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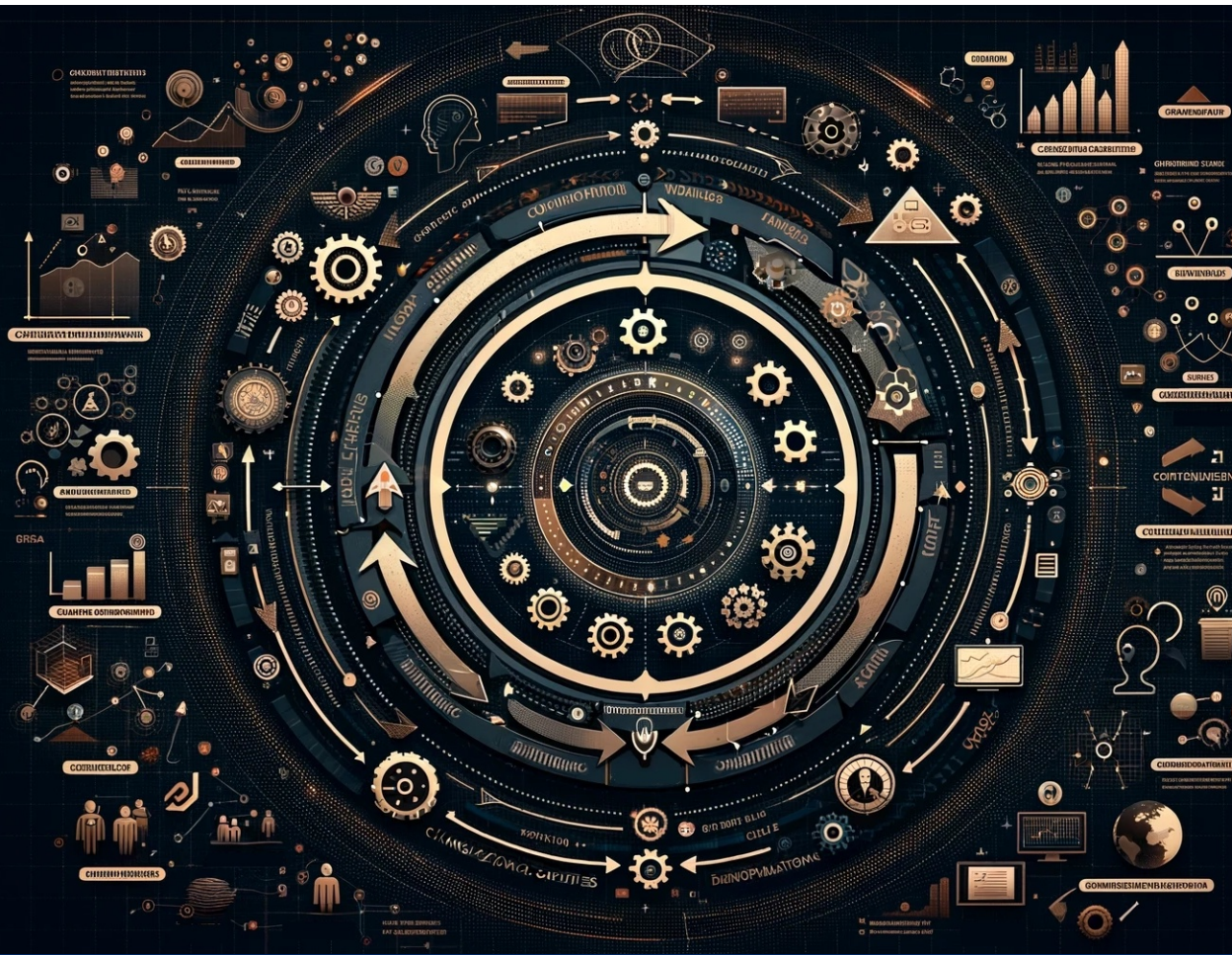
KYKLOS - A modeling method and tool for managing changing capabilities in organizations

Georgios Koutsopoulos



Doctoral Thesis in Computer and Systems Sciences at Stockholm University, Sweden 2024

KYKLOS - A modeling method and tool for managing changing capabilities in organizations

Georgios Koutsopoulos

Academic dissertation for the Degree of Doctor of Philosophy in Computer and Systems Sciences at Stockholm University to be publicly defended on Thursday 21 March 2024 at 09.00 in L30, NOD-huset, Borgarfjordsgatan 12.

Abstract

The environments within which modern organizations are operating are characterized by constantly increasing volatility and diversity, which act as a driving force that continuously presents opportunities and threats to the organizations. The result of this situation is that these environments have become so dynamic that the phenomenon of organizational change is slowly becoming the new constant, rather than being an exception as in earlier years. The challenges arising from the need to handle constant change and evolution naturally lead to changing organizational capabilities. Information systems, as one aspect of an organization, can provide efficient support for the design and analysis of capabilities, and enterprise modeling can facilitate the development of specialized methods for this task. Hitherto, a plethora of capability modeling methods exist, providing a wide spectrum of perspectives.

However, the support provided for managing the phenomenon of changing organizational capabilities remains limited, since existing methods have omitted to capture the elements necessary to depict organizational capabilities in motion and the motivations triggering such transitions. In addition, managing change requires more structured approaches, which should be methodologically supported and conceptualized.

The goal of this PhD thesis is to develop a capability modeling method, called KYKLOS, that can support organizational change by modeling the changing capabilities of organizations and all the relevant aspects of this phenomenon. This work followed the Design Science Research framework, and started by explicating the problem via a literature review of existing capability meta-models; this was followed by the elicitation of method requirements, drawn from both the existing literature and a case study conducted in the domain of public healthcare in Sweden. Based on these requirements, an initial meta-model was developed, which was then demonstrated using the same case study and evaluated by experts through interviews. This activity resulted in an extension to the initial version of the meta-model, which was then instantiated via a case study conducted in the domain of public arts and culture in Greece. In parallel, the compatibility of other modeling approaches was explored. An extended version of the meta-model was then converted to its final version, which was suitable for the implementation of the modeling language in a tool, using the ADOxx meta-modeling platform. Simultaneously with the development of the tool, the syntax, semantics and procedure of the modeling method were created. The complete method was demonstrated through a case study at a company providing ERP solutions and consulting in Sweden, and the results were used to evaluate the method by two groups representing the stakeholder roles.

The thesis contributes towards an improved management of change in organizations through the development of a method and complementary supporting tool, with the capability perspective as the focal point for the design and analysis of organizational change.

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To all the enquiring minds out there, questioning the unquestionable, envisioning better worlds.

“μεταβάλλον ἀναπαύεται”
(metavallon anapavete = changing, it rests)

-Heraclitus

Abstract

The environments within which modern organizations are operating are characterized by constantly increasing volatility and diversity, which act as a driving force that continuously presents opportunities and threats to the organizations. The result of this situation is that these environments have become so dynamic that the phenomenon of organizational change is slowly becoming the new constant, rather than being an exception as in earlier years. The challenges arising from the need to handle constant change and evolution naturally lead to changing organizational capabilities. Information systems, as one aspect of an organization, can provide efficient support for the design and analysis of capabilities, and enterprise modeling can facilitate the development of specialized methods for this task. Hitherto, a plethora of capability modeling methods exist, providing a wide spectrum of perspectives.

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were created. The complete method was demonstrated through a case study at a company providing ERP solutions and consulting in Sweden, and the results were used to evaluate the method by two groups representing the stakeholder roles.

The thesis contributes towards an improved management of change in organizations through the development of a method and complementary supporting tool, with the capability perspective as the focal point for the design and analysis of organizational change.

Sammanfattning

Moderna organisationer verkar inom miljöer som kännetecknas av ständig förändring, detta innebär kontinuerligt nya möjligheter och hot för organisationerna. Dessa miljöer har blivit så föränderliga att organisatoriska förändringar snararare än att vara ett undantag blir den nya konstanten. De utmaningar som uppstår när ständig förändring ska hanteras leder till behovet av förändrade organisatoriska förmågor. Informationssystem, som en del av en organisation, kan ge effektivt stöd för design och analys av förmågor, och verksamhetsmodellering kan underlätta utvecklingen av specialiserade metoder för denna uppgift. Det finns existerande metoder för förmågemodellering, som erbjuder flera perspektiv för att beskriva förmågor.

Stödet för hantering av föränderliga organisationsförmågor är dock begränsat, eftersom befintliga metoder har utelämnat de element som är nödvändiga för att avbilda organisationsförmågor i förändring och de motiv som utlöser sådana förändringar. Dessutom kräver hantering av förändring av förmågor mer strukturerade tillvägagångssätt, som bör vara metodologiskt stödda och konceptualiserade.

Målet med denna doktorsavhandling är att utveckla en metod för förmågemodellering, kallad KYKLOS, som kan stödja organisationsförändring genom att modellera föränderliga förmågor hos organisationer och aspekter av förmågeförändring. Detta arbete följde Design Science Research ramverket och började därmed med en kartläggning av problemet via en litteraturstudie av befintliga förmågemetamodeller; detta följdes av framtagandet av metodkrav, hämtade både från befintlig litteratur och en fallstudie som genomfördes inom området offentlig hälsovård i Sverige. Baserat på kraven utvecklades en initial metamodell, som sedan demonstrerades med hjälp av samma fallstudie och utvärderades av experter genom intervjuer. Detta resulterade i en utvidgning av metamodellen, som sedan instansierades via en fallstudie som genomfördes inom området offentlig konst och kultur i Grekland. Parallellt utforskades kompatibiliteten med andra modelleringsansatser. Den utvidgade versionen av metamodellen omvandlades sedan till en slutlig versionen, lämpad för implementering av modelleringsspråket i ett modelleringsverktyg, med hjälp av ADOxx-metamodelleringsplattformen. Samtidigt med utvecklingen av verktyget skapades syntax, semantik och arbetsprocess för modelleringsmetoden. Den kompletta metoden demonstrerades via en fallstudie hos ett företag som

erbjuder affärssystemslösningar och rådgivning i Sverige, och resultaten användes för att utvärdera metoden av två grupper som representerade intressenternas roller.

Avhandlingen bidrar till en förbättrad hantering av förändring i organisationer genom utvecklingen av en metod och ett tillhörande modelleringsverktyg, med förmågeperspektivet som utgångspunkt för utformning och analys av organisationsförändring.

List of publications

The present PhD thesis is an extension of the following Licentiate thesis:

- Koutsopoulos, G. (2020). Managing Capability Change in Organizations: Foundations for a Modeling Approach [Licentiate thesis, comprehensive summary, Stockholm University]. In *Report Series / Department of Computer & Systems Sciences* (Vol. 1–20–012). DiVA. http://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-185231

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Paper 1: Koutsopoulos, G., Henkel, M., & Stirna, J. (2021). An analysis of capability meta-models for expressing dynamic business transformation. *Software and Systems Modeling*, *20*(1), 147–174. https://doi.org/10.1007/s10270-020-00843-0

Paper 2: Koutsopoulos, G., Henkel, M., & Stirna, J. (2019b). Requirements for Observing, Deciding, and Delivering Capability Change. In J. Gordijn, W. Guédria, & H. A. Proper (Eds.), *The Practice of Enterprise Modeling* (Vol. 369, pp. 20–35). Springer International Publishing. https://doi.org/10.1007/978-3-030-35151-9_2

Paper 3: Koutsopoulos, G., Henkel, M., & Stirna, J. (2020c). Modeling the Dichotomies of Organizational Change: A State-based Capability Typology. In C. Feltus, P. Johannesson, & H. A. Proper (Eds.), *Proceedings of the PoEM 2019 Forum* (Vol. 2586, pp. 26–39). CEUR-WS.org. http://ceur-ws.org/Vol-2586/paper3.pdf

Paper 4: Koutsopoulos, G., Henkel, M., & Stirna, J. (2020a). Conceptualizing Capability Change. In S. Nurcan, I. Reinhartz-Berger, P. Soffer, & J. Zdravkovic (Eds.), *Enterprise, Business-Process and Information Systems Modeling* (Vol. 387). Springer International Publishing. https://doi.org/10.1007/978-3-030-49418-6_18

Paper 5: Koutsopoulos, G., Henkel, M., & Stirna, J. (2020b). Improvements on Capability Modeling by Implementing Expert Knowledge About Organizational Change. In J. Grabis & D. Bork (Eds.), *The Practice of Enterprise Modeling* (Vol. 400, pp. 171–185). Springer International Publishing. https://doi.org/10.1007/978-3-030-63479-7_12

Paper 6: Koutsopoulos, G. (2021). Capabilities in Crisis: A Case Study Using Enterprise Modeling for Change Analysis. In R. A. Buchmann, A. Polini, B. Johansson, & D. Karagiannis (Eds.), *Perspectives in Business Informatics Research* (Vol. 430, pp. 100–114). Springer International Publishing. https://doi.org/10.1007/978-3-030-87205-2_7

Paper 7: Koutsopoulos, G., & Henkel, M. (2021a). An Experience Report on the Implementation of the KYKLOS Modeling Method. In E. Serral, J. Stirna, J. Ralyté, & J. Grabis (Eds.), *The Practice of Enterprise Modeling* (Vol. 432, pp. 103–118). Springer International Publishing. https://doi.org/10.1007/978-3-030-91279-6_8

Paper 8: Koutsopoulos, G., Henkel, M., & Stirna, J. (2022). Modeling the Phenomenon of Capability Change: The KYKLOS Method. In D. Karagiannis, M. Lee, K. Hinkelmann, & W. Utz (Eds.), *Domain-Specific Conceptual Modeling* (pp. 265–288). Springer International Publishing. https://doi.org/10.1007/978-3-030-93547-4_12

Paper 9: Koutsopoulos, G., Andersson, A., Stirna, J., & Henkel, M. (2022). Applying and Evaluating the KYKLOS Method. In B. S. Barn & K. Sandkuhl (Eds.), *The Practice of Enterprise Modeling* (Vol. 456, pp. 118–133). Springer International Publishing. https://doi.org/10.1007/978-3-031-21488-2_8

The author has also contributed to the following articles, which are not included in this thesis:

i. Koutsopoulos, G., Henkel, M., & Stirna, J. (2019a). Dynamic Adaptation of Capabilities: Exploring Meta-model Diversity. In I. Reinhartz-Berger, J. Zdravkovic, J. Gulden, & R. Schmidt (Eds.), *Enterprise, Business-Process and Information Systems*

Modeling (Vol. 352, pp. 181–195). Springer International Publishing. https://doi.org/10.1007/978-3-030-20618-5_13

ii. Koutsopoulos, G. (2018). Modeling Organizational Potentials Using the Dynamic Nature of Capabilities. *Joint Proceedings of the BIR 2018 Short Papers, Workshops and Doctoral Consortium*, *2218*, 387–398. http://ceur-ws.org/Vol-2218/paper39.pdf

iii. Koutsopoulos, G., & Bider, I. (2017). Teaching and Learning State-Oriented Business Process Modeling. Experience Report. In I. Reinhartz-Berger, J. Gulden, S. Nurcan, W. Guédria, & P. Bera (Eds.), *Enterprise, Business-Process and Information Systems Modeling* (Vol. 287, pp. 171–185). Springer International Publishing. https://doi.org/10.1007/978-3-319-59466-8_11

iv. Koutsopoulos, G., & Bider, I. (2018). Business Process Canvas as a Process Model in a Nutshell. In J. Gulden, I. Reinhartz-Berger, R. Schmidt, S. Guerreiro, W. Guédria, & P. Bera (Eds.), *Enterprise, Business-Process and Information Systems Modeling* (Vol. 318, pp. 49–63). Springer International Publishing. https://doi.org/10.1007/978-3-319-91704-7_4

v. Koutsopoulos, G., Kjellvard, N., Magnusson, J., & Zdravkovic, J. (2020). Towards an Integrated Meta-Model for Requirements Engineering. In C. Feltus, P. Johannesson, & H. A. Proper (Eds.), *Proceedings of the PoEM 2019 Forum* (Vol. 2586, pp. 40–53). CEUR-WS.org. http://ceur-ws.org/Vol-2586/paper4.pdf

vi. Bider, I., & Koutsopoulos, G. (2018). Introducing Goal Patterns for State-Oriented Business Process Modeling. *2018 IEEE 22nd International Enterprise Distributed Object Computing Workshop (EDOCW)*, 43–47. https://doi.org/10.1109/EDOCW.2018.00018

vii. Henkel, M., Koutsopoulos, G., Bider, I., & Perjons, E. (2019a). Using Enterprise Models for Change Analysis in Inter-organizational Business Processes. In C. Di Ciccio, R. Gabryelczyk, L. García-Bañuelos, T. Hernaus, R. Hull, M. Indihar Štemberger, A. Kő, & M. Staples (Eds.), *Business Process Management: Blockchain and Central and Eastern Europe Forum* (Vol. 361, pp. 315–318). Springer International Publishing. https://doi.org/10.1007/978-3-030-30429-4_21

viii. Henkel, M., Koutsopoulos, G., Bider, I., & Perjons, E. (2019b). Using the Fractal Enterprise Model for Inter-organizational Business Processes. *Joint Proceedings of the ER Forum and Poster & Demos Session 2019*, *2469*, 56–69. http://ceur-ws.org/Vol-2469/ERForum5.pdf

ix. Henkel, M., Koutsopoulos, G., & Perjons, E. (2020). A Case Study on the Use of Enterprise Models for Business Transformation. In Á. Rocha, H. Adeli, L. P. Reis, S. Costanzo, I. Orovic,

& F. Moreira (Eds.), *Trends and Innovations in Information Systems and Technologies* (Vol. 1159, pp. 404–414). Springer International Publishing. https://doi.org/10.1007/978-3-030-45688-7_42

x. Martinez, A., Melin, M., Koutsopoulos, G., & Zdravkovic, J. (2021). An Empirical Study on Data-driven Requirements Elicitation: Reflections from Nordic Enterprises. In B. Barn, K. Sandkuhl, E. S. Asensio, & J. Stirna (Eds.), *Proceedings of the Forum at Practice of Enterprise Modeling 2021 (PoEM-Forum 2021) (PoEM 2021), Riga, Latvia, November 24-26, 2021* (Vol. 3045, pp. 39–48). CEUR-WS.org. http://ceur-ws.org/Vol-3045/paper05.pdf

xi. Koutsopoulos, G., & Henkel, M. (2021b). Is Enterprise Modeling a Data Analysis Method? In B. Barn, K. Sandkuhl, E. S. Asensio, & J. Stirna (Eds.), *Proceedings of the Forum at Practice of Enterprise Modeling 2021 (PoEM-Forum 2021) (PoEM 2021), Riga, Latvia, November 24-26, 2021* (Vol. 3045, pp. 21–30). CEUR-WS.org. http://ceur-ws.org/Vol-3045/paper03.pdf

xii. Koutsopoulos, G. (2023). Compass: A Canvas for Changing Capabilities. In T. Clark, S. Zschaler, B. Barn & K.Sandkuhl (Eds.) *Proceedings of the Forum at Practice of Enterprise Modeling 2022 (PoEM-Forum 2022) (PoEM 2022), London, United Kingdom, November 23-25, 2022* (Vol. 3327, pp. 66-80). CEUR-WS.org https://ceur-ws.org/Vol-3327/paper07.pdf

xiii. Koutsopoulos, G., Henkel, M., & Stirna, J. (2023). The KYKLOS Tool for Modeling Changing Capabilities. In C. Cabanillas & F. Pérez (Eds.), *Intelligent Information Systems* (Vol. 477, pp. 146–155). Springer International Publishing. https://doi.org/10.1007/978-3-031-34674-3_18

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There are moments in life when things change dramatically. Unexpectedly, and unlike what everyone thinks, finishing a PhD is not one of these moments. This have never been a journey of achieving anything. It always was a journey of becoming. Becoming that someone who can achieve, and this happens long before the official end of the journey.

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Abbreviations

4EM	For Enterprise Modeling
7S	Strategy, Structure, Systems, Shared Values, Skills, Style, Staff
ADKAR	Awareness, Desire, Knowledge, Ability, Reinforcement
ARIS	Architecture of Integrated Information Systems
BP	Business Process
BMC	Business Model Canvas
BMM	Business Motivation Model
BPM	Business Process Management
BPMN	Business Process Model and Notation
CaaS	Capability as a Service
CAP	Change Acceleration Process
CDD	Capability-Driven Development
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CIA	Change Impact Analysis
CIO	Chief Information Officer
CM	Change Management
CMO	Chief Marketing Officer
CODEK	Capability-Oriented Designs with Enterprise Knowledge
COO	Chief Operating Officer
CRediT	Contribution Role Taxonomy
CTO	Chief Technology Officer
DI	Digital Intelligence (Case study anonymized label)
DoDAF	Department of Defense Architecture Framework
DS	Design Science
DSR	Design Science Research
DSV	Department of Computer and Systems Sciences
EA	Enterprise Architecture
EM	Enterprise Modeling
EMF	Eclipse Modeling Framework
ERP	Enterprise Resource Planning
FEDS	Framework for Evaluation in Design Science
GME	Generic Modeling Environment
GOPPRR	Graph Object Port Property Role Relationship
HEI	Higher Educational Institution

IDEF	Integration Definition
IMRaD	Introduction, Methods, Results and Discussion
IS	Information Systems
IT	Information Technology
KPI	Key Performance Indicator
MEM	Method Evaluation Model
MODAF	Ministry Of Defence Architecture Framework
NAF	NATO Architecture Framework
NIST	National Institute of Standards and Technology
OCL	Object Constraint Language
OMG	Object Management Group
OMiLAB	Open Models Initiative Laboratory
PESTLE	Political, Economic, Social, Technological, Legal, Environmental
RBV	Resource-Based View
RE	Requirements Engineering
RH	Regional Healthcare (Case study anonymized label)
RTU	Riga Technical University
SME	Small to Medium Enterprise
SOA	Service-Oriented Architecture
SU	Stockholm University
SWOT	Strengths Weaknesses Opportunities Threats
TAM	Technology Acceptance Model
TOGAF	The Open Group Architecture Framework
UI	User Interface
UML	Unified Modeling Language
VIA	Verksamhets och Informationsanalys
VDML	Value Delivery Modeling Language
VOS	Visualization Of Similarities

1. Introduction

Change, as a phenomenon, has generated and motivated a plethora of cogitations, reflections, and research in every aspect of the human world. This is not a contemporary or recent development; since ancient times, the importance of change for analyzing and comprehending the complexity of the mechanics of the world has been emphasized by many individuals. One example is the ancient Greek pre-Socratic philosopher Heraclitus of Ephesus, whose famous aphorism "πάντα ῥεῖ" (panta rhei = everything flows) positions change as the point of focus of his entire philosophy. This statement may seem simplistic, but a more elaborate viewpoint on the phenomenon of change, which he considered the driving force of the universe, is provided through his other aphorisms. One such aphorism states that "no man can step into the same river twice". This statement includes two viewpoints on change: the first and most obvious point of Heraclitus is that the water in a river is constantly replaced, and therefore cannot be the same river; however, the second and less obvious point is that a person stepping into the water has been changed by the experience, and is no longer the same person (Narecki, 2012). The philosopher's theory can be summarized as the statement that change is the only constant in the world, since everything is constantly changing. This statement is still valid, and serves as the underlying principle for this thesis, in which it is assumed that environmental dynamism exists in every domain of the world, and that both the environment and its observer are changed by it.

The domain of organizations is no exception and, as a result, change in modern organizations is drawing wide research interest. Contemporary organizations are considered dynamic systems (Proper et al., 2017) and the need for a deeper understanding of both the organizations themselves and the phenomenon of organizational change itself is clearer than ever (Burke, 2017). In this specific domain, the high level of environmental dynamism affecting changing organizations is a result of the gradual digital transformation of wider society (van Gils & Proper, 2018). The dynamic environment of an organization refers to a set of interacting forces that originate internally, externally, or from both sides. This dynamism continuously motivates changes with the aim of improving the organization, either in terms of improving its efficiency in achieving its goals (Burnes, 2014), or simply to ensure its survival (Zimmermann, 2011). A combination of this dynamism with new emerging technologies and strategies is a source for numerous changes, threats and opportunities

for organizations (van Gils & Proper, 2018). The pace of change in the organizational environment is now higher than the pace of change within the organizations themselves (Burke, 2017). In addition, the speed and direction of these environmental changes have become harder to anticipate. Naturally, an organization's ability to provide efficient responses to sudden and unpredictable changes is considered highly valuable (Sandkuhl & Stirna, 2018b). Its survival and continuity depend on its flexibility and adaptability, two properties of an organization that are often reflected in how it can change what it is capable of.

Capability, as a concept, has been introduced and widely researched as a way to explain an organization's competitive advantages in terms of a combination of resources and knowledge (Leonard-Barton, 1995). Capability has also been used to explain the dynamic nature of changing organizations, by introducing the concept of dynamic capability (Helfat et al., 2007; Teece et al., 1997). The concepts of capability and change bear a strong association with each other, since the management of a changing organization includes the management of changing capabilities. Capability has not only gained ground in organizational research (Wißotzki, 2016), but can also be used to address the complexity of turbulent organizational environments (Wißotzki, 2018). Capability thinking, which lies at the core of capability management, improves productivity and flexibility, especially when it concerns digital organizations (Sandkuhl & Stirna, 2018a). It can also support the configuration and development of information systems (IS), and has been used in several approaches to facilitate the design and analysis of organizational capabilities. The introduction of efficient capability thinking and management requires methodological support.

Changes to organizational capabilities can be methodologically supported by enterprise modeling (EM), a discipline whose focal point is to capture and analyze organizational knowledge from multiple perspectives. Capability modeling (Sandkuhl & Stirna, 2018a), a specialization of EM that focuses on the capability perspective, forms part of the majority of capability management methods. There are now a plethora of capability modeling methods and techniques, most of which also include modeling notations (Zdravkovic et al., 2017), although they employ differentiated sets of concepts in their meta-models as a means of capturing and analyzing the nature of organizational capabilities. The main areas of focus of current approaches are Enterprise Architecture (EA) management and the design and configuration of information systems.

The outcome of this PhD thesis is a specialized capability modeling method of capturing and analyzing the phenomenon of capability change. The method is called KYKLOS, meaning both cycle and circle in Greek, thus reflecting the iterative and cyclic nature of change. KYKLOS employs the concept of capability, and is suitable for providing methodological support for changing business and IT in organizations. The method consists of a syntax, semantics,

graphical notation, and modeling procedure. It is also complemented by a homonymous modeling tool.

1.1 *Research problem*

The problem addressed in this thesis involves the challenges associated with the use of EM to support development in organizations that are in motion, constantly changing and evolving. In modern organizations, IS have been integrated into almost every aspect of the business (Pearlson et al., 2020), to such a degree that they can be considered "fused" into one (van Gils & Proper, 2018). As a result, changes to business and to IT need to be congruent, and capability is a suitable conceptual mechanism for this task.

One significant challenge involves capturing the motion itself, in terms of the organization's current and future affairs (van Gils & Proper, 2018). Even though evolutionary steps have been taken in EM, current models are predominantly used to capture (i) the current affairs of an organization, via the "as-is" model; (ii) future affairs, via the "to-be" model, or (iii) the transition between them. However, it may not be adequate to apply such discrete categories (Sandkuhl et al., 2018). As a result, EM methods have to evolve, in a similar way to any method that aims to support organizational change. No existing capability modeling method enables the capture and analysis of changing capabilities in a single model, together with documentation and analysis of the decision that leads to a change, as indicated in literature reviews such as that of Zdravkovic et al., (2017). For example, an analysis of a capability that has changed twice during its life-cycle requires the development and comparative analysis of three separate models. The need to compare and analyze a multitude of separate models in order to capture and decide on the states of a changing capability should be avoided by including multiple versions of a capability in the same model, to improve the communication and analysis of the results of a modeling activity.

Even if this is achieved, the way in which changing capabilities transition from one state to another will still be missing when existing modeling methods are used. Modeling methods that are associated with managing and analyzing change often fail to recognize the need to capture and analyze the information that concerns and is generated during the transition between states of an organization's capability. In addition, even though adapting single organizational aspects separately always has value, the endgame of a flexible organization is to change what it is capable of, and everything that this involves, including all the relevant aspects in the adaptation. For this reason, the inclusion of the concept of capability has gained in practicality and significance, and its use in EM methods for modeling change has become widespread. However, there is no known capability modeling method that enables the capture of how a transition between the states of a changing capability takes place

or the attributes of this transition, as shown by Zdravkovic et al. (2017). In other words, current capability modeling methods cannot capture how a capability change is delivered.

Another common omission during the analysis of change in organizations is the capture of the need to change. Current practices in the management of change, for example the method suggested by Kotter (2012), consist of steps that suggest that the first task in the management of change is to establish a sense of urgency for the given change. The initiation of a change process requires the given organization to be already aware of the need to change, and in practice, this is not always realistic. Missed opportunities are becoming common for organizations that are unaware of an absent value-generating capability or an existing loss-generating capability. For this reason, it is important for methods and approaches that support the management of change to include the aspect of capturing the need to change. That is, a method should provide ways to observe and monitor the internal and external environment to enable capture of the need to change.

The need to change is most often associated with the nature of a changing capability. A common theme among the numerous existing modeling methods and approaches is that they address only the positive side of capabilities, as shown in research works such as that by Wißotzki (2018). More specifically, contemporary approaches to organizational design are focused on the positive aspects of an organization that produce value or sustain its advantages. This is another unrealistic approach, since negative aspects also exist and are often overlooked. Any method employed to capture and analyze changing capabilities should take into consideration the possibility that an organizational capability has become outdated or is otherwise poorly suited to a degree that is harming the organization. Furthermore, an organization may possess the potential to create value but not to benefit from it, as in the case of unexploited or poorly allocated resources. All of the abovementioned states of organizational capabilities should be taken into consideration when analyzing capabilities, especially since they motivate and trigger changes.

Finally, in addition to the analysis of both advantageous and disadvantageous capabilities, a method should also capture and analyze the transition from disadvantages to advantages. Capturing and analyzing elements related to the external context and the organization's intentions in regard to a capability will facilitate the identification of potential opportunities and threats, and the need to change as a response to these. To improve on the state-of-the-art approaches that aim to manage a change that the organization is aware of, a new method should identify, capture, and analyze the origins of the need to change, arising either from the external dynamic context or from shifts in the internal organizational goals, requirements and problems.

These challenges can be achieved by improving existing approaches or by developing new modeling approaches and methods, which are specifically de-

signed for capturing and analyzing the phenomenon of capability change. Capability modeling needs to evolve as a response to these change-related challenges. It should also support the capability life-cycle and phases of IS (Sandkuhl & Stirna, 2018a), and particularly the design phase, in which a capability is designed, and the IS run-time phase, in which a capability is operationally active. Furthermore, a changing capability involves IS, meaning that IS changes should also be considered. A capability modeling method needs to address both the implementation of capabilities in the design phase and changes and adjustments during the run-time phase in order to be efficient.

The research problem of this thesis can therefore be summarized as follows. Although change management and analysis methods, as-is and to-be models exist, there is a lack of methodological guidance in regard to describing the transition of capabilities, capturing the need to change, and identifying the origins of the need, in any phase of the capability life-cycle.

1.2 *Research goal*

The aim of this thesis is to provide methodological support for organizations that are undergoing changes (or which need to), by focusing on modeling organizational capabilities. The development of a homonymous tool that is complementary to the method also forms part of the project; however, the method is the main artifact, since it may be applied without the tool. The aim of the tool is to significantly facilitate the application of the method. Based on these conditions and in response to the research problem in general, the main goal of this thesis can be formulated at a high level as follows:

To develop a method called KYKLOS that can support change in organizations by modeling the changing capabilities of organizations.

An operational refinement of the goal, which is closely related to the details of the research problem, can be formulated as follows:

To design a capability modeling method that can effectively describe the transition of capabilities, both in terms of deciding about it and delivering it, and which can capture the imperative for change and identify the origins of these needs throughout the various phases of the capability life-cycle.

The goals set out above are further refined into six sub-goals, which were constructed in line with the steps of the Design Science Research (DSR) framework (Johannesson & Perjons, 2014) to guide the research process. These sub-goals are described in detail in the Methodology chapter (Section 3.3). The complete set of sub-goals is as follows:

G1. To explore the existing capability modeling approaches using their meta-models. This includes the following sub-goals:

a. *To provide an overview of the concepts used in capability meta-modeling;*
b. *To explore how these concepts are related to change;*

c. *To elicit directions for improving the modeling of capability change.*

G2. To elicit requirements for the method under development, which includes the following sub-goal:

a. *To investigate, describe and conceptualize the states through which a capability goes when it changes, including the process of change itself.*

G3. To establish a foundation for developing a method of modeling capability change, which includes the following sub-goals:

a. *To develop a meta-model for capability change;*
b. *To explore expert knowledge on the phenomenon of capability change, in order:*
   - *To evaluate the meta-model's concepts;*
   - *To improve the meta-model by enriching it with expert knowledge;*
c. *To explore the semantic consistency between the concepts used in this method and other modeling methods, as a way to identify candidate components for the method.*

G4. To develop this method and a complementary supporting tool, which includes the following sub-goals:

a. *To provide modeling guidelines;*
b. *To develop a language meta-model;*
c. *To implement the method in a tool.*

G5. To demonstrate the method.

G6. To evaluate the method.

1.3 *Delimitations*

This thesis aims to address the phenomenon of capability change; however, both for capability and change, a diverse set of definitions exists in the literature of various scientific fields. This results in a need to delimit the scope of this project as a means to avoid any potential source of confusion.

