Dynamic Capabilities for Sustainable Enterprise IT – A Modeling Framework

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Abstract. A key consideration of researchers and practitioners alike in the field of information systems engineering is the co-development of information systems and business structures and processes that are in alignment, that this alignment reflects the challenges presented by the business ecologies and that the developed systems are sustainable through appropriate responses to pressures for their evolution. These challenges inevitably need to be addressed through development schemes that recognize the intertwining of information systems, business strategy and their ecosystems. The paper presents the conceptual modeling foundations of such a scheme providing a detailed exposition of the issues and solutions for sustainable systems in which *Capability* plays an integrative role using examples from an industrial-size application. The contribution of the paper is on its proposition of conceptual modeling techniques that are applicable to both business strategies and information systems development.

Keywords: Capability modeling · Enterprise engineering · Sustainability

1 Introduction

As enterprises compete in fast-paced changing ecosystems they need to constantly adapt their service/product offerings to gain and sustain competitiveness. There is an intrinsic relationship between an enterprise, its ecosystems, and its information technology (IT) systems to the extent that changes in one affect the others. This intertwining [1] is central to achieving sustainability for IT systems [2, 3]. Sustainability has been a major concern in strategic management [4] and more recently in Information Systems Engineering (ISE) due to adaptation requirements and the aforementioned intertwining relationship [5, 6].

The approach proposed in this paper is motivated by long-standing research in strategic management, particularly in research that deals with change and the creation of sustainable advantage. Such research has shown that there is sustainable advantage

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in possessing, building and protecting valuable, rare and inimitable competencies, in accordance to environmental changes [4]. These meta-level abilities that allow the continuous integration and reconfiguration of an organization's resource base and processes are referred to as Dynamic Capabilities [4].

In this context Enterprise Capabilities are defined as an organization's ability to appropriately assemble, adapt, integrate and deploy valued resources, differentiated skills and organizational routines, usually in combination or co-presence [4, 7].

Building on the notion of capability, this paper presents a conceptual framework upon which the concept of "capability" is operationalized, and presents a set of analytical processes that exploits this notion for designing sustainable IT capabilities and services. The concepts being proposed in the paper are exemplified through examples from a pilot project involving a world-leading digital enterprise.

2 Existing Works on the Notion of Enterprise Capability

In the various strands of research within strategic management one can distinguish between two prevailing views namely those of the Resource Based View (RBV) and the Dynamic Capability View (DCV). In RBV, researchers focus their attention on identifying possession of valuable, rare, inimitable and non-substitutable resources of enterprise as a source of sustainable advantage [4, 8]. In contrast, researchers in DCV focus on the dynamic aspect of enterprise and propose (i) sensing mechanisms that identify dynamic and changing requirements within the enterprise ecosystem, (ii) promotes shared vision and adoption of appropriate business models to seize opportunities, and (iii) reconfigures the resource base through collaborative and complementary capabilities to transform the enterprise into a new desirable state [4].

In the field of ISE the notion of capability has been considered as a means of dealing with agility, flexibility, and business/IT alignment [4]. ISE researchers and practitioners argue that capability as the fundamental abstraction concept focuses on stable business components and that business capability modeling and SOA complement each other thus facilitating the alignment between technical and business architecture [9, 10]. Nevertheless, the use of capability within the ISE field is still in its infancy and the body of knowledge is still fragmented and indeterminate [11]. There are open issues on the role of capability in Business Process Modeling (BPM) [11–13], in SOA [14, 15], and in Enterprise Architecture (EA) [16, 17]. However the definition and relationships of capabilities to other artifacts used in the design process is not investigated thoroughly which can results in misuse [18].

3 'MariServ': An Example Use Case

This section provides a brief description of an industrial use case that is used in the remainder of the paper to demonstrate concepts and processes of the proposed approach. This use case concerns a company, hitherto referred to as MariServ that provides IT services to shipping companies from the construction of a ship, to its lifetime of chartering, to its eventual decommissioning. Typically, these services

include commercial operations, financial management, optimal routing, communication support, fleet performance management, social networking for cooperating shipping companies, and regulatory compliance.

Focusing on regulatory compliance, the capability of MariServ is limited to a particular standard consisting of rules referring to security issues. It lacks a wide and general compliance monitoring system concerning all of the different types of maritime regulations that apply on approximately 15,000 ports worldwide as well as in international waters. In this case study, the notion of capabilities is used to depict the "to-be" requirements of MariServ and its relations to other capabilities, goals and objectives, business processes and operational resources, services, and organizational structure and actors. The compliance capability of MariServ has the potential for application in wider spectrum of its business ecology.

