DNM for decisional support logic within our architectural engineering and analytics research.

4 Decision Support

A Decision support system (DSS) in general is a system "[…] to help improve the effectiveness of managerial decision making in semi structured tasks" ([42] p. 255 according to [43]). Semi structured tasks like in EAM need a basement to improve architectural decision-making trough a DSS. In the following we consider decisional prerequisites from previous section and look how they are fulfilled using an EA cockpit [29]. A cockpit is characterized as a room with multiple displays to be able to consider several coherent viewpoints in parallel. Each stakeholder who takes place in a cockpit meeting has his own information because each stakeholder can say, which views are relevant for him and all these views are displayed simultaneously. Each stakeholder has his own specific knowledge because stakeholders have different roles like Application Architect, Business Process Owner or Technology expert and comes from different areas of the enterprise. A meeting moderator can put together the relevant stakeholder's knowledge by discussion. By using our architectural cockpit we make impacts of a change on other views visible.

Jugel et al. [44] enhanced the approach from [45] with collaborative aspects. The authors developed a collaborative decision-making case by using methods of ACM and case modeling techniques by using CMMN [39] (see Fig. 3).

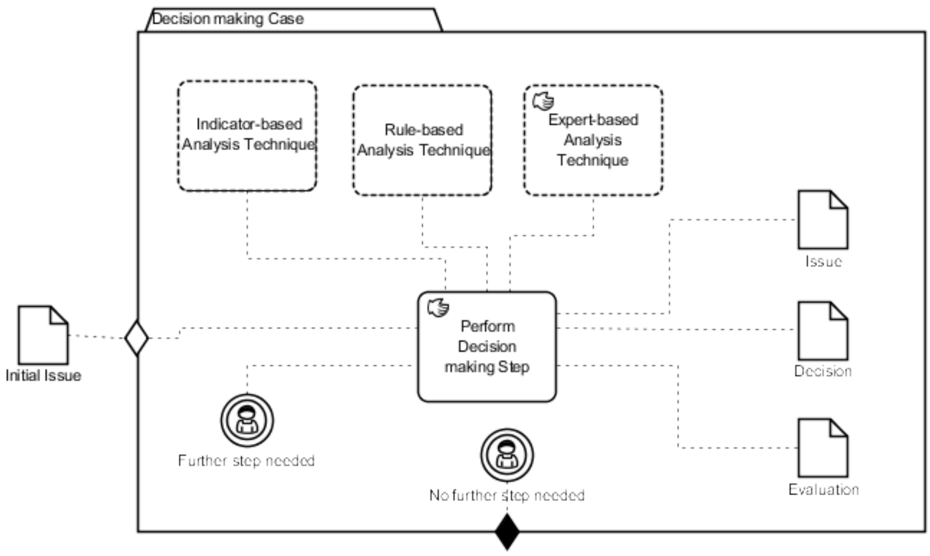

Fig. 3. CMMN model of a collaborative decision-making case

The starting point of the case is an initial issue. The issue is the reason why an EA has to be adapted. For instance, new business requirements have to be realized. A decision-making case consists of several "Decision-making steps". For each step one or more stakeholders are responsible to perform it. Thereby stakeholders can employ analysis techniques of a predefined and case independent catalogue to obtain additional insights. For each step the basis is the underlying EA model and results of previous steps. Buckl et al. [46] defines three kinds of analysis techniques: (1) expert-based, (2) rule-based, and (3) indicator-based analysis techniques.

Expert-based analysis techniques are done manually without any formalization. Stakeholders perform such a technique by using their experience. Rule-based analysis techniques are formalized and can be automated by performing an algorithm (e.g. an impact analysis). Indicator-based analysis techniques are also formalized. Instead of rule-based techniques, the results of indicator-based technique are values of KPIs and not identified elements in case of an impact analysis.

The result of an analysis technique is made visible for stakeholders e.g. by highlighting calculated elements of an impact analysis within different views. Thus stakeholders are able to consider results within the views they are interested. After considering the analysis technique's result stakeholders can choose how they want to finish the current step. They can model an evaluation to assess the analysis technique's result. In case they are able to take a design decision they can model a decision to describe the change. The last option is modeling another issue, e.g. to refine the initial issue based on new findings. After each step the stakeholders have to decide whether they need further decision-making steps or if they have finished. In case of performing another step, the outputs of previous steps provide the basis for the following steps.

Furthermore the authors enhanced the decisional metamodel of [45] by adding collaborative concepts and elements to support modeling the case. Thereby the decisional metamodel enables a retraceable documentation of decision-making works. The presented metamodel contains only a few elements to fuel practicability through reduced modeling overhead [44].

5 Conclusions and Future Work

In this paper we identified the need for an integral understanding and support of collaborative decisions in the process of architectural adaptation and enterprise transformation. According to our research questions we have leveraged a new model of extended digital enterprise architecture, which is well suited for adaptive models and transformation mechanisms. We have extended the previous more static defined basic enterprise reference architecture by new metamodel elements for supporting cooperative decisions using mechanisms from adaptive case management.

Related to our second research question we have presented our approach for collaborative processes in architectural engineering and transformation endeavors. We have additionally combined architectural engineering and transformation processes with elements from adaptive case management. We have extended typical architectural engineering processes with elements from social production, collective decision-making, value co-production, and week ties. Adaptive case management offers a lightweight model for knowledge-intensive processes.

We have finally merged architectural viewpoints with user decision-making processes within cooperative distributed environments for enterprise architecture management. We have introduced suitable individual decision support models and embedded them into cooperative analysis and engineering environments. We are currently working on extended decision support mechanisms for an architectural cockpit for digital enterprise architectures and related engineering processes. Additionally we are currently considering elements from collaborative systems combined with semantic support, as in Gruber [46].

Future work will extend both mechanisms for adaptation and flexible integration of digital enterprise architectures as well as will extend decisional processes by rationales and explanations. There are also a need to integrate more analytics based decisions support [47], [48], [49] and context-data driven architectural decision-making [50].

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