The concept of capability has transcended its original meaning. Within the context of this PhD project, the term 'capability' is limited to mean the capability of an organization, and especially a contemporary organization. Alternative perspectives on capability with a focus outside the organizational context, such as approaches related to the capabilities of individuals (Gasper, 1997), are considered outside the scope of this thesis, and have not been taken into consideration. Another perspective on capabilities that lies outside the scope of this thesis concerns maturity models that use the concept of capability, such as the Capability Maturity Model (Paulk et al., 1995), which relates to the level of formalization of organizational processes.

One noteworthy concept that should be mentioned in this section is associated with both capability and change, and is known as "dynamic capability" (Helfat et al., 2007; Teece et al., 1997). The concept has been identified as a potential source of confusion in relation to this PhD project (Koutsopoulos, 2018), and its inclusion has been eschewed. A discussion of the concept of dynamic capability and the reasons for not including it here are provided in the Background section.

1.4 *Thesis structure*

This thesis is structured as follows:

Chapter 1: Introduction consists of a brief presentation of the thesis research area and its context, the problem addressed in this thesis, its goal and sub-goals, limitations and structure.

Chapter 2: Background contains a description of the disciplines and concepts that are relevant to the research in this thesis, in particular organizational change, change management, capabilities, and EM, along with an overview of the related literature.

Chapter 3: Methodology provides a detailed description of the methods employed to review the literature, with an analysis of the existing capability meta-models and visualization of the results of mapping concepts related to change. The chapter also describes the methods that can be used for eliciting and modeling the requirements of a method, identifies the dimensions of capability and change, and develops the StateMachine diagram and meta-model for capability change. The case studies considered in this project and the framework that is developed to drive the structuring of the goals and the meta-model are also introduced. The method decisions that involve data collection and analysis, the philosophical assumptions and the ethical considerations affecting this research also form part of this chapter.

Chapter 4: Summary of contribution presents an overview of the findings of the meta-model analysis and a visualization in the form of concept mapping. The elicited requirements are presented in the form of a goal model, with a StateMachine diagram that depicts the dimensions of capability and change, the developed meta-model, and a demonstration of the meta-model. The chapter presents an evaluation and an extension of the meta-model, and describes its conversion during the implementation of the tool, and the development of the syntax, notation and procedure. Finally, the method is demonstrated and the results are evaluated.

Chapter 5: Discussion, conclusions and future work summarizes the results of the thesis, identifies its contribution and limitations, and presents concluding remarks, including the ethical implications of this work and suggestions for related future research.

2. Background

This chapter provides a description of some fields and concepts used in this work and an overview of related research. The majority of the sections in this chapter have been presented previously (Koutsopoulos, 2020) in the form of a Licentiate thesis that introduced the project. Gregor (2018) suggests that a thesis on a PhD project, like any other research project, should start by positioning the research in the context of the relevant fields and concepts in order to facilitate the identification of its contribution. This PhD project relates to the areas of organizational change and EM; in particular, it is associated with capability modeling, a subset of EM, and organizational change. Figure 1 illustrates this association.

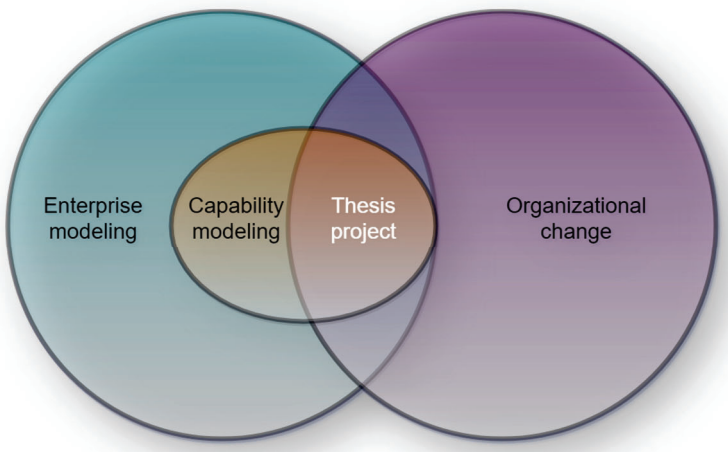


Figure 1. Positioning the PhD project in the context of the relevant fields and concepts (Koutsopoulos, 2018).

2.1 *Organizational change*

Organizations are social goal-directed systems that maintain boundaries that reflect their goals (Zimmermann, 2011). Organizations undergoing

change represent an important focus of research areas such as business informatics, which relates to the role of IS in these changes (Proper et al., 2017). As a phenomenon, organizational change has been widely researched from diverse perspectives derived from several scientific fields. Various terms have been used to describe it, such as change, transformation, and adaptation; these are sometimes used interchangeably, and in other cases reflect the scope of change (Maes & Van Hootegem, 2011). This also applies to terms such as 'business', 'organization', and 'enterprise', since these are sometimes used as synonyms (Merriam-Webster, n.d.-c). This is despite the fact that there is a diverse set of definitions of an enterprise; for example, Merriam-Webster (n.d.-b) defines it as a unit of economic organization or activity, whereas Proper et al. (2017) defines it as a group of organizations that share common goals.

In the following sections, both the drivers of change and organizational changes with respect to IS are examined.

2.1.1 Drivers of change

The drivers of organizational change have also been researched from several perspectives, and several associated theories have been developed. A detailed analysis has been presented by Zimmermann (2011). The main category of perspectives are ones that can be considered deterministic, in which the environment is assumed to be the factor that sets the direction and the point of time for a change. In contrast, voluntaristic perspectives and theories underline and build on the importance of the strategic choices of the decision-makers of an organization and their role as its shapers. A further category consists of hybrid combinations of the first two, including organizational inertia (Zimmermann, 2011), in which the two perspectives are reconciled, with an emphasis on understanding change as driven by both environmental and managerial forces. An example is the cognitive approach, which addresses organizational change as an environmental influence on managerial mental models, which in turn leads to organizational decisions. This approach aims to understand organizational processes that result in prosperity or decline, and takes into consideration the failure to change. Finally, Zimmermann (2011) identifies another important factor related to the causality and causal associations among the drivers of change, even though they should be implemented in any method with the objective of capturing the complexity of phenomena of change.

2.1.2 Organizational change and Information Systems

One aspect of organizations that is affected by change is their IS. The digitalization of organizations is leading to their increasing dependence on IS, which can no longer be considered as a separate feature, as they are now an innate part of the business. The significance of IS for any organization lies in

the fact that they can facilitate the execution of the organization's activities and processes, and thus have become integrated into every aspect of business (Pearlson et al., 2020) to such a degree that business and IT can be considered "fused" into one entity (van Gils & Proper, 2018). Hence, a discussion of adaptive organizations also refers to adaptive IS, which rely on constant availability and adaptability to changing environmental conditions and requirements (Morin et al., 2009). As a response, adaptive IS have been developed that are characterized by degrees of variability that depend not only on contextual run-time fluctuations but also on user requirements. These are usually designed with predefined variation points and variants; based on the existing contextual conditions, the most suitable variant is activated to realize a given variation point (Morin et al., 2009). Modern IS need to have the ability to deliver business value based on contextual variations, for instance in terms of user preferences, business models of suppliers, resource pricing, or location or local legislation (Sandkuhl & Stirna, 2018a).

2.2 *Change management*

Change management (CM) is treated as an essential part of organizational changes and administrative reforms, as it is considered as one of the critical success factors that determine the outcome of a change initiative (Huerta Melchor, 2008; Nograšek, 2011). CM is most commonly encountered as a set of principles and practices developed to support organizations in transitioning from one existing state to a new one, and including both new implementations and the updating of existing ones.

The literature includes a variety of definitions for the concept of CM from a diversity of perspectives. From the viewpoint of transition, it has been defined as a structured approach to the transitions of organizations, teams and individuals from a current state to a desired one by empowering employees to accept changes in their work environments (Nograšek, 2011). Other definitions use the human element as the focal point of change, for instance, "the art and science of encouraging individuals to adopt a change to their work resulting from a departmental effort". Further examples include "the application of a set of tools, processes, skills and principles for managing the people side of change to achieve the desired outcomes of a change project or initiative", and "a system used to anticipate, activate and accelerate people's engagement in a changing environment aimed at a particular objective" (Department Of Administrative Reforms & Public Grievances, 2010). Alternative definitions with different focal points also exist; for example, Huerta Melchor (2008) defines CM as "a way to deal with, both intended or unintended, consequences of a reform program", which uses the impact of change as the focal point.

There are no limitations on CM's areas of application, and it is commonly practiced in both the private and public sector. It can be used for planned and

unplanned changes, and there are several models corresponding to both planned (Burnes, 2004) and improvised changes (Orlikowski & Hofman, 1996). Two significant challenges associated with planned changes are resistance to change and a reliance on expert opinions instead of scientific evidence (van de Ven, 2021).

Regarding the role of the change manager, various perspectives also exist in the literature. Motiwalla and Thompson (2014) and Goll et al. (2007) have stated that this role is essential for proper preparation for performing a change. In contrast, Franklin (2021) suggests that CM should not be restricted to one role, and that the tasks connected with this process should be included in all the other roles in the organization.

These different perspectives on CM have led to the development of various CM models, the most popular of which are described in the following subsection. From the viewpoint of this thesis, a common pattern that can be identified among all the models described below is that the need for an organization to change is taken for granted, and, as a result, there is no element of these models that provides support for any type of monitoring or identification of the imperative for a change in an organization. This formed one of the main sources of motivation for the development of KYKLOS.

2.2.1 Change management models

CM models represent a synthesis of research and practice in the field, and are used to understand procedures of change at both the organizational and individual levels (Talmaciu, 2014). The purpose of including them in this thesis is to support the argument that all the prominent approaches are human-centric, and do not focus on the identification of the need to change.

The objectives of these models of organizational change have been summarized by Talmaciu (2014), as (i) defining change through exploration, analysis and understanding the situation of a change in the context of an organization, and identification and assessment of potential solutions; (ii) implementing a change, which involves applying the change in an organization according to the selected strategy; and (iii) consolidating the change.

A set of popular CM models were identified and analyzed by Galli (2018). The models described in that study are presented below.

- Kurt Lewin's CM model

Kurt Lewin's model of CM is the most popular option for tackling planned changes. It focuses on the human factor perspective, and consists of three basic stages: unfreeze, change, and re-freeze (Burnes, 2004). These stages correspond to an in-depth analysis of the need to change, the actual transition, which also includes considering the resistance to change and the allocation of resources for it, and the establishment and assessment of change, respectively. The model is based on three main assumptions (Galli, 2018): the first is that a

change motivator is required for a change; the second is that employees form the core of a change; and the third is that those who are impacted by the change are mostly those who need to adapt.

- Kotter's eight-step change model

Kotter's (2012) model for CM consists of the following eight steps:

1. Establish urgency, which refers to realizing the need to change.
2. Form a coalition for change, meaning that a team of leaders needs to create a coalition to build urgency around the need for change.
3. Create a strategic vision for the change, which includes the formulation of a clear transformation vision.
4. Communicate the created vision, which is important in order to avoid potential resistance to change.
5. Empower employees and remove obstacles, which includes supporting employees in removing any obstacles to the vision.
6. Generate short-term wins, which are important to demonstrate that the effort is constructive and motivate adjustments if needed.
7. Consolidate the gains from the change and produce more change, which is associated with not reverting back to previous states.
8. Anchor new changes in the culture of the organization, with the aim of institutionalizing the change in the culture of the organization.

- ADKAR model

The ADKAR model (Hiatt, 2013) has a stronger focus on the human aspects of individual changes, and less on the actual change; in particular, its focal point is how an individual experiences the phenomenon of change. The name of the model is an acronym that reflects on the five goals that it aims to fulfill. The first element is *awareness*, which involves informing the employees about the need to change and determining the level of it. *Desire* relates to the employees' motivation to change and the ability to perform it; *knowledge* is required for changing, *ability* is needed to implement the change, and *reinforcement* relates to maintaining and sustaining the change within the organization (Hiatt, 2013).

- McKinsey 7S model

The McKinsey 7S model (Peters & Waterman, 2008), which was developed within McKinsey and Company, focuses on the analysis of seven organizational aspects and emphasizes the changes that need to be made. The seven aspects, which are considered equally important, are (i) *strategy*, which involves the objectives of the organizational transformation, (ii) *structure*, which relates to the roles, responsibilities and accountability relations, (iii)

systems, related to the formal organizational procedures and control, performance measurement, information and resource allocation systems, (iv) *skills*, which refers to the employees' abilities to do the work, (v) the *staff* who possess the above mentioned abilities, (vi) *style*, which concerns the adopted style of leadership, and (vii) *shared goals*, which refers to the beliefs and attitudes used to understand the organization's purpose and how the impact of change affects the organizational environment. These elements are classified into two main categories: the first three are considered the hard elements of the model, and the last four its soft elements.

– General Electric Change Acceleration Process Model

The last of the models considered here was developed within the company General Electric. The Change Acceleration Process (CAP) model is this company's version of a CM model of how people accept, operate and implement the introduction of a new business strategy. The model reflects that combining an amount of technical work with acceptance of change results in efficient results (Polk, 2011). The model consists of seven layers that do not describe a linear process; on the contrary, the activities that are associated with each layer can happen simultaneously (Davids et al., 2002). These layers are *leading change*, which involves the identification of a change leader, owner and motivator; *creating a shared need*, which refers to the establishment of the need to change and to tackle any resistance; *shaping a vision*, which defines the outcomes of change; *mobilizing commitment*, which involves the identification of stakeholders; *making changes last*, which includes the institution of systems and structures for sustaining the change; *monitoring progress*, which involves setting and measuring benchmarks; and *changing systems and structures*, which refers to integrating changes into the culture of the organization (Holloway, 2015).

2.3 *Capabilities*

As stated in an earlier work by the author that is not included in this thesis (Koutsopoulos, 2018), the concept of capabilities has been widely discussed in the literature and a wide range of definitions exist, based on the researchers' point of focus regarding the nature of capabilities. These various definitions of capability include the following:

- "[An] organizationally embedded firm-specific non-transferable resource that enhances the productivity of the firm's other resources" (Makadok, 2001);
- "The ability of an organization to perform a coordinated set of tasks, utilizing organizational resources, for the purpose of achieving a particular end result" (Helfat & Peteraf, 2003);

- "[The] ability and capacity that enables an enterprise to achieve a business goal in a certain context" (Grabis et al., 2016).

It can be seen that there is currently no agreement on the definition of the term 'capability'. This lack of agreement is also evident in a study by Zdravkovic et al. (2017), where a variety of different definitions of capability are presented and reviewed. Hence, any discussion of capabilities should start with a clarification of this concept, as advised by Schreyögg and Kliesch-Eberl (2007).

Although there is no clear and unanimously accepted capability definition, a common theme found in all definitions is the association with a specific organizational context. However, there are arguments against this attribute in the research literature related to the nature of capability. Adopting a general viewpoint on capability may be problematic, considering what a capability is or is not (Tell, 2014); however, as far as the domain of organizational change is concerned, the association between capabilities and turbulent environments is clear. In other words, an organization cannot exist independently of its environment, and neither can the organization's capabilities.

Restricting the approach adopted in this PhD project to organizational capabilities fulfills the necessary requirements for considering the capabilities' association to context as significant. In a similar way, a capability exists to serve a purpose, that is, to fulfil a specific intention of the organization (Sandkuhl & Stirna, 2018a). A capability also requires the organization to possess the ability and capacity to realize it on an operational level, and this realization involves the use of resources and behavior elements such as processes. Finally, from the definition of the word (Merriam-Webster, n.d.-a), a capability is a potential; in other words, it expresses something that has not necessarily been realized, but which can be—for example, individuals who have the capability to walk for three hours per day are not necessarily actually performing this activity.

Based on this justification, the definition of capability in the papers included in this thesis was "a set of resources and behaviors, whose configuration bears the ability and capacity to enable the potential to create value by fulfilling a goal within a context". However, during the course of the project, this definition changed. In particular, the awareness that Sandkuhl and Stirna (2018) used the term 'ability' to refer to behavior elements, and 'capacity' to refer to resources resulted in the need to avoid including the same aspects twice in the definition. The final definition of capability used in this PhD project is therefore as follows:

> *A capability is a potential to produce outcome(s) to fulfill an organization's intention(s) within a context, using a configured set of resources and behaviors.*

A diagram illustrating this definition in terms of the relationships between capability and other concepts is shown in Figure 2.

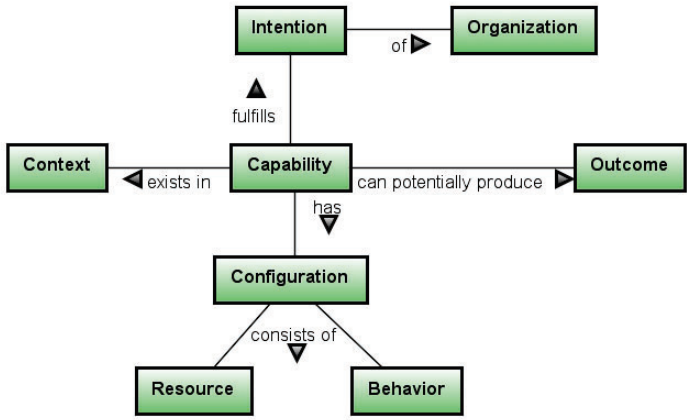


Figure 2. Diagram illustrating the definition of capability.

The inclusion of resources and behaviors in this definition is in line with earlier definitions of capability in the literature that included these as the main components of a capability (Amit & Schoemaker, 1993; Makadok, 2001; Sandkuhl & Stirna, 2018a). The inclusion of these as components of capability was valuable, although earlier definitions were missing other essential features such as the aspect of potentiality, and this consideration resulted in a decision to not reuse any earlier definition in its entirety. In addition, the concept of the configuration of resources and behaviors was included to enable reasoning about different ways to achieve a capability. This was found to be very valuable during the elaboration of the case studies, where the concept of configuration was used to describe changes in capabilities.

A key aspect of capability is its availability, meaning that the organization can execute it in a given situation and at a given time. In most cases, the latter is constrained by the availability of resources. The term 'resources' can be used to refer to both tangible (e.g., equipment, hardware, buildings) and intangible (e.g., information, organizational structures) elements of value to an organization, including human resources. In contrast to Makadok's (2001) definition, which was given at the beginning of this section, this thesis adopts the perspective that a capability is not a resource. There is agreement with Makadok's definition that one of the main differences between a capability and a resource is that the former is firm-specific, non-transferable, and needs to be built within the organization, whereas the latter is not firm-specific, transferable, and can be acquired externally. Based on the definition provided in this thesis, capabilities cannot be transferable, as they would refer to identical intentions and context. As an example, we can consider the capability of mari-

time rescue; its overall design is widely known and hence can be seen as transferable. However, this design is a resource, not a capability. Thus, the capability for maritime rescue for the Swedish Coast Guard cannot be transferred unchanged to Latvia, due to the differences in context (such as the different length and type of the coastline) and available resources (such as the vessels and aircraft in operation). Even in Makadok's contribution, a capability is considered a very special type of resource (Makadok, 2001). This thesis adopts the perspective that capabilities cannot be perceived simply as resources in an organization. This view is in line with other sources in the literature, such as the study by Tell (2014).

Behavior is an abstract term that describes and includes activities, processes, services etc. The term 'configured' refers to how the resources and behaviors that are used to realize a capability are combined and associated to produce outcomes with the aim of fulfilling an organization's intentions. That is, the term configuration refers to a set of components that needs to be complete for the realization of the capability. Variations of configurations may result in variations of a capability that produce the same outcome(s). The reason for delimiting the production of outcomes in our definition to organizational intentions is the fact that it refers to organizational capabilities.

An example of a capability with all the concepts that are associated with it, as per the definition provided here, is the capability to educate students in modeling languages in a higher educational institution (HEI). More specifically, we consider the capability to educate students in UML, through a specialized course. The potential outcome of the capability is a specific percentage of enrolled students that graduate from the course. The capability fulfills the HEI's intention to provide state-of-the-art education in UML. The context of the capability includes factors such as the state of the art in UML and the educational standards of the other university departments. The specific HEI is the owning organization. If we assume that an on-campus configuration is used to educate the students in UML, various resources will be required, such as educators, classrooms, teaching equipment such as microphones and projectors, funds, and modeling and teaching expertise. Further requirements will include elements of behavior, such as a grading process, examination development process etc. Alternatively, if we assume that a distance configuration is used, a different set of resources will be required; for example, educators will still be needed, but there will be no requirement for classrooms. A communication platform resource would be required instead.

The definition of a capability is not sufficient to describe the concept of a changing capability[1]. Even if we have a deep understanding of what a capability is, dealing with changing capabilities requires additional explanations. In particular, the definition of a capability provides an answer to the question

[1] Changing capability and capability change are used as synonyms in this thesis.

"How much can a capability change until it is no longer a capability?" although it does not provide an answer to the question "How much can a capability change until it is no longer the same capability?" From a different perspective, we can see that in addition to a generic definition, a specific definition is also needed to comprehend the phenomenon of changing capabilities. A proper answer to these questions requires us to identify the characteristics of a capability that cannot change in order for it to remain the same specific capability. For this reason, one or more criteria of identity need to be defined. A criterion of identity is "a principle specifying, in a non-circular way, the identity conditions of objects of a given kind" (Honderich, 2005), and it provides a logically sufficient condition for the identity to be true (Lowe, 1989). The same capability may fulfill different organizational intentions, and can also exist within different contexts. It may require different sets of resources and behavior elements for its operational realization. However, the value delivered by the outcome(s) produced by the capability may not be different. Thus, the identity criterion for capabilities, as they are defined within this PhD project, is the potential of the organizational capability to produce the same outcome(s) for an organization. The literature reviewed as part of this PhD project makes no explicit mention of a criterion of identify for a capability, meaning that a comparative analysis is not possible, even though the definitions presented in the beginning of this section indicate different criteria.

Capabilities are often considered the missing link in business and IT transformation (Ulrich & Rosen, 2011). The popularity of this concept can be explained by the fact that it facilitates transformations. According to Ulrich & Rosen (2011), it:

- Provides the business with a common language;
- Enables investments with accurate focus;
- Serves as a basis for change management, strategic planning and impact analysis; and
- Can lead directly to business design and specification.

The notion of capability is steadily gaining ground, both in business and academia, in view of its practical relevance (Wißotzki, 2016). The importance of the concept of capability also lies in the fact that the organizational viewpoint that it depicts is holistic, as it encompasses a wide spectrum of notions significant to organizational change, such as goals, resources, actors, processes, and context (Sandkuhl & Stirna, 2018a; Wißotzki, 2016) as well as owners, ecosystems, outcomes and services (Loucopoulos et al., 2015) that have been used in the literature to describe an organization's value-generating elements. These are also the core concepts of EM approaches, as noted in work by Loucopoulos and Kavakli (2016a) and Sandkuhl and Stirna (2018) and in EA frameworks such as the NATO Architecture Framework (NAF) (NATO, 2018) and The Open Group Architecture Framework (The Open Group, 2018).

2.3.1 Capability modeling

EM is a discipline that concerns the creation of an enterprise model that captures all the organizational aspects that are deemed relevant to a specific modeling objective, such as processes, goals, business rules, and concepts (Sandkuhl et al., 2014). The most important part is an integrated view of these aspects, which results in an enterprise model consisting of interconnected sub-models, each focusing on one specific viewpoint of the organization. EM can be applied to any public or private organization, or one part of it. By capturing the complexity of an organization, EM allows the people within the organization to develop a better understanding of how their work is integrated into the bigger picture and the role of the supporting IS and their interplay with action patterns (Frank, 2014).

Enterprise models and the meta-models used to define modeling languages and approaches are of value to (i) modelers, as they are interested not only in understanding but also applying the language; (ii) researchers, as they are interested in the evaluation and possible adaptation of a language, such as a domain-specific version; and (iii) tool vendors, as they are interested in the development of tool for the language (Bork et al., 2018).

In the context of capability management, EM provides methods, tools, and practices for capturing and visualizing the current (as-is) situation and for developing the future (to-be) situation. The as-is model forms one of the bases for capability management, since without it, the systematic design and development of future capabilities is considered difficult, or even impossible (Sandkuhl & Stirna, 2018a).

EM has been used in several ways to capture and analyze organizational capabilities and organizational change. The capture and analysis of organizational capabilities using EM is known as capability modeling. In other words, capability modeling is a specific area of EM in which the focus is on the aspect of capabilities. In capability modeling, the focus is on the organization's ability and capacity to achieve a goal or the sustainability of a long-term function.

Three strategies for capability modeling were suggested by España et al. (2015). Each of these strategies consist of three steps, namely (i) capability design; (ii) capability evaluation; and (iii) development of capability. In Step 1 (capability design), goals, processes or concepts are used as a starting point. Regardless of the starting point for the design and the possible differences between the strategies, Steps 2 and 3 are common to all three strategies. Step 2 involves evaluating the design before implementing the capability. This evaluation is performed from both the technical and business perspectives. Finally, Step 3 involves packaging the indicators used for monitoring and the algorithms required for run-time adjustments (España et al., 2015).

As stated in Paper 3 of this thesis, stand-alone capability modeling methods have been developed, such as Value Delivery Modeling Language (VDML)

(Object Management Group, 2018) and Capability-Driven Development (CDD) (Grabis et al., 2016).

Several popular EA frameworks include the concept of capability in their official notation through the inclusion of capability viewpoints. The most popular of these frameworks are (i) the Department of Defense Architecture Framework (DoDAF) (USA Department of Defense, 2009); (ii) the NATO Architecture Framework (NAF) (NATO, 2018), which has been based on the Ministry of Defence Architecture Framework (MODAF) (UK Ministry of Defence, 2010) since version 3; (iii) The Open Group Architecture Framework (TOGAF) (The Open Group, 2018); and (iv) Archimate (The Open Group, 2017).

In addition, researchers have provided suggestions on how to model the dynamic nature of capabilities based on extensions to existing modeling methods such as i* (Danesh & Yu, 2014) or capability maps (Beimborn et al., 2005; van Riel & Poels, 2023) or by introducing new notation to include the elements required to capture how a capability can change or be changed in dynamic environments, such as the Capability-Oriented Designs with Enterprise Knowledge (CODEK) approach (Loucopoulos & Kavakli, 2016b).

2.3.2 Capability typologies

This topic is discussed in Paper 3, from which this section originates. In the literature, there are several typologies of capability, the majority of which are hierarchical or domain-specific typologies. A hierarchy of capability types suggests that there are different levels of capabilities; in other words, the purpose of a higher-level capability is to affect the lower levels of capabilities, and these hierarchical typologies aim to classify capabilities based on their purpose. More details of hierarchical typologies are provided in Paper 3.

The domain-specific capability typologies in the literature are relevant to capability thinking in general, but the majority do not address change-specific concepts. A few examples are discussed below.

A literature review of organizational IT capability typologies has been presented in a study by Lee et al. (2004). The two perspectives that were used as dimensions were the functional technology level and the IS strategy level. The functional technology level typologies involved: (i) IT capabilities for process redesign; (ii) technological capabilities; (iii) the infusion of IT into new product development; and (iv) capability-based IT classification. The components of the IS strategy typologies (Lee et al., 2004) were (i) business design, (ii) IT business value, (iii) digital options, and (iv) IT for organizational design.

In a study by White et al. (2015), another domain-specific capability typology for multi-agent systems was developed using complexity and locality as overlapping dimensions. In terms of complexity, capabilities are classified as primitive or composite, whereas in terms of locality, they are classified as external or internal capabilities. Domain-specific rules are also used to define

the dual nature of capabilities according to this typology; for example, an external capability is always primitive.

Arena et al. (2013) conducted a study of risk management and capabilities and presented a typology of macro-capabilities with relevance to change. Four types were identified. The first type was delivery, which refers to an enterprise's capabilities in regard to the execution of tasks, ranging from services and the production of goods, to scheduling, controlling and monitoring the production. The second type was integration and coordination, which relates to support for the delivery capabilities from management and coordination of the dependences among resources in order to find new ways to perform activities. The third identified type was learning capabilities, which concerns the generation of new knowledge in order to improve the efficiency and effectiveness of existing resources. Finally, reconfiguration capabilities involve reconfiguring existing resources to potentially lead the organization towards change.

2.3.3 The concept of dynamic capability

The concept of a capability is associated with the dynamic environment in which it exists, and this has given rise to the concept of dynamic capability (Helfat et al., 2007; Teece et al., 1997). Derived from the field of strategic management, and in particular as a response to the resource-based view (RBV), the concept and theory of dynamic capabilities attempts to bridge the gap between the static resources suggested by RBV and the dynamism that exists in organizational environments. Despite being relevant to change, the term 'dynamic capability', which has become popular, especially in management literature, is eschewed in this PhD project, since it is considered too imprecise to allow organizational designs to be represented at a sufficiently detailed level, as discussed in an earlier study (Koutsopoulos, 2018). Organizational capabilities can be classified as operational or dynamic; the former is the type that enables an organization to perform an activity on an on-going basis, using more or less the same techniques on the same scale to support existing products and services for the same customer population (Helfat & Winter, 2011), while the latter is discussed below. The term 'dynamic capabilities' has been defined in many different ways in the literature, based on the different approaches and points of focus of the researchers. The result is a set of definitions in which dynamic capability is defined as an *ability* (Teece et al., 1997), *orientation* (Wang & Ahmed, 2007), *process* (Eisenhardt & Martin, 2000) *capacity* (Zollo & Winter, 2002), *creation/design* (Griffith & Harvey, 2001) or *mechanism* (Lee et al., 2002).

These diverse definitions are probably derived from the inclusion of the term 'dynamic'. This term, which refers to change, has a dual meaning: it means something that "is always active or changing" and in parallel, "something that causes change or growth in something else" (Merriam-Webster,

n.d.-b). In other words, the term 'dynamic' refers to both something that is being changed and something that is provoking change in something else. This may be the source of confusion concerning the understanding of capability change. As mentioned in the Introduction section, the term 'dynamic capability' is not used in this PhD project to avoid overextension to discussions outside the scope of this research. Nevertheless, since organizational dynamism is undeniably a phenomenon that is closely associated with change, the existing knowledge base on dynamic capabilities has not been rejected. Thus, in the course of this research, the concept of dynamic capability has been used as Wittgenstein's (1922) ladder to gain a deeper understanding of the concept of capabilities.

The theory of dynamic capabilities also considers operational (ordinary) capabilities as stable and static; however, even among research that adopts the theory of dynamic capabilities, there are studies such as the one by Schriber and Löwstedt (2020) that identify the evolving and changing nature of capabilities, even at the operational level. In view of this, it is safe to assume that capabilities are 'dynamic' at every level.

2.4 *Interrelations among organizational change, strategy, and capabilities*

Strategy is needed by modern organizations to address the unpredictable changes in their environment in order to remain competitive and sustainable (Wißotzki, 2016). It involves deciding on coherent choices and goals that relate to the activities, resource allocation and approaches needed to realize these goals (Petrevska Nechkoska, 2020). Strategy also involves the decisions, planning and actions that are necessary for this realization (Cunliffe, 2008).

Business strategy is significantly affected by change, since strategy and change are considered to be associated. By (2005) emphasizes the alignment between organizational change and organizational strategy: change drives strategy, and strategy drives change. Both strategy and change are also associated with the concept of capability (Hoverstadt & Loh, 2017). There is also typically an association between capabilities and strategy. The capabilities owned by an organization support its strategy, and conversely, its strategy dictates which capabilities the organization develops. In addition, any type of organizational change or improvement is associated with change or improvement in capability (Hoverstadt & Loh, 2017). Capability change may refer to an introduction of a new capability and the retirement or modification of an existing one. In this regard, an organization may be perceived as a set of capabilities for realizing its strategy. All three concepts are inextricably linked.

2.5 *Inter-organizational capabilities*

The formation of a network of interconnected organizations via collaboration is not a new phenomenon (Albani & Dietz, 2009; Mäkipää, 2006). The main benefit is that this facilitates the sharing and combining not only of resources and knowledge, but also of the accomplished outcomes. When specific resources such as financial resources, systems, equipment, human resources, work processes, skills and information are shared, organizations gain access to a wide range of available tools, and this gain comes at a cost that is significantly lower than would otherwise be the case (Diirr & Cappelli, 2018).

However, organizations do not only reap benefits from their collaborations; considerable problems and challenges can also emerge, which are usually associated with the high degree of complexity resulting from changes in inter-organizational collaborations. A change in the collaboration may involve the aligning of IT systems, which is a costly and time-consuming task (Norta & Grefen, 2007). Hence, in the face of changes in the organizational environment, networked organizations need to handle inter-organizational collaboration (Grefen & Turetken, 2017). Being unable to change a dysfunctional inter-organizational relationship may lead even to the dissolution of the collaboration (Breu et al., 2013).

Within a collaboration, the realization of capabilities involves multiple organizations, meaning that these capabilities can be considered inter-organizational. The realization of any capability requires behavior elements such as business processes (BPs), but in a collaboration, inter-organizational processes are also involved, and this increases the level of complexity. Single-organization BPs are often centrally controlled, and can be managed with a reduced level of complexity, whereas the increased level of complexity of inter-organizational BPs hinders their management and change (Breu et al., 2013) and, in turn, hinders the management of inter-organizational capabilities.