4 The Conceptual Framework for Capability-Centered Modeling

This paper proposes the notion of capability as an *integrative* conceptual representation that can relate the ecosystem and changes within the context of an enterprise to operational and service implementations while describing strategic objectives and social settings. Figure 1 presents this role in specifying and integrating different viewpoints within an enterprise. Each view has been studied in the literature and there exist conceptual models that represent an individual view. However, the interrelation and alignment of artifacts among different views has received less attention.

Each one of these views and their interrelationships are described, through the prism of capability, in the remainder of this section. This is done in the form of presenting graphically a meta-model for each view together with an instantiation of selected concepts of a meta-model from the MariServ case (distinguished by "e.g." in each diagram) and followed by a narrative explanation. It should be noted that these meta-models (in Figs. 2, 3, and 4) are sections of a single integrated meta-model but presented separately for reasons of readability.

The Teleological and Social Views: The sub meta-model shown in Fig. 2 elaborates on the concepts in the teleological and social views. Research in conceptual modeling

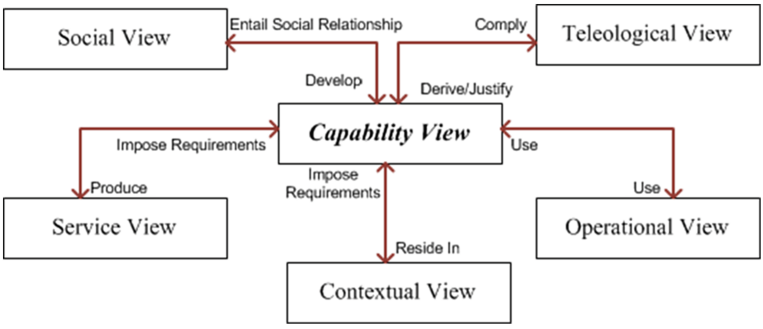

Fig. 1. Conceptual framework – overview of the centrality of capability

has dealt with the social view by modeling actors, roles and business partners and teleological view by modeling goals and business rules [19, 20].

We posit that representing capabilities as the conduit in which strategic objectives and social collaborations unite allows evolutionary decision making. This is supported by studies in strategic management that identify a social and teleological perspective when building capabilities caused by deliberate learning processes that individuals with different skillsets participate in as part of a team [21]. Furthermore, enterprise capabilities develop an identity over time as a result of gradual learning which makes them "path dependent" [7]. By relating *capabilities* and *social aspects* and their relations to both organizational actors and the strategic objectives of the enterprises one can identify and plan for barriers to change and development [7].

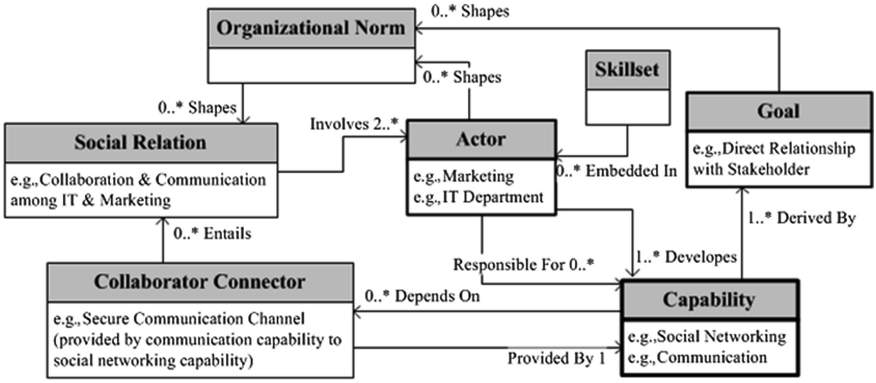

Fig. 2. Concepts of social and teleological view

MariServ Examples. By analyzing relations among capabilities and strategic objectives, MariServ realizes it can outsource its capability to update and maintain back-end software without compromises. On the other hand by analyzing the importance of *Direct Relationship with Stakeholders*, MariServ identifies the need to attain a *Social Networking* capability.

In MariServ, the *Social Networking* capability is dependent on a *Secure Communication Channel* and the *Marketing* capability of MariServ to operate. The social setting responsible for each of the mentioned dependencies can pose resistance towards the implementation of the new capability. In this case, one should consider facilitating collaboration and communication among IT and marketing departments within MariServ as presented in the examples of Fig. 2.

