A Socio-Technical Modeling Framework for Designing Enterprise Capabilities

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Abstract. The need for flexible and adaptive IT is ever more pressing as enterprises compete in global digital economies and ecosystems. To enable flexibility and adaptability of IT, one requires tools and techniques that enable co-design of IT and business. Hence, this research builds on the strategic management literature, particularly the research on dynamic capabilities, to propose a socio-technical modeling framework for designing enterprise capabilities. An agent-oriented modeling framework for understanding social and technical requirements when designing enterprise capabilities is proposed by building on conceptual modeling practices and techniques. An overview of the research design consisting of objectives, questions, and methodology is presented in this paper.

1 Introduction

The challenge of dynamic and evolving requirements faced by enterprise IT is twofold, the need for (1) adaptable and reconfigurable software services/systems that can adjust to changes [1], and (2) a flexible organization that can develop, support and leverage such systems/services [2–4]. Understanding and analyzing the complexities and behaviors of interdependent enterprise actors, systems, processes, and structures are required to overcome the design hurdles [5]. In this process methods and constructs that enable co-design of IT and the business organization is key [6].

This research started with the question of "how to architect flexible IT to enable adaptive enterprises". The first step in answering the question was to understand what kinds of flexibilities are needed to design adaptive enterprises, i.e., answer the question of "flexibility towards what". An investigation into the literature revealed that enabling business and enterprise evolution in response to environment dynamism is the primary concern of flexibility [5, 13].

The above answer provoked an investigation into the strategic management literature. The flexibility aspect of the research motivation narrows down the scope of the investigation to inside-out views in strategic management which directed us to the Dynamic Capability View (DCV) of the firm.

Capabilities in DCV are defined as *an organization's ability to appropriately assemble, adapt, integrate, reconfigure and deploy valued resources, usually, in combination or co-presence* [14, 15]. They are created through collaborative learning processes that individual agents participate in, and are supported by the norms and culture

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of the organization [2, 16]. Enterprises succeed by nurturing the ability to continuously create valuable and difficult-to-replicate capabilities, often referred to as “dynamic capabilities” [15].

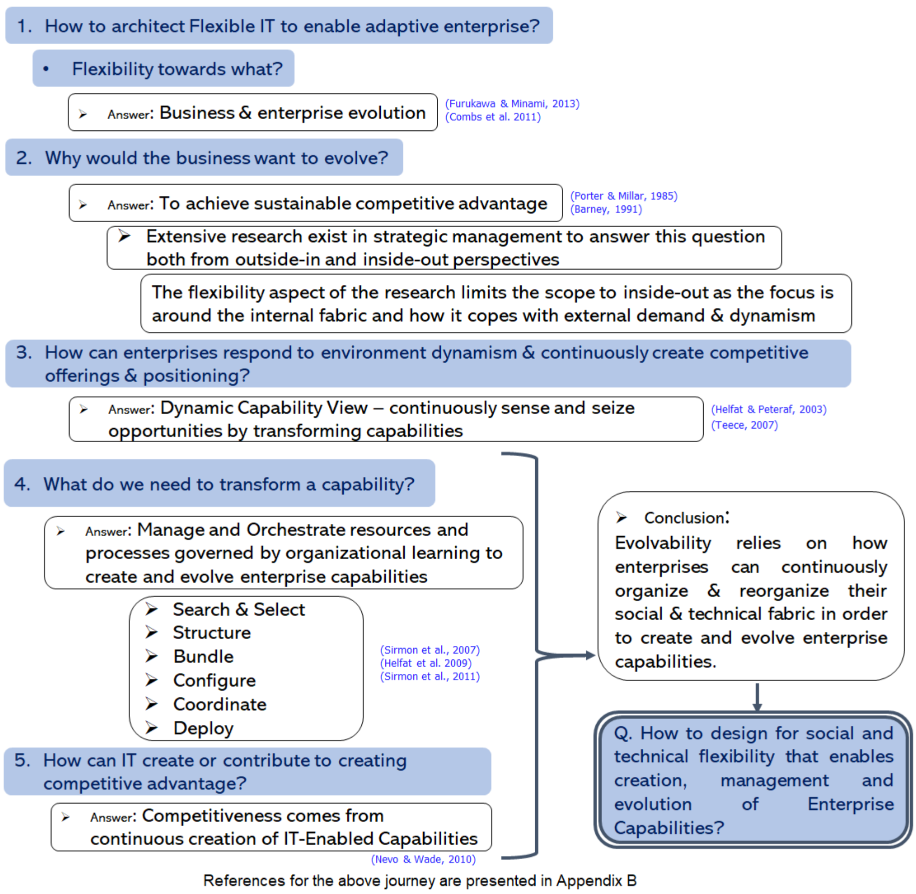

Fig. 1. Journey to Formulate Research Objective

Fig. 1 depicts the described journey from the initial motivating research question around IT flexibility to the refined question that enterprises are dealing with on a day to day basis. Therefore, the research objective is defined as enabling enterprises, particularly managers and architects within enterprises, to answer the question of “*How to design for social and technical flexibility that enables creation, management and evolution of Enterprise Capabilities?*”.

Conceptual modelers and IS designers have raised the abstraction level of the design artifacts to better understand enterprise context and design higher quality information systems [1]. For example, concepts such as value [7], goals [8], actors [9], and business processes [10] have been used as abstractions to design information systems. Similar to our quest into the strategic management literature, other practitioners and researchers have also used the notion of *capability* to identify requirements and infer strategic direction when designing information systems [1, 11, 12].

2 Research Objectives and Questions

To enable the design of flexible enterprise capabilities, the ability to perform analysis and answer the questions presented in **Table 1**, is necessary. In this research, a conceptual modeling approach is adopted to develop a framework consisting of modeling constructs, methods, and tools that intend to answer the analysis questions of **Table 1**.

The choice of using conceptual modeling practices is supported by the success of the IS community in a) developing conduits that can represent and analyze technical, business and organizational context [18, 19], b) guiding and enabling socio-technical design and requirements engineering [20, 21], and c) allowing reuse of design artifacts in terms of patterns and architectural decisions [1, 22].

Table 1. Research Objective Framed as Questions that Designers Should Answered

How to design for social and technical flexibility that enables creation, management and evolution of Enterprise Capabilities?	What Alternatives (including architectural patterns) are there available for the evolution/creation of an enterprise capability?
	How to identify possible inflexibilities that inhibit evolution/creation of enterprise capabilities?
	What is the impact of choosing one alternative over the other and what is the tradeoff?

The above questions that elaborate the research objectives trigger the following research questions as presented in **Table 2**.

Table 2. Research Questions

1	What are enterprise capabilities?	1-1	What would be an appropriate representation of enterprise capabilities for modeling and analyzing competitiveness?
		1-2	How does the concept relate to other concepts within the enterprise such as services, processes and resources?
		1-3	How can one represent and analyze the formation of enterprise capabilities to enable answering the questions of **Table 1**?
2	How can one identify and analyze different options for evolving enterprise capabilities?	2-1	What are the different kinds of choices?
		2-2	How does one evaluate capabilities?
		2-3	How can one identify and represent the tradeoffs among alternatives?
3	How can one understand and balance the impact of investment choices on quality goals such as flexibility?		
4	How to identify possible inflexibilities in a given set of capabilities?		

3 Research Methodology

Design Science Research (DSR) has become a prominent research method in both IS engineering and IS management communities [23]. Different steps of a typical design cycle of the DSR methodology is presented in **Fig. 2**. The approach recommends multiple cycles of the process to refine and enhance designed solution(s) through evaluation and feedbacks.

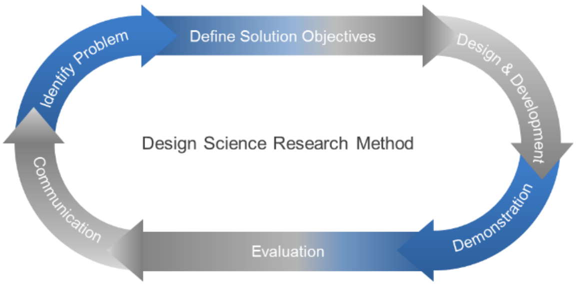

Fig. 2. Phases of the DSR

This thesis has adopted the DSR methodology. Throughout the research, a few rounds of DSR design cycles with feedback received from both academia and industry case studies are conducted. As an example, feedback from academia suggested the need for a holistic understanding of the notion of capability and how it is related to other modeling constructs and concepts. This feedback triggered a new design cycle. In the interest of space more in depth discussion of the design cycles are not presented in this paper, instead, we focus on elaborating the outcomes of the design iterations.

4 Overview of the Framework and its Components

A modeling framework consisting of ten components as laid out in **Fig. 3** is proposed in response to discussed research questions. The first component is the conceptual foundation serving as the main theoretical contribution of the thesis. It builds on an in-depth review of concepts from literature and proposes an integrated meta-model for enterprise capability and its relationships. The second component of the framework focuses on the i* based instantiation of the meta-model. The third and fourth components are practical guidelines for using and instantiating the modeling framework in the context of an enterprise. Each component is developed as part of a case study.

The next five components of the framework are analysis techniques that help decision makers investigate and answer what-if questions. The last component as depicted at the top of **Fig. 3** is an overarching view and categorization of all decisions that must be made throughout the lifecycle of a capability.

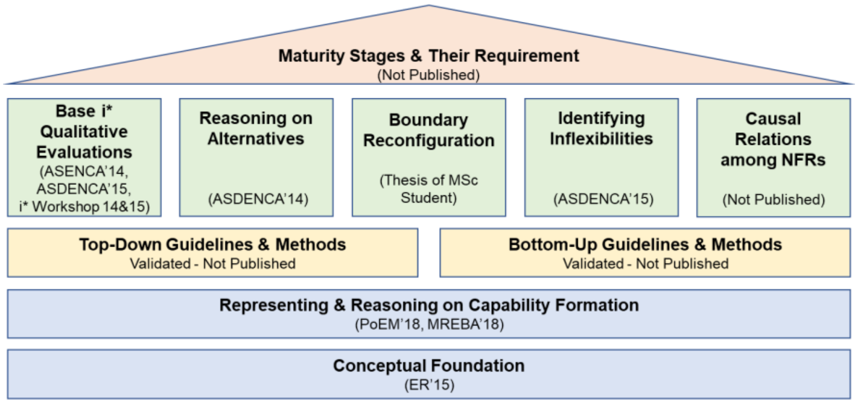

Fig. 3. Overview of the Proposed Modeling Framework

In **Table 3**, the components are described with a specification of their purpose and contributions to answering the research questions. The last column of **Table 3** focuses on the feedbacks or triggers that initiated the development of the component. The order of the components presented in the table do not describe the sequence in which they were developed.

Table 3. Description of the Components

	Component	DSR Type[1]	Purpose	Trigger/ Feedback
1	Capability modeling requirements and maturity stages	Design Theory Constructs Methods	• Explicate capability modeling requirements • Categorized maturity stages for management • Will guide creation and selection of approaches • **Answers Q1-1, Q2, Q3, Q4**	Why are there many approaches?
2	Conceptual Foundation (Meta-Model)	Design Theory Constructs	• clarify what enterprise capabilities are • How do they relate to other concepts within the organization? • **Answer Q1**	What are Enterprise Capabilities & how are they different?
3	Representing & Reasoning on Capability Formation	Constructs Methods	• Justify the suitability of i* to represent capabilities • Describe how to instantiate the meta-model using i* • **Answers Q1, Q2**	A socio-technical approach that enables reasoning on capability formation is needed

[1] DSR types are described in the Appendix [23]

4	Alternative Kinds & Reasoning Guidelines	Design Theory Constructs Methods	• Give a better understanding on how to identify, represent and reason on the different kinds of alternatives throughout the capability lifecycle • **Answers Q2, Q3**	Capability development happens over time
5	Identifying Inflexibilities	Constructs Method	• Test the applicability of Architectural techniques • Identify possible inflexibilities • Make tradeoffs • **Answers Q3, Q4**	Design for Flexibility
6	Cause & Effects of NFRs	Design Theory Method	• How do quality requirements impact one another, can we model causal effects? • Demonstrate how capability models can help us in finding the casual relations • How do we study the impacts and tradeoffs among Quality attributes at the enterprise level? • **Answer Q2-2, Q2-3, Q3, Q4**	Need to understand causal relations among NFRs overtime
7	Boundary Reconfiguration	Method	• How to analyze what to include or exclude from a capability boundary? • What is the social impact of moving an element from one boundary to another? • How does moving elements impact alternatives and satisfaction of goals?	How to assign responsibilities among capabilities and teams.
8	Top-Down Modeling Approach	Method	• Guidelines on how to perform modeling starting from strategic objectives • **Answer Q1, Q2, Q3**	How to use the framework
9	Bottom-Up Modeling Approach	Method	• Guidelines on how to perform modeling starting from technological needs • **Answer Q1, Q2, Q3**	How to use the framework

Instantiations in DSR are used to demonstrate the usage of an approach and validate the contribution of the research. In **Table 4**, the series of instantiations, their purpose, and publication venues are presented. The final item in the table refers to an ongoing case study in evaluating the usage of the framework.

Table 4. Describing Instantiations of Components

	Instantiations	Purpose	Published
1	An Educational Institute	• Used to draft the first version of the framework • Used in practice to guide the delivery of IS artifacts • Used as the case study for Causal modeling of NFRs	[24]
2	ACORD Insurance Reference Model	• Used as a publicly available reference capability model to demonstrate capability alternatives	[25]
3	A Maritime Servicing Company	• Understand the concept of capability and its relationships in a second case study • Instantiate & validate the meta-model	[26]
4	An Internet Service Provider	• Used to describe the future state (visionary) capabilities • Explicate collaboration requirements & responsibilities with the intention to onboard all stakeholders • Serve as a roadmap to define & prescribe solutions • Serve as a roadmap to define & prescribe KPIs • Used to develop bottom-up guidelines and methodology	No

5	RFP Evaluation Employee Enablement	• Model a vendor proposal to evaluate
		  ○ satisfaction of persona requirements
		  ○ identification of tool and platform bias
		  ○ identify and propose alternatives for shortcomings
		• Used to develop top-down guidelines and methodology
			No

6	In-Progress	TBD	

In the remainder of this section a brief overview of the components of the framework is presented.

4.1 Conceptual Foundation

The integrated meta-model for the modeling framework is based on different conceptual viewpoints coordinated through the notion of enterprise capabilities as outlined in **Fig. 4**. The views enable describing what forms a capability, how it relates to other enterprise concepts and how one can determine the value of the capability in the ecosystem. Enterprise capabilities (EC) are defined as *intentional combination of firm-specific assets, organizational routines (business processes), and human knowledge (skillset/know-how) that take advantage of complementary relations and are created and evolved overtime through social collaboration and learning.*

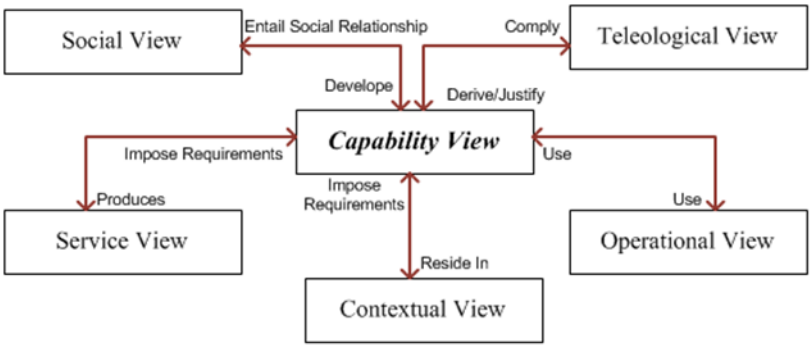

Fig. 4. Overview of the Conceptual Framework with the Central Role of Capability

Examples of enterprise capabilities we have investigated as part of our instantiations are “Enterprise IT Risk Management”, “Customer Interaction Management”, “Business Process Management”, “Social Media Analytics”, and “Integrated Information Provisioning”.

The proposed meta-model represents the confluence of the results from two domains of strategic management and information systems engineering. It serves as the keystone of a socio-technical approach for developing information systems and has been validated in more than three case studies. Because of such validations, the meta-model has been extended particularly in the social view as presented later in **Fig. 9**.

4.2 Maturity Stages & Their Requirements

Building on the variety of research efforts on using capabilities, a capability modeling practice is proposed consisting of six maturity stages as presented in **Fig. 5**. The initial stage is to use capabilities as blueprints for communicating investment priorities. At stages two and three the focus is on enabling representation of capability formation and its alternative evolution paths. At stages four and five, the capability concept is used to reorganize the enterprise and enable design for flexibility, while exploring different configurations of roles and responsibilities. At stage six in response to demands of ecosystems, the capability concept is used to enable re-design and re-alignment of the enterprise and its service propositions.

For each of the stages, a set of questions are identified that will guide a) researchers in developing methods and techniques for reasoning and decision making, and b) practitioners in selecting appropriate methods and performing required analysis for capability design.

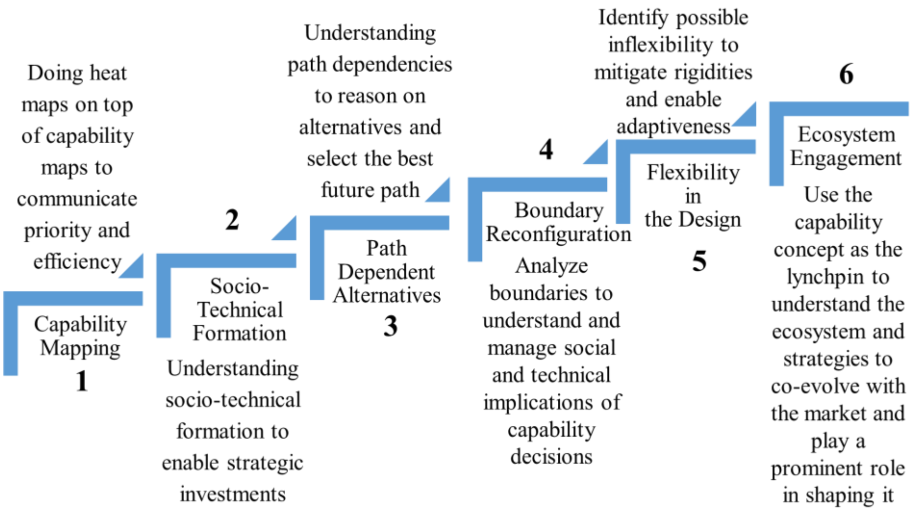

Fig. 5. Maturity Stages of Capability Modeling Practice

4.3 Representing and Reasoning on Capability Formation

This component consists of three parts a) justification of applying an agent-oriented modeling paradigm, b) guidelines to model and reason on different aspects of capability formation, and c) the formal specification that enables instantiating the meta-model using the i* framework. Without these key components, the analysis techniques that help decision makers and designers will not be applicable.

Adopting an Agent Oriented Modeling Paradigm.
There are five characteristics evident in the definition of EC as reviewed in section 4.1. (1) ECs are **intentionally** built and evolved in accordance with enterprise strategy while striving for survival and relevance at enterprise scale [14, 27]. (2) ECs achieve their objectives by **intelligently coupling** enterprise-specific resources and processes [2, 14, 27]. (3) ECs often create value in **complementary** settings forming a network of interdependent capabilities [15, 27]. (4) ECs are built in the **social setting** of the enterprise i.e., they are influenced by the social capital, reputation, and relationships of the responsible managers and teams [2, 28]. (5) ECs are continuously evolving through meta-level **learning** processes that codify and extend enterprise knowledge base [2, 16].

An agent-oriented modeling approach is adopted to model and represent enterprise capabilities and its characteristics. To this end, in this research ECs are represented as specialized i* actors. The ability of the i* framework to represent goals, means-ends, quality attributes, contributions, and tradeoffs are beneficial in capturing the intentionality and internal structure of capabilities. The i* dependencies and actor associations empower understanding of the social and complementary aspects of ECs. An example of a capability represented with the i* language is presented in **Fig. 6**. This figure illustrates how goals, resource, business processes, capabilities, and their relationships are instantiated using i*.

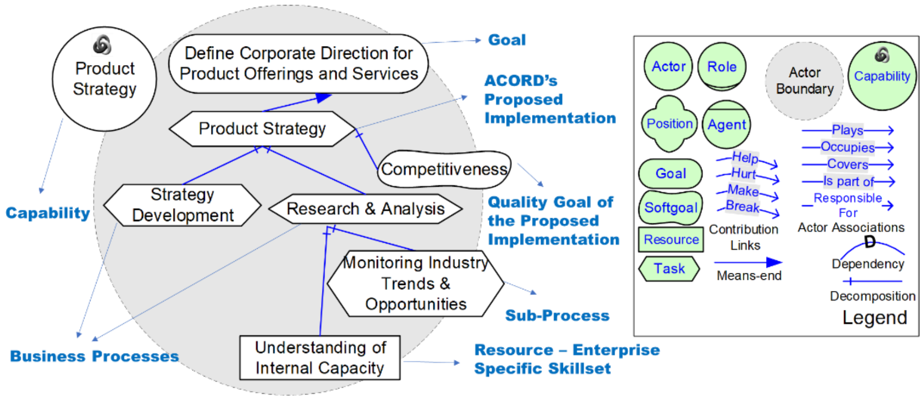

Fig. 6. An Example for Representing Capabilities [25]

Fig. 7 demonstrates the social context in which a capability is built in. The figure focuses on instantiating the relationships among social actors and capabilities while capturing different desires and norms of teams within the organization.

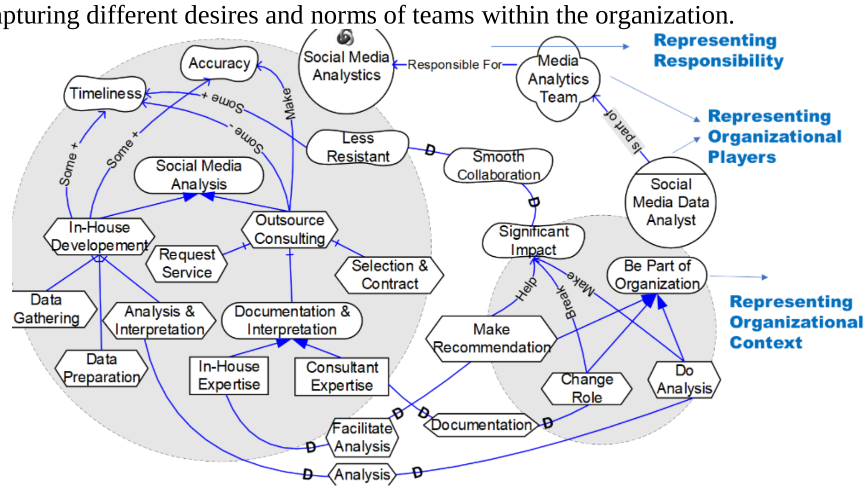

Fig. 7. An Example of Representing Social Context of a Capability [25] – legend in **Fig. 6**

Modeling & Reasoning on Formation of Enterprise Capabilities

This part of the component focuses on guidelines for modeling and reasoning on the formation of capabilities that will empower understanding of (1) why a capability is needed, (2) how it is achieved, (3) how it fits within the organizational and social setting of the enterprise, and (4) what relationships are required for its success. Addressing these requirements satisfy the second maturity stage presented in **Fig. 5**.

The guidelines enable a) explication of choices for coupling enterprise-specific resources and processes that differentiate emerging quality attributes, b) expression of the social and organizational setting to empower analyzing the influences and interests of multiple stakeholders, and c) representation of interdependent networks of capabilities to enable orchestration of design choices among capabilities, information systems and organizational structure(s). In **Fig. 8**, an example of complementary relationships among capabilities and their impact on alternative are presented.

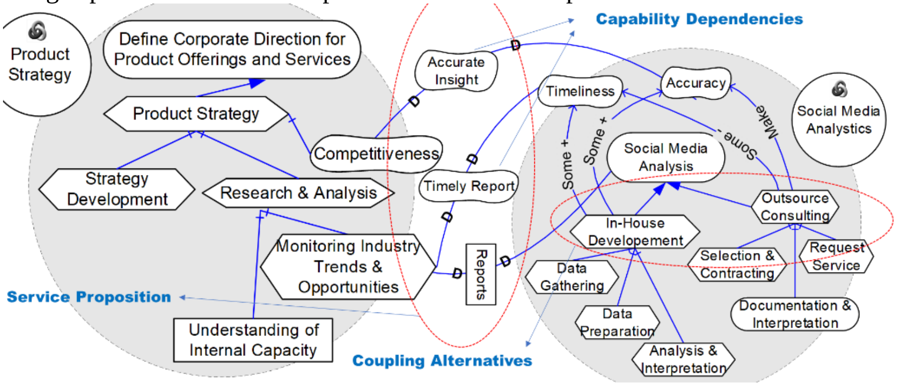

Fig. 8. Representing Complementary Capabilities using the i* Language– legend in **Fig. 6**

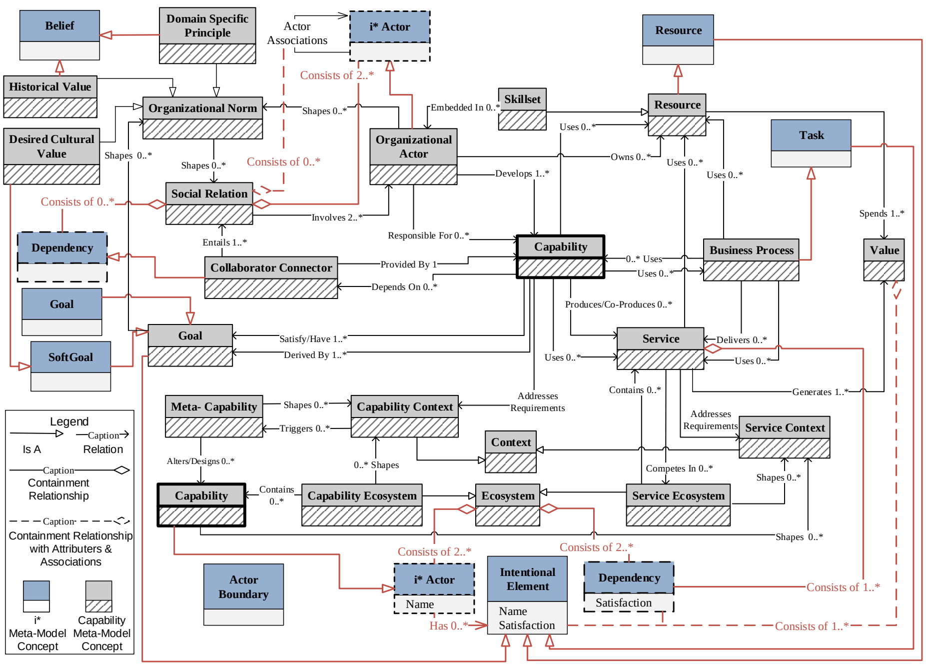

Fig. 9. Meta-Model of the Extended i* Framework

Formal Description of Framework

The third part of this component focuses on a formal description of the extended i* language. A set of guidelines accompany the meta-model presented in **Fig. 9** to enable instantiating ECs. The details of the guidelines to perform the instantiation are left for future publications.

4.4 Analysis Techniques

Supporting analysis techniques are required to understand consequences of decisions about ECs. An in-depth review of each of the analysis techniques is beyond the scope of this paper, but a brief overview of each one is discussed:

1. ***Base i* Qualitative Evaluations***: Uses i*to analyze and infer the degree of which intentions are satisfied within and beyond the boundary of an actor.
2. ***Reasoning on Alternatives*** [25]: The analysis technique focuses on demonstrating different kinds of choices about ECs. The first class of choices are *Development* alternatives that focus on (a) options for acquiring/building resources and processes, and (b) alternative couplings of resources and processes. The second class of choices refer to options for *Deployment Configuration* of capabilities both from a technical and organizational perspective. Finally, the third class of choices refer to *Orchestration* alternatives which entail a) coordination among development and deployment alternatives, b) coordination of choices available for interdependent capabilities, and c) tradeoffs in employing information systems.
3. ***Boundary Reconfiguration*** [29]: The analysis supports answering what-if questions about the division of roles and responsibilities among i* actors. The analysis approach is supported by a series of guiding questions. The intention is to identify potential reconfigurations in actor boundaries leading to better satisfaction of intentions, particularly softgoals.
4. ***Identifying Inflexibilities*** [24]: The proposal focuses on identifying critical relationships among capabilities, information systems, and organizational actors by analyzing their propagation effects.
5. ***Causal Relations among NFRs:*** The analysis technique consists of a set of guidelines that build on the dependency propagations to identify causal relations among quality goals. The causalities are modeled using the Causal Loop Diagrams (CLD) [30] and enable asking what-if questions regarding short-term and long-term impacts of alternatives.

5 Outstanding Research Activities and Future Work

Ongoing activities to finalize the proposed framework are outlined as follows:

- Organizing findings from case studies into playbooks that serve as “Top-Down Guidelines & Methods” and “Bottom-Up Guidelines & Methods” to facilitate the modeling activity.

- Finalizing an ongoing case study which demonstrates the ability of the framework to appropriately navigate from high-level capabilities and drill down into the analysis as necessary.
- Applying minor changes and updates received from feedbacks of the DSR design cycle for the causal modeling technique.

The following components are planned for future iterations of the framework beyond this thesis as outlined in dark color and white text in **Fig. 10**. The two new components on the right intend to enable integration of other researchers' analysis techniques and design patterns into the proposed modeling framework with tool support. The three analysis techniques at the top focus on the external relationships of ECs and how one should evaluate their value. The two components in the lower part of the figure focus on conceptual and practical aspects of modeling enterprise structure. The added component on the left focuses on decisions on bundling service propositions into platforms.

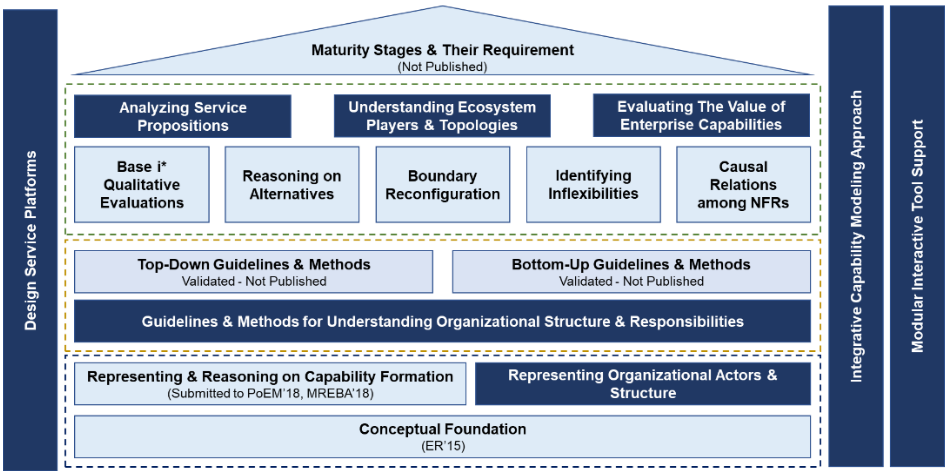

Fig. 10. Overview of the Next Iteration of the Proposed Framework beyond the Thesis

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Appendix A

Constructs, which provide the vocabulary and symbols used to define and understand problems and solutions; for example, the constructs of "entities" and "relationships" in the field of information modeling. The correct constructs have a significant impact on the way in which tasks and problems are conceived, and they enable the construction of models for the problem and solution domains.

Models, which are designed representations of the problem and possible solutions. For example, mathematical models, diagrammatical models, and logic models are widely used in the IS field and new and more useful models are continually being developed. Models correspond to "principles of form" in the Gregor and Jones (2007) taxonomy: the abstract blueprint of an artifact's architecture, which show an artifact's components and how they interact.

Methods, which are algorithms, practices, and recipes for performing a task. Methods provide the instructions for performing goal-driven activities. They are also known as techniques (Mokyr 2002), and correspond to "principles of function" in the Gregor and Jones taxonomy and Bunge's (1998) technological rules.

Instantiations, which are the physical realizations that act on the natural world, such as an information system that stores, retrieves, and analyzes customer relationship data. Instantiations can embody design knowledge, possibly in the absence of more explicit description. The structural form and functions embodied in an artifact can be inferred to some degree by observing the artifact.

A design theory, which is an abstract, coherent body of prescriptive knowledge that describes the principles of form and function, methods, and justificatory theory that are used to develop an artifact or accomplish some end (Gregor 2006; Gregor and Jones 2007). Design theory can include the other forms of design knowledge: constructs, models, methods, and instantiations that convey knowledge.

Appendix B

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