We note that the term ‘inter-organizational’ means that at least two autonomous organizations are involved. An autonomous organization may be not only a legally independent organization, but also any acting unit or subsidiary within an organization (Legner & Wende, 2007).

2.6 *Current topics in capability modeling*

Capability modeling is an ongoing research field, and there have been studies that can be considered related to this field, for example on the topics of capability as used in EA, and the dimensions of adaptability.

Capability modeling has been improved before, with a focus on different aspects, for example on the context of a capability, which was the focal point

of a project conducted by Koç. This researcher started with a systematic mapping study of methods for designing, modeling and developing capabilities (Koç, 2015), and identified that the existence of RBV and environmental dynamism were the main factors that motivated the inclusion of the concept of capability. Frameworks and development approaches were the main types of solution artifact that were identified. Methodological support for capability management was reported to be scarce, and the most important finding was that the exploitation of enterprise models was limited to some extent. In another relevant study, Koç et al. (2014) conducted a systematic review of the literature on context modeling, which is considered one of the essential elements of capability management. Their findings suggested a lack of a methodology or language for modeling context; this was addressed in later studies (Koç, 2017; Sandkuhl & Stirna, 2018a) that analyzed capability modeling and its relation to context, although these did not address the issue of changing capabilities.

The concept of capability and its inclusion in several business architecture, EA, EM and business analysis frameworks were analyzed by Zdravkovic et al. (2017, 2018). The results indicated that this concept was used similarly in all the frameworks that were studied, that is, to depict the ability to achieve a specific result. The concept of capability has been implemented in existing frameworks for different purposes. The same studies found that there is an agreement that capability facilitates the bundling and definition of discrete functional organizational abilities and outcomes. The concept of capability itself was addressed with relative conceptual consistency, although the different purposes of developing a modeling technique resulted in differentiated sets of concepts, and hence meta-models with significant differences (Zdravkovic et al., 2017). Nevertheless, there were noteworthy differences in the point of focus around the concept of capability. This arose as a result of the differences in the purposes of the frameworks; for example, a framework focusing on strategic management will not only include the concept of capability but also associate it with the concept of goal. This facilitates the establishment of an association between capabilities and the context for research, such as the one presented in this thesis.

The adaptation of capabilities has also been addressed in the literature in association with terms such as business services, delivery adjustments and BP variants. The purpose of these adjustments is to change the delivery of the capability in response to environmental changes or the performance of the delivery while avoiding the need to redesign the capability and the supporting IS (Grabis & Kampars, 2016). This point has also been emphasized in other studies, as in the work of Caesar et al. (2019), where the importance of the dynamic reconfiguration of capabilities at run-time was highlighted in regard to collaborative manufacturing systems.

Loucopoulos et al. (2019) conducted a study in which capability modeling was used to analyze the main challenges regarding the requirements for developing a dynamic system with awareness of its environment. They identified three main challenges:

- The design challenge, which is related to the emergent behavior and dynamics of a system and its associated environment; that is, there is a need to consider whether a system is able to address not only the goals elicited using traditional requirements engineering (RE) but also emergent goals that appear at run-time.
- The modeling challenge, which concerns the expectation and proper depiction of dynamically emerging system behaviors; this implies that approaches with the potential to depict, analyze and communicate the system need to be developed, so that emergent requirements can be met.
- The predictability challenge, which concerns the system and the impact of its behavior on its environment; in other words, the constant dynamic interaction between the system and its environment, and the way they are affecting each other, need to be predicted.

The common theme among these challenges is the requirement for self-awareness of the system at run-time (Loucopoulos et al., 2019). This confirms the need for capability adjustments at run-time. All three of these challenges are considered in this PhD research project; however, the main focus is on the modeling challenge, which is a prerequisite for a modeling method that addresses all of the abovementioned challenges, since a meta-model is a core component of a method (Karagiannis & Kühn, 2002).

It is common to describe adaptability in terms of the functionalities and dimensions of adaptive systems. The concept of adaptability of capabilities is addressed in a study by Petrevska Nechkoska et al. (2018) with the introduction of a framework consisting of the main dimensions and interrelated aspects for the analysis and evaluation of enterprise adaptability. This framework has three dimensions: (i) the complexity of the environment; (ii) managerial profiling; and (iii) artifact-integrated components. In a similar way, Morandini et al. (2008) and Weyns et al. (2012) conducted studies that included these dimensions. The common theme of these studies is the distinction that is drawn between functionalities and information types. This inspired the framework that was developed and used in this PhD project, and which is presented in Chapter 3.

3. Methodology

This chapter introduces the philosophical assumptions underpinning this work, and gives an overview of the research. It gives a detailed explanation of the way in which design science (DS), the selected research framework, has been applied, and the steps involved. It also provides descriptions of the case studies, the strategies and methods used for collecting, visualizing and analyzing data, and the modeling techniques used. Finally, information is provided regarding the development of the supporting tool, the quality of the research and ethical considerations.

3.1 *Philosophical assumptions*

This section describes the philosophical assumptions made in this thesis regarding the selection of a constructivist research paradigm, with compatible guidelines from pragmatic naturalism. This selection affected the case studies that were chosen to form part of this thesis.

Kuhn (2012) defines paradigms as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners". In contrast to behavioral research within the field of IS, in which the aim is to explore and explain existing IS as phenomena and to identify attributes and causal relations regarding specific attributes of systems and their context (Österle et al., 2011), research into EM and conceptual modeling involves the development of representations of given structures in a given domain. Its significance lies in the fact that these models have the potential to facilitate the early detection and correction of errors in system development, or to assist in BP reengineering and the documentation of best practice models for enterprise resource planning systems (Wand & Weber, 2002).

The objectives of design-oriented IS research are to develop and provide guidelines for action that enable and facilitate the design and/or operation of an information system or innovative concepts within it. Thus, a model describing the future (to-be) state is developed in research projects for each information system under development (Österle et al., 2011).

The research area of this thesis falls into the domain of social science, according to Kagan's (2009) framework, with the addition of technological attributes. This is based on several criteria and attributes of the research field and project, for example the fact that the primary focus is on the consideration of organizational entities and the prediction and explanation of their behaviors and states (Kagan, 2009). These have all been utilized in this thesis, as described in the following sections.

The positivist paradigm of research seemed to be dominant for a considerable period (Dubé & Paré, 2003; Orlikowski & Baroudi, 1991), especially in regard to the study of the acceptance criteria applied by top-tier journals in the field (Frank, 2006). Positivism is based on the application of natural science methods within social sciences, and is generally considered to be associated with quantitative data collection and analysis methods (Boudreau et al., 2001; Chen & Hirschheim, 2004; Krauss, 2005; Mingers, 2003). However, the positivist approach has several shortcomings regarding complex sociotechnical phenomena such as organizational change. Examples of these shortcomings are the oversimplified theory-fact relationship, the inevitability of determinism and reductionism, and its inability to deal with emergent formulations (Mills et al., 2020).

For this reason, the interpretive paradigm is adopted in this thesis, and specifically constructivism, with compatible guidelines derived from pragmatic naturalism (Williams, 2007). From an ontological perspective, this means that reality is complex, dynamic and independent of human minds, although multiple constructed subjective realities may exist and should be researched holistically (Mills et al., 2020). From an epistemological viewpoint, constructivism treats knowledge as a construct that is revisable, since it is shaped by the context (Aliyu et al., 2015). Constructivists aim to construct and measure the world using models, theories, patterns, rules, logic etc. (Mills et al., 2020). From an axiological standpoint, both constructivism and naturalism are value-bound. Finally, from a methodological point of view, a combination of these approaches that share interpretive values suggests a set of research guidelines, for example the utilization of a natural setting, human instruments, tacit knowledge, qualitative methods, purposive sampling, and negotiated outcomes (Mills et al., 2020). Naturalistic and constructivist approaches bear many similarities with the approaches used in IS research related to DS and EM. A principle of naturalism (Williams, 2007) suggests that a case study should be conducted in the environment that is being researched. This is relevant to the nature of IS research, especially when conducted in an organizational context using DS and EM.

DS emerged as an attempt to provide structure to the research methodology in view of the uncertainties associated with the field of IS. The difference between IS research and research in other fields is that it has the objective not only of studying existing systems but also of providing guidance for decision-

making and planning in practice, including new and innovative ways of working, coordination and cooperation. It is safe to assume that research in the IS field is also designing new possible worlds (Frank, 2006), which may be constructs that bear value for practical applications, although from a scientific perspective, they are hard to evaluate scientifically. An empirical test with the aim of evaluating whether a possible world has scientific validity would require its prior implementation, a condition which is sometimes not feasible (Frank, 2006).

DS has also been considered as both a paradigm (Frank, 2006; Hevner & Chatterjee, 2010) and as a research framework (Johannesson & Perjons, 2014). In this work, it is treated as a framework that is employed within a constructivist approach. Even in the case where it is considered a paradigm, it is driven by the philosophy of critical realism (Hevner & Chatterjee, 2010), which converges epistemologically with constructivism (Al-Amoudi & Willmott, 2011). In addition, in a constructivist approach, "we invent concepts, models and schemes to make sense of experience" (Schwandt, 1994). This indicates the suitability of using DS within the constructivist paradigm in the IS field.

As the research framework selected for this work, DS provides the required principles for designing solutions to problems such as the one addressed in this thesis.

3.2 *Overview of the research process*

The aim of this PhD project was to develop a modeling method for capability change. The purpose of the KYKLOS method, which is the designed and developed artifact, is to use modeling to support organizational change by depicting the changing capabilities of modern organizations.

We first need to clarify what it means to develop a modeling method. A short response would be that the components of the method, which are required for its development, are created and tested. A more detailed response is provided in this chapter in terms of the research strategies, methods and processes that drove the various research activities, including brief theoretical explanations, justifications for selecting them, and how they were applied.

DS principles (Hevner & Chatterjee, 2010) were followed in this PhD project when developing the method components. More details on DS are provided in Section 3.3. The framework driving the research consists of five steps for artifact development within DSR projects, as described by Johannesson & Perjons (2014). These steps are (i) explicate problem; (ii) outline artifact and define requirements; (iii) design and develop artifact; (iv) demonstrate artifact; and (v) evaluate artifact. A full description of each of these steps is given in this chapter. These steps were performed in the development of the

KYKLOS method, as reflected both in the papers included in this thesis and the comprehensive summary of the project presented here.

Achieving the goal of this thesis required a variety of research strategies and methods to be employed within the DSR framework. The main research activities were a literature review, which was performed iteratively in accordance with the different sub-goals, and three case studies based on three DS steps (in particular, the definition of requirements, demonstration, and evaluation of KYKLOS). Modeling was used in three of the DS steps to structure the information and to develop artifacts, while expert interviews, along with creative, programming and evaluation methods, were employed in the last three steps of the DSR framework.

The DSR process can be represented as an IDEF0 (Integration Definition 0) model (National Institute of Standards and Technology, 1993). An IDEF0 model consists of activities, input, output, resources and controls, as shown in Figure 3.

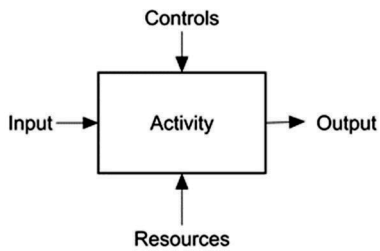


Figure 3. The IDEF0 model elements.

This approach is applied to create the overview of the research process of this thesis shown in Figure 4 and in Appendix 1, following the employed DSR framework.

The DSR framework includes controls and project resources. Controls consist of research strategies and methods along with creative methods, whereas resources form the contextual knowledge base of the DS project. The initial problem is the input that initiates a DS project, and the created artifact is the output of the process (Johannesson & Perjons, 2014).

In the IDEF0 model in Figure 4, the initial input is the need to manage capability change. This formed the motivation for using the literature on capability modeling and on change, expert knowledge, a meta-modeling platform and three case studies as resources for the thesis. The research strategies and methods used during the procedure consisted of literature reviews, modeling methods, creative methods, programming methods, evaluation methods, expert interviews, and case studies. The problem was first explicated, resulting in a need to improve capability change modeling requirements were then defined for the solution in the form of two models, and a tool-supported method was designed and developed in an iterative manner, and was demonstrated and

evaluated as shown in Figure 4. The figure presents the main steps of the procedure, although the entire development of KYKLOS was an iterative process consisting of three design cycles. This is not depicted in the overview diagram, but additional information is provided in Sections 3.3.1–3.3.5, along with specific IDEF0 models for each step.

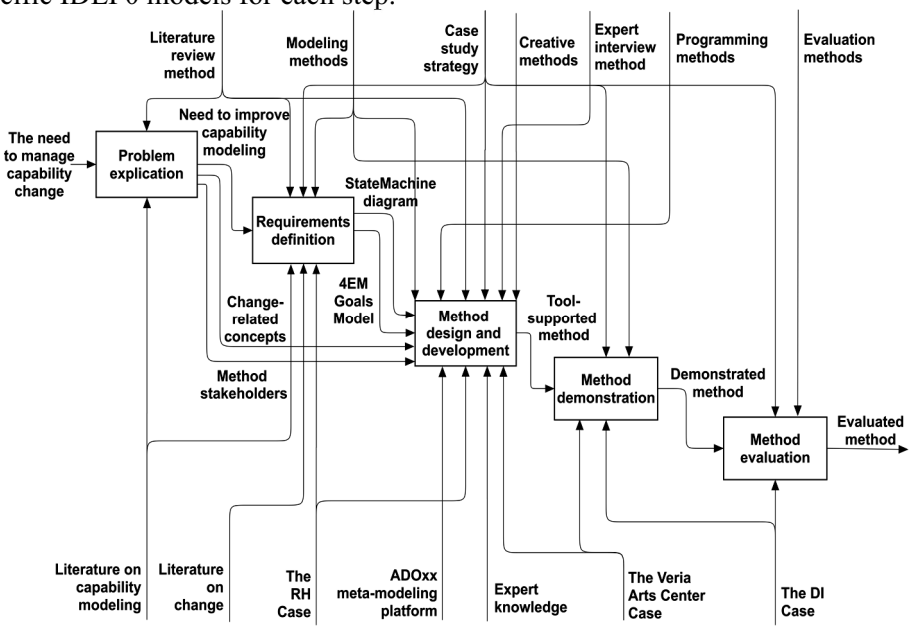


Figure 4. Overview of the research process of this thesis.

The procedure reflects not only on the project and its goals, but also on the papers included as part of this thesis. A mapping of Papers 1–9 in relation to the steps of the DSR, the goals of the thesis, and the methods employed is presented in Table 1.

Table 1. Associations among the steps of the DSR, the goals of the thesis, the strategies and methods employed, and the papers included in the thesis.

DSR step (Goal) / Approach	Explicate problem (G1)	Define require-ments (G2)	Design artifact (G3-G4)	Demonstrate artifact (G5)	Evaluate artifact (G6)
Literature review	Paper 1	Paper 2 Paper 3	-	-	-
Case study	-	Paper 2	-	Paper 4 Paper 6 Paper 8 Paper 9	Paper 9
Expert interviews	-	Paper 5	-	-	Paper 5

Modeling	-	Paper 2 Paper 3	Paper 4 Paper 5 Paper 6 Paper 7	Paper 4 Paper 6 Paper 8 Paper 9	Paper 9
Creative and programming methods	-	-	Paper 7 Paper 8	-	-
Evaluation methods	-	-	-	-	Paper 9

3.3 *Design Science Research process*

DSR (Hevner et al., 2004) is a research framework "that seeks to consolidate knowledge about the design and development of solutions, to improve existing systems, solve problems and create new artifacts" (Dresch et al., 2015). An alternative definition suggested by Johannesson and Perjons (2014) described DSR as the "scientific study and creation of artefacts as they are developed and used by people with the goal of solving practical problems of general interest". Wieringa (2014) stated that "Design Science is the design and investigation of artifacts in context", and explained that artifacts are designed to interact with the context of a problem in order to improve an aspect of the specific context. Another definition was suggested by Hevner and Chatterjee (2010), as follows: "Design science research is a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem". The theme common to all the definitions given above is the problem-solving and knowledge-contributing nature of DS, which assists humans in overcoming challenges and difficulties through the development of artifacts.

On a practical level, DS is typically applied within a research project in the form of guidelines, research rules and frameworks. There are several DS frameworks in the literature, such as that proposed by Peffers et al. (2007). This consists of six steps, which include activities and the required resources for each step, as follows: (i) problem identification and motivation; (ii) definition of the objectives for a solution; (iii) design and development; (iv) demonstration; (v) evaluation; and (vi) communication. However, the framework selected to drive this research project was the one suggested by Johannesson and Perjons (2014); this bears similarities to the framework of Peffers et al. (2007), but was chosen as it includes methodological guidance regarding the resources and controls that drive the transformational activities performed in the suggested steps.

It is notable that the communication guideline suggested by Peffers et al. (2007) and Hevner and Chatterjee (2010) is absent from the suggested steps of the framework selected here. However, Johannesson and Perjons (2014) emphasize the importance of the structure used to present a DSR project, and suggest the IMRaD (introduction, methods, results and discussion) format (Swales & Feak, 2012). The present research complies with their suggestion, and is presented using a variation of the IMRaD format.

The following sections give detailed descriptions of the steps of this framework and their application in this project. Parts of these descriptions are drawn from the author's earlier work (Koutsopoulos, 2018).

3.3.1 Explicate problem

In the first activity in the framework of Johannesson and Perjons (2014), a practical problem is investigated and analyzed thoroughly. This task is followed by a precise formulation and justification of the given research problem. The purpose of this activity is not only to identify a problem or opportunity, but also to demonstrate its significance in regard to some global practice. More specifically, the aim of this step of the research process is to answer the question "What is the problem experienced by some stakeholders of a practice and why is it important?" (Johannesson & Perjons, 2014).

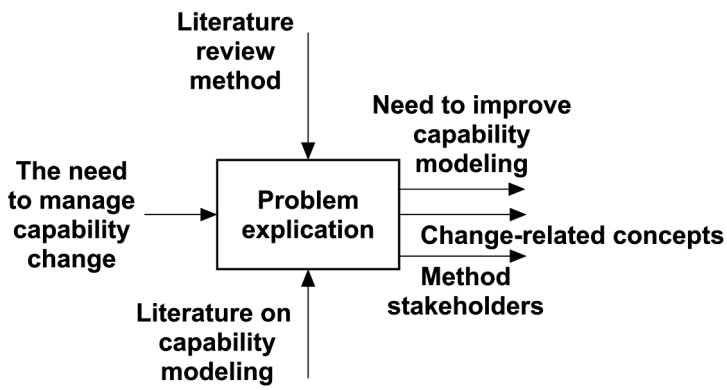


Figure 5. The problem explication step.

In this PhD project, an opportunity was explicated. It was initially observed that none of the existing capability modeling methods was specifically designed for depicting capability change, despite the importance of changing capabilities, which provided an opportunity for improvement. The next step was therefore to explore the field, with a particular focus on which aspects of change had already been included in existing methods, and a way to achieve this was to explore the existence of change-related concepts in their respective meta-models. A literature review (see Section 3.5.1) was carried out to assist

in this task. Having identified the existing capability meta-models in the literature, the concepts of the meta-models were extracted, analyzed from several perspectives, and classified according to a framework developed for this purpose. These two tasks formed the explication of the opportunity to develop a modeling method that was specially designed for capability change modeling and analysis. A detailed description of the literature review and the data collection and analysis methods involved in this step are given below. Figure 5 shows an IDEF0 model of this step.

3.3.1.1 KYKLOS stakeholders

An activity that complements the explication of the problem is the initial identification of the stakeholders of the given problem. For KYKLOS, a preliminary stakeholder analysis (Brugha, 2000) was conducted, and the results, which consisted of documentation of these stakeholders, were used as a basis for selecting case studies and participants.

By definition, the potential stakeholders in the phenomenon of organizational capability change are mainly related to organizations. However, there are no limitations on the specific type of organization that is undergoing change: organizations may be private or public, profit-driven businesses or non-profit institutions, or governments aiming for financial gain or social value respectively.

Of the roles that are most relevant to the phenomenon of organizational capability change, managerial roles are usually involved with and have to deal with changing capabilities. Any manager with decision-making responsibilities is a potential stakeholder for this project, including those in human resources, finance, project, change and product managers. Even more important are the executive roles that make up the main decision-making bodies of the organization (for example, CEO, CTO, CFO, CIO, COO, and/or CMO). Finally, there are also roles that specialize in dealing with organizational change by analyzing the organization and facilitating transitions. A characteristic examples of this type of role is that of a business analyst, and in particular, a new business developer, enterprise architect and modeler, and/or consultant.

As a phenomenon, capability change is also important to researchers, who may be private members of R&D units, or public researchers in universities or other institutions.

Universities are also affected by organizational change, as this is a course topic that is taught not only within departments that teach business studies and management, but also in departments that include courses on the infrastructure of organizations, such as business informatics and IS; these treat organizations as socio-technical systems and teach students how to deal with organizational change, especially when it concerns the IT infrastructure of the organization. As a result, the contributions of this project are of interest to both teachers and students.

Finally, as a timely and interesting topic, improving the way to deal with organizational change is of interest to publishers, who may seek to promote this to the other stakeholders that form an interested community.

3.3.2 Outline artifact and define requirements

The activities involved in the second step in the framework of Johannesson and Perjons (2014) relate to the transformation of the explicated problem or opportunity into a set of elicited requirements.

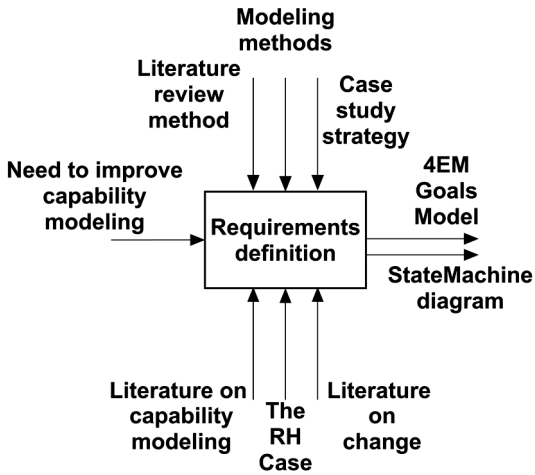


Figure 6. The requirements definition step.

In this PhD project, the elicitation of requirements needed to be based on a deep understanding of organizational capabilities. Similarly to any other designed artifact, KYKLOS, as a capability modeling method, required not only to be scoped but also to have a set of requirements defined for it. The objective of this step of the process was to provide an answer to the question "What artifact can be a solution for the explicated problem and which requirements on this artifact are important for the stakeholders?" (Johannesson & Perjons, 2014). The set of requirements for a method aiming to model changing organizational capabilities was defined using two different sources. A literature review (see Section 3.5.1) provided an initial set of requirements, and a case study (Section 3.4.1) provided complementary requirements. The combination of theoretical and empirical methods provided a holistic approach and a deeper understanding of the envisioned artifact. In order to avoid any confusion, it should be clarified that the case study activities performed in this step resulted in requirements that were elicited only for the modeling method.

Requirements were also elicited for the states of capability change based on the literature review, as described below in Section 3.5.1, and were structured in the form of a StateMachine diagram due to the nature of the particular

set of requirements. This was then used as a complementary input to the meta-model during the artifact design step. The strategies and methods applied in this step are discussed in detail later in this chapter. Figure 6 depicts this step in the form of an IDEF0 model.

3.3.3 Design and develop artifact

The process of developing the artifact followed the requirements elicitation step suggested by Johannesson and Perjons (2014). Any artifact designed during this activity is expected to properly address not only the explicated problem, but also the elicited requirements, in terms of both functionality and structure.

A DSR framework suggested by Wieringa (2014), which differs in two main respects from that of Johannesson and Perjons (2014), provided an alternative approach that was also taken into consideration. The first point of difference is that it focuses on the problem context, extended with the stakeholder and knowledge contexts. The DSR project's context consists of this extended context. The second point is that DS is separated into two problem-solving tasks, design and investigation, that are complementary to each other. Hence, knowledge questions and design problems motivate each other in an iterative manner until the problem is solved and the questions are answered. Figure 7 provides a detailed description of the procedure followed in this step, and includes information on the three design iterations that were performed. The numbers 1, 2, and 3 in the figure indicate the artifacts produced in each respective design iteration. In particular, the meta-model designed in iteration 1 was demonstrated (see Section 3.4.2) and evaluated using expert interviews (see Section 3.5.2), which resulted in the design of an extended version of the meta-model in iteration 2. A combination of the KYKLOS requirements and the tool requirements resulted in the final language meta-model, which was used for implementation of the tool. The exploration of method components, which resulted in potential integration points, and the development of the remaining method components led to the finalization of the method and tool support. The tool on its own does not form an integral part of the method, as explained in Section 1.2; however, the tool significantly facilitates the application of the method, and therefore forms an integral part of this PhD project.

An essential aspect that needs to be acknowledged in this step is creativity. Any innovative DSR project is characterized by its reliance on creativity and a trial and error approach (Hevner & Chatterjee, 2010). Human creativity has been criticized for introducing non-repeatability into the DS framework, as it remains poorly understood as a cognitive process (Vaishnavi & Kuechler, 2004); in other words, human creativity is believed to undermine the scientific validity of DSR. Vaishnavi and Kuechler (2004) also state that there is no way for creativity to be diminished from DSR. Nevertheless, they argue that the creative step existing in DSR has analogues in all research paradigms. As an

example, they state that in positivist research, creativity is a significant aspect of the leap from curiosity about a phenomenon to the creation of constructs to operationalize the phenomenon and research design for measurements (Vaishnavi & Kuechler, 2004).

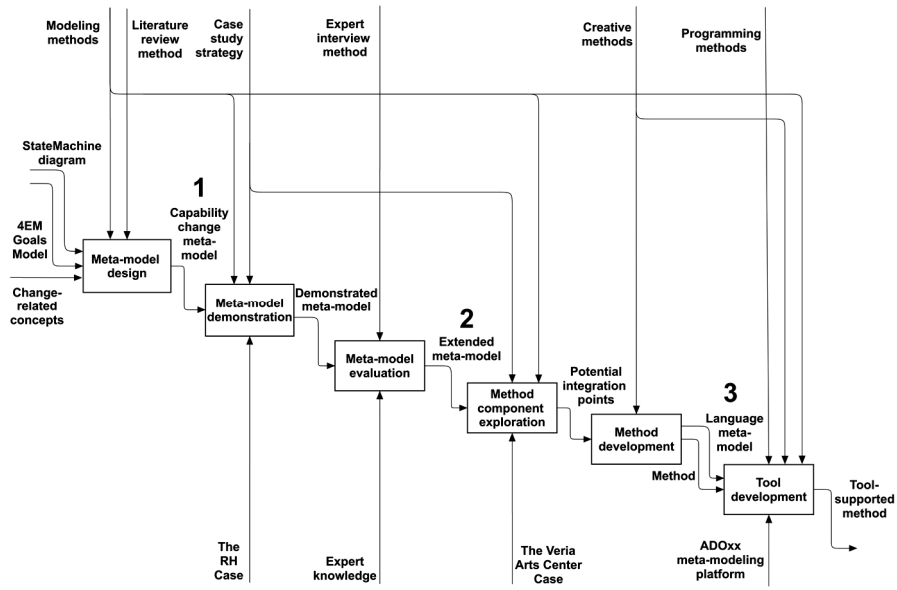


Figure 7. The artifact design and development step.

The iterative nature of DSR (Wieringa, 2014) and creativity were the drivers of this step. Developing a method involves the development of essential component artifacts, and in particular a meta-model that captures the essential semantics and syntax of the modeling method, along with a modeling procedure and notation. When developing the component artifacts, the input from the previous steps was used, which provided results that fulfilled the elicited requirements. Descriptions of the development of the meta-models and the other components of the artifact are given in Sections 4.4 and 4.5, and more details are given in Papers 4–8.

3.3.4 Demonstrate artifact

This step involves the use of the artifact in the solution of a problem instance, i.e., a real-life or illustrative case, to prove its feasibility as a problem-solving creation (Johannesson & Perjons, 2014). In order to provide proof of feasibility of the method as a solution to the problem which is being addressed, the researcher needs to select a specific instance of the problem. The purpose of the demonstration step is to include the functionality of as many components as possible, as described in the guidelines suggested by Johannesson and Perjons (2014).

A comparison of the problem and the requirements must also be made, as Baskerville et al. (2009) suggest that during the demonstration step, a clear comparison of the specific problem selected as a case and the previously elicited and defined requirements is needed.

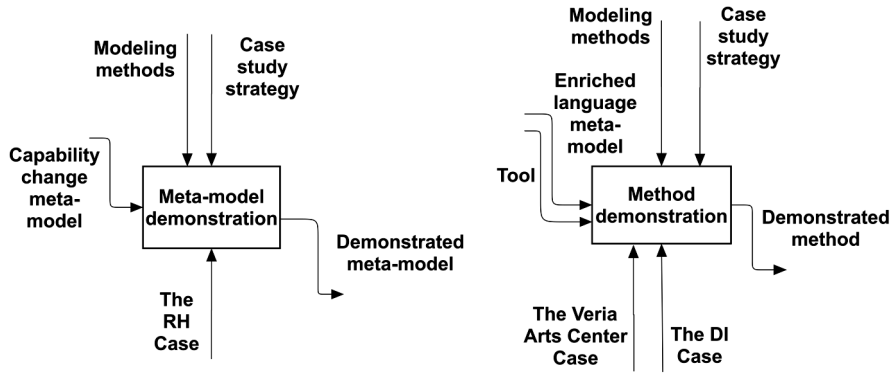


Figure 8. The artifact demonstration step.

The meta-model, as a method component developed in the artifact development step, was demonstrated in this project before the remaining method components had been developed. Its importance as the basis of syntax and semantics for the method, through its structure and textual description respectively, was emphasized and compared to the elicited requirements, using a mapping of the goals to the concepts included in the meta-model. The meta-model was applied in the Regional Healthcare (RH) case study (see Section 3.4.1), which was the same that used for the elicitation of requirements, following the suggestions of Dresch et al. (2015). The complete KYKLOS method and tool were demonstrated in two additional case studies involving the Veria Arts Center (see Section 3.4.2) and Digital Intelligence (DI) (see Section 3.4.3) case studies. Detailed information about the case studies is given in Section 3.4 of this chapter. Figure 8 shows IDEF0 models of the two demonstrated parts of the project: the meta-model, and the method itself.

3.3.5 Evaluate artifact

In the last step of the DSR process, which involves evaluating the artifact, the problem-solving capabilities of the designed artifact are determined based not only on its feasibility identified during the previous step but also on the degree to which the set of elicited requirements are fulfilled.

The evaluation step of DSR may be performed in various different formats (Johannesson & Perjons, 2014). It is called a summative or formative evaluation, terms which refer to an artifact that has been developed or that is still under development, respectively. In addition, evaluation activities are known as naturalistic when they are conducted in the natural environment of the case, exploring a real case, involving real users, and dealing with a real problem.

When the evaluation is not bound to reality, the evaluation is called artificial. The last classification of evaluation activities is that they may be ex ante, meaning that the designed artifact is being evaluated on a conceptual level without using it, or maybe without it being fully developed yet, or ex post, which requires the artifact to have been fully developed and employed for the evaluation (Johannesson & Perjons, 2014).

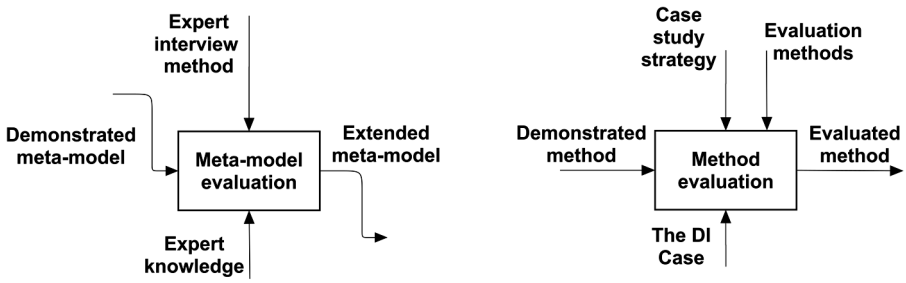


Figure 9. The artifact evaluation step.

The evaluation strategy selected for this project and used within the DSR framework was the Human Risk and Effectiveness strategy of FEDS (Venable et al., 2016). This selection was justified by the fact that the KYKLOS method has both user-oriented and social challenges. For this reason, different evaluation activities were conducted according to the progress level of the project.

A demonstration of the meta-model by instantiating it using the same case study as that used to elicit the requirements served as a preliminary ex ante evaluation of the artifact, as it provided the opportunity to explore whether the mapping of the meta-model elements to the requirements resulted in an efficient conceptual structure. The initial official evaluation based on expert interviews concerned the meta-model only. It was an ex ante, artificial, and formative evaluation, since it was conducted before the development of the method with the purpose of enabling the artifact to be revised based on the findings, and did not involve any real case, users or problem. The final evaluation of the completed method that used the DI case study (see Section 3.4.3) was summative, since the artifact had already been developed to a reasonably stable version when it was conducted; it was also naturalistic, as the case study was real, with a real problem and real users, and was ex post, because the evaluation was conducted after the artifact had been used. The evaluation also resulted in possible future directions for this research project. The two evaluation activities performed in this project are shown in the two IDEF0 models in Figure 9.