Operational and Service Views: The operational view (which deals with concepts such as processes, resources and transactions) and the service view (that focuses on business and IT service modeling and alignment) have been investigated thoroughly in combination or individually. Figure 3 represents the sub meta-model describing concepts from the operation and service views.

By modeling the relations among technical and operational alternatives and capabilities, one can reason about how different viewpoints and interpretations of multi-faceted functional and non-functional requirements are satisfied using capability and social views. This requirement is amplified as studies find decentralization and complementarities as factors that boost innovative product/service offering [4]. Modeling relations among capability, operational and service views is proposed to address such requirements by expressing orchestration choices and providing means to describe the effects of alternatives on strategic objectives. Furthermore, through the relations among capability and social views, one can depict kinds of collaborations required among actors to achieve such complementary relations.

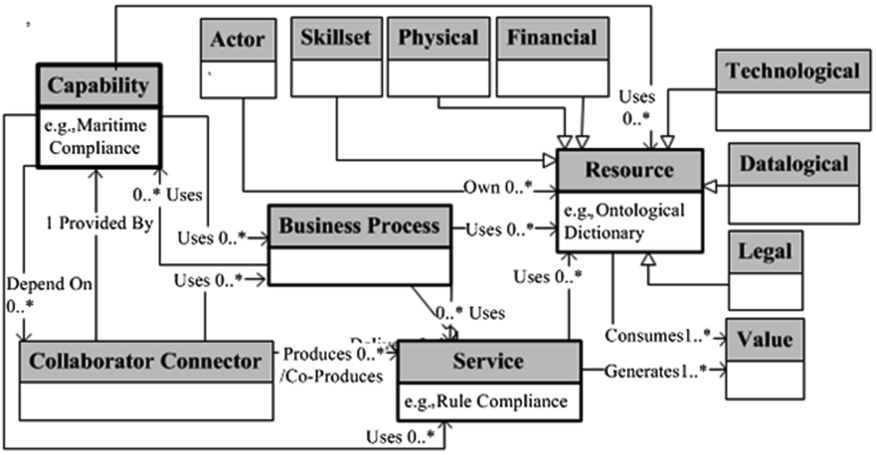

Fig. 3. Concepts of operational and service views

The operational view complements the social views by linking alternative implementations to the rightful stakeholders and their intentions to enable decision making regarding both technical and social aspects of the relationship. The capability view allows linkage and integrated reasoning among the concepts in different views.

MariServ Examples. The *Ontological Dictionary* (a resource) chosen to interpret rules and the depth of its coverage (a quality attribute of the resource) can affect other capabilities and their owners such as MariServ's legal team due to the dependencies among the capabilities. By capturing such relationships one can identify technical, strategic and social consequences of a change. At MariServ considering the input of the legal team when making decisions regarding *Ontological Dictionary* can result in a *Maritime Compliance* capability that is aligned with legal competencies and enables effective implementation of the *Rule Compliance* service.

Contextual View: Context in ISE refers to situational cognition of an IS and its specification and modeling is used to enable system and service adaptation [6]. However, in this framework we go beyond the boundaries of an IS and deal with the organizational setting and the ecosystem in which the IS resides in.

Identifying the value of business processes and capabilities is vital when making strategic decisions [17]. However, since neither generate value directly it is difficult to assign values and far more difficult to understand how stakeholders benefit from the generated value. By modeling the relationships among capabilities, business processes and services, one can analyze the path in which the value is generated. The relations among these artifacts and the ecosystem they reside in are provided in Fig. 4.

MariServ Examples. *Maritime Compliance* capability cannot generate value unless it provides *Rule Compliance* and consequent services that allow automated identification of inconsistencies at the right time and in the right place. One needs to answer questions regarding how a service generated by capability produces revenue whether directly or indirectly e.g. through improving efficiency such as the *Maritime Compliance*, to evaluate capabilities and services.

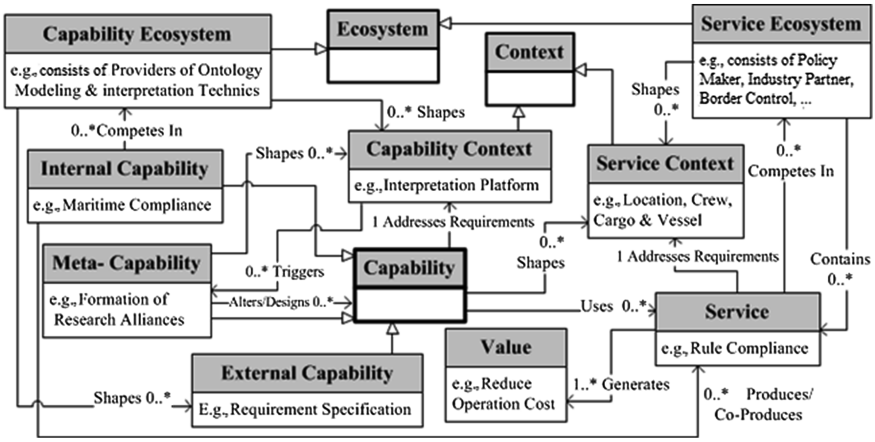

Fig. 4. Concepts of the contextual view

By tracing the value to the social view through capabilities, one can get a sense on how the value is appropriated to different stakeholders. The relationship among generated value and the teleological view can analyze the outcome of strategic objectives and enable decision making on investment choices. Capabilities and services reside in their corresponding ecosystems and hence need to change at different pace and in response to different requirements. Therefore in Fig. 4 two separate entities represent service and capability ecosystems.

MariServ Examples. The *Maritime Compliance* capability relies on ontological interpretation of rules and regulations; hence the capability ecosystem deals with O*ntology Modeling and Interpretation Technics*. On the other hand the *Rule Compliance* service resulted from the capability enables reporting inconsistencies according to ports and regulations, hence the service ecosystem deals with *Policy Makers*, *Industry Partners*, and *Boarder Control* among others. While changes in the capability ecosystem relate to techniques and technologies, changes in the service ecosystem deal with regulatory bodies and policy-making procedures.

The context of capabilities and service are shaped by their ecosystems, hence changes in the ecosystem will impact their situational conditions.

MariServ Examples. The *Rule Compliance* service should adapt its consistency reporting to its situational conditions, i.e., *Local legislation*, *Crew medical state*, *Cargo state*, and *Vessel emission*. To enable such adaptation the capability should be flexible towards change i.e., the *Interpretation Platform* should accommodate changes in business and regulatory dictionaries.

The separation of contexts among capabilities and services does not indicate isolation; in fact research indicates that the relationships among capability and service ecosystems will impose changes to their contexts. However the influences often appear with a certain delay. Modeling such relationships will allow designers to (i) identify trends in the ecosystem and plan for adaptation ahead of time and (ii) study consequences of design decisions in the ecosystem and enterprise.

MariServ Examples. Changes in the regulatory body (service context) can trigger changes in the interpretation requirements of the compliance capability (capability context). To address the new requirements of the capability context, one should perform research on ontological interpretation techniques that in turn will produce new trends in the capability ecosystem.

5 Using the Meta-Model to Design Capabilities and Services

The meta-model presented in Sect. 4 provides an overview of the concepts that we propose in order to have a fully integrated capability-centered approach to sustainable enterprise IT. To answer how these concepts may be used we present a process that depicts three ways of exploiting the capability-centered models namely *descriptive*, *relational* and *evaluative* models in a synergetic manner.

The descriptive models will allow answering questions regarding (i) functional and non-functional requirements of capabilities, processes, services and the supporting organizational structure, (ii) strategic objectives and investment profile of the enterprise and capabilities contribution in satisfying them, (iii) abstraction levels particularly

meta-capabilities and meta-processes that trigger and execute change within the enterprise, and (iv) orchestration alternatives and deployment configurations [22]. The relational models enable answering questions regarding (i) economic benefits of services, capabilities and business processes, (ii) collaboration requirements of actors within and outside the boundaries of the enterprise, and (iii) the influences that the alternatives might have on the contextual variables and situations. The evaluative models answer questions regarding (i) the causes and effects among attributes from capability and service context and their interplay with the ecosystem, (ii) the short-term and long-term impacts of a decision on competitive positioning of the enterprise in the ecosystem by analyzing the structure of capabilities, services and their contexts, and (iii) the consequences and impacts of a change in different views.

6 Discussion

In fast paced environments where continuous adaptation and realignment of IT services is required, the challenge in identifying the correct evolutionary requirements is amplified. This paper has argued that there is a need for the development of an ISE methodology and support software tools for the design of services that meet the challenges of alignment, agility and sustainability in relation to requirements that arise as a result of changes in the enterprise domain. To this end the paper proposes an interdisciplinary approach exploring insights from strategic management, systems thinking and information systems engineering.

The integrative factor in the proposed work is the notion of 'enterprise capability', which represents the confluence of research from strategic management and ISE. The conceptual models and the analytical processes presented herein represent the genesis of a *capability-centric* development paradigm.

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