Architecting Enterprise Capabilities: Creating Dynamic Capabilities from IT and Software Architecture

Mohammad Hossein Danesh[1], Eric Yu[2]

[1]Department of Computer Science, University of Toronto, Toronto, Canada
[2]Faculty of Information, University of Toronto, Toronto, Canada
{danesh,eric}@cs.toronto.edu

Abstract. In this fast-paced world, enterprises are facing increasing difficulties to sustain competitive advantage. The dynamic capability view (DCV) in strategic management suggests that the ability to continuously create valuable and rare capabilities is the basis for competitiveness in rapidly changing environments. Flexible information technology (IT) capabilities that are aligned to enterprise capabilities and which can facilitate agile operation and decision making play a fundamental role in dynamic capabilities. In this paper we outline a vision of architecting enterprise capabilities building upon the *i** modeling framework to facilitate design of more flexible and adaptive IT capabilities. We discuss how the proposed modeling framework facilitates reasoning on capability development, orchestration and deployment alternatives considering non-functional requirements with flexibility as a fundamental concern.

Keywords: Dynamic Capabilities, Capability Modeling, Enterprise Architecture, Capability Orchestration, Software Architecture

1 Introduction

The notion of capability is introduced in the strategic management literature to identify strengths and weaknesses of an organization and their influence on competitive advantage. The Dynamic Capability View (DCV) is a theoretical view within the Resource Based Theory (RBT) that focuses on the dynamic nature of resources and capabilities in strategic management. It argues that the ability to continuously create valuable, rare and difficult to replicate capabilities are the bases for competitiveness [1]. Capabilities emerge from knowledge embedded in people, business processes and technical systems and are shaped by organizational culture and norms [2]. Decisions regarding capability development and evolution is influenced by the organization's environment, governance structure and is limited by the historical paths of the capabilities [3].

Information Systems (IS) and IT-enabled enterprise capabilities can play a strategic role in business competitiveness [4]. The software engineering community has raised the abstraction level of design artifacts to facilitate and enhance articulation of business stakeholders' requirements. Service Oriented Architecture (SOA), Model Driven Development (MDD) and Enterprise Modeling (EM) are examples of such engineer-

ing approaches that facilitate better understanding and implementation of business requirements [5]. Recently researchers have used the notion of capabilities to facilitate alignment of business architecture with IT artifacts, identify associated risks with adoption of a certain technology, evaluate and maintain IT projects, map capabilities to service-oriented implementation and facilitate run-time adaptation of IS alternatives in response to changes in business context [6].

Recognizing the socio-technical nature of enterprise capabilities, in this paper we outline the potential of the *i** modeling framework to reason on capability alternatives. We propose extensions to the *i** framework and discuss its ability to analyze implications of capability alternatives on each other and the overall logic of value creation. Research indicates that decentralizing capabilities will foster innovation and allows architects to create advantage from the complementary nature of capabilities in organizations [7]. This complementary nature of capabilities is of greater importance for IT capabilities as it can be a direct source of competitive advantage [2], [4], [8]. In this paper we explore how *i**-based capability modeling can help analyze the capability development and evolution decisions that architects face.

2 Modeling Enterprise Capabilities

Enterprise capabilities emerge from investment in a strategy that is realized through collaboration of multiple stakeholders and uses resources, processes, skill sets, and is shaped by its historical path and organizational culture [7]. Such capabilities can act autonomously towards new capability development decisions [2]. A review on the IS engineering literature on capabilities indicates that capability modeling approaches to-date have focused on deployment configuration and implementation alternatives. These research works propose design and alignment of IT services to address capability requirements. However existing approaches do not facilitate business driven coordination and orchestration of capabilities that drive decentralized configuration management of software architecture [6]. In order to achieve competitive advantage, organizations require flexible enterprise and IT capabilities that will facilitate creation of new capabilities through structuring, integrating, coordinating and deploying capabilities [9,10].

Capability design and evolution consists of decision making regarding three sets of alternatives: (1) Capability Development which focuses on building, selecting and acquiring the right resources and processes to form capabilities. The choice to employ a centralized Enterprise Service Bus (ESB) with a service registry or use of a mash up portal with RESTful web services for implementation of Service Oriented Architecture (SOA) is an example of development alternatives. The implications of each choice on required resources and skill sets and non-functional requirements are significantly different. (2) Capability Orchestration focuses on analyzing multiple sets of capabilities and their coordination strategies. For example how each of the SOA alternatives communicate with domain applications and integrate them to facilitate Enterprise Application Integration (EAI) is an orchestration alternative. (3) Capability Deployment Configuration concentrates on configurations of capabilities at deployment

time. For example, whether Application Programming Interfaces (APIs) should be developed and maintained by the SOA team or by developers of domain applications are two alternative deployment configurations.

3 Adapting *i** to Model Enterprise Capabilities

The *i** modeling framework facilitates socio-technical exploration of organizations by graphical representation of actors, intensions, dependencies, responsibilities and alternatives. Different actors and their associations express the social aspect of *i**. Tangible and intangible intentions of actors are represented by goals and softgoals. The Strategic Dependency (SD) model of *i** depicts actors dependencies on each other to accomplish tasks, provision resources and satisfy goals and softgoals. More detail reasoning and decomposition of actors intensions are provided in the Strategic Rational (SR) model [11].

We use *i** goal models to reason on capability development, orchestration and deployment configurations. In particular we propose modeling core capabilities of an enterprise as *i** actors to embody their independence that is built over time. Capabilities modeled as specialized actors are indicated with intertwined circles added to the *i** symbol for actor. In figure 1, we discuss a set of IT capabilities in a hypothetical case that are used to facilitate more efficient *Enterprise Management*. The *Business Process Management (BPM)* capability is part of the *Enterprise Management* and enables *Business Process Operation* with a certain *Modifiability* that facilitates *Smooth* transition and execution. The Business Intelligence provides data driven *Insight* with high degree of *Reliability* as part of the *Enterprise Management* to facilitate confident decision making. The *SOA* capability is provided by the *IT Support Team* to enable *Application Integration* with *Flexibility in Resource Orchestration* to facilitate *Smooth and Modifiable* BPM implementation. The *BI* capability also depends on the SOA implementation to gain *Integrated Information Access.*

A position, or, in the case of collaborating partners, multiple positions are responsible for a capability. Modeling positions relations and dependencies with capabilities will facilitate better understanding of the social context of capabilities within the organization and allows better decision making when architecting capabilities. As an example in figure 1 each of the three *BPM*, *SOA* and *BI* capabilities have different positions responsible for them and effective *Enterprise Management* requires their collaboration. Roles and agents in the organization can be part of the positions that are responsible for a capability and can be dependent or depend on capabilities. The *Data Analyst* as part of the *Decision Maker* presented in figure 1 is dependent on the *BI* capability to play a role in the organization (this dependency is not shown in the model to save space) and the *BI* capability is dependent on the *Data Analyst* to perform *Analysis and Interpretation* on the data to produce *Insight*.

Modeling capabilities as specialized *i** actors will allow: (1) Reasoning on capability alternatives and their influence on each other. As an example in figure 1, we presented three development alternatives for *BI* implementation. The choice among these alternatives will influence the *Data Accuracy and Consistency*, and the *Flexibility*

softgoal. The *Enterprise Management*'s reliance on the *Data Accuracy and Consistency* will prioritize alternatives that better satisfy the softgoal. This originates from the *Consumer's* demand for *High Quality Service*. As depicted in figure 1, each of the alternatives will result in distinctive capability orchestrations and SD models (areas labeled Alternative 1, 2 and 3 in figure 1).

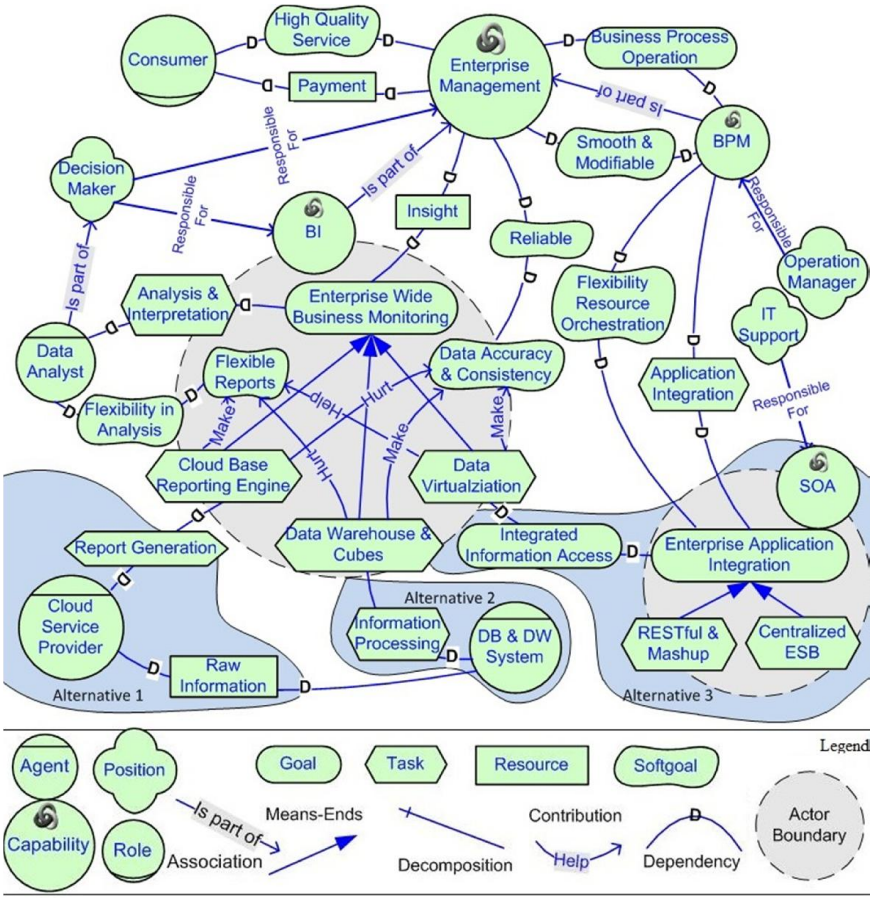

Fig. 1. Enterprise Capability Management –Development & Orchestration Alternatives

(2) Expression of the social context of capabilities alongside their rationales facilitates analysis of their receptiveness or resistance to a certain alternative. For example, the *Data Analyst* will likely resist to the *Data Warehouse* alternative of *BI* implementation because of its hurtful contribution to the *Flexibility* softgoal. (3) Analysis of how architecting capabilities will affect enterprise competitiveness. The SD model will serve as a roadmap to understand the organizational value creation and facilitates the architect to analyze the consequences of changes on the value network. Each of

the SOA alternatives presented in figure 1 will have different impacts on the *Flexibility of Resource Orchestration* which in turn can affect the *Modifiability* of BPM implementation. The SD model will serve as a roadmap for analyzing such relations and their impact on the organization's *Quality of Service* offered to the *Consumer*. This analysis on flexibility and modifiability softgoals from multiple stakeholders' viewpoints will facilitate a better understanding of the flexibility requirements of the enterprise architecture as a whole.

4 Discussion

Capability models have been proposed in recent research to present investment profiles, facilitate business-IT alignment, plan and map service-oriented implementation, identify risks, and to make run-time adjustments to changing business context [6]. However our review of the literature suggests the need for analyzing alternatives at different stages while considering the decentralized, complementary and social nature of capabilities. *i*- based modeling has the potential to capture socio-technical aspects of capabilities and reason on development, orchestration and deployment alternatives. The models allow expression of both top-down strategic intentions and bottom-up integration of organizational resources and skill sets. Reasoning approaches on goal models can facilitate making trade-off decisions among capability alternatives with regards to intangible drivers modeled as softgoals.

The quality of proposed analysis is highly dependent on identification of the capabilities and the definition of their boundaries. This can be a potential limitation on practical application of the approach. Few of the IS capability modeling approaches have provided methodological support or criteria for identifying or evaluating capabilities alternatives. The proposed evaluation criteria are limited to operational performance or context dependent qualities and do not consider strategic competencies [5, 6]. By representing capabilities as *i** actors which are modeled alongside stakeholders in the proposed modeling framework, we facilitate analysis on value creation and appropriation which are among the main criteria for evaluating how capabilities contribute to competitive advantage [12].

In order to evaluate the contributions that IT capabilities make to organizational value creation and appropriation, two sets of analysis should be performed: (1) what capabilities and which stakeholders should be included in the capability model? In the case presented in figure 1, are the presented capabilities and their relations to stakeholders enough for making decisions? Does the modeled relation between the *Consumer* and *Enterprise Management* contain enough detail or is it oversimplified? Can one decide among *SOA* alternatives without considering other IT capabilities and operational requirements of the organization? Are all the stakeholders and capabilities that influence and use the *BI* and *BPM* capabilities represented in this model? The *i** capability models allow asking and answering such questions in multiple iterations and depict the relations among capabilities and their beneficiaries. (2) The second set of analysis focuses on what to include or exclude when designing a capability. In the case example, should the organization merge the *SOA* and *BPM* capabilities or will

the enterprise benefit from their separation? The second option allows the two capabilities to fall under the responsibilities of two different organizational stakeholders (modeled as *i** positions in figure 1). The *i** model expresses that if the organization is planning to implement *Data Virtualization* as part of the *BI* capability, it will benefit from reusing the SOA infrastructure. Therefore there is an opportunity to gain more efficiency by assigning the responsibility of managing and scaling the *SOA* capability to the *IT Support Team*.

The *i** dependencies in capability models provide a basis for further analysis on the causes and propagation of inflexibilities and their influences on organizational value creation. Without a methodology and tool support, the task of analyzing the influences of dependencies on each other is difficult. The *i** models need to be further extended to depict the constraints that limit dependencies and capability orchestration alternatives.

References

1. Teece, D.J., Pisano, G., Shuen, A.: Dynamic Caability and Strategic Management. Strategic Management Journal. 18, 509–533 (1997)
2. Leonard-Barton, D.: Core capabilities and core rigidities: A paradox in managing new product development. Strategic Management Journal. 13, 111–125 (1992)
3. Helfat, C.E., Peteraf, M.A.: The dynamic resource-based view: capability lifecycles. Strategic Management Journal. 24, 997–1010 (2003)
4. Nevo, S., Wade, M.: The Formation and Value of IT-Enabled Resources: Antecedents and Consequences. Management Information Systems Quarterly. 34, 163–183 (2010)
5. Stirna, J., Grabis, J., Henkel, M., Zdravkovic, J.: Capability Driven Development – An Approach to Support Evolving Organizations. In: Sandkuhl, K., Seigerroth, U., and Stirna, J. (eds.) PoEM 2012. LNBIP, vol. 134, pp. 117–131. Springer, Heidelberg (2012)
6. Danesh, M.H, Yu, E.: Modeling Enterprise Capabilities with i*: Reasoning on Alternatives. In: L. Iliadis, M. Papazoglou, and K. Pohl (eds.): CAiSE 2014 Workshops, LNBIP, Vol 178, pp. 112–123, Springer International Publishing (2014)
7. Teece, D.J.: Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal. 28, 1319–1350 (2007)
8. Bhatt, G.D., Grover, V.: Types of Information Technology Capabilities and Their Role in Competitive Advantage: An Empirical Study. Journal of Management Information Systems. 22, 253–277 (2005)
9. Sirmon, D.G., Hitt, M.A., Ireland, R.D., Gilbert, B.A.: Resource Orchestration to Create Competitive Advantage Breadth, Depth, and Life Cycle Effects. Journal of Management. 37, 1390–1412 (2011)
10. Aral, S., Weill, P.: IT Assets, Organizational Capabilities, and Firm Performance: How Resource Allocations and Organizational Differences Explain Performance Variation. Organization Science. 18, 763–780 (2007)
11. Horkoff, J., Yu, E.: Evaluating Goal Achievement in Enterprise Modeling – An Interactive Procedure and Experiences. In: Persson, A., Stirna, J. (eds.) PoEM 2009. LNBIP, vol. 39, pp. 145–160. Springer, Heidelberg (2009)
12. Molloy, J.C., Chadwick, C., Ployhart, R.E., Golden, S.J.: Making Intangibles "Tangible" in Tests of Resource-Based Theory A Multidisciplinary Construct Validation Approach. Journal of Management. 37, 1496–1518 (2011)