3.4 *Case studies*

A case study is a research strategy that should be preferred when an investigation needs to be performed in depth (Yin, 2003). It is an appropriate strategy when the researcher aims to ask questions concerning the how and why of a phenomenon, when the researcher has little control over the events being studied, when the objective of the study is a contemporary phenomenon existing in a real-life context, when the boundaries between the phenomenon and its context are not clear, or when it is desirable to use multiple sources of evidence (Schwandt, 2007).

It is a research strategy for making inquiry, although which methods are constituting it is a matter of debate (Schwandt, 2007). The main point of focus of a case study is the case itself, rather than its variables. Several data collection methods can be applied, which may provide valuable insight into the investigated topic; however, as a research strategy, a case study depends on the data collection and analysis methods that are employed within the case study.

Three applications of the case study strategy were employed as part of the research activities of this PhD project. The descriptions that follow are adapted from Paper 2 (Koutsopoulos et al., 2019b), Paper 6 (Koutsopoulos, 2021) and Paper 9 (Koutsopoulos et al., 2022).

3.4.1 Case 1 overview – Regional Healthcare

Case 1 involved a collaboration between an academic research team from the Department of Computer and Systems Sciences (DSV) of Stockholm University (SU) and a team of expert strategists from a public organization responsible for providing healthcare services in a Swedish county. Case 1 was not conducted exclusively for this research project; it was an independent project that was considered in this thesis due to its high level of relatedness and consistency with the topic of this research. The organization, its members, and the collaborating organizations desired to remain anonymous, and the case will therefore be referred to here as RH. The collaboration project between DSV and RH focused on capability and value-based change analysis, hence its relatedness to the present thesis.

The author was a member of the academic research team, and participated in all the activities except the data collection processes. The team performed all the data collection and analysis, and all the other research and modeling activities of the RH project. The author contributed to these activities as described in Appendix 2.

The RH case is considered in this thesis in regard to the elicitation of requirements for the artifact and the demonstration of one of the initial method's semantics in the form of the meta-model. In other words, this case study assisted in the fulfillment of sub-goals G2 and G3.

The objective of the RH project was to improve the support for analyzing changes requested on the organization's capabilities. Part of the project involved examining whether various types of enterprise models included the types of information needed to analyze the impact of changes. RH is responsible for healthcare provision within the boundaries of a county in Sweden, and one of its main capabilities is to provide advice on health issues via phone to the county's residents or visitors. The delivery of this capability is performed by professional nurses who are specially trained for the task, supported by specialized software that includes a variety of information sources. The capability is known as 1177, which is the four-digit telephone number used by patients to contact the nurses. The goal of 1177 is to filter the callers and to advise those who are not in need of a physician's attention. This enables a reduction in the workloads of other organizations.

Although RH is the owner of 1177, there are several other private and public collaborating organizations that contribute by providing resources. Thus, the capability is inter-organizational, which results in a high level of complexity in terms of its configuration.

Two proposed changes were selected, as they represented both internal and external improvements. These two change cases were complex, due to the complexity of the capability's configuration. The range of component resources and processes were owned by several parties, both private and public, and their collaboration needed to be regulated and governed by legislation. Both changes had an impact on the collaboration between organizations and their IT systems. A detailed description of the two changes is provided in Paper 2 (Koutsopoulos et al., 2019b).

3.4.2 Case 2 overview – Veria Arts Center

The second case study was conducted in a Greek public organization called the Veria Arts Center, which is the main body responsible for planning and implementing cultural policy within the municipality of Veria.

This organization produces and manages a variety of cultural activities including art events and festivals, for example, music, dance and film festivals. It also handles various aspects of art education, such as music, dance and visual art education, and manages culture-related institutions including libraries and museums. As a legal entity, the Center is governed by private law, despite the fact that it is a public organization; this results in a complex condition where the organization is funded both by the municipality's resources and the Center's own earnings gained from organizing events. In other words, it operates as a private entity that needs to comply with the regulations imposed on public agencies.

The capabilities of relevance to this case study of Veria Arts Center are producing and organizing art festivals, providing art education, and managing culture-related institutions. Although the dynamic conditions that affected the

organization had an impact on all the abovementioned capabilities, the main focus of this case study was the capability to organize art festivals, as this was not only suitable for this project but was also the main priority of the Center for analysis, since its changes were considered the most important.

This specific capability has been subjected to minor changes throughout the years, but the Greek economic crisis and the COVID-19 pandemic resulted in two major changes that affected it. These were modeled and analyzed, and a third change was also planned and designed.

The capability's configuration normally consists of appropriate infrastructures, maintenance and technical staff, specialized equipment and the expertise to use it, financial resources, and a reputation for attracting audiences. During the exploration of the details of the case, a weakness was identified in regard to the absence of any means of collecting data to evaluate a festival's success.

More details about the organization, the changes and their attributes and the way they were structured according to the capability change framework are presented in Paper 6.

3.4.3 Case 3 overview – Digital Intelligence

The third case study took place in a company in the IT domain which provided consulting services. For reasons of confidentiality, the company is referred to here as DI. DI is a Sweden-based company with a number of offices operating around the country. It is an SME, established over 20 years ago, and not only specializes in selling Enterprise Resource Planning (ERP) products, but also offers consulting to its customers with regard to the purchase of products customized to their business needs. Their clients are supported in their digital transformation via software systems and IT solutions.

In recent years, DI has started to respond to changes in the ERP market, for example the increasing need to deploy ERP systems as cloud services. DI has implemented a variety of change initiatives in order to retain its share of the market, focusing not only on the services it provides but also on the structure of the company. The specific change that was analyzed in this case study arose because DI had observed a shift in the requirements of its client base. Until recently, customers had requested consulting services that were limited to equipping the client with a requested specific IT solution; however, the company's client base was starting to display a tendency to request a broader supply of services. In particular, an assessment of a client based on a wide spectrum of dimensions to support the their decision on the most suitable solution was now being requested from DI.

For this reason, a need had emerged for the company to monitor and examine its supplied services, which in turn required an analysis of its working processes. This state led to a need for transformation and change in DI, meaning that this case was suitable for the application of the KYKLOS method.

A thorough exploration of the case led to an analysis of the capabilities that supported the main capability, which were the consulting capability, at the operational level, and the customer assessment capability. Two further capabilities that were included in the analysis were product acquisition and company role clarification, although these were only indirectly associated with the actual transition.

The analysis facilitated exploring the configurations of the supporting capabilities and the components required for their realization, both the available and the required ones.

A detailed description of the case is given in Paper 9.

3.5 *Data collection*

This section describes the data collection methods that were employed during the elaboration of this thesis. These were: (i) literature reviews (for Papers 1–3); (ii) interviews (for Papers 2, 4, 5, 6, 8, and 9); (iii) a questionnaire (for Paper 9); (iv) focus groups/workshops (for Papers 2, 4, and 9); and (v) a document analysis (for Papers 2 and 4).

3.5.1 Literature review

In this section, the steps taken to conduct a systematic review are described in detail. Three review activities were performed on the same set of papers, in order to provide insight for sub-goals G1, G2 and G2a, respectively, related to the explication of the problem and the definition of requirements. The following sub-sections describe the details of these activities.

3.5.1.1 Guidelines for systematic literature review

As a secondary study, the objectives of a systematic literature review (SLR) are to identify, analyze and interpret all the available research literature deemed relevant to a given research question, topic area, or phenomenon of interest (Kitchenham & Charters, 2007). An SLR aims to enable a fair evaluation of a research topic in an unbiased and repeatable way. This is achieved by employing a rigorous, trustworthy and auditable methodology. The SLRs conducted as part of this PhD project followed the guidelines proposed by Kitchenham and Charters (2007).

3.5.1.2 Meta-model review

The primary specific literature review conducted in this thesis was a not typical one, as it concerned a meta-model review rather than a traditional literature review. It combined the attributes of an SLR, which aims to explore a given domain, with the attributes of a systematic mapping study, which aims to synthesize and structure the derived information (Petersen et al., 2015).

During the stages associated with planning the review, the need for a review was identified as a result of the lack of an existing capability modeling method that was specially designed to depict capability change. Thus, the review was necessary to identify which aspects and concepts related to change already existed in capability meta-models in the literature, so that time and effort spent on reinventing the wheel of capability change could be avoided. This was the research goal that drove this part of the research.

The identification and selection of primary studies was systematic, based on search terms and criteria described in the following sections, and data extraction was performed on the meta-models rather than the studies including them. For the synthesis part, the data were classified according to a framework developed for this reason and visualized as a concept map. The details of these tasks are given below in this chapter. Finally, the main report was realized and published as Paper 1, included in this thesis.

3.5.1.3 Capability change reviews

A set of papers was obtained that included the capability meta-models, with the addition of specific papers that were excluded as they did not include meta-models and papers identified using a snowballing technique from the initially included papers, and these provided additional value during the next steps of the project.

In particular, although the meta-model review served the first sub-goal G1, the contents of the papers, and especially the parts where the inclusion of specific concepts was justified in the meta-model semantics, provided a valuable source of requirements for the second step of the DSR process. The data extracted from the second review of the papers consisted of goals and requirements for managing capability change. In certain cases, the capability change requirements were extracted directly from papers on a topic related to capability or indirectly from papers on the topic of organizational change. In these cases, the identified change-related requirements were associated with capabilities in an organizational context. This activity contributed towards the fulfillment of sub-goal G2. The resulting report was formatted and published as Paper 2.

A third review of the same papers provided valuable information for sub-goal G2a. The aim of this review was to identify information related to the dimensions and attributes of both change and capability. The work of Maes and van Hootegem (2011), consisting of a review of organizational change dimensions in the literature, played an important role as it was used as the basis for the development of a set of juxtaposed dimensions of organizational change in the context of capability. The resulting report was formatted and published as Paper 3.

3.5.1.4 Databases and search terms

Capability meta-models in the literature were identified through a process of keyword searches of the database dblp.org using the terms

«capabilit AND model»*

and of Google Scholar using the terms

« "capability OR capabilities AND model" AND "enterprise modelling OR modeling"»

The reason for using different search terms lay in the fact that dblp.org is a database with specialization in computer science literature; when using Google Scholar, there was a need to narrow down the search with additional search terms. These searches resulted in 672 papers from dblp.org and 169 from Google Scholar.

3.5.1.5 Inclusion and exclusion criteria

The criterion for including a paper was that it should contain a conceptual meta-model that included at least one concept of capability. Having removed duplicates, an initial set of papers was formed and a snowballing technique was applied to this set based on the references in each paper, in order to identify more capability meta-model-sources in the literature, until a point of saturation was reached, where no new meta-models could be identified. Certain meta-models that were included were different versions from the same project; in some cases, this meant that they represented different levels of elaboration of a meta-model, while in others the differences arose as a result of different levels of abstraction. The decision for including them was based on the fact that they included variations in their concept sets which were deemed worth exploring.

In addition, several specifications and documentations of popular EA frameworks (NATO, 2018; The Open Group, 2017, 2018; UK Ministry of Defence, 2010; USA Department of Defense, 2009) and modelling languages (Object Management Group, 2018; Sandkuhl & Stirna, 2018a) that included the concept of capabilities as viewpoints were considered in the final set of 64 capability meta-models to be explored. Approaches based on capability mapping, for example that of Beimborn et al. (2005), were not included in the final set, despite being considered valid approaches, unless a meta-model also existed in the study. Any publication in any language other than English was also excluded. A detailed list of the selected studies that served as sources of meta-models is presented in Appendix 3.

3.5.2 Interviews

Interviews were used in several stages of this project, either as stand-alone elements of the research or as part of case studies.

An interview is a conversation between a researcher and a participant, where the agenda is controlled by the researcher (Johannesson & Perjons, 2014). It is a popular choice for knowledge-producing practices in qualitative projects (Given, 2008), including DS projects in the area of IS. An interview is considered an excellent data collection method when exploring complex and subtle phenomena (Denscombe, 2011), and is therefore useful and appropriate for in-depth inquiry in IS research, as a high degree of complexity is usually involved, as is the case for capability change. Interviews can be classified based on the communication channel used, the number of respondents or their structural format, as face-to-face, phone or internet interviews (Given, 2008), which may take place synchronously or asynchronously. They can also be classified as individual or group interviews. The format can be classified as structured, semi-structured or unstructured (Johannesson & Perjons, 2014). Unstructured interviews often involve a few initial guiding questions, and this type of interview is commonly known as guided interview (Gubrium et al., 2012). A drawback of unstructured interviews is that there is no fixed range of responses, which structured and semi-structured interviews may benefit from (Given, 2008); in addition, the researcher has limited control over the given topic and the overall direction of the investigation. A popular practice during the application of this data collection method involves conducting expert interviews.

The aim of using interviews in the first case study of RH (see Section 3.4.1) was to identify the recent changes requested by customers of the organization along with the potential consequences of these changes, in order to provide insight related to the definition of requirements, as stated in sub-goal G2. Furthermore, the interviews were held in such a way as to allow for an understanding the organization's business. In the second case study, in the Veria Arts Center, the objective was to collect data in order to gain adequate insight into its changing capabilities. The collected data and insights served as input for the modeling tasks, both during the phase of exploring the semantic consistency among KYKLOS and other methods, and for the demonstration using the tool. In the third case study of DI, interviews were conducted to enable an initial exploration of the organization and identification of the specific needs for change indicated by the shift in customer requests. More specifically, the aim was to structure the collected data for use as input during the modeling activities of the case study, in a similar way to the second case study. Finally, the aims of conducting expert interviews as a data collection method were to explore the experts' knowledge of the phenomenon of capability change and its pre/identified functions, and to evaluate the structure of the initial metamodel and the concepts included.

The method used for the RH case study involved one unstructured group expert interview and three unstructured individual ones. Two experts participated in the group interview. The interviews were conducted synchronously and face-to-face on the organization's premises. No data were recorded or

transcribed other than manual note taking, as coding and analyzing the data did not form part of the objectives of these interviews. This data collection method was selected because the respondents could be given the opportunity to expand on the topic from their own perspective, and possibly introduce the researcher to previously unknown topics. The experts' knowledge had significant value in terms of identifying the requested changes and their potential impacts. No restrictions were imposed in terms of requesting clarification or asking follow-up questions whenever needed. In total, eight change requests were identified, two of which were considered in this project.

For the Veria Arts Center case study (see Section 3.4.2), the method involved face-to-face guided interviews. One group and six individual interviews were conducted with the entire team of managers and the unit heads of the organizations, both individually and as a group, in order to compare and combine the perspectives of the individuals with the perspective of the team as a whole. The average duration of the sessions was about one hour, for both the individual and group interviews. The questions that guided the interview were generic, and were derived from the study's sub-goals; for example, questions such as "How does your organization deal with changes?" were posed to initiate and motivate a fruitful and insightful discussion while allowing the participants to "tell their own story" (Gubrium et al., 2012). The fact that the entire managerial team of the organization participated ensured that multiple perspectives on the same change phenomena would be acquired and that no aspects were missed.

The DI case study (see Section 3.4.3) involved four semi-structured interviews that were conducted individually and online. The questions guiding the discussion were derived from the specialization and roles of the participants within the company, and how their roles affected or were affected by changes, and this eventually led to a discussion about the specific changes that formed the focus of the case study. All the initial interviews were conducted by a collaborating Master's student, and the data collection protocol and the selection of the interviewees were developed in a collaborative manner by the author and this student. The set of questions consisted of initially asking for a detailed description of the interviewee's role, followed by asking the participant to elaborate on the association of their role with the company's change initiatives, with the main focus being the change initiative of the case study and its details, such as the goals, motivation, context, challenges and procedures related to the change.

The last part of this research in which interviews were employed as a data collection method were the expert interviews, as described in Paper 5. This stage of the research was most strongly affected by the COVID-19 pandemic, and the semi-structured interviews were therefore conducted online and asynchronously via email, both for the initial communication and for the follow-up questions where necessary. The question set involved (i) participant data; (ii) questions on the phenomenon of capability change overall; (iii) questions

specifically addressing the three change functions identified previously, particularly in regard to the responsibility, procedure, factors affecting and challenges associated with each function of change; and (iv) questions about the identification of the need to change. The generic question set included questions about what the concept of capability meant to the interviewee, whether and how it was used in their organization, and the types of capability change that were considered the most common. The questions with a specific focus on the functions of change asked about the determination of criteria before deciding on a capability change, and the challenges of observing and delivering a changing capability. Each interview session also included a part where the interviewees were asked to evaluate the association and relevance of the concepts that had been included in the meta-model to the phenomenon of capability change, based on their expert perspectives, and to identify potential omissions that they considered to be valuable for describing the phenomenon. For reasons of efficiency and practicality, the results were documented using a Likert-scale grading, but this task was treated as part of the interview rather than as an independent task, since it also motivated part of the discussion. The complete list of questions posed during the interviews is given in Appendix 5.

3.5.3 Questionnaire

A questionnaire is a data collection method in which questions are used to collect data in a structured manner (Bhattacherjee, 2012). Questionnaires are suitable for collecting both quantitative and qualitative data, and a variety of types exist, such as questionnaires that are self or group administered, and internet questionnaires. This is considered an efficient method of collecting direct answers about the topics that concern the researcher (Denscombe, 2011). When quantity is favored over quality, a questionnaire is probably the most appropriate data collection method, although this is not always the case. When numerous simple questions are to be put to all the participants, there is practical value in replacing these parts with a questionnaire.

In this project, one questionnaire was used in the evaluation of the meta-model's concept set, as presented in Paper 5. This questionnaire did not involve traditional data collection, as it was only intended to act as an assessment for each of the concepts included, in the form of a five-point Likert-scale grading, and no actual questions were posed. In practice, it formed a complementary part of the interviews carried out to evaluate the concept set. For reasons of feasibility in terms of time and effort, rather discussing each single concept with all the interviewees, an online questionnaire was provided with a predefined grading scale for the concepts.

The second questionnaire used within this PhD project was applied in the evaluation step of the DSP process. The design and development of the questionnaire was based on the Method Evaluation Model (MEM) (Moody, 2003), which was derived from the Technology Acceptance model (TAM) (Davis,

1989). MEM consists of a set of specific aspects that are evaluated during the application of the model, as follows:

- Perceived ease of use
- Actual efficiency
- Actual effectiveness
- Perceived usefulness
- Intention to use
- Actual usage

The evaluation questionnaire consisted of 15 Likert-scale questions which were inspired by the aspects given above and which reflected the specific features of KYKLOS. The questions were posed in the form of statements, and the interviewees were asked to express their level of agreement or disagreement on a five-point scale. The application of MEM resulted in the following set of questions, corresponding to the aspects of MEM, which related to KYKLOS: (i) perceived ease of use (Q1–Q3); (ii) actual efficiency (Q4); (iii) actual effectiveness (Q5–Q13); and (v) intention to use (Q14–15). The actual usage of KYKLOS could not be assessed, since it was a recently developed method and had not undergone actual usage, apart from its application to the case studies within this project for reasons of demonstration and evaluation.

3.5.4 Focus group/workshop

Workshops and focus groups were carried out as part of the case studies conducted for this PhD project, with different aims and purposes depending on the nature of the research step and the case study.

A focus group, as a data collection method, was used in the first study as a means of developing a value model that was later used to understand and analyze the requested changes, and provided data related to the definition of requirements, as stated in sub-goal G2. Focus groups are collective conversations with varying numbers of participants (Liamputtong, 2011) that examine specific topics. They are "focused" because collective reflection is involved. Their goal is to gain insight into the understanding and interpretations of a topic by a selected group (Liamputtong, 2011). Focus groups are similar to group interviews, but with a slight practical difference: interviews have an exploratory nature, while focus groups are used to confirm existing results. In addition, interviews tend to capture data from the respondents' answers and feelings, whereas focus groups also tend to capture data from the participants' interactions. Another use involves the development, evaluation or validation of an artifact, where the artifact is considered as a research result that is to be confirmed. This is the way in which a focus group was used in RH, the first case study of this project. A focus group for the development of a model would not typically be considered a data collection process, but in this case, the objective of the focus group was to develop a model that would form part of the documents that would be analyzed. In particular, the model created through this collaborative process was a value network model that used the E^3value

syntax (Gordijn & Akkermans, 2018). The roles of the participants in the session were those of a facilitator and a modeling group (Stirna & Persson, 2018). One of the researchers took the role of the facilitator, while the domain experts from the organization and the rest of the SU participants made up the modeling group. The objective of the focus group was reached iteratively and incrementally, and this required three meetings, which were held on the organization's premises. At the end of the focus group process, the model was also validated by the organization's participants.

In the remaining two case studies, a similar approach was employed, with an analyst-driven approach used in the focus groups for the development of the case study models, for both the Veria Arts Center and DI. The author acted as the analyst, facilitator and method expert for KYKLOS, whereas the participants were domain experts that provided the required information for development of the model. Four representatives from the Veria Arts Center participated in a four-hour long focus group for the second case study, and one representative from DI participated in three four-hour long workshops for the third case study. In both cases, data collected from the previous interviews were used, and the participants verified their correct depiction in the models.

Workshops were also employed to evaluate the KYKLOS method in the last step of the DSR process. Nine workshops were held to evaluate the results of applying the method to the DI case study, as a means of evaluating the method itself. A total of 21 respondents participated in the workshops, acting as method evaluators. They were classified into two groups based on their modeling expertise: a business group, and a group of modeling experts. The business group consisted of 10 employees and representatives from DI, while the group of modeling experts consisted of 11 participants with modeling expertise, representing and affiliated with various academic institutions and private companies. The majority of the experts were affiliated with Riga Technical University (RTU). Four workshops were conducted with the business group, all of which were held online using Skype, with between one and five participating evaluators per workshop. Five workshops were held with the group of modeling experts, two online and three in person, with between one and six participating evaluators per workshop. The evaluation workshops involved an initial presentation of the method, including its aims, semantics, syntax and the tool, a detailed explanation of the goals, the developed model, and an analysis of the case study. Finally, the method was evaluated, which consisted of discussion, feedback and a questionnaire. A live demonstration of the tool and its usage was also included during the workshops conducted in person with the group of modeling experts.

3.5.5 Document analysis

The use of documents as a data collection method, as in the RH case study, is suitable for any type of research, as long as the content of the documents is

relevant to the phenomenon being researched. In this case, the documents were analyzed to identify how their use reflected the requested changes, in order to gain insight related to the definition of requirements, as set out in sub-goal G2.

Documents can be classified into various types based on their accessibility and format. Generic types of document format include images, textual files, audio files, video files, photographs etc. (Johannesson & Perjons, 2014), whereas more specific types of documents include existing records, diagrams, plans, maps, diagrams, correspondence, biographies, handbooks, guidelines, articles, artifacts, minutes of meetings, journals, annual reports, files, legal documents, policies, and evaluation reports. Depending on their accessibility, documents can be classified as public domain, restricted or secret documents (Denscombe, 2011). Documents are often used as a secondary source for data collection, to complement other data collection methods.

In this study, the documents used were diagrams, and in particular, enterprise models. A set of 15 diagrams of different types were examined that had been developed by RH before the case study began, consisting of BP models, goal models, concept models, a value network model, a service design model and a business model. Several languages and methods were employed in regard to the syntax of the models. The four BP models were developed using the Verksamhets och Informationsanalys (VIA) method (Lundmark & Rosenälv, 2017), which is similar to the Business Process Model and Notation (BPMN) (Object Management Group, 2011), one of the most popular languages in Business Process Management (BPM). The four goal models were developed using the Business Motivation Model (BMM) (Object Management Group, 2015) syntax, and the four conceptual models followed the Unified Modeling Language (UML) (OMG, 2017) standards. The value network model was developed using the E^3value method (Gordijn & Akkermans, 2018), the service design model was designed with the Service Blueprints technique (Curedale, 2017), and, finally, the business model was developed as a Business Model Canvas (BMC) (Osterwalder et al., 2010). The documents were restricted access files, and are therefore not included in this thesis.

3.5.6 Participants

The research activities performed throughout this PhD project required the participation of various individuals, particularly during the case studies and the evaluation of the initial meta-model. The selection of participants for these activities involved a sampling strategy, unlike the other data collection activities to which this requirement did not apply, since no data were collected from human participants.

In each case, the required information was only available from individuals with expertise in specific domains, such as expert strategists, domain experts or modeling experts. This limited the possibility of putting together a larger

group than the one employed in each case. The participants who were approached were those who could actually provide the required information.

This limited research population suggested a need for non-probability sampling, as described by Denscombe (2011), since there was no reason for a random selection of participants during the data collection process. The strategy used here involved purposive and convenience sampling (Denscombe, 2011). Purposive sampling is appropriate when the researcher selects a limited number of participants, using as a criterion their potential to provide high-quality, relevant data. Convenience sampling refers to the selection of participants based on feasibility criteria, such as time and cost. In addition, the participants selected by the researcher were those who were more likely to respond.

In all three case studies, the participants were members of the organization concerned. For the first case study, the participants selected for the interviews and the focus group were the two expert strategists of RH with the highest degree of relevance to the change under consideration. For the second case study, the six participants selected from the Veria Arts Center represented the entire managerial team of the organization, consisting of the president (an elected politician from the municipality), and five employed heads of the organization's units (the CEO, CMO/COO, CFO, CIO and CTO). For the third case study, five employees of DI were involved in the data collection activities. These participants were selected based their function within the organization and their involvement and experience in its strategic work and new initiatives. They were the director of the organization, the head of customer success, a data scientist, a consultant and an employee responsible for new initiatives.

The participants in the evaluation activities were affiliated with various organizations in several countries. The 10 participants for the evaluation of the meta-model were drawn both private and public organizations in Sweden, Greece and the United Kingdom. They were selected based on their long experience in managerial positions with decision-making responsibilities and involvement in change management, as directors, top managers, and unit heads. They worked in large and medium-sized organizations, had diverse educational backgrounds, and represented different organizational domains and roles, such as risk analysis, strategic product management, sales growth excellence, and customer service. The participants involved in evaluating the method were divided into two main groups. The first group consisted of 10 employees of DI, the majority of whom were consultants, with a solution architect, the head of customer success, and the director. They were selected based on their familiarity with the case study and their business expertise. The second group consisted of 10 academics and a private employee, who were all selected in view of their modeling expertise. They originated from Latvia, Sweden and the United States.

3.6 *Data visualization*

Due to the high number of meta-model concepts and associations elicited in Step 1, the dataset could not be presented in textual or tabular form. A graphical depiction of the dataset was therefore created in the form of a concept map, to provide an overview of the concepts included in the capability meta-model and their relationships. Having collected the meta-models and extracted their concepts, each term was entered into a database and imported into the VOSviewer tool (van Eck & Waltman, 2010). This tool employs the VOS (visualization of similarities) (van Eck & Waltman, 2007) algorithm, and was useful in terms of depicting occurrences and co-occurrences of terms in the selected meta-models. Common occurrences were used to group the concepts into thematic clusters. This tool is typically used for the automatic visualization of bibliographic networks, but it is also valuable for visualizing any type of network. Based on the analysis decisions described in Paper 1, the result was a concept map consisting of nodes and lines. Each node had a proportional size and a label to reflect the number of occurrences across all meta-models; the distances between nodes represented their relatedness, and the thickness of the connecting lines depicted the link strength between two elements, which is the frequency of co-occurrence of the terms in the set of meta-models. The minimum number of concept occurrences was selected, the map was generated and the normalization method, along with label and line size finalize the task, since the clustering is automatic.

3.7 *Data analysis*

This section describes the methods used to analyze the collected data. The nature of this research project meant that various types of analysis needed to be employed. Initially, the literature review did not require data management or reading and memoing, tasks suggested by Creswell (2007) for qualitative analyses, as the concepts were extracted directly from the meta-models, while the quantitative aspects were analyzed statistically. In the empirical work, interviews, focus groups and workshops were conducted to gain insights into the case studies, and various formats of thematic analysis were employed, often driven by the previously developed framework, which is presented in the following sub-section of this chapter. The analysis of change performed as part of the first case study aimed to identify the requested changes, while the aim of the focus group was to develop a model, and the document analysis involved diagrams rather than textual data. Change impact analysis (CIA) was employed to explore the impact of these changes.

Statistical analysis was carried out in Papers 1, 5, and 9, while thematic analysis was also used in Papers 1, 5 and 9, and CIA was used for the RH case study in Papers 2 and 4.

3.7.1 Concept classification framework

The classification activity described in the previous section required a classification approach to be selected. A framework was therefore developed to facilitate the classification of the meta-model concepts during the literature review. This framework was based on the literature in the area of adaptive IS, and included the essential features needed to express adaptability. More specifically, it was inspired by several works, and combined top-down development as described by Weyns et al. (2012) and Morandini et al. (2008) with bottom-up development as described by Grabis and Kampars (2018). The framework was also aligned with other change-related approaches and frameworks (Boyd, 1996; Dobson et al., 2006; Loucopoulos et al., 2019). Table 2 presents the framework, which includes the main identified change functions, the types of information related to each function, and example concepts. More details on the framework and its development are given in Paper 1.

Table 2. The classification framework (adapted from Koutsopoulos et al., 2019a).

Function	Information Type	Example Concepts
Observation	Measurement	KPI, Metric
	Context	Context element, Environment
	System itself	Capability
Decision	Intention	Goal, Objective
	Alternatives	Variation
	Criteria	Policy
Delivery	Delivery	Process, Service
	Capability architecture	Dependent (capability), Specialized (capability)

Based on these three change functions, the concepts extracted from the capability meta-models were classified, grouped and presented in Paper 1.

In addition, the three change functions were aligned with the operational refinement of the goal of this thesis. In practice, observation is related to the identification of the need to change and its origins, while decision and delivery describe the transition, in terms of deciding about it and delivering it, respectively.

3.7.2 Statistical analysis

A variety of statistical tests have been developed to facilitate the quantitative analysis of data. Each type of test serves a different purpose, and is described separately here. During the elaboration of this thesis, the following tests and techniques were employed.

- Chi-square test: This explores the significant associations between a pair of variables (ordinal or nominal). In contrast to a t-test and an analysis of variance (Bray & Maxwell, 1985), it is non-parametric. It can indicate whether groups in a sample are significantly different (Salkind, 2010). It was used in Paper 1 at the problem explication stage of DS.
- T-test: One of the most popular statistical tests, a t-test estimates the difference between two means to handle cases where the distribution is not normal (Lewis-Beck et al., 2004). A variation is the paired t-test, which compares the difference between groups of correlated variables (Vogt, 2005). It was used in Paper 9 in the artifact evaluation stage of DS.
- Descriptive statistics: These are the simplest tests performed during a quantitative analysis. The most commonly applied are the mean, which gives the average value, and the median, which represents the middle value in a set (Allen, 2017). They were used in Papers 1, 5, and 9 at the problem explication and artifact evaluation stages.

The results were visualized using 100% stacked column charts, pie charts, and box and whisker graphs (Vogt, 2005).

3.7.3 Thematic analysis

Thematic analysis is a specific method of qualitative data analysis that was used to explicate the problem and define requirements during the literature review. It is a method of organizing, analyzing and reporting themes within data (Braun & Clarke, 2006). This process may be inductive, as when a research question is derived from a dataset, or deductive (also known as theoretical), where the analysis is driven by an existing research question. The themes created in this way are either semantic, where their nature is mainly descriptive and explicit, or latent, where they represent underlying meanings in the data.

The data collection methods used in the first two steps of the DSR process traditionally require qualitative analysis, such as interviews, focus groups and document analysis; however, in this case they did not require such activities, as they concerned either the identification of existing conditions, as in the interviews, where impact analysis was the appropriate analysis method, or modeling activities and analysis.

A variation of thematic analysis was applied to classify the meta-model concepts. The focus was on the class elements, as their nature is descriptive and explicit, meaning that they result in descriptive themes. An analysis of the relationship elements was also performed, but these typically bridge first class concepts and their existence cannot be independent; they therefore represent

the underlying meanings, resulting in underlying themes that can be considered latent (Braun & Clarke, 2006). Identification of descriptive themes is possible at the manifest level; in other words, they can be observed directly at their source, and can be used as means for categorizing information, whereas latent themes require interpreting activities (Saldaña, 2009). Since the aim of producing concept maps was to provide a descriptive overview of the capability modeling field by applying the lens of adaptability, the class concepts were included in the results but the relationship concepts were not. This decision ensured the descriptive nature of the concept maps.

The aim of this analysis was to classify the concepts according to the framework and to map them to types of information and change-related functions. In this process, each concept is associated with one of the three functions (observation, decision, delivery), or is not relevant to capability change. Thematic analysis (Braun & Clarke, 2006) is usually initiated by becoming familiar with the dataset and coding; however, in this case, these first steps were omitted and replaced with direct extraction from the meta-models. The three activities of generating, reviewing and defining themes (Braun & Clarke, 2006) were driven by the framework, meaning that the approach applied here was theoretical. This deviation from the suggested thematic analysis process was made because there were pre-existing themes. The concepts were treated as codes, while the information types played the role of categories and the themes represented the change functions. Concepts that were classified as not relevant to change were also placed in a category, but this was not considered in the results. The final report was produced in textual form.

In the remaining last three steps of the DSR process, thematic analysis was applied to the data collected from the expert interviews, as described in Paper 5. A deductive approach was applied, since the framework and the functions of change were used as driving questions for the analysis in this case. This analysis was conducted in a similar way to the concept classification process, except that the results were visualized as a mind map before being converted to a UML meta-model and integrated with the existing version of the artifact. The results are presented in Chapter 4.

3.7.4 Change Impact Analysis

The objective of the CIA was to explore the effects of implementing the requested changes to RH and its IS. Several authors have addressed this issue, and have shown that analysis of the extent to which a software system is affected by a change can be done by measuring the number of affected functions. The approaches that can be used to determine the impact of a change, as emphasized by Kilpinen (2008), are a ‘trace and dependency’ approach, in which a model associates the functions of IT systems to organizational elements such as goals and processes, and an experiential approach, in which experts analyze

the change based on their existing tacit organizational knowledge. An experiential approach may involve informal discussions, individual judgements, change review meetings, or any combination of these.

In this research project, the second approach was selected, and the participating experts from the organizations were asked during the meetings to describe the impacts of implementing the requested changes in the organization, based on their individual judgements. The results of this analysis are presented in Chapter 4, which provides a detailed description of the case studies.

3.8 *Modeling*

This section provides information on the methodological aspect of the research activities in this project, which involved various modeling approaches and perspectives. The approaches used in this thesis were (i) meta-modeling (Papers 4, 5, 7, 8), (ii) goal modeling (Papers 2 and 6), (iii) state modeling (Paper 3), and (iv) value modeling (Paper 6).

3.8.1 Development of the modeling method

The KYKLOS method, which was developed during the artifact design and development steps of this research, is a modeling method. A modeling method consists of two main components: a modeling technique, and mechanisms and algorithms (Karagiannis & Kühn, 2002). The mechanisms and algorithms a are applied to the models, which are described by the modeling language. The modeling technique is divided into a modeling language and a modeling procedure. The modeling procedure consists of a description of the steps used to apply the modeling language to create the desired models. A graphical modeling language contains the elements used to describe a model. The language itself consists of a syntax, semantics and notation (Karagiannis et al., 2019). In this thesis, the artifacts were developed as components of the method artifact.

The syntax sets out the rules and elements used to create models. It is described by a grammar, which can be defined using two main approaches: graph grammars and meta-models. A meta-model is a model of a modelling language (Karagiannis & Kühn, 2002). The class diagrams of UML (Object Management Group, 2017) are often used to describe meta-models, and this description may be complemented by additional constraint languages such as Object Constraint Language (OCL) (Object Management Group, 2014).

The semantics of the modeling language consist of a semantic domain and semantic mapping. The meaning is described using ontologies, mathematical expressions etc. in the semantic domain, while the semantic mapping connects

the syntactical constructs with their meaning as defined in the domain. A common practice is the use of only informal textual descriptions to define semantics (Karagiannis & Kühn, 2002).

The notation describes how the language is graphically visualized. Static and dynamic approaches can be used; static approaches use graphics associated with syntactical constructs, without considering the state of the construct, whereas dynamic approaches combine a static approach for representation with a control part that queries the model and adapts the representation according to the state of the construct (Karagiannis & Kühn, 2002).

Finally, mechanisms provide the functionality to use the models that are created using the modeling language. They can be classified as generic, when they are implemented in the meta^2-model and are usable for all the meta-models; specific, when they are usable for a particular meta-model; and hybrid, when they are implemented in the meta^2-model but need to be adapted to specific meta-models (Karagiannis & Kühn, 2002).

This perspective drove the development of the KYKLOS method. The components of the KYKLOS method are described in Section 4.4 of this thesis.

3.8.2 Meta-modeling

This was applied at the artifact design and development stages. A meta-model is the part of a modeling language that describes its syntax. There are many meta-model specification techniques that result in different types of meta-models, such as slicing, referencing, generic, notation-aware, matrix or tabular meta-models. The meta-model developed in this thesis is a generic meta-model, and its role is to focus on an understanding of the structure by providing generic concepts (Bork et al., 2018). The notation of the modeling language is a component that was addressed in Papers 7 and 8, and is described in Section 4.4.3. The principles of UML (Object Management Group, 2017) were applied to create the syntax of the meta-model itself. There are various types of elements of meta-models, with the most common being (i) first class concepts, (ii) relationships, (iii) attributes, (iv) inheritance, and (v) others (Bork et al., 2020). These types were used in this research for the development of the meta-model.

Input on the semantics of the artifact was derived from the literature review and the case studies. The meta-model concepts, which have been classified according to specific change functions from Paper 1 (Koutsopoulos et al., 2019a), the set of requirements elicited in Paper 2 (Koutsopoulos et al., 2019b), the capability typology and the state diagram introduced in Paper 3 (Koutsopoulos et al., 2020c) are the three sources that have been combined in the conceptual structure of the proposed meta-model of Paper 4 (Koutsopoulos et al., 2020a). The meta-model was then expanded based on the insight gained from the expert interviews, and, when the implementation process was

initiated, it was converted to the language meta-model that was used for the development of the tool.

In addition, the set of constraints suggested by Kurpjuweit & Winter (2007) was considered during the development of the model. According to these authors: (i) the meta-model should be minimal; in other words, each element included should be motivated by the elicited information needs; (ii) the design rationale for the set of included elements should be recorded; and (iii) the semantics of each included element should be accompanied by clarification, in order to avoid any possible misunderstanding among different stakeholders.

3.8.3 Goal modeling

Definition of requirements is an activity commonly associated with the field of RE. The objective of RE is to contribute towards changing the current reality by providing a brief and precise definition of the essence of the desired change (Pohl, 2010). In other words, RE defines only the goal, rather than the way in which the goal should be met.

Several research strategies and methods can be applied to define the requirements for an artifact, such as surveys, action research, observation, interviews, case studies and document studies. In this thesis, a literature review and case studies were employed, and the requirements for the KYKLOS method were expressed as a goal model. A goal is a type of requirement artifact (Pohl, 2010), which has been defined as a desired state of affairs that needs to be attained (Sandkuhl et al., 2014), and is often decomposed into sub-goals, resulting in the formation of a goal hierarchy.

The goal models for the artifact's requirements and for the Veria Arts Center case study were developed using the "For Enterprise Modeling" (4EM) method (Sandkuhl et al., 2014). The models presented in this thesis consist only of goals, although the components of a 4EM Goals model also include problems, causes, constraints and opportunities. The software used for their development was the 4EM modeling toolkit, which was developed at the University of Rostock using the ADOxx meta-modeling platform (Fill & Karagiannis, 2013).

3.8.4 State modeling

As stated in Paper 3 (Koutsopoulos et al., 2020c), sub-goal G2a involved the examination and description of the states through which a capability goes when it changes, while incorporating several dichotomies to describe the change process. Literature sources related to the dimensions and attributes of change were identified and used to facilitate the development of a set of dimensions and their associated attributes, which were then applied to the concept of capability and expressed as states. The process of capability change was treated as a separate system for modeling purposes. Hence, the dimensions of change were depicted as a juxtaposition of opposing states in a UML

StateMachine diagram (Object Management Group, 2017). The selection of the specific notation was a result of the semantic association between change and state transitions, as used in StateMachine diagrams. Each state transition represents a change, and the model allows the inclusion not only of numerous parallel states, but also the triggering factors that initiate the state transition and change.

3.8.5 Value modeling

Value generation is one of the most important aspects of organizational analysis, and one of the critical factors affecting decision making. As a result, it is an aspect that bears significance for both the stakeholders and the organization. This fact also indicates the relationship between the concepts of value and capability, which was verified in the exploration of potential compatibility of modeling approaches performed in Paper 6.

Modeling of the valuable outcomes involved in the Veria Arts Center case required a specialized modeling approach, and the E^3value (Gordijn & Akkermans, 2018; Gordijn & Wieringa, 2021) approach was selected. This was developed for the creation of models of value networks, and the concepts included in this approach enable it to be used to model the value activities of an organization, the actors and market segments, which refer to the independent entities responsible for realizing the value activities, the value transfers, which refer to the interaction between different actors which is combined with exchanges of value in the form of services, products, information, money, etc. E^3value also includes elements for modeling bundles of value exchanges using value ports and value interfaces (Gordijn & Wieringa, 2021).

3.9 *Tool development*

Developing a modeling method has the conceptual methodological aspect which has been discussed in the previous sections. However, the fact that the method is also complemented by a tool requires a technical aspect of the methodology that involves a meta-modeling platform and development languages for the programing activities.

There are a variety of meta-modeling platforms that provide the opportunity to implement modeling methods to tools or develop stand-alone applications. Examples of existing meta-modeling platforms include the Architecture of Integrated Information Systems (ARIS) (Scheer, 2000), the Microsoft Domain-Specific Language tool (Cook et al., 2007), which is used in conjunction with Visual Studio, the MetaEdit+ tool (Kelly et al., 1996), which utilizes the Graph Object Port Property Role Relationship (GOPPRR) meta-model, the OpenPonk modeling platform (Uhnák & Pergl, 2016), the ADOxx meta-modeling platform (OMiLAB, n.d.), the Eclipse Modeling Framework (EMF),

which uses the Ecore Meta-model (Steinberg et al., 2009), the Generic Modeling Environment (GME) (Ledeczi et al., 2001), and Microsoft Visio (Biafore, 2007). Each of these approaches is based on a meta-meta-model, also known as a meta^{2}model. An extensive comparative analysis of the meta2models of the majority of the meta-modeling platforms mentioned here has been carried out by Kern et al. (2011).

The meta-modeling platform selected for the development of the KYKLOS method was the ADOxx platform (OMiLAB, n.d.), developed by the Open Models Laboratory (OMiLAB). The reasoning behind this selection lay in the fact that the ADOxx environment's core platform facilitates different levels of automation. The advantages of the ADOxx platform can be summarized as a pre-existing meta-modeling structure and functions that save significant amounts of time and effort for a developer. At a theoretical level, since the requirements of the tool are not dependent on any specific platform, an alternative such as Eclipse may seem to be equivalent, but this would overlook the value of the existing functions of ADOxx.

An additional aspect that complements the basic ADOxx platform is the external coupling functionality, which consists of various specialized development languages (OMiLAB, n.d.). The development languages that are used with ADOxx are (i) AdoScript, (ii) GraphRep, (iii) AttrRep, (iv) AQL, (v) ADL, and (vi) ALL.

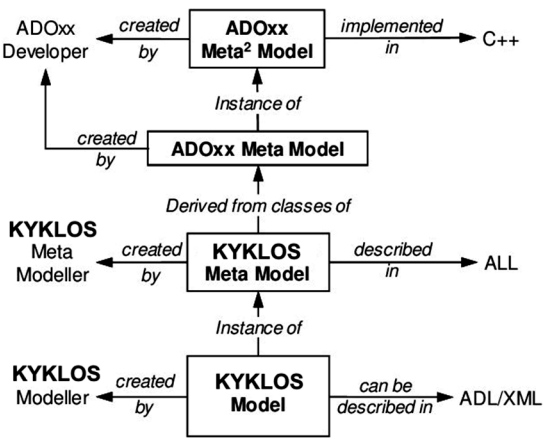


Figure 10. Modeling hierarchy of ADOxx and KYKLOS.

To develop the method, the ADOxx platform, its core functionalities and the development languages were used. ADOxx has its own two-layered meta-model (the ADOxx meta-model and the meta^{2}model), from which the KYKLOS ADOxx meta-model was derived. The user of the tool can create instances of the concepts in the KYKLOS meta-model, thereby creating a KYKLOS model. The modeling hierarchy is shown in Figure 10.

3.10 *Research quality*

The present PhD thesis is a DSR project, meaning that its quality can be assessed using DSR quality assessment approaches. A set of guidelines for conducting effective, high-quality DSR in the IS field has been proposed by Hevner and Chatterjee (2010). Table 3 summarizes these guidelines and gives brief explanations. These guidelines are discussed further in the section dealing with the contributions of this thesis (see Section 6.1.6).

Table 3. Design Science Research guidelines (Hevner & Chatterjee, 2010)

Guideline	**Description**
Design as an artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Problem relevance	The objective of design science research is to develop technology-based solutions to important, relevant business problems.
Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Communication of research	Design science research must be presented effectively to both technology-oriented and management-oriented audiences.

In addition to the overall DSR and modeling guidelines, which were applied to ensure the quality of the project as mentioned in previous sections, further guidelines for quality of the research were taken into consideration in several of the DSR steps, and were discussed in the respective papers reporting the results. In particular, for the literature review, the validity evaluation guidelines proposed by Petersen et al. (2015) were used, and the results are provided in Paper 1. The details of the validity assessment of the evaluation questionnaire are given in Paper 9.

3.11 *Ethical considerations*

There are a variety of guidelines and frameworks for ethical research in the literature, many of which, such as those by Denscombe (2011) and Myers and Venable (2014), emphasize notions such as anonymity and confidentiality. The repetition of these notions highlights their importance. Their priority over the alternatives is justified by Oliver (2010). An individual or organization may prefer to reap the benefits of a report's publicity, and may therefore prefer to have their name published rather than choosing anonymity; however, the collected data may not present a given respondent in a flattering light. This may result in the researcher coming under pressure to exclude specific pieces of information, as otherwise, the respondent may claim that the research method was flawed or problematic. In order to avoid such situations, anonymity should be ensured and considered as an advantage. This also encourages objectivity: for example, human resource management may be a weak sector in an organization, but respondents will not share genuine facts and feelings if there is any possibility of having their data traced back to them.

The importance of applying ethical principles in the writing process have also been mentioned. Examples of practices to avoid include plagiarism, improper citations, and improper co-authorship of publications. In particular, Brand et al. (2015) have introduced a taxonomy for crediting authorship called Contributor Role Taxonomy (CRediT). This includes terms that correspond to the activities performed by roles in academic work, and is in line with the Swedish authority's guidelines, called Vetenskapsrådet (2017). Table 4 summarizes these terms and their definitions.

Table 4. The CRediT terms and their definitions, from Brand et al. (2015)

Term	**Definition**
Conceptual-ization	Ideas; formulation or evolution of overarching research goals and aims
Methodology	Development or design of methodology; creation of models
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components
Validation	Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs
Formal Analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection

Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools
Data curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse
Writing—Original Draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)
Writing—Review & Editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision—including pre- or post-publication stages
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/data presentation
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team
Project Administration	Management and coordination responsibility for the research activity planning and execution
Funding Acquisition	Acquisition of the financial support for the project leading to this publication.

Finally, another concept that has been emphasized in the literature is the ecology of the research environment (Oliver, 2010), and the need to avoid threatening its stability. This is a common phenomenon; when respondents know that their daily routines will be subject to inquiry or observation, they may deviate from these routines in order to present an environment unlike the one the researcher was aiming to explore. This may be a troublesome situation, not only due to the anxiety that may be caused to the respondents but also because the validity of the collected data will be questionable, since the collected data will not reflect the actual state that the researcher intended to explore.

Hence, the research process of this PhD project was guided by the need for anonymity, confidentiality and the ecology of the research environment, along with all the other principles mentioned above.

Interviews, focus groups, and workshops were conducted at several different stages of this DSR project, in particular those dealing with requirements elicitation, artifact development, and demonstration and evaluation. All the respondents were members of decision-making bodies within the organizations involved in the case studies, or were individuals with modeling expertise.

They all explicitly consented to voluntarily participate in the project by signing the informed consent form presented in Appendix 4. Explicit clarifications about the aim and nature of this research were provided, and the participants had the right to withdraw their participation at any time. The anonymity of the respondents was ensured by not reproducing their names in any publication. Although it may have been preferable to publish their real names, this was avoided, in view of the discussion above and the desires of the participants. The documents analyzed as part of this project were classified as restricted, and hence have not been shared in this report or in any of the published papers, either included or excluded in this thesis. No vulnerable groups formed part of the sampling process, and there was no risk connected with this. It was also made clear to the respondents that there were no extra benefits from participating. The data and documents collected for analysis were stored anonymously for a given period of time, as the publication of the results in both the papers included and excluded from this thesis required a significant amount of time. No conflict of interest affected the researcher's ability to conduct the study according to ethical principles; otherwise, this would have been reported. Finally, the papers that are included in this thesis were published after being reviewed by scientific committees, and the co-authorship conditions of Vetenskapsrådet (2017) and Brand et al. (2015) were respected. A detailed report of the author's contributions to the papers included here is given in Appendix 2.

4. Summary of Contribution

This chapter provides a brief summary of the contributions made by the nine papers included in this thesis. These papers address the six sub-goals G1–G6, which were created to facilitate the development of the KYKLOS method of modeling capability change. Hence, the process fulfilled the goals of the project and the thesis, while following the suggested DSR steps for the development of the method artifact. The sections referring to Papers 2–4 have been presented previously, and are adapted from Koutsopoulos (2020). The remaining sections are adapted from Papers 1 and 5–9.

4.1 *Exploration of existing capability modeling approaches*

Paper 1 addressed sub-goal G1, which was *to explore the existing capability modeling approaches using their meta-models and*

a. To provide an overview of the concepts used in capability meta-modeling,
b. To explore how these concepts are related to change.
c. To elicit directions for improving the modeling of capability change.

An overview of these concepts is presented in Figure 11, in the form of concept maps with different levels of abstraction. A concept map depicts several attributes of the relationships between concepts. The sizes of the circular nodes and the labels represent the number of occurrences in all meta-models, the distance between nodes depicts their relatedness, and the thickness of the lines reflects the frequency of co-occurrence in the meta-models, known as the link strength. The colors indicate the results of node clustering, which is performed automatically by the tool (van Eck & Waltman, 2010). A description of concept mapping is provided in Paper 1, which addresses sub-goal G1a.

In order to address sub-goal G1b, the most popular concepts included in the meta-models were identified and classified. This enabled a connection to be established between the existing capability meta-models and the phenomenon of capability change, resulting in a pool of change-related concepts that were taken into consideration during the development of the initial meta-model introduced in this thesis.

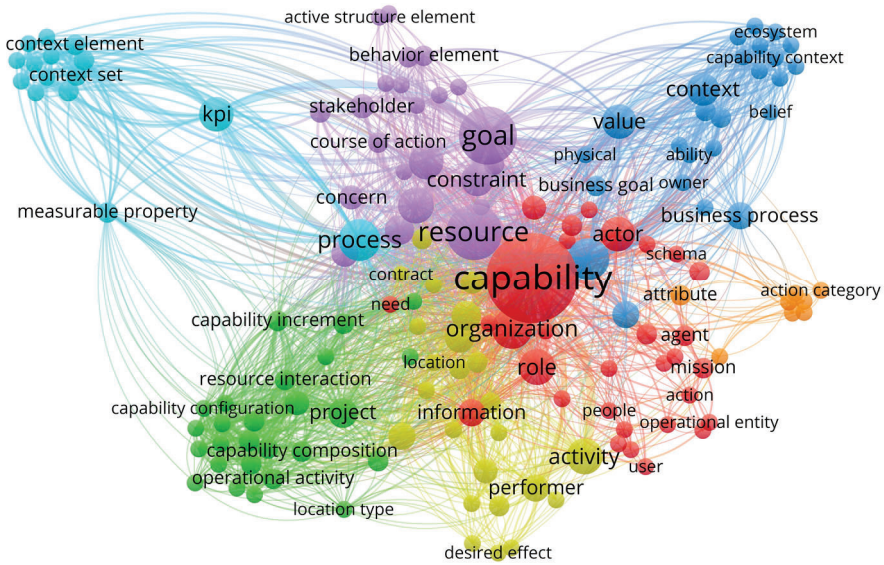


Figure 11. Concept map of the identified capability meta-model elements (Paper 1).

These concepts were visualized as three concept maps, each of which was associated with a specific change function, as shown in the observation-specific map in Figure 12.

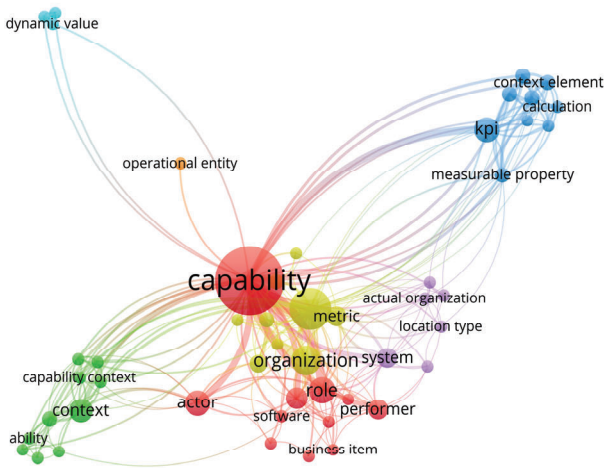


Figure 12. The observation-specific concept map.

In addition, the collected set of capability meta-models was subjected to analyses from different perspectives. The meta-models were first analyzed according to the context that influenced their development according to the developers' stated purpose. The outcome, either implicit or explicit, was classified according to the static and/or dynamic context of the meta-model. Several

statistical analyses were also applied, which used specific attributes of the meta-models, for example, their scope, which was classified as business, IT, or a combination of these; the year of publication of the meta-model; the number of concepts included; and the number of change-related concepts per specific function. Paper 1 presents the results of these statistical analyses, the corresponding graphs, and their explanations.

To address sub-goal G1c, suggestions for modeling were discussed, in particular: (i) the alignment of modeling approaches; (ii) the reduction of the level of abstraction of change-related elements; (iii) the addition of concepts that were implied but missing; and (iv) the identification of other missing but useful concepts. A detailed elaboration of the findings is presented in Paper 1.

4.2 *Method requirements*

Paper 2 addressed sub-goal G2, which was *to elicit requirements for the method under development*, which included:

a. *To investigate, describe and conceptualize the states through which a capability goes when it changes, including the change process itself.*

A set of main goals for the artifact was identified from the existing literature. The goals were structured around the three functionalities of change, i.e., observation, decision and delivery. This means that they were also structured in accordance with the operational refinement of the goal of this thesis. Table 5 summarizes the goals for the KYKLOS capability change modeling method that were elicited from the literature review. A detailed description is provided in Paper 2 (Koutsopoulos et al., 2019b).

Table 5. Goals elicited from the literature review (adapted from Koutsopoulos et al., 2019).

Goals elicited from the literature review	
• To manage capability change	• To manage capability architecture
• To observe business context	• To observe external business context
• To support decision on capability change	• To observe internal business context
• To manage capability delivery	• To measure relevant properties
• To identify decision criteria	• To establish KPIs
• To identify capability alternatives	• To manage introduction of a new capability
• To analyze observed context data	• To manage retirement of existing capability

- To ensure that decision complies with intentions
- To elicit internal and external business context
- To manage transition delivery
- To manage modification of existing capability
- To manage capability configuration
- To allocate resources to capability

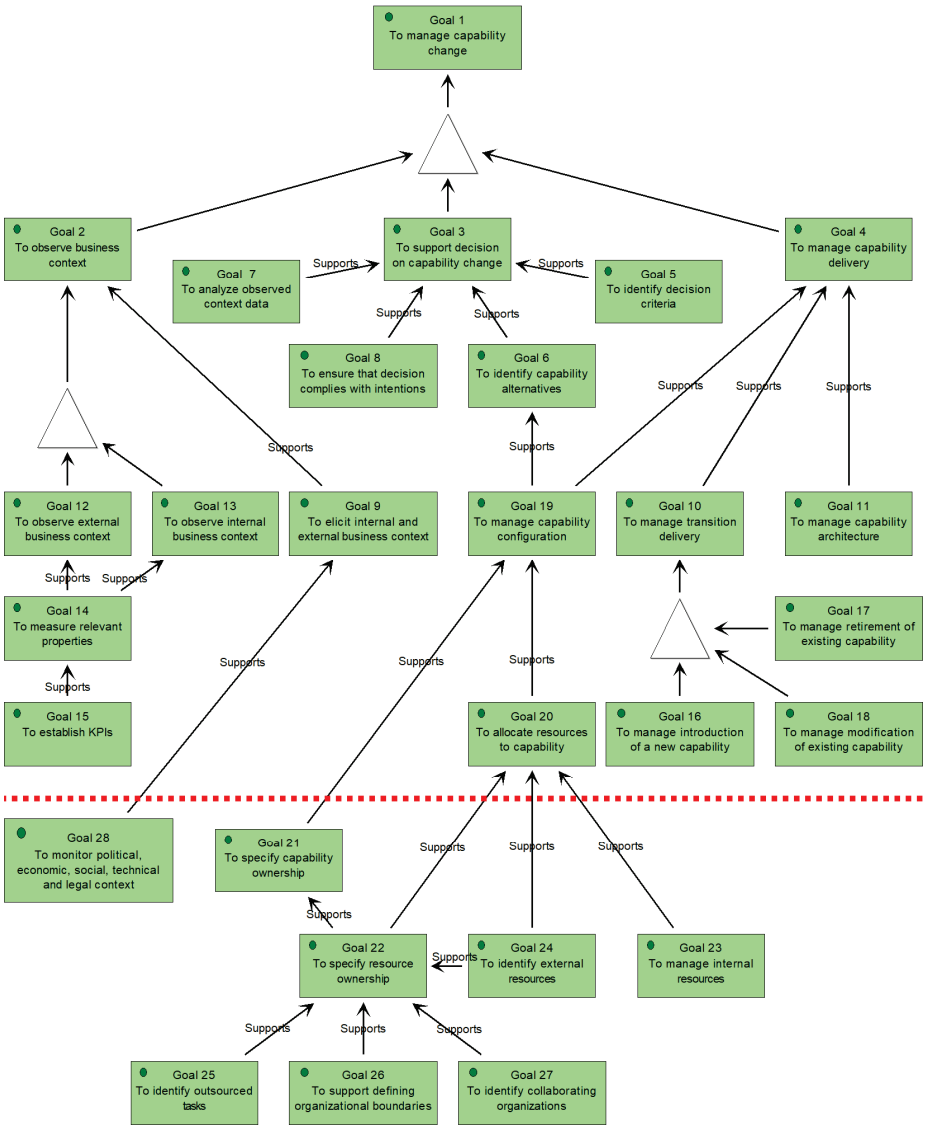


Figure 13. The 4EM Goals model for capability change (Paper 2).

In addition to the goals elicited from the literature review, a complementary set of goals was defined using the 1177 capability. A summary of the goals

elicited from the RH case study are shown in Table 6, and a detailed explanation of their sources and definitions is given in Paper 2. The requirements for business capability change are expressed in the form of a goal model using the 4EM notation (Sandkuhl et al., 2014) in Figure 13, which depicts the Goals model that integrates goals elicited from both sources. An explanation of the model and the relationships between goals is provided in Paper 2.

Table 6. Goals elicited from the case study (adapted from Koutsopoulos et al., 2019b).

Goals elicited from the case study	
• To specify capability ownership	• To identify outsourced tasks
• To specify resource ownership	• To support defining organizational boundaries
• To manage internal resources	• To identify external resources
• To identify collaborating organizations	• To monitor political, economic, social, technological and legal context

4.2.1 States of changing capabilities

Paper 3 addressed sub-goal G2a. Initially, the states of a capability and the states of change were explored, which resulted in two sets of dimensions. These were combined and visualized in the form of a UML StateMachine diagram. A brief summary follows.

4.2.1.1 Dimensions of capabilities

The primary dichotomies of capabilities, as derived from the existing literature and personal reflection, are listed below. A detailed explanation is provided in Paper 3 (Koutsopoulos et al., 2020c).

- Ownership: Single organization vs. inter-organizational
- Purpose: Fulfilling goal vs. avoiding problem
- Potentiality: Enabled vs. disabled

A consideration of the last two of these dichotomies resulted in the introduction of a new capability typology, as shown in Table 7.

Table 7. The initial capability classification (Paper 3).

	Achieve Goal	Avoid Problem
Enabled (Advantages)	Capability	Sustainability
Disabled (Disadvantages)	Incapability	Anti-capability

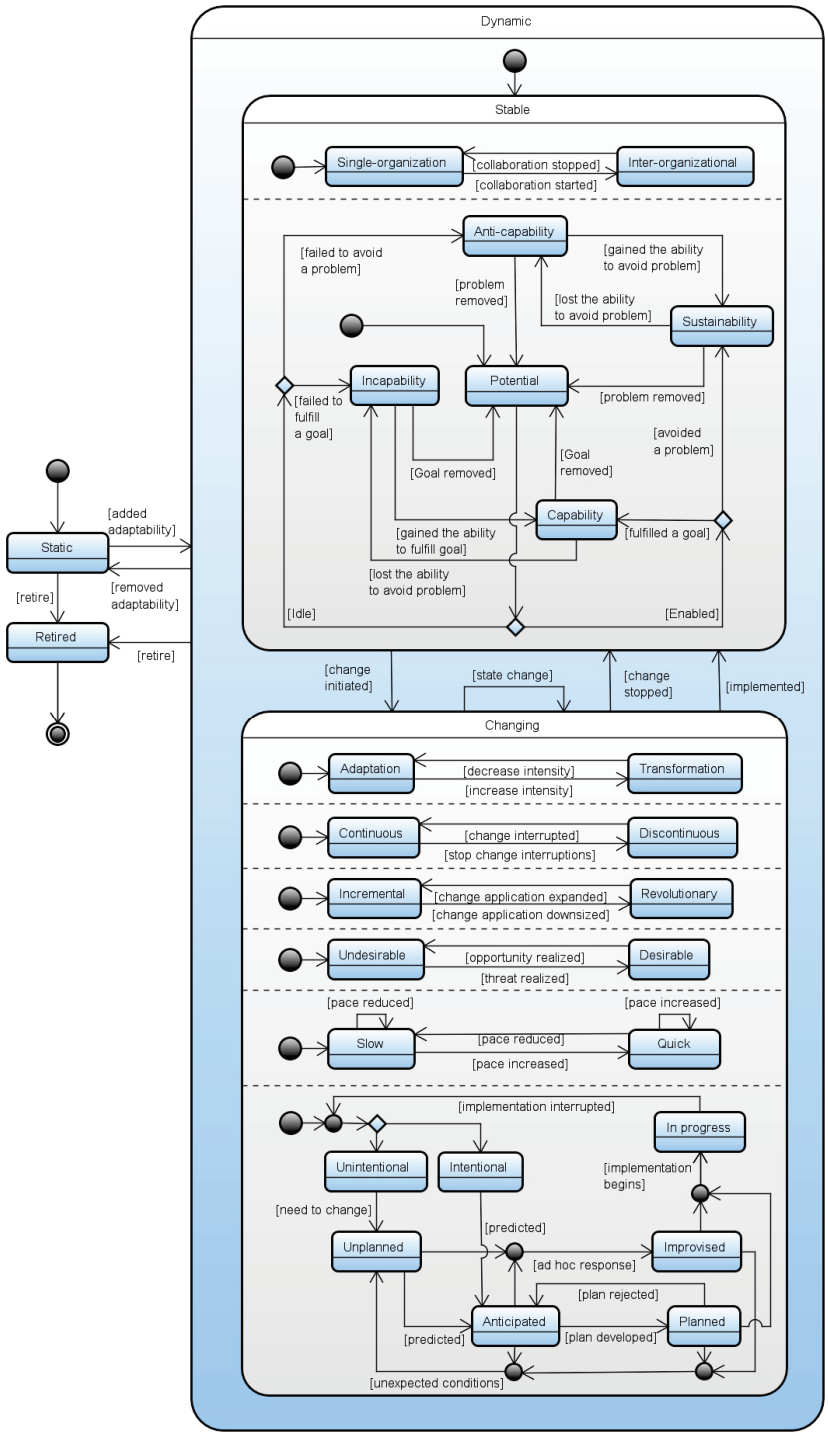


Figure 14. The capability and change typology visualized as a StateMachine diagram (Koutsopoulos et al., 2020c).

4.2.1.2 Dimensions of change

A multitude of aspects need to be considered in order to address the phenomenon of change (Iveroth & Hallencreutz, 2016). The existing literature was reviewed by Maes and van Hootegem, (2011) and the result was a homogenous set of eight dimensions describing change in a dynamic way. Most of these have been included in the suggested typology. The set presented by Maes and van Hootegem (2011) consists of the following dimensions: (i) control, (ii) scope, (iii) frequency, (iv) stride, and (v) tempo (which were included in the diagram) and (vi) time, (vii) goal, and (viii) style (which were not included). A detailed description of these dimensions is provided in Paper 3.

4.2.1.3 A StateMachine diagram for capability and change

The typology of capability change is visualized in Figure 14 as a UML StateMachine diagram. A detailed explanation of the diagram is provided in Paper 3.

4.3 *Method foundation*

This part of the research concerns sub-goal G3, which was *to establish a foundation for developing a method of modeling capability change,* which includes the following sub-goals:

a. *To develop a meta-model for capability change.*
b. *To explore expert knowledge on the phenomenon of capability change, in order:*
    - *To evaluate the meta-model's concepts,*
    - *To improve the meta-model by enriching it with expert knowledge.*
c. *To explore the semantic consistency between the concepts used in this method and those of other modeling methods, as a way to identify candidate components for the method.*

4.3.1 The meta-model for capability change

In Paper 4, a meta-model of capability change was proposed to address sub-goal G3a, which was *to develop a meta-model for capability change*. The meta-model and an illustrative example of its use were presented and explained in detail in Paper 4.

The meta-model is presented in Figure 15 as a UML class diagram that includes all the relevant concepts. As can be seen, a central part is the three change functions of observation, decision, and delivery.

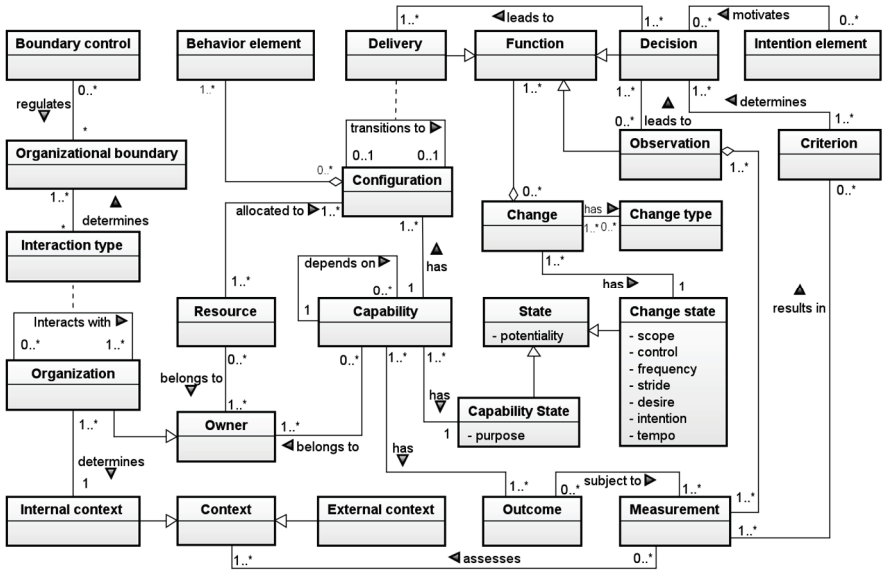


Figure 15. The capability change meta-model (Koutsopoulos et al., 2020a)

The components of the meta-model address the information needs elicited as goals for capability change in Paper 2, and the capability and change states in Paper 3. The elements of the meta-model and the goals they address are discussed in Paper 4.

1. Capability
2. Context
3. Internal context
4. External context
5. Resource
6. Outcome
7. Organization
8. Owner
9. Interaction type
10. Organizational boundary
11. Boundary control
12. Configuration
13. Change
14. Change type
15. Function
16. Observation
17. Measurement
18. Decision
19. Intention element
20. Criterion
21. Delivery
22. Behavior element
23. State
24. Capability state
25. Change state

The RH case was modeled as an instance of the meta-model, and the result was an object diagram, which is presented in Appendix 6 in a high-resolution format. An explanation of the object diagram can be found in Paper 4.

4.3.2 Evaluation of the meta-model's concepts

Goal G3b was addressed in Paper 5, which involved an ex ante evaluation of the initial meta-model by experts. The concepts were subjected to evaluation via a Likert-scale question for each concept in the meta-model; the exceptions were the concepts of capability, change, context, state and change

function, as the first two are highly relevant by definition, and the last three are super-classes that are represented in the questions by their subclasses. The questions addressed the relevance of the concept to capability change according to the experts' understanding of the phenomenon. Predefined responses from "Highly irrelevant" to "Highly relevant" were offered, with numerical values of one to five, respectively.

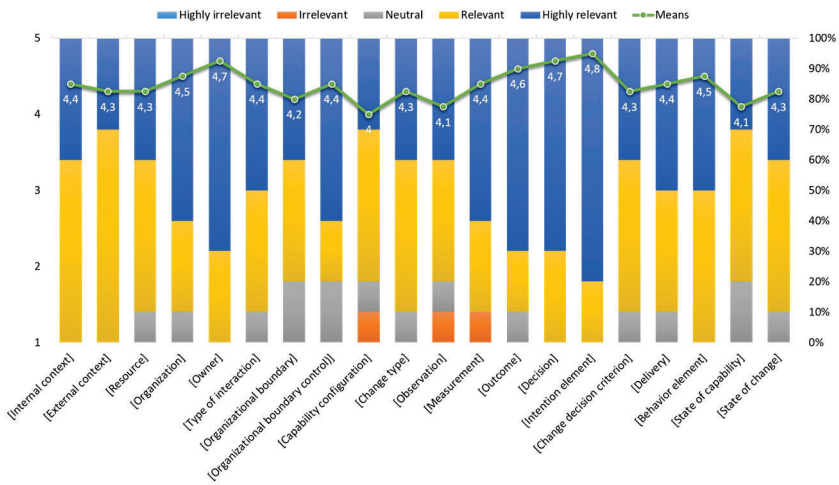


Figure 16. The results per meta-model concept, from Koutsopoulos et al., (2020b).

An overall view of the results indicates that all of the concepts were relevant or highly relevant to the phenomenon of capability change. The highest-ranking concept in the meta-model was the intention element, and the lowest was capability configuration. Figure 16 depicts the results for each concept and the distribution of the responses.

The interviews provided interesting insights into the phenomenon of capability change, and gave rise to some significant concepts and associations that could be added to the meta-model. A brief summary of the interviews is given below.

In regard to capability change overall, we found that there was a widely diverse understanding of the core concepts involved, and an evenly divided view on whether or not a capability should be considered a resource, although the majority of the experts believed that a capability consisted of resources. The results also indicated that this was a commonly encountered phenomenon, with modification of an existing capability being the most common type. Capability could be both a positive and negative concept, and several tools and methods were used for managing capabilities.

The discussion of the specific functions of change revolved around the responsibility, initiation, transition, communication of, and challenges associ-

ated with each function. Specific aspects were also discussed for every function, for example identifying a need to change, criteria for deciding to change, and monitoring the impact of a change, which were associated with observation, decision and delivery, respectively. A detailed elaboration of the interview findings is provided in Paper 5.

4.3.3 Extension of the meta-model

The findings of Paper 5 were converted to a meta-model fragment that depicted all the concepts and associations that needed to be implemented in the initial meta-model in order to extend it. The extension was converted into a UML class diagram, which was presented in Paper 5. The suggested extension was then integrated with the initial meta-model and published in Paper 6. The results of its implementation are shown in Figure 17. The details of the meta-model (for example the fact that a capability object can be associated with multiple configurations, while a configuration object can be associated with only one capability) result from the fact that a configuration is meant to be a 'recipe' for a specific capability. More details are provided in the respective papers.

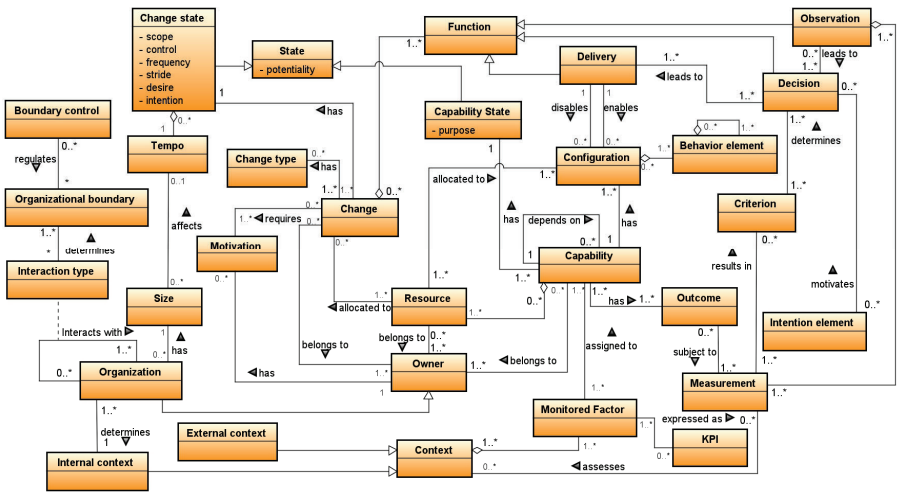


Figure 17. The extended meta-model of capability change.

4.3.4 Exploration of candidate method components

In addition to introducing the updated meta-model, Paper 6 addressed subgoal G3c. In order to explore the semantic consistency between the KYKLOS method and other existing modeling methods, the Veria Arts Center case was considered using three modeling approaches. Initially, a 4EM Goals model

(Sandkuhl et al., 2014) was developed with the aim of capturing the organization's goals and the desired state of the capability at a given time. The next was an E^{3}value (Gordijn & Akkermans, 2018) model, which aimed to capture all the value transitions that were associated with the capability changes that were associated with the case. The E^{3}value and 4EM Goals models were published in Paper 6. The E^{3}value model was used to capture the value transactions of the organization (in other words, how it interacts with its stakeholders and how it produces value for them), which enabled an improved understanding of the business. The 4EM Goals model provided not only documentation of the 'new normal' configuration of the festival organization capability, but also a decomposition and analysis of the requirements for the desired state of the capability.

After applying the 4EM and E^{3}value models, the described changes were captured using an instantiated fragment of the meta-model. This showed that there were objects in the model that also existed in the models created with other methods, which resulted in an examination of these sets of matching objects for semantic consistency, using their definitions. The semantic consistencies identified through this process are shown in Table 8. More detailed descriptions of the models and the process can be found in Paper 6.

Table 8. Consistency between the concepts of three models.

Capability change model	**E^{3}value model**	**4EM Goals model**
Behavior element	Value activity	-
Outcome	Value transfer	-
Collaborating organization	Actor/Market segment	-
Intention element	-	Goal

4.4 *Method and tool development*

As discussed in previous sections, a modeling method consists of a modeling language and a modeling procedure. In turn, a modeling language consists of a syntax, semantics and notation. This section describes the development of all the required method elements, along with the tool that complements the method.

Implementing KYKLOS in the form of a tool was an essential step of the project. Although the method can be applied without the tool, this does not reduce the value of the tool: using the tool as a means of facilitating the application of the method produces significant value for the KYKLOS user. The

reason for this is that several important parts of the method, such as the graphical notation and algorithms, are provided by the tool and would require a lot of time and effort to apply manually.

The focus of Paper 7 and 8 was on addressing sub-goal 4, which was *to develop the method and a complementary supporting tool,* and which included the following sub-goals:

a. To provide modeling guidelines;
b. To develop a language meta-model;
c. To implement the method in a tool.

4.4.1 Method syntax via meta-model transformations

The initial meta-model resulted in complex and cluttered models, meaning that its use as a language model was not an efficient solution. For this reason, it needed to be transformed by applying different types of conversions. These involved (i) converting classes to attributes; (ii) converting classes to association classes; and (iii) reserving classes to be converted to tool functionalities.

The process was also facilitated by removing existing classes and introducing new classes in accordance with the meta-modeling platform and the method requirements. The result of this transformation process was the language meta-model (Figure 18), which is color-coded, with the remaining classes shown in orange, the converted classes in purple and the introduced classes in green.

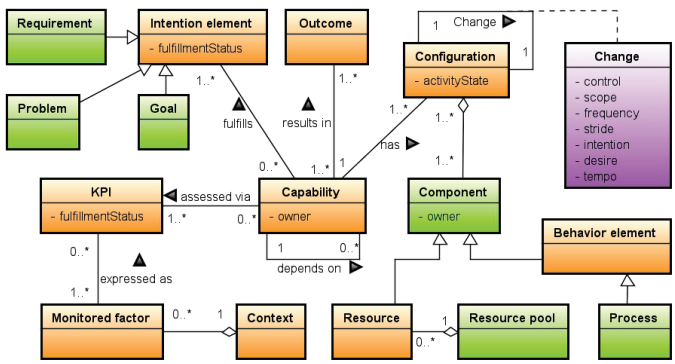


Figure 18. The language meta-model (Paper 7).

For additional details and explanations of the meta-model transformation, see Paper 7.

4.4.2 Method semantics

The semantics of the method are presented in Table 9, which shows the complete set of the concepts used in the method and their definitions.

Table 9. The complete set of language concepts (Paper 7).

Concept	Description
Capability	A capability is a potential to produce outcome(s) to fulfill an organization's intention(s) within a context, using a configured set of resources and behaviors.
Configuration	The set of resources that are used by the capability along with the behavior elements that deliver it. A capability may have several different configurations but only one may be active at any given moment in time.
Resource	Any human, infrastructure, knowledge, equipment, financial or reputation asset that can be used by an organization to enable the capability's realization. It can be allocated to one or more capability configurations, based on its capacity.
Resource pool	The complete set of an organization's available resources.
Context	All the factors that form the setting in which a capability exists, are relevant to its performance and within which the capability is perceived.
Outcome	The result of the capability's realization. Comparing it to KPIs and Intention elements can provide insight on whether a capability change is necessary or not.
KPI	A preset measurable value that expresses an important aspect of the context that a capability depends on to reach the desired outcome. Used to assess the efficiency of the capability's realization when compared with outcome values.
Monitored Factor	A context factor that has been identified and associated to a capability's performance and is being observed in relation to the capability. It is usually expressed as a KPI.
Intention element	An abstract element that includes all the concepts that refer to the intentions governing the capability, for example, goals, problems or requirements.
Goal	A desirable state that an organization aims to achieve. It is a type of Intention element.
Problem	An undesirable condition that an organization aims to avoid or tackle. It is a type of Intention element.
Requirement	A necessary state that an organization has to fulfill. It is a type of Intention element.
Behavior element	An abstract element that describes a structured set of activities whose execution delivers the outcomes of the capability, for example, a process, service, activity or task.

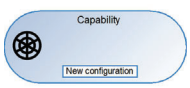
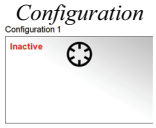
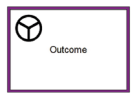
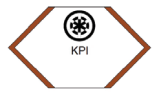
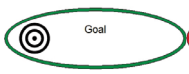
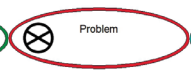
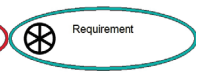
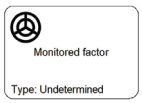
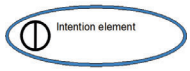
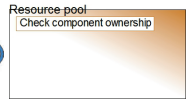
Process	A behavior element that consists of activities aiming to fulfill a certain goal.
Change	Change represents the transition from one configuration to another. It can be described using several change properties (see section 4.2.1 and Fig.14). A capability change is finalized when a configuration's activity state is modified.

4.4.3 Method notation

The notation for the method was developed as shown in Table 10.

Both a primary and a secondary notation were developed for KYKLOS. More details and explanations are provided in Paper 7.

Table 10. The secondary notation of KYKLOS (Paper 7).

Capability	*Configuration*	*Resource*	*Outcome*	*KPI*
				
Goal	*Problem*	*Requirement*	*Process*	*Change*
				
Monitored Factor	*Intention element*	*Resource pool*	*Context*	*Behavior element*
				N/A

4.4.4 Modeling guidelines

Sub-goal G4a required the development of guidelines for the phases and steps involved in the application of the method, in the form of the main actions performed and the modeling elements used during each phase.

The three change functions that made up the capability change framework were used as phases of the modeling procedure, with the addition of an initial foundation phase in which the capability to be modeled is identified. A brief overview of these modeling guidelines is shown in Table 11, and a more detailed description of the modeling procedure is provided in Paper 8.

Table 11. Modeling procedure of KYKLOS (Paper 8).

Phase	Main actions
Foundation (of analysis)	Describe the basis for the analysis in terms of an identified capability.
Observation (of context and intentions)	Analyze the internal and external context in which the capability must function. Identify needs for change.
Decision (among alternatives)	Analyze the alternatives for capability configurations that address the need for change, including the needed resources and behavior.
Delivery (of change)	Understand what needs to be done in order to deliver the change in the form of a transition from current to a future capability configuration.

The modeling procedure is iterative, which means that the end of the delivery phase may trigger changes in the outcome of the capability; this, in turn, may trigger a new foundation phase and a new modeling iteration, if this is within the scope of the modeling task. The KYKLOS procedure and guidelines are presented in detail in Appendix 7.

4.4.5 Tool development

The implementation of the method in the form of a tool was performed using the ADOxx meta-modeling platform. This resulted in a series of functionalities that combined the pre-existing functionalities with additional coding using the AdoScript language.

The main user interface of the tool is shown in Figure 19. The main modeling area is illustrated with an example model, which depicts the objects and their connections, and the Modeling Toolkit is shown with all the options for creating instances of the language's classes and associations.

The meta-modeling platform, combined with the AdoScript code, provided the opportunity to develop a series of functionalities to enhance the tool with dynamic and automated aspects. These functionalities were (i) *new configuration*, (ii) *containment*, (iii) *configuration activation*, (iv) *component ownership*, (v) *prevention of loose components*, (vi) *change attributes* (derived from Figure 14), (vii) *decision motivation*, and (viii) *relationship grouping.*

A more detailed explanation and a visual depiction of the included functionalities are provided in Paper 7.

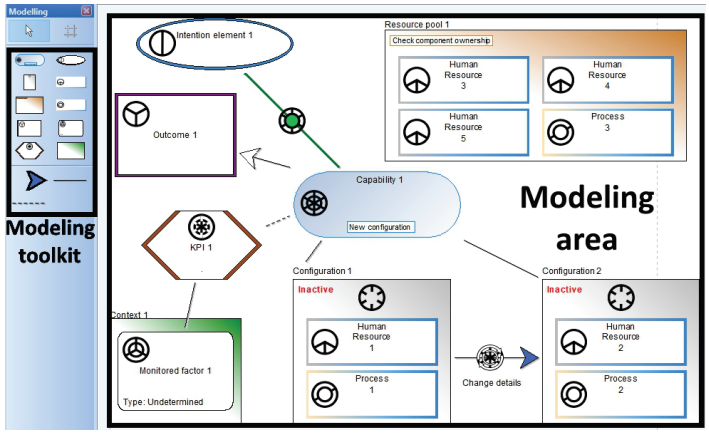


Figure 19. The main areas of the KYKLOS tool (Paper 8).

4.5 *Method demonstration*

Papers 8 and 9 focused on addressing sub-goal 5, which was *to demonstrate the method.*

This section demonstrates the method through its application to two case studies of real organizations, the Veria Arts Center and the DI cases. The procedures and results are described in the following sub-sections.

4.5.1 The Veria Arts Center Case

This case study was presented in Paper 8, and a detailed explanation was provided. In this thesis, a brief summary of the results is given for each phase of the modeling procedure.

4.5.1.1 Phase 0: Foundation

The Art Festival Organization capability and its outcomes were documented.

4.5.1.2 Phase 1: Observation

In this phase, the context, its contained monitored factors and associated KPIs, the intention elements, and the fulfillment status of all these relevant factors were modeled, as shown in the model fragment in Figure 20.

4.5.1.3 Phase 2: Decision alternatives

This phase involved capturing the configurations of the capability and the allocated resources, including the association of the capability with its normal configuration and the components of the configuration allocated to it.

4.5.1.4 Phase 3: Delivery of change

In this phase, the transitions between the configurations were captured, including the transitions from normal to lean, from lean to digital, and from digital to new normal. This also involved capturing all the attributes of each change case (see Section 4.2.1).

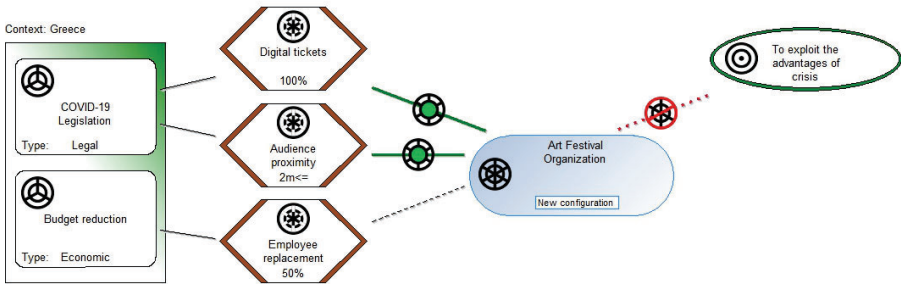


Figure 20. Context and intention elements in the Veria Arts Center case (Paper 8).

4.5.1.5 The Veria Arts Center model.

When all the phases of KYKLOS had been carried out, the model was complete. The entire model was large and complex, and for improved visibility and comprehensibility, it is presented in Appendix 6 (Figure: Veria Arts Center model).

4.5.2 The Digital Intelligence case

The case was reported in detail in Paper 9, and was used for both the demonstration and evaluation of the method. This section presents a brief summary of the case study in terms of the developed model, the application of the modeling procedure of the KYKLOS method, and the opportunities that emerged during the modeling process that drove the analysis towards specific suggestions for improvement.

4.5.2.1 Phase 0: Foundation

In this phase, all the capabilities that were relevant to the given change initiative were identified, and the value produced during their realization was captured as outcomes of the capabilities. The main capability was ERP sales.

4.5.2.2 Phase 1: Observation

This phase focused on capturing the context, monitored factors, KPIs, and special or generic intention elements that were associated with each capability and relevant to the given change. The KPIs and intention elements were associated with the capabilities, and their fulfillment status was captured. Each

unfulfilled intention or KPI was an identified motivator for change, such as the goal *to gain insight into the customers' needs*.

4.5.2.3 Phase 2: Decision alternatives

The existing, potential and desired configurations of the most relevant capabilities were explored and captured in this phase, together with the components required for activating each configuration. DI's existing resources were also documented and allocated to their respective configurations, along with the missing components. The introduction of a new capability was identified as a way to provide the missing components, and reallocation of the existing resources was the only activity required. A new goal was established in relation to the new capability, with its own new captured configuration elements and the transition to its active configuration.

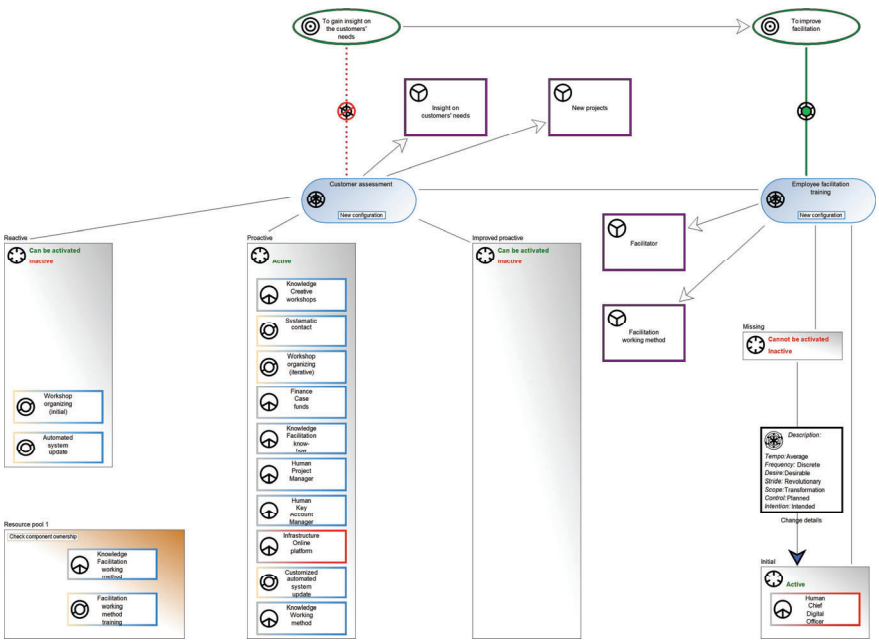


Figure 21. Model fragment depicting the integration of a new capability, the Employee facilitation training.

Integration of the new capability into the model showed that it produced the outcomes that were required, which could be used as components for configurations that could not be activated previously due to missing components, such as the 'improve proactive' configuration (Figure 21).

The desired improved proactive configuration of ERP sales will gradually reach the state 'Can be activated', indicating that the organization can perform the change, as shown by modeling and analyzing the case with KYKLOS.

4.5.2.4 Phase 3: Delivery of change

The last phase involved capturing all the remaining transitions between configurations and documenting the attributes of each change (see Section 4.2.1). The model was then finalized. Due to the size and complexity of the model, it is presented in full in Appendix 6 (Figure: Digital Intelligence model).

4.6 *Method evaluation*

The evaluation of the method fulfilled sub-goal G6, which was *to evaluate the method*. This was reported in detail in Paper 9, and this section presents only a brief overview. Likert-scale items, in the form of statements about the method, were presented to two groups of evaluators. Based on the initial documentation of the method's stakeholders, the two groups of evaluators consisted of business experts and modeling experts. A detailed report on the participants and their roles was provided in Section 3.5.6 of this thesis. Additional information about the evaluation was also provided in Section 3.3.5. The results were grouped per evaluation aspect, per stakeholder group, and overall. The scores were based on an assignment of the values 1–5 to the responses "Strongly disagree" to "Strongly agree", respectively. The results are also presented in the form of a diagram in Paper 9.

4.6.1 Perceived Ease of Use

The questions about the clarity of the phases and procedure of the method and its overall ease of use elicited negative scores from the business group and positive scores for the group of modeling experts, resulting in an overall positive score from the entire team of evaluators.

4.6.2 Actual efficiency

This aspect was used to evaluate the effort required to use KYKLOS, as compared with other methods for addressing the problem known to each evaluator, and the respective effort required. The results from the business group and the modeling experts were positive, both at the group level and as a whole.

4.6.3 Actual effectiveness

To evaluate the actual effectiveness of KYKLOS, the participants were asked how useful they found the method in terms of modeling the specific areas derived from the initially elicited requirements of (i) context, (ii) intentions, (iii) decision-making, (iv) configuration components, (v) transitions, (vi) ownership, and (vii) capability dependencies.

The scores obtained from the business group ranged from neutral to positive, whereas those of the modeling experts were positive. The overall combined scores from the entire group of evaluators represented a positive response to the effectiveness of KYKLOS.

4.6.4 Perceived Usefulness

This aspect was evaluated by checking whether the concept set of KYKLOS was adequate and also whether the method as a whole was useful for the specific domain. The results from the business group varied from negative to positive, and the scores from the modeling experts were positive. The combined results from the two groups were positive, both for the overall usefulness and the concept set. The results show a clearly positive response regarding the perceived usefulness of KYKLOS.

4.6.5 Intention to use

The intention to use KYKLOS was evaluated by asking about the overall intention to use it and the preference for using it over other methods for the given domain. These questions received negative responses from the business group, whereas the expert modelers gave positive responses. The results for the group of evaluators as a whole were neutral for both questions.

4.6.6 Overall

The assignment of weights to the responses according to the five-point scale enabled the highest and lowest scores of the evaluation aspects to be identified. The highest rated aspect was the usefulness of KYKLOS for modeling the configuration components, while the aspects of intent and preference to use KYKLOS shared the lowest position in the list. The scores from the business group ranged between −9 and 8, whereas those of the group of modeling experts were between 8 and 18. These results were also supported by the means of the scores, which indicated the differences not only between the groups, but also between the different aspects of KYKLOS. In particular, the effectiveness of KYKLOS received the highest scores, with the configuration components receiving the highest score overall; the intention to use KYKLOS received the lowest score overall, with intention and preference to use KYKLOS sharing the lowest score. The means represent the differences between the groups. The results for all the valid questions showed significant differences between the two groups in each case.

5. Discussion, Conclusions and Future Work

This chapter discusses the contribution of this PhD thesis in terms of fulfilment of the research goals, and presents some insights derived both from the results and the research process itself. It also provides concluding remarks, alongside a discussion of the limitations of the thesis, its ethical implications, and suggestions for future work.

5.1 *Discussion of the contribution*

In this section, the goals and sub-goals of the thesis are discussed in terms of their fulfillment. Parts of the discussion that refer to Papers 1–4 were previously published in (Koutsopoulos, 2020).

5.1.1 Sub-goal G1

Sub-goal G1, which was *to explore the existing capability modeling approaches using their meta-models, and (a) to provide an overview of the concepts used in capability meta-modeling, (b) to explore how these concepts are related to change, and (c) to elicit directions for improving the modeling of capability change,* was addressed in Paper 1, and this section contains text adapted from that paper.

The majority of capability meta-models were included in the review conducted in Paper 1. The analysis was conducted at a concept level, to facilitate classification according to the developed framework. A summary of the contributions of this paper was presented in Section 4.1 of this thesis. The main contributions are not limited to the overview and visualization of the concepts in the form of maps and the classification of these concepts, but also involve the framework itself (see Section 2.3.3), which drove the design of the goal model in Paper 2 (see Section 4.2), the meta-model in Papers 4, 5 and 7 (see Sections 4.3.1, 4.3.3, and 4.4.1, respectively), and the modeling procedure in Paper 8 (see Section 4.4.4). The generic and the change-specific concept maps, in combination with the statistical and context development analysis, enabled the diversity of the existing capability meta-models in the literature to be identified and reported from several perspectives. In particular, the areas of diversity that were identified were:

- Diversity in terms of scope and number of concepts;
- Diversity in terms of change function inclusion;
- Diversity in terms of domain-specific concepts;
- Diversity in terms of concept semantics.

More details of these areas of diversity are provided in Paper 1. The identification and classification of the most popular elements resulted in suggestions for specific modeling practices, one of which was to evolve capability modeling for change by aligning the examined meta-models. The initial idea behind the development of a meta-model could be a composition of all the examined meta-models; however, assuming that what is true for the parts is also true for the whole is a logical fallacy (Sinnott-Armstrong & Fogelin, 2015). This means that a composition does not possess the characteristics of its parts. This is useful for avoiding problematic generalizations, for example those associated with the attempt to design a "mega-model" (Barbero et al., 2008), that is, a model whose elements are other models. Hence, instead of focusing on such compositions, this research contributed by identifying and classifying concepts related to capability change extracted from the existing approaches, which facilitated the alignment of meta-models. This task has been suggested previously (Zdravkovic et al., 2017), and the results of Paper 1 indicate the existence of a solid core of change-related concepts, which make the task feasible.

Another suggestion was to reduce the level of abstraction in existing concepts. There were concepts in the meta-models whose relevance to capability change could be considered high, although their abstract nature may require a decomposition based on their associations with capability and/or change. An example is the concept of a gap (Mikloš, 2012; The Open Group, 2018). Identifying the concepts relevant to these useful abstract concepts is a suggested activity, and Paper 1 contributes by identifying these abstract concepts; however, to ensure that no essential information is missing, they need to be decomposed and their relations to the less abstract concepts need to be clarified.

The remaining suggestions concerned the identification and inclusion of implied and missing concepts, which were commonly encountered in the examined meta-models. Certain concepts are latent (Saldaña, 2009), meaning that they are not included in a meta-model, but are implied through other concepts or their associations, such as "capability meets goal" where measurement is implied. In addition, there are concepts that can facilitate the capture of capability change in a meta-model that were omitted from all of the meta-models. This suggestion gave rise to the later steps of the research by identifying essential concepts related to change, such as the 'state' and its attributes, which were explored in Paper 3 and integrated in Paper 4.

Finally, a further aspect that needs to be discussed is that not every capability meta-model includes a means of addressing change in detail, although

this is not a deficiency. Certain domains require domain-specific approaches and their respective concept sets to address the identified needs. In any case, change is becoming the new constant in organizations, and this needs to be addressed by any method aiming to support change.

5.1.2 Sub-goal G2

Sub-goal G2*,* which was *to elicit requirements for the method under development,* and included the sub-goal *(a) to investigate, describe and conceptualize the states through which a capability goes when it changes, including the process of change,* was addressed in Papers 2 and 3. A summary of the results was presented in Section 4.2 of this thesis.

The set of requirements, which forms an essential part of the method's development, was elicited by combining a literature review with a case study. This section is adapted from Paper 2.

The literature review and the case study resulted in highly consistent and complementary requirements. Although the requirements from the case study may seem like a limited set, most of the requirements from the literature review were included in the case study set but were omitted from the second set because they overlapped. One example is the generic goal of observing the business context, which formed part of the literature review set. Identifying the need to observe political, social, technological and any other specific type of context in the case does not simply imply the existence of the generic goal, it is a specialization of it. The generic goal and all the more generic goals it supports are implied; thus, the overlap is clear.

The two requested changes in the RH case that were selected for analysis (see Section 3.4.1) concerned two types of capability change. The modeling and analysis of these cases provided valuable insight for the development of the method, as described in detail in Paper 2.

In summary, in addition to the definition of a set of goals for the KYKLOS method, the contributions of Paper 2 include the essential concepts and their associations which were implemented in the meta-model, such as the attributes of inter-organizational capabilities and their associated concepts.

With regard to sub-goal G2a, the dichotomies that were investigated and modeled provided a structured set of additional requirements for the meta-model, which were derived from the nature of changing capabilities. The section that follows is adapted from Paper 3.

The use of dichotomies for the development of the typology does not imply that the attributes are exclusive extremes; on the contrary, each dichotomy represents a spectrum of states. From the low-level dichotomies of capability change to the highest level of continuity and change, an organization should aim to embrace duality thinking, in which the merits of both sides are recog-

nized (Graetz & Smith, 2008) on different occasions and under different circumstances. The concept of negative aspect of capabilities is missing from capability thinking, and this thesis has addressed this gap.

The main contribution of Paper 3 is the conceptualization of the negative aspect of capabilities and its combination with the dimensions of change (see Section 4.2.1), to which no research effort has previously been devoted. Conceptualizing the absence and the negative aspect of a capability provides the opportunity to identify missing opportunities or problems that an organization is unaware of, since the inclusion of the associated concepts can serve as a starting point for an improved monitoring function in a capability-based system.

The capability and change states presented in the typology in Section 4.2.1 were combined with the framework elements to enable the development of a detailed meta-model that was optimized for supporting capability change (see Section 4.3.1). For example, control-related states can be valuable for improving the observation and decision functions. Any emergent, unintentional or improvised change directly represents a run-time adjustment, which would lead to a response in terms of selecting a suitable capability configuration, if one can efficiently address the emergent need, or suggests the development of a new configuration. In other words, any change that is identified as unplanned, unintentional or improvised should be associated with the run-time phase of capability development, whereas a change that is planned or intentional can be associated with the design phase of the system. To take another example, identifying the tempo of change as slow or fast can affect the allocation of resources for the change activities based on the identified state. These examples relate to the application of a modeling method in combination with domain knowledge.

Similarly, the dimensions can act as a restriction on the possible courses of action by guiding the capability transition according to the state transitions of the typology. For example, an emergent change does not involve intention (Maes & van Hootegem, 2011), meaning that all the possible attributes associated with an emergent capability can support an organization in excluding all the possible attributes associated with an intentional or planned capability design or change.

5.1.3 Sub-goal G3

Sub-goal G3, which was *to establish a foundation for developing a method of modeling capability change*, and also included *(a) to develop a meta-model for depicting capability change, (b) to explore expert knowledge on the phenomenon of capability change, in order to evaluate the meta-model's concepts and to improve the meta-model by enriching it with expert knowledge, and (c) to explore the semantic consistency between the concepts used in this method*

and those of other modeling methods, as a way to identify candidate components for the method, was addressed in Papers 4–6 and discussed in Section 4.3 of this thesis.

Regarding sub-goal G3a, the introduction of the initial capability change meta-model (see Section 4.3.1) was based on the results of the previous sub-goals G1 and G2 (see Section 1.2). Hence, the three change functions and their associated concepts (see Section 3.7.1), the defined goals (see Section 4.2), and the typology (see Section 4.2.1) formed the three sources of input for the meta-model. The meta-model and a description of its elements, which represent the syntax and semantics respectively, were presented to address sub-goal G4, and the meta-model was demonstrated in the context of the RH case study. This section is adapted from Paper 4.

In regard to the efficiency of the meta-model, the structure of the information captured the elements required for this case study, and the relevant factors were taken into consideration. Despite the fact that the set of requirements (see Section 4.2) was fulfilled due to the mapping of the included elements to the goals, the case cannot be considered optimal as there was no need to identify a need for change; this step had already been performed by the case stakeholders.

Although the meta-model can be considered efficient in terms of depicting capability change, the complexity of the models created in this way was an issue that had to be addressed. Certain elements were purposely omitted from the model, as they did not affect or were not affected by the capability change, such as resources that remained the same in both configurations (for example, the nurses and the telephone system), but this is not always possible. Any model with a limited ability to communicate the necessary information to domain experts and other interested parties should be improved.

The development of the meta-model revealed certain interesting points, for example the fact that the configuration class and its recursive association formed the focal point of the meta-model. This part could be decomposed further while still being following the principle of the minimum number of elements, since the main goal of modeling capability change would be promoted. Certain aspects of capability change were neglected, such as omitting details and applying a higher level of abstraction. Two examples of these aspects were the goals and the realization of a capability, which were represented by the abstract classes of the intention element and behavior element, respectively. However, this is not coincidental, since these generic elements can be decomposed into entire models. In particular, the intention, behavior and context elements can be decomposed into goal, BP (Sandkuhl et al., 2014) and context models (Koç & Sandkuhl, 2018), respectively. This was an indication that the KYKLOS method, which was still under development at that time, could be designed based on components developed in this part of the project, and would potentially benefit from the technique of slicing meta-models (Bork

et al., 2018), which involves the integration of specific viewpoints. BP, goal and context models could use existing approaches, for increased feasibility of the project.

Sub-goal G3b involved an empirical ex ante evaluation of the meta-model's set of concepts (see Section 4.3.2), which was performed by interviewing expert decision-makers, and the results confirmed the association between the developed concept set and capability change as a phenomenon. Several omissions and opportunities for improvement were also identified, for example the ownership of change, the processes involved in identifying the need to change, and the finding that KPIs were only involved in a systematic sense during the design phase of capabilities; it was also found that 'experience and common sense' were employed during run-time, which gave rise to additional requirements for the meta-model and the method in general.

New concepts and associations emerged, although not all of these were deemed worthy of including in the meta-model. In particular, the ownership and resources required for a particular change should to be taken into consideration as a means of improving the planning for capability change, and for this reason, they were included in the updated meta-model. Change planning is also supported by the concept of motivation, which was added as a way to capture the required need to shift the attention of each party involved in the change initiative towards the change. The correlation between size and tempo was depicted via the conversion of tempo to a class, following the UML (OMG, 2017) standards. The monitored factor and KPI were also included, although experience and common sense were not, as their vagueness posed challenges in terms of implementing these without resorting to potential ambiguous assumptions and logical fallacies.

The main contribution of the step in which the meta-model was evaluated and improved was that it advanced the conceptualization of the phenomenon of capability change, not only by refining the set of concepts and associations included in the meta-model before using these as input for the development of a modeling language, method and tool, but also by placing more focus on the neglected concept of transition within capability change.

Paper 6 addressed sub-goal G3c by considering the Veria Arts Center case study (see Section 3.4.2), and provided insight not only from a modeling perspective, but also from a business management perspective.

From the point of view of business management, the findings resulted in several generalizable points regarding the management of changes in organizations. Firstly, the popular view suggested in the crisis management literature that crises are closely associated with opportunities (Alas & Gao, 2012) was confirmed from this case study. The analysis focused on the unexpected benefits that emerged during changes and the importance of hidden valuable outcomes, a concept that is neglected in the majority of modeling approaches, even those whose scope includes value modeling.

An additional important point that was raised during the case analysis was the importance and benefits that are derived from applying EM to a structure and analyzing the organization's data. An analysis of this type, and particularly a multi-perspective one as in this case, has value that is augmented during changing conditions, especially in situations that are characterized as crises. In such cases, multi-perspective analysis can become the determining factor between desirable and undesirable outcomes.

With regard to modeling, we found that the approaches that were tested for semantic consistency with the KYKLOS method could be identified as candidate components (see Section 4.3.4). This means that the models developed using the E^3value and 4EM approaches were identified as potential input for the method. The points for potential integration were also identified. In the last two statements, potentiality refers to the fact that the integration was not tested empirically. The most interesting finding was that the integration points coincided with the abstract concepts of the meta-model. This indicates that the remaining abstract elements of the meta-model can use other existing modeling methods as input; for example, observation elements such as the monitored factor, measurement and KPI can use an existing context modeling method such as that of Koç and Sandkuhl (2018), and the resource element could use the 4EM actor and resources model (Sandkuhl et al., 2014), meaning that these could also be checked for semantic consistency before being used as integration points. This also indicates that the approaches checked in Paper 6 are not exclusive suggestions. For example, the Business Motivation Model (BMM) (Object Management Group, 2015) could replace the 4EM Goals model, the BPMN (Object Management Group, 2011) or UML activity diagram (Object Management Group, 2017) or any other process or service modeling concepts could be consistent with the behavior element, and value concepts may also be consistent with VDML's (Object Management Group, 2018) value propositions.

5.1.4 Sub-goal G4

When the foundation for the method was complete, the actual development took place. This corresponded to sub-goal G4, which was *to develop the method and a complementary supporting tool*, which included (a) *to provide modeling guidelines,* (b) *to develop a language meta-model,* and (c) *to implement the method in a tool.*

In response to sub-goal G4a, the modeling guidelines of the method were presented in Paper 8 and in Section 4.4.4 of this thesis. They were motivated and based on the capability change framework introduced in Paper 1 (see Section 3.7.1). Hence, the decision to use a set of modeling guidelines that would be aligned with the framework resulted in a decision to split the modeling procedure into phases that were homonymous with the change functions that

made up the framework, i.e., observation, decision and delivery. The addition of an initial foundation phase before the change functions was necessary because the iterative nature of the change cycle of a capability required a starting point for the procedure to commence, and follow the change functions.

The development of the language meta-model (see Section 4.4.1) and the tool (see Section 4.4.5) addressed sub-goals G4b and G4c. The opportunity to refine the meta-model emerged at the implementation stage, and this resulted in a simplified version; this reduced the complexity and clutter of the initial meta-model (see Section 4.3.1), as described in Paper 4, while the language meta-model was expected to be equally effective as the initial meta-model.

One important aspect of the conversion of the initial meta-model to the language meta-model was the reduction in the number of classes from 30 to 16, which indicated that a significant simplification was achieved. This resulted in a shorter learning curve and a reduction in the modeling experience required to apply the KYKLOS method. In addition, grouping the visualization of all the associations into three categories reduced the learning steps required of a user. This led to the realization that the initial meta-model, which was designed to capture all the concepts of the phenomenon of capability change, was not appropriate as input for a modeling language, due to the number of its classes and the complexity of the resulting models.

All of the implementation activities and interventions connected with the meta-model were driven by the aim to achieve a balance between simplicity or utility and descriptive power, and to ensure that the advantages outweighed the disadvantages of every decision. Even in cases where new classes were introduced, which naturally increased the level of complexity for the models, the user experience was improved, as in the example of the resource pool class.

The means used to implement the method, in terms of the modeling decisions and practices, can be divided into two main categories; scoping, which involved making the scope of the meta-model narrower, and concretization, which involved making the meta-model less flexible. In particular, scoping was performed by: (i) increasing focus, meaning that the viewpoint was limited to the phenomenon while reducing side aspects such as ownership and organizational boundaries; and (ii) removing concepts related to the method, such as observation, decision and delivery, which formed part of the modeling procedure but not the model itself. Concretization involved (i) the inclusion of reference data for improved usability, for example a capability state that could only be ‘active’ or ‘inactive’, rather than providing a spectrum of potential states; (ii) generalization, for example the specialization of a context as internal or external, which was removed to reduce the complexity; and (iii) specializing, in terms of replacing abstract classes with their specific counterparts, as in the case of the behavior and process elements.

The greatest challenges encountered during the conversion involved retaining the operational and semantic consistency between the different versions

of the artifacts, and ensuring operational alignment between the modeling procedure and the tool. These challenges were addressed by providing an adequate set of primitives in order to capture the necessary elements for the documentation, analysis and communication of the phenomenon of capability change during the various phases of the modeling procedure. Another activity that contributed towards addressing these challenges was the implementation of functionalities in the tool. The tool enables more than just static objects to be modeled, which improves the model's descriptive power, despite the exclusion of classes. Finally, regarding the user experience, we note that several functionalities can assist the user in the development of a model based on the tool, as for example the automatic capability configuration design and the restrictions applied to the selection of the association type. These result in a reduction in the learning curve of the KYKLOS method and the tool, and a mitigation of the risk of syntactic mistakes.

All these functionalities and the dynamic behavior of the tool and models were made possible by the combination of creative and programming techniques with the pre-existing functionalities and meta-modeling structure of the ADOxx meta-modeling platform, which also saved a significant amount of time and effort for the developer.

5.1.5 Sub-goal G5

G5, which was *to demonstrate the method*, was addressed through the Veria Arts Center and DI case studies (Sections 4.5.1 and 4.5.2, respectively).

The application of KYKLOS to the Veria Arts Center case study represented the first application of the method to a real organization after the development of the syntax and notation; the focal point was therefore the successful documentation of the different configurations of the festival organization capability. The identified configurations highlighted the existence of hidden valuable outcomes and the need to avoid ignoring these. The detailed specification of the capability configurations and the analysis of the reallocation potentials led to the design and planning of a desired configuration that involved existing resources. In this way, the feasibility of KYKLOS as a method for designing and planning capabilities was successfully demonstrated. This is in line with the initial conceptualization of change in this PhD project, in which change was considered in different forms, including the introduction of a new capability, the modification of an existing one, and the retirement of an obsolete capability.

During the application of KYKLOS to the DI case, the method's effectiveness was proven, both in terms of capturing and documenting the phenomenon of capability change, and its ability to facilitate the analysis of capabilities using their configurations was demonstrated. The latter process gave rise to suggestions for improvements to the realization of the capability, and hence

KYKLOS also supports decision-making. In this case, in-depth exploration of the configurations of the customer assessment capability highlighted omissions that could be countered by reallocating existing resources. This eventually led to the suggestion to introduce a new capability, employee facilitation training.

The demonstration cases confirmed the feasibility of the method as an artifact, which is the aim of the demonstration step in DSR (Johannesson & Perjons, 2014). However, a practical evaluation by potential users was required, and this was performed in the last step of DSR.

5.1.6 Sub-goal G6

G6, which was *to evaluate the method*, is the last goal of this PhD thesis, and was addressed through the DI case study (see Section 4.6), and the evaluation techniques described earlier in this thesis (see Section 3.3.5).

The results of the evaluation indicated that the method was useful, despite difficulties regarding its adoption and use that were expressed by the business group of evaluators. These difficulties do not negate the method's usefulness, as the description given in the Human Risk and Effectiveness evaluation strategy of FEDS (Venable et al., 2016) clearly states that the strategy's activities ensure that an artifact with user-oriented challenges still remains operational "on the long run".

The difficulties encountered by the business group were directly related to the significant differences identified between the two groups. This finding was not expected at any earlier stage of the development of KYKLOS. All of the aspects of the method that were evaluated received significantly higher scores from the group of modeling experts, thus proving that existing modeling expertise is a desired characteristic of potential users of the method.

The groups agreed that the method was effective, efficient and useful, but significantly disagreed on the degrees of ease and intention to use, which raised issues regarding the complexity of the method. This finding helped to identify the optimal user group to which KYKLOS should be communicated, that is, users with previous modeling experience. Users without modeling experience should avoid the current version of this method, because even if they found it useful for addressing the phenomenon of capability change, difficulties would be encountered in the process; in other words, it would be hard for them to understand, apply and benefit from the method.

In addition to the complexity of the method, another issue that was raised during the evaluation sessions was the scope flexibility of the method. The current version of KYKLOS does not address the phenomenon of capability change from the perspective of individual capabilities; this is not considered an omission of the current version, but this finding does highlight the opportunity for additional research to expand the method and augment the scope

flexibility of the KYKLOS method, so that it can support this aspect of change. This is discussed further in the future research section, along with additional suggestions made by modeling experts regarding the extension and potential of the method.

5.1.7 Overall discussion and quality of the contribution

The main goal of this PhD thesis, which was *to develop a method called KYKLOS that can support change in organizations by modeling the changing capabilities of organizations,* can be considered fulfilled. To ensure the quality of this research, the guidelines of Hevner and Chatterjee (2010) were applied, as shown in Table 12.

Table 12. DSR quality guidelines applied in this thesis

Guideline	**Application**
Design as an artifact	KYKLOS, the main artifact produced from this PhD project and described in this thesis is a method consisting of a syntax, semantics, notation and guidelines. A supporting artifact was also developed in the form of a tool that complements the method and facilitates its application.
Problem relevance	Capability change is an important business problem that can be addressed with the developed method and supporting tool, as shown through relevant case studies.
Design evaluation	The method was demonstrated to confirm its feasibility, and was evaluated in both ex ante formative and ex post summative and naturalistic ways, in a real case study, to confirm its efficiency, effectiveness, usefulness, etc.
Research contributions	The method enables modeling of all the different aspects associated with changing capabilities, which were identified as opportunities for improvement to existing capability models and approaches to change management.
Research rigor	In this project, a systematic review of the literature and the structuring of requirements led to the development of a UML standards-compliant meta-model which was peer-reviewed to ensure its quality. These activities led to the development of the method and complementary tool in ADOxx, which were evaluated using the MEM and FEDS evaluation frameworks.
Design as a search process	The design process was iterative, and involved identifying and assessing several sources for the elicitation of requirements and the development of the meta-model, based on

	three iterations. Three cases were also carried out to demonstrate and evaluate the method throughout the entire design process.
Communication of research	All the included articles were accepted and published in journals and conference proceedings relevant to the area of business informatics and IS, whose audiences are both technology and management-oriented.

Following the DSR guidelines, the domain of capability modeling was explored and reviewed to identify the majority of the existing meta-models and to classify their concepts according to the developed framework, which included three main functionalities of change: observation, decision and delivery. The identified concepts were classified according to these functionalities and visualized in the form of concept maps (see Section 4.1).

Following this, the literature was reused and combined with a case study to define the requirements in the form of a goal model and to provide an outline of the artifact. Two complementary sets were elicited and combined to form a goal model (see Section 4.2). The previously elicited functionalities of change were also used to structure the goals. The elements included in this model served as the basis for the element set that made up the structure of the capability change meta-model.

The literature was then reviewed again, in combination with personal reflection, to identify and structure the states of capability and change and to combine them in a typology that included the missing and negative aspects of organizational capabilities, which was introduced in the form of a StateMachine diagram (see Section 4.2.1). The previously elicited sources were combined to develop a meta-model with the purpose of introducing the syntax of a capability modeling method. The description of the elements served as an informal textual description of the semantics of the KYKLOS method. The findings of the expert interviews were integrated with the initial meta-model, resulting in the final version of the meta-model, which was then implemented in ADOxx. The development of the meta-model was aligned with the suggestions derived from the analysis in Paper 1; in particular, the modeling approaches were aligned and the most common elements from the existing approaches were included. The level of abstraction was reduced by including abstract elements such as the intention and behavior elements, while eliminating numerous specific lower-level concepts. Useful implied and missing concepts were also included, such as the concepts of measurement and observation.

The development of the method and tool also provided the opportunity to demonstrate the iterative nature of DSR. This was not always as a result of

new requirements or updated goals, as trial and error activities drove the development of KYKLOS. This resulted in situations where a concept may have been included in one iterative cycle and then later re-designed as an attribute used for the method's algorithms and mechanisms.

The application of the KYKLOS method to the Veria Arts Center case study used the meta-model. One issue that needs to be noted here is that no integration with other modeling approaches was performed, despite the fact that potential candidates and integration points have been identified; this was due to external conditions that hindered this activity, and reporting these falls outside the scope of this thesis. Hence, this part of the project is left to future research.

In addition, each domain had its own particular attributes. The RH case study focused on a public organization in the healthcare sector, whereas case studies in different domains could provide additional valuable insights and introduce aspects that would otherwise be overlooked. For this reason, efforts were made to include cases from different areas in the subsequent stages of the project. The Veria Arts Center case study was a hybrid between public and private organizations in the domain of arts and culture, whereas the DI case originated from the private sector, in the domain of IT sales and consulting.

In the last two of these case studies, both the KYKLOS method and tool were used, and the results provided a validation of the method. A complementary systematic evaluation based on FEDS and MEM resulted in outcomes that fell within the range of successful method artifacts. This evaluation confirmed the effectiveness, efficiency and usability of the method, despite the difficulties experienced by users without modeling expertise regarding the ease and intention to use it. The last parts of the project also provided interesting research paths for the future evolution of KYKLOS.

In regard to overall advancements in the domain of EM, we note that one of the main contributions of this thesis is the introduction of an approach that enables simultaneous modeling of the as-is and to-be states of a capability. In addition, KYKLOS provides a means of capturing the analysis itself, by capturing attributes of the transition, which was highlighted as an omission of existing modeling approaches, techniques and methods. This contribution can be applied to any phase of analysis that includes a comparison of two models.

From the business perspective, this work makes essential contributions related to potential applications in regard to CM. KYKLOS provides a solution that enables the identification of the need to change, in regard not only to monitoring the origins of the need, but also measuring them. In addition, KYKLOS contributes towards a more structured way to the analysis of changes in regard to decision-making and CIA.

Finally, from the perspective of DS, the contribution of this thesis consists of both phase-specific and overall design decisions that were made throughout the project. The phase-specific decisions provide insights into specific aspects

of method development, and have been discussed in the respective subsections of this thesis. The overall DS contributions can be summarized in regard to the integration between DSR and the development of the method, which was the specific design artifact developed in this project. The KYKLOS project is an example of a complete method development process, consisting of several iterations of design and evaluation cycles integrated within a DSR project.

From the point of view of research methodology, it was found that the IDEF0 notation, which was suggested by the selected DSR framework (Johannesson & Perjons, 2014) as a means to capture and visualize the methodological decisions, became cluttered. This was a result of the complexity of the project, which included a variety of strategies and methods. A technique that involved "slicing" the models (Bork et al., 2018) provided an improved visualization. In the evaluation process, it was found that the FEDS and the MEM used during the evaluation were well integrated into the DSR context. With regard to the overall presentation of the project in this thesis, we note that despite the guidelines concerning communication in DSR, there is no explicit set of guidelines regarding the packaging of the design artifact. For example, KYKLOS could have been presented here with a focus on the results; however, it was deemed more valuable to present the project with a focus on the design procedure, as this provided deep insight for potential method developers within the area of DSR.

5.2 *Limitations*

This section discusses the limitations of the present research in relation to the methodological and practical decisions and conditions.

Firstly, the analysis of the capability meta-models (see Section 4.1) can be considered a methodological novelty, which implies that improved analytical approaches may be applied in the future. However, this approach resulted in a minimum interpretive activity for the data extraction. The thematic analysis of the concepts was performed individually by the author, and critically reviewed by the co-authors of Paper 1. This methodological decision reduced the possibility of biased results but did not mitigate it entirely.

The RH case study was adequate for the initial pre-implementation version of the meta-model, although the identification of the need and reasons to change were missing from the existing conditions, as this activity had already been performed by RH's experts. The cases selected for later demonstration and evaluation therefore focused on including this activity.

The two later applications of the KYKLOS method concerned cases where the need to change was not obvious, or was predefined, in both cases. These

two cases were therefore used to check how KYKLOS responds to the challenge of identifying and specifying the need to change, along with the reasons and motivation behind a change. However, with reference to the introduced capability typology described in Paper 3 and Section 4.2.1, we note that the three case studies involved situations where capability, incapability, and sustainability were encountered and addressed, but anti-capability was not encountered. As a result, the full spectrum of the typology was not explored in practice, which may mean that the selected cases were not optimal, even though they were appropriate and suitable.

The practical application of the method to the case studies confirmed the value of multi-perspective analysis enabled by KYKLOS and EM as a whole. In addition to the capability analysis, the method facilitates analysis of context, intentions, ownership, resources, etc. The fact that KYKLOS has not been combined and integrated with other modeling methods does not reduce the value of its potential for multi-perspective analysis, as confirmed during the case studies. However, KYKLOS does not claim to be an efficient replacement for approaches that are specialized to particular perspectives; for example, the 4EM Goals model was specifically designed for modeling goals, whereas the aim of KYKLOS was solely to support the creation of models of changing capabilities.

5.3 *Ethical and societal implications*

DSR involves "an ethical change from describing and explaining of the existing world to shaping it" (Iivari, 2007). The values of IS research may be considered questionable, in particular with regard to the values that it serves. For example, research may openly "serve the interests of particular dominant groups" (Iivari, 2007), such as the top management of an organization participating in the research. However, in this thesis, the principles of utilitarianism were followed for the development of an artifact, and the ethical aspects of this work are discussed in this section.

The KYKLOS method was developed in this PhD project, together with a supporting tool, with the aim of facilitating the identification of an organization's weaknesses and guiding the capability transition process by suggesting the acquisition, replacement or removal of resources, including human resources. This may raise several ethical and societal implications.

For example, removal or replacement of human resources based on the results of applying the developed artifact is a possibility. In other words, specific individuals and/or roles may face dramatic changes in their employment status. However, this will only occur only if the results of the method prove that the contribution of the given roles to the organization is highly questionable.

Nevertheless, these aspects are complicated, and there are several different approaches to resolving them. Reallocation of resources does not necessarily result in unemployment; providing training may be a way to improve the human resources situation, taking into consideration the requirements of the given role within the organization.

There does not seem to be a perfect solution for this possible scenario, as it belongs to a grey area where every decision and path is associated with different ethical implications. This can probably be attributed to the concept of change in general, since common sense suggests that change is rarely satisfactory to everyone involved. When there is no solution where everyone involved is satisfied, the optimal solution is to minimize harm. This thesis provides a method and supporting tool that are intended to make suggestions, which an organization may or may not decide to accept.

Thus, it is the development of the method that provides the organization's decision makers with the power to make the decision. In case of poor decisions made as a result of misusing the method as a tool, the responsibility falls on the user rather than on the tool. Furthermore, the evolution of technology has always been a means to allow fewer people to produce more value for an organization. In the vast majority of cases, this is associated with the loss or replacement of employment positions, meaning that the ethical implications raised in this project are not new or limited to the research topic.

5.4 *Future research*

Future research arising from this PhD thesis can be classified into two main directions. Firstly, there is the potential for the evolution of KYKLOS into an enhanced version in the future; and secondly, there are topics that may serve as inspiration and sources for further research in the IS field.

Although the current version of KYKLOS presented in this thesis can be considered a reasonably stable first version, further development is envisioned. One aspect of KYKLOS that has potential for future evolution concerns the context capturing activities. Rather than manually identifying and documenting the context and monitored factors, modern technology enables the model's database to be connected to external open databases to feed live data to the model. These datasets can be processed and used as automatic input for the external context elements of the method. This will assist towards the development of models which are more "live", and the iterative nature of KYKLOS will gain more automatic attributes, further improving the user's interaction with the tool and model creation.

As mentioned in the previous sections of this thesis, the complexity of the KYKLOS method was noted; however, this is associated with the actual complexity of the domain, and addressing this issue is not straightforward.

On the one hand, preserving KYKLOS in its current version would preserve the complexity, but there would also be no sacrifice in terms of the descriptive power of the method. This would also mean that the target group of KYKLOS users would be limited to a significant extent, since, as identified during the evaluation, it is mainly targeted at modeling experts.

On the other hand, another way to address the issue of complexity would be to make systematic efforts to bridge the existing significant gap between the potential categories of users. This could be achieved via the development of a structured training process for the method, or a "light" version of KYKLOS with reduced complexity and fewer modeling elements, which could be used to create higher-level models of changing capabilities, or a solution based on the canvas approach, in which the details of the modeling language are hidden, which could be used as a pre-modeling step for KYKLOS. These potential solutions would not produce the same results: the first would not actually bridge the gap, since its aim is to convert non-experts to experts, whereas the other two solutions have the potential to provide valid bridging solutions, although these are likely to result in reduced descriptive power and/or increased workload for the analyst, which should be taken into consideration. The significant differences between expert and non-expert users of KYKLOS and any other modeling method is an issue that is worthy of further research within the community, along with a means of bridging gaps between these groups.

The expert modelers who participated in the evaluation also expressed suggestions; in particular, they wanted improvements to the method and tool in terms of implementing a functionality to use existing enterprise models as input to KYKLOS models, the ability to create capability views and capability maps, and the potential to use the method and tool for capability decomposition.

Another issue that emerged during the evaluation workshops, and specifically during the discussion of the usefulness of the method, was the scope flexibility of KYKLOS. The issue relates to the use of KYKLOS to model the individual perspective on change, in other words, the human factor of change, and potentially even individual capabilities. This is currently outside the scope of the method, although it generates motivation for exploring potential extensions to KYKLOS that would include this aspect. Further research into whether this aspect could be integrated with existing concepts, or even converting the method to an updated and more flexible scope that could switch between organizational and individual perspectives, would be an interesting and challenging topic for any researcher in this domain.

With regard to research outside this project, the contributions made by this thesis may serve as a starting point for the implementation of change-specific viewpoints using different EM approaches, since these may have different focal points; however, organizational dynamism is undeniably a phenomenon that needs to be addressed in any method, capability-oriented or otherwise. For example, new viewpoints could be elaborated, such as capability, observation, decision, delivery and ownership.

An alternative angle for future research is the combination of changing capabilities with product line engineering and product line variability (Pohl et al., 2005), a paradigm that shares several goals and approaches with those of KYKLOS. For example, enhancing quality, reducing effort, addressing complexity and improving planning (Pohl et al., 2005) are motivational points that are common to both product line engineering and KYKLOS. The approaches used are also similar, as they focus on the design of different alternative versions of the same product or capability, based on components that can be reused and reallocated to the various versions. For example, it has been identified that product line engineering is limited in terms of proactivity (Alves et al., 2010), and KYKLOS may provide possible improvements in this direction.

The contributions of this thesis are therefore not limited to the development of KYKLOS, but raise new directions for future research in the field of IS.

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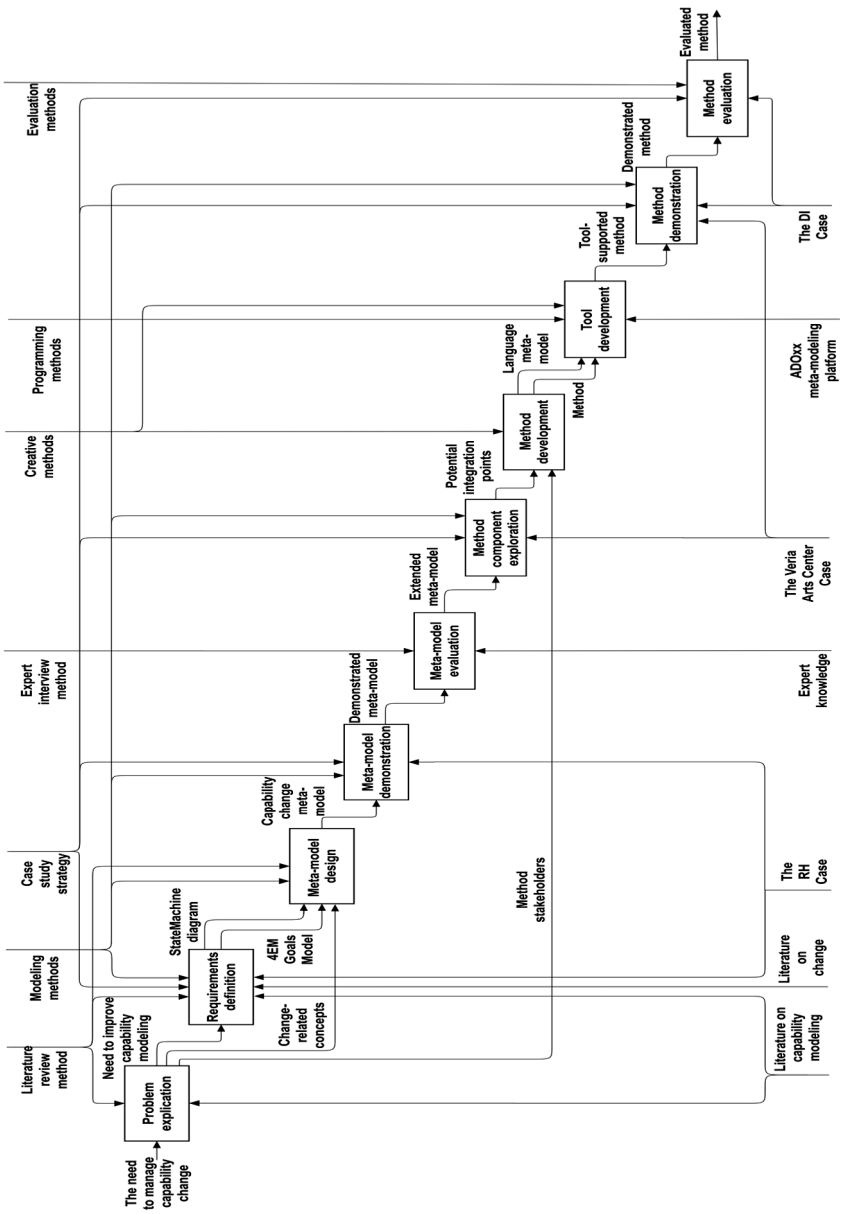
Appendix 1: The complete research process



Appendix 2: Author's contributions to the included papers

The author's contributions to the included papers are presented using the CRediT guidelines of Brand et al. (2015), with the addition of a quantitative estimation of the contribution to each role. Not all of the roles are applicable to all of the included papers, and hence certain terms are assigned no value. Tables 16 to 24 report the author's contributions to each role for Papers 1 to 9, respectively.

Paper 1

Koutsopoulos, G., Henkel, M., & Stirna, J. (2021). An analysis of capability meta-models for expressing dynamic business transformation. *Software and Systems Modeling*, *20*(1), 147–174. https://doi.org/10.1007/s10270-020-00843-0

Abstract

Environmental dynamism is gaining ground as a driving force for enterprise transformation. To address the changes, the capabilities of digital enterprises need to adapt. Capability modeling can facilitate this process of transformation. However, a plethora of approaches for capability modeling exist. This study explores how concepts relevant to change have been implemented in the meta-models of these approaches, aiming to visualize relationships among change-related concepts, and identify ways to improve capability modeling toward a more efficient depiction of capability change. The concepts are visualized in concept maps, and a framework is developed to assist the classification of concepts relevant to change functions. Similarities and differences among the existing models are discussed, leading to suggestions toward improvements of capability modeling for capability adaptation.

Table 13. Author's contributions to Paper 1.

Term	**Author's contribution**	**Term**	**Author's contribution**

Conceptualization	90 %	Methodology	75%
Software	-	Validation	100%
Formal Analysis	100%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	100%	Writing – Review & Editing	75%
Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 2

Koutsopoulos, G., Henkel, M., & Stirna, J. (2019b). Requirements for Observing, Deciding, and Delivering Capability Change. In J. Gordijn, W. Guédria, & H. A. Proper (Eds.), *The Practice of Enterprise Modeling* (Vol. 369, pp. 20–35). Springer International Publishing. https://doi.org/10.1007/978-3-030-35151-9_2

Abstract

Dynamic business environments create the need for constant change in modern enterprises. Enterprise transformation is associated to changes in enterprise capabilities since capabilities are an essential element in business designs. Capability modeling methods need to evolve accordingly and the development of such methods needs to be systematic. This study, as part of a Design Science project, aims to elicit requirements for a capability modeling method for addressing change. Literature sources and a case study at a healthcare organization that undergoes several changes are used to elicit requirements. The requirements are presented in the form of a goal model for the method under development.

Table 14. Author's contributions to Paper 2.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	85%
Software	-	Validation	100%
Formal Analysis	65%	Investigation	50%
Resources	-	Data curation	100%
Writing – Original Draft	90%	Writing – Review & Editing	75%

Visualization	90%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 3

Koutsopoulos, G., Henkel, M., & Stirna, J. (2020). Modeling the Dichotomies of Organizational Change: A State-based Capability Typology. In C. Feltus, P. Johannesson, & H. A. Proper (Eds.), *Proceedings of the PoEM 2019 Forum* (Vol. 2586, pp. 26–39). CEUR-WS.org. http://ceur-ws.org/Vol-2586/paper3.pdf

Abstract

Modern digital businesses are facing a constant challenge in adapting to dynamic environments. Therefore, change has become a significant element of business analysis. Capability thinking, when applied to business management, is associated to design and analysis of supporting information systems and is inextricably linked to strategy and change. This results in the need to monitor and analyze how and when the organization's capabilities need to change. Capability and change dimensions have been explored in the literature in order to identify dimensions relevant to organizational change. The identified capability dimensions are purpose, potentiality and ownership while the relevant change dimensions are control, scope, stride, frequency, desire and tempo. The two sets of dimensions have been combined forming a typology and visualized in a StateMachine diagram. The contribution of this task lies in the conceptualization of the dimensions, including the negative aspect of capabilities, which can provide a starting point for an Enterprise Modeling method optimized for identifying the need for capability change and guiding the transition.

Table 15. Author's contributions to Paper 3.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	100%
Software	-	Validation	100%
Formal Analysis	100%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	100%	Writing – Review & Editing	75%

Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 4

Koutsopoulos, G., Henkel, M., & Stirna, J. (2020a). Conceptualizing Capability Change. In S. Nurcan, I. Reinhartz-Berger, P. Soffer, & J. Zdravkovic (Eds.), *Enterprise, Business-Process and Information Systems Modeling* (Vol. 387). Springer International Publishing. https://doi.org/10.1007/978-3-030-49418-6_18

Abstract

Organizations are operating within dynamic environments that present changes, opportunities and threats to which they need to respond by adapting their capabilities. Organizational capabilities can be supported by Information Systems during their design and run-time phases, which often requires the capabilities' adaptation. Currently, enterprise modeling and capability modeling facilitate the design and analysis of capabilities but improvements regarding capability change can be made. This design science research study introduces a capability change meta-model that will serve as the basis for the development of a method and a supporting tool for capability change. The meta-model is applied to a case study at a Swedish public healthcare organization. This application provides insight on possible opportunities to improve the meta-model in future iterations.

Table 16. Author's contributions to Paper 4.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	85%
Software	-	Validation	100%
Formal Analysis	100%	Investigation	0%
Resources	-	Data curation	100%
Writing – Original Draft	90%	Writing – Review & Editing	75%
Visualization	80%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 5

Koutsopoulos, G., Henkel, M., & Stirna, J. (2020b). Improvements on Capability Modeling by Implementing Expert Knowledge About Organizational Change. In J. Grabis & D. Bork (Eds.), *The Practice of Enterprise Modeling* (Vol. 400, pp. 171–185). Springer International Publishing. https://doi.org/10.1007/978-3-030-63479-7_12

Abstract

Modern digital organizations are constantly facing new opportunities and threats, originating from the highly dynamic environments they operate in. On account of this situation, they need to be in a state of constant change and evolution to achieve their goals or ensure survival, and this is achieved by adapting their capabilities. Enterprise Modeling and capability modeling have provided a plethora of approaches to facilitate the analysis and design of organizational capabilities. However, there is potential for improving management of capability change. This Design Science research aims to provide methodological and tool support for organizations that are undergoing changes. A previously introduced meta-model will serve as the basis for a method supporting capability change. The goal of this study is to explore expert knowledge about organizational change in order to evaluate the initial version of the meta-model and identify possible weaknesses. Ten semi-structured interviews have been conducted to explore the perspectives of experienced decision-makers on capability change. Three categories emerged from the analysis, reflecting on how capability change is observed, decided and delivered respectively. These have been used as input for revising the conceptual structure of the capability change meta-model.

Table 17. Author's contributions to Paper 5.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	90%
Software	-	Validation	100%
Formal Analysis	100%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	100%	Writing – Review & Editing	90%
Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 6

Koutsopoulos, G. (2021). Capabilities in Crisis: A Case Study Using Enterprise Modeling for Change Analysis. In R. A. Buchmann, A. Polini, B. Johansson, & D. Karagiannis (Eds.), *Perspectives in Business Informatics Research* (Vol. 430, pp. 100–114). Springer International Publishing. https://doi.org/10.1007/978-3-030-87205-2_7

Abstract

Changing capabilities is a measure that businesses employ as a response to emerging opportunities, threats and necessary adaptations derived from the dynamic environment they operate in. Enterprise Modeling is a discipline that can provide support during the transition of capabilities and facilitate the process. This study is part of a project aiming to develop a method specifically designed for managing capability change using enterprise modeling. This paper's goal is to identify candidate components for the method by exploring semantic consistency among different enterprise models developed in the context of a case study. The reported case study has been conducted in an organization of the public arts and culture sector in Greece that is dealing with multiple difficulties and challenges simultaneously and is driven to adapt its capabilities. Different Enterprise Modeling approaches are employed to capture the wide spectrum of concepts necessary for modeling the complex capability change phenomenon. Potentials for model integration and candidate method components are identified along with business transformation insight derived from the analysis of changes.

Table 18. Author's contributions to Paper 6.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	100%
Software	-	Validation	100%
Formal Analysis	100%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	100%	Writing – Review & Editing	100%
Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 7

Koutsopoulos, G., & Henkel, M. (2021a). An Experience Report on the Implementation of the KYKLOS Modeling Method. In E. Serral, J. Stirna, J. Ralyté, & J. Grabis (Eds.), *The Practice of Enterprise Modeling* (Vol. 432, pp. 103–118). Springer International Publishing. https://doi.org/10.1007/978-3-030-91279-6_8

Abstract

Several types of enterprise models and methods have been developed that may help an organization to describe and improve its business. A common practice is also the development of tool support to complement an enterprise modeling method's application. The development of tool support for a modeling method includes creating a representation of the modeling concepts, but also designing how the user should interact with the tool. This paper reports on the challenges and opportunities encountered during the process of implementing the KYKLOS modeling method in a modeling tool. The KYKLOS method, which is an enterprise modeling method, is specialized in supporting the design and analysis of changing capabilities. Using as input an initial metamodel of capability change, all the necessary tasks are performed to elicit a language model, which is required for the implementation of the method in a tool.

Table 19. Author's contributions to Paper 7.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	100%	Methodology	100%
Software	-	Validation	80%
Formal Analysis	100%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	100%	Writing – Review & Editing	80%
Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 8

Koutsopoulos, G., Henkel, M., & Stirna, J. (2022). Modeling the Phenomenon of Capability Change: The KYKLOS Method. In D. Karagiannis, M. Lee, K. Hinkelmann, & W. Utz (Eds.), *Domain-Specific Conceptual Modeling* (pp. 265–288). Springer International Publishing. https://doi.org/10.1007/978-3-030-93547-4_12

Abstract

The dynamic environments where modern businesses operate in are a source of continuous change. As a result, change has emerged as an indispensable aspect of business management and analysis. The notion of capability is an essential element in business designs; therefore, business transformation is associated with monitoring and analyzing changing capabilities. Enterprise modeling can facilitate these tasks, and even though a plethora of capability modeling approaches exists, there is a lack of a method specialized for modeling capability change. The KYKLOS method, which is introduced in this chapter as a means to address the abovementioned challenge, is the result of an ongoing Design Science project aiming to provide methodological and tool support for businesses whose capabilities undergo changes or need to do so in the future. Its purpose is not only to capture the information types that are essential to the complex capability change phenomenon but also to guide the transition of capabilities. It is complemented by a homonymous tool developed using the ADOxx meta-modeling platform.

Table 20. Author's contributions to Paper 8.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	70%	Methodology	50%
Software	-	Validation	50%
Formal Analysis	70%	Investigation	100%
Resources	-	Data curation	100%
Writing – Original Draft	70%	Writing – Review & Editing	70%
Visualization	100%	Supervision	-
Project Administration	-	Funding acquisition	-

Paper 9

Koutsopoulos, G., Andersson, A., Stirna, J., & Henkel, M. (2022). Applying and Evaluating the KYKLOS Method. In B. S. Barn & K. Sandkuhl (Eds.), *The Practice of Enterprise Modeling* (Vol. 456, pp. 118–133). Springer International Publishing. https://doi.org/10.1007/978-3-031-21488-2_8

Abstract

Organizations are dealing with a continuous need to adapt to their dynamic environments by changing their business capabilities. KYKLOS is a recently developed modeling method aiming to provide methodological and tool support for the phenomenon of capability change in organizations. This paper reports on a case study used to demonstrate and evaluate KYKLOS. The case study has been performed in a company in the ERP system consulting domain, and the results have been used to evaluate the method using two groups of evaluators, a business user group and a group of modeling experts. The paper reports the insights and findings that validate and motivate future research about the method and the different perspectives between the two groups of evaluators.

Table 21. Author's contributions to Paper 9.

Term	**Author's contribution**	**Term**	**Author's contribution**
Conceptualization	80%	Methodology	100%
Software	-	Validation	
Formal Analysis		Investigation	70%
Resources	-	Data curation	90%
Writing – Original Draft	100%	Writing – Review & Editing	70%
Visualization	100%	Supervision	15%
Project Administration	-	Funding acquisition	-

Appendix 3: Sources of capability meta-models in the literature

This section presents a complete list of literature sources from which the capability meta-models that were used for the literature review were derived. The list is presented in Table 22.

Table 22. Literature sources for the capability meta-models.

ID	Author and Year	Title
1	Du Toit and Tanner (2015)	A Business Architecture Capability Meta Model and Tool-set for Providing Function Point Estimation for Enterprise Architecture Management
2	Barroero et al. (2010)	Business Capabilities Centric Enterprise Architecture
3	Straube and Kranzlmüller (2014)	Model-Driven Resilience Assessment of Modifications to HPC Infrastructures
4	Azevedo et al. (2015)	Modeling resources and capabilities in enterprise architecture: A well-founded ontology-based proposal for ArchiMate
5	Becker, Antunes, Barateiro, Vieira, et al. (2011)	Modeling digital preservation capabilities in enterprise architecture
6	Kudryavtsev et al. (2014)	Strategy-focused and value-oriented capabilities: Methodology for linking capabilities with goals and measures
7	Klinkmüller et al. (2010)	Visualising Business Capabilities in the Context of Business Analysis
8	DeLoach et al. (2008)	A capabilities-based model for adaptive organizations
9	Loucopoulos et al. (2018)	Capability-oriented Analysis and Design for Collaborative Systems: An example from the Doha 2022 World Cup Games
10	Anteroinen (2012)	The holistic military capability life cycle model
11	Loucopoulos and Kavakli (2016a)	Capability Modeling with Application on Large-scale Sports Events

12	Bhiri et al. (2013)	Modelling Capabilities as Attribute-Featured Entities
13	DeLoach and Garcia-Ojeda (2010)	O-MaSE: a customisable approach to designing and building complex, adaptive multi-agent systems
14	Loucopoulos and Kavakli (2016b)	Capability Oriented Enterprise Knowledge Modeling: The CODEK Approach
15	Homann et al. (2006)	Efficient and flexible business modeling based upon structured business capabilities
16	Walker (2005)	Capabilities-based planning-how it is intended to work and challenges to its successful implementation
17	Danesh et al. (2015)	Dynamic Capabilities for Sustainable Enterprise IT – A Modeling Framework
18	Rauffet et al. (2016)	Managing resource learning in distributed organisations with the organisational capability approach
19	Aldea et al. (2015)	Capability-based planning with ArchiMate
20	Sandkuhl and Stirna (2018a)	Capability Management in Digital Enterprises
21	Danesh (2018)	A Socio-Technical Modeling Framework for Designing Enterprise Capabilities
22	Baccar et al. (2016)	A capabilities driven model for web services description and composition
23	Antunes et al. (2013)	Capabilities and Requirements Engineering: Research Challenges
24	Papazoglou (2014)	Capability-based planning with TOGAF® and ArchiMate®
25	The Open Group (2017)	Archimate 3.0.1. Specification
26	USA Department of Defense (2009)	Department of Defense Architecture Framework 2.02
27	NATO (2018)	NATO Architecture Framework v.4
28	UK Ministry of Defence (2010)	Ministry of Defence Architecture Framework V1.2.004
29	The Open Group (2018)	The TOGAF® Standard, Version 9.2
30	Object Management Group OMG) (2018)	Value Delivery Modeling Language v.1.1

31	Qi et al. (2015)	Modeling and verifying SoS performance requirements of C4ISR systems
32	Rauffet et al. (2012)	Conceptual model and IT system for organizational capability management
33	Tingting et al. (2016)	Capability-oriented architectural analysis method based on fuzzy description logic
34	Bravos et al. (2017)	A Capability – Driven modelling approach applied in smart transportation & management systems for large scale events
35	Antunes et al. (2011)	Modeling Contextual Concerns in Enterprise Architecture
36	Pastor et al. (2018)	Capability-based Communication Analysis for Enterprise Modelling
37	Wang et al. (2012)	A Light Way of Enterprise Modeling and Simulation for C4ISR System Based on xUML
38	Antunes and Borbinha (2013)	Capabilities in Systems Engineering: An Overview
39	Iacob et al. (2012)	Capturing Business Strategy and Value in Enterprise Architecture to Support Portfolio Valuation
40	Plum (2018)	TRAK Enterprise Architecture Metamodel
41	Mikloš (2012)	A meta-model for the spatial capability architecture
42	Malik (2013)	Enterprise business motivation model: Full model documentation v.4.2
43	Bergström (2015)	Modelling Business Capabilities with Enterprise Architecture: A Case Study at a Swedish Pension Managing Company
44	Object Management Group (OMG) (2012)	Service oriented architecture Modeling Language (SoaML) Specification Version 1.0.1
45	MODAF Ontological Data Exchange Mechanism MODEM) (2012)	MODAF ontological data exchange mechanism (MODEM)
46	Rafati et al. (2018)	A Domain-specific Modeling Technique for Value-driven Strategic Sourcing
47	Feltus and Petit (2009)	Building a Responsibility Model Including Accountability, Capability and Commitment
48	Liu et al. (2009)	Modelling and simulation of Network Enabled Capability on service-oriented architecture

49	Ge et al. (2013)	A data-centric capability-focused approach for system-of-systems architecture modeling and analysis
50	Li et al. (2013)	Improving Web Service Composition with User Requirement Transformation and Capability Model
51	Zhang et al. (2012)	Generating Executable Capability Models for Requirements Validation
52	Iacobucci (2012)	Rapid Architecture Alternative Modeling (RAAM): a framework for capability-based analysis of system of systems architectures
53	Stirna and Zdravkovic (2016)	Development of a Modeling Language for Capability Driven Development: Experiences from Meta-modeling
54	Derguech et al. (2018)	Using Ontologies for Business Capability modelling: Describing What Services and Processes Achieve
55	Becker, Antunes, Barateiro, and Vieira (2011)	A Capability Model for Digital Preservation: Analysing Concerns, Drivers, Constraints, Capabilities and Maturities
56	Derguech et al. (2017)	Designing business capability-aware configurable process models
57	Rafati and Poels (2014)	Capability sourcing modeling a high-level conceptualization based on service-dominant logic
58	Roubtsova and Michell (2014)	Behaviour Models Clarify Definitions of Affordance and Capability
59	Nunes and Faccin (2016)	Modelling and implementing modularised BDI agents with capability relationships
60	Malamateniou et al. (2017)	A Context-Aware, Capability-Based, Role-Centric Access Control Model for IoMT
61	Kolini and Janczewski (2015)	Cyber Defense Capability Model: A Foundation Taxonomy
62	Gongolidis et al. (2016)	Migrating eGovernment Services in the Cloud: A Capability Modelling Approach
63	Radeck et al. (2017)	Modeling and Calculating Capabilities of Composite Web Applications for Assisted End User Development
64	OASIS Committee (2012)	Reference Architecture Foundation for Service Oriented Architecture Version 1.0.

Appendix 4: Informed Consent form

This form concerns a research conducted by Georgios Koutsopoulos, who is a PhD candidate at the Department of Computer and Systems Science of Stockholm University in Sweden. The research is part of a PhD research project aiming to provide methodological and tool support for changing capabilities in organizations. The collected data will be saved until the end of the research. The results of this research may be published as part of academic articles. By agreeing to participate:

✔ I agree that the data I provide will be analysed so that the research may provide an evaluation for the KYKLOS modeling method.

✔ I have been fully informed about the process of this research, all my questions have been answered and I can still contact Georgios Koutsopoulos at georgios@dsv.su.se if any further questions exist. I agree to participate in the study conducted by the above-mentioned student by providing honest data.

✔ I understand that my anonymity will be respected and preserved.

✔ I understand and agree that as a voluntary participant in the present study, I have the right to discontinue participation at any time.

✔ I understand that the study is only for research purposes and will in no way be used for
any purpose other than research.

✔ I agree to immediately raise any concerns or areas of discomfort and understand that I can withdraw participation at any time.

1. Please select one of the options below.

Mark only one oval..

- ◯ YES, I have read all the above, understand it fully and agree to participate in this research.
- ◯ NO, I choose not to participate.

2. Name

3. Email address

4. Date

5. Signature

Appendix 5: Data collection protocols

Paper 5: Expert interview questions

Participant data

1. How many years of work experience do you have?
2. What is your educational background?
3. What is the size of your business?
4. What are or have been your managerial responsibilities?
5. Are you familiar with the concept of organizational capability?
6. Are you familiar with Enterprise Modeling?

Questions on capability change

7. What does the concept of capability mean to you? Is it a term used in your organization?
8. Which of the following statements do you mostly agree with?

    - A capability of an organization is a resource that consists of other resources.
    - A capability is not a resource but it consists of organizational resources.
    - A capability is not a resource but is configured by allocating resources to it.
    - A capability is a resource and is configured by allocating other resources to it.

9. Based on your experience, what is the most common type of capability change?

10. Is capability change a common phenomenon in your organization/unit?

11. Have you used any methods or tools to support capability changes? If yes, which ones?

12. How would you describe the differences between the business concepts of capability and potential, if any?

13. Do you consider a capability as an exclusively positive concept or there can also be negative capabilities (e.g. ability and capacity to harm the organization)?

14. Are any concepts that you would use to describe capability change missing from the above list?

15. Who is responsible for observing a capability's performance and identifying a need to change?

16. How are the observed data communicated to any interested parties?

17. Are there any general factors or general factor types being observed that are affecting a capability's performance, or each capability has its own specific factors?

18. How do you identify which aspects of the capability's context (politics, society, economy, technology, competitors etc.) to observe in order to recognize a need for change? For example, if a capability is observed by monitoring KPIs, how is the association between the specific capability and the specific KPIs established?

19. Which of the below statements do you mostly agree with?

    - A capability is contextual on its own.
    - A capability is not contextual, it only depends on the context of the organization that owns it.

20. What are the challenges when observing a capability?

21. Who is responsible for decisions regarding a capability change?

22. How are the criteria determined for deciding on the best alternative for a capability change?

23. Is it possible to derive decision criteria by measuring a capability's outcome?

24. How is a capability change initiated?

25. How is a change request communicated?

26. How are the observed data analyzed? (gap analysis, SWOT analysis, PESTLE analysis etc.)

27. What are the challenges when deciding on a capability change?

28. Who is responsible for delivering a capability change?

29. How is the delivery communicated among involved organizations/units?

30. How is a capability change delivered?

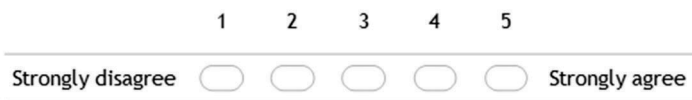
31. Is a delivered change always affecting the realization of the capability (changing processes, services etc.)?

32. How is the impact of the delivered change analyzed (impact analysis etc.)?

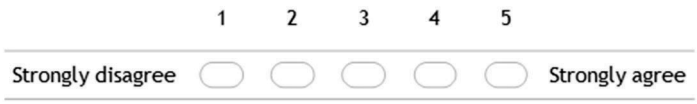
33. What are the challenges of delivering a capability's change?

Paper 9: Evaluation questionnaire

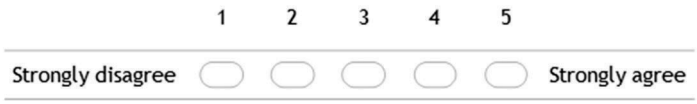
Q1. I consider the KYKLOS phases clear and easy to understand.



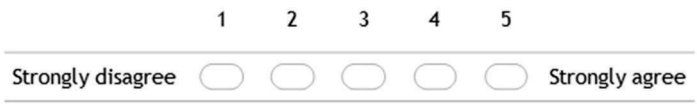
Q2. I consider the procedure for applying the method easy to follow.



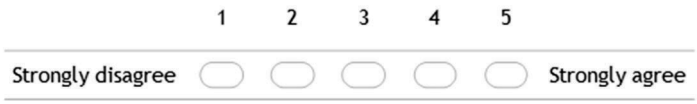
Q3. Overall, I consider the method easy to use.



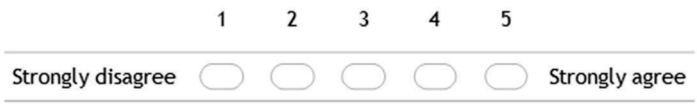
Q4. I believe that the KYKLOS method reduces the effort required to model changing capabilities.



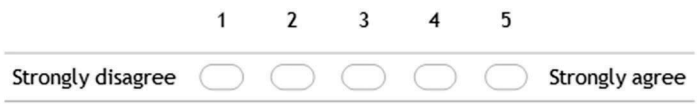
Q5. KYKLOS is useful for describing the context (external aspects) that affect capabilities.



Q6. KYKLOS is useful for describing the intentions (internal aspects) that affect capabilities.



Q7. KYKLOS is useful for making decisions on how a capability can change.



Q8. KYKLOS is useful for describing the resources and processes that are needed for a capability.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q9. KYKLOS is useful for describing the transition of capabilities, such as introducing, changing or retiring capabilities.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q10. KYKLOS is useful for capturing the ownership aspect of capabilities and their components.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q11. KYKLOS is useful for describing the associations of a changing capability with other capabilities.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q12. KYKLOS contains the concepts that I need to describe capability change.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q13. Overall, I found the method to be useful.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q14. For future tasks, I would use KYKLOS to model changing capabilities.

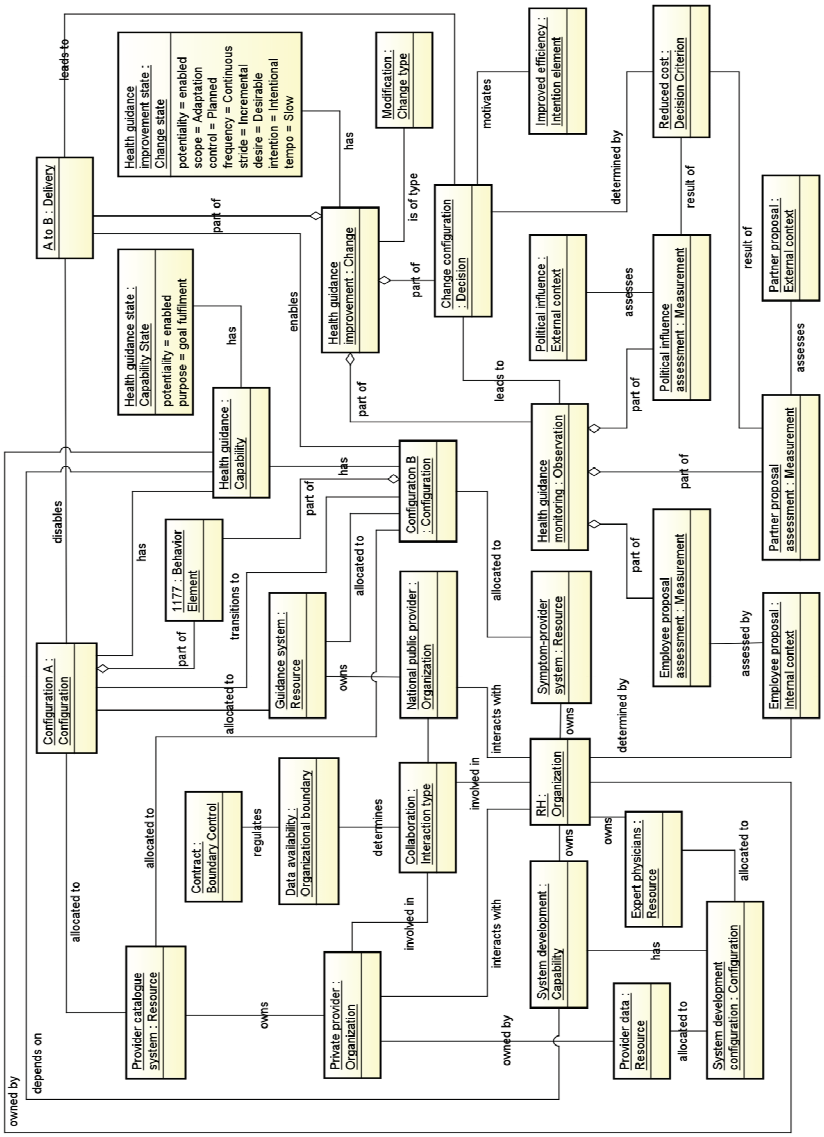
	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Q15. I intend to use KYKLOS in preference to other modeling methods if I have to model changing capabilities.

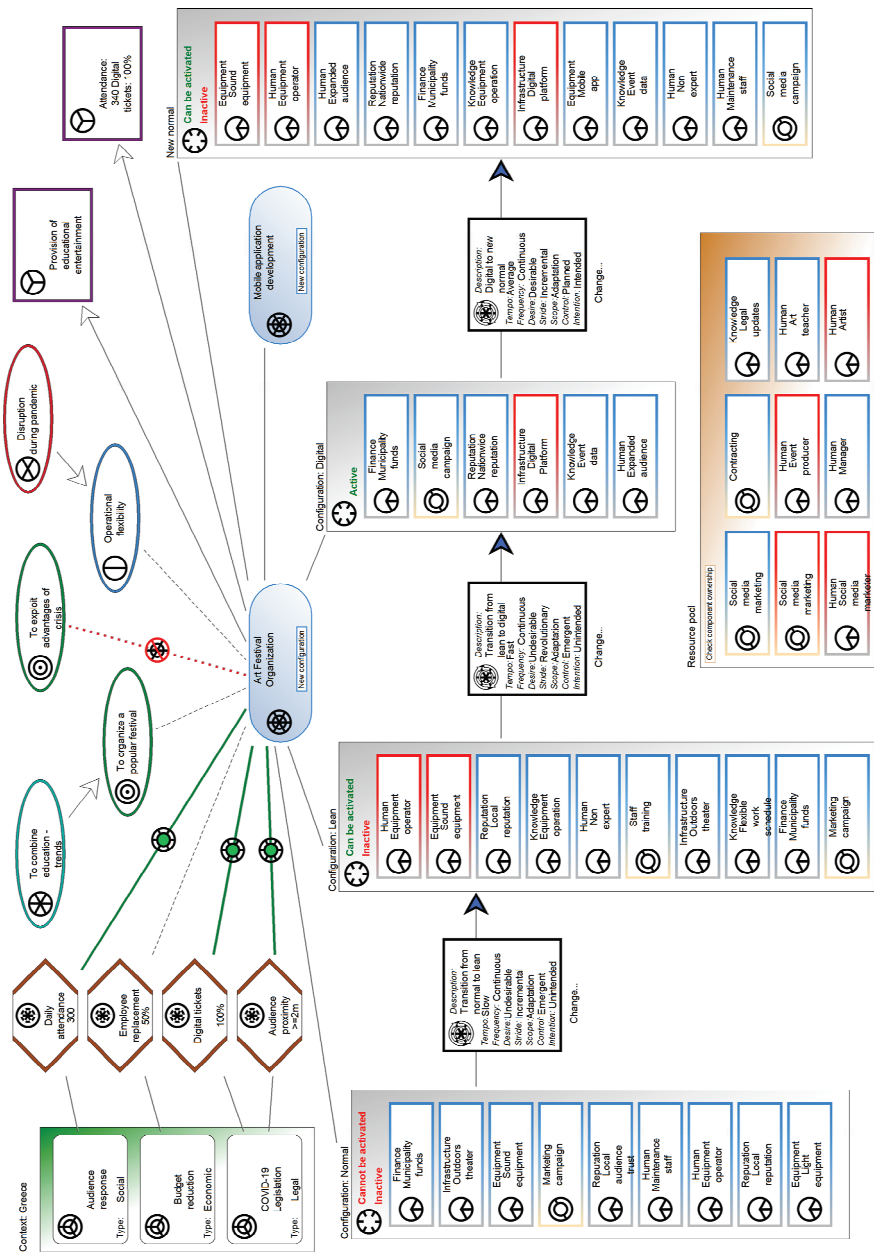
	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Appendix 6: The Case Study Models

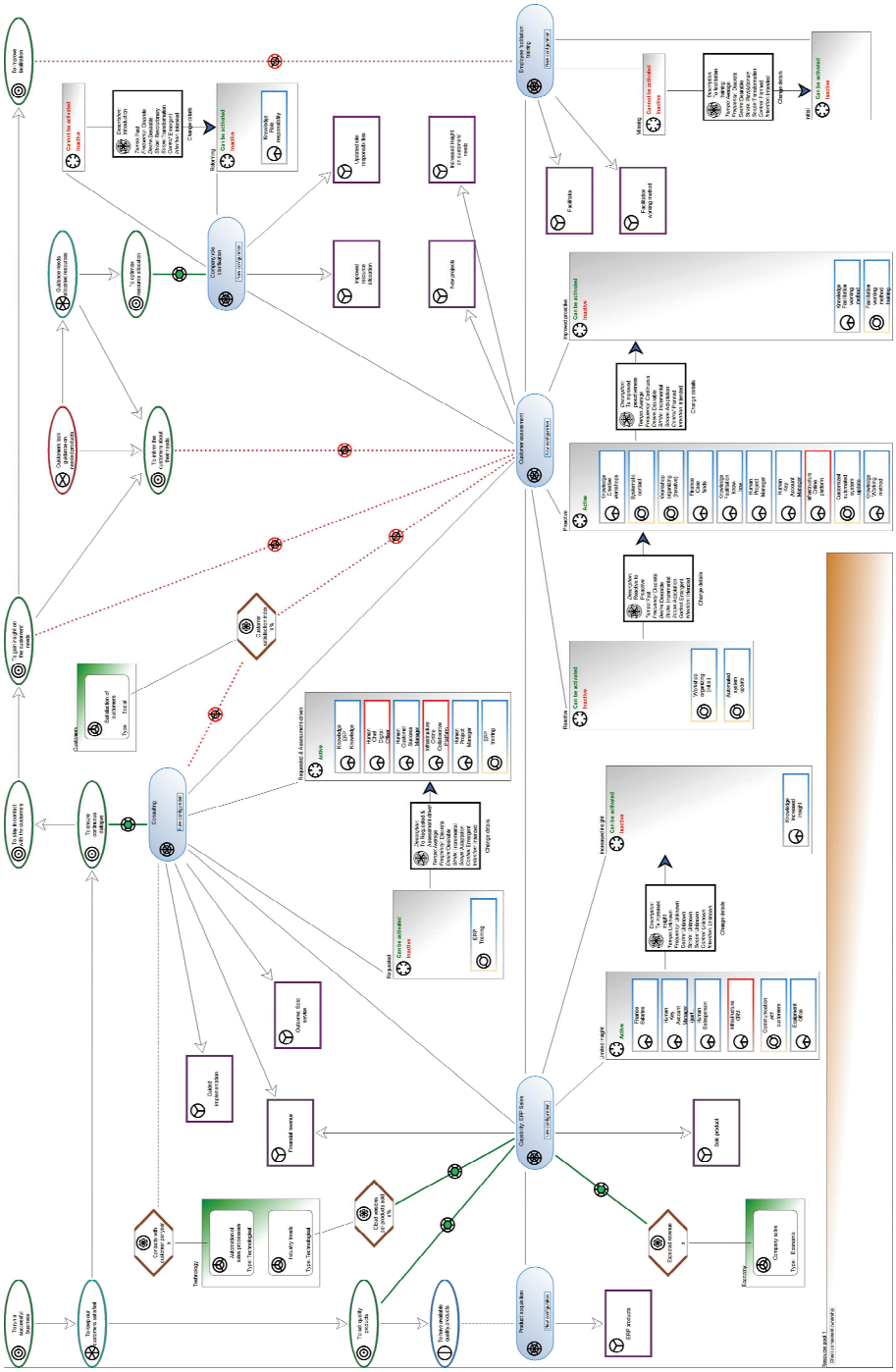
Case 1: Regional Healthcare model



Case 2: Veria Arts Center model



Case 3: Digital Intelligence model



Appendix 7: KYKLOS User Guidelines

The present guidelines are adapted and extended from Paper 8. KYKLOS is a method that can be used for both analyzing existing proposals for change and designing new ones. It supports the analysis of options for delivering the change. This is achieved by considering three areas: (i) the environment of the capability (observation of context and intentions); (ii) its internal structure (decisions on capability configurations); and (iii) the potential changes (delivery of configuration changes). The modeling procedure supports knowledge capture, documentation and analysis of these areas.

The modeling procedure is split into four phases: one foundational phase for initial analysis, followed by one phase for each area (observation, decision alternatives, and delivery of change). The focus of the procedure is on the last two phases, and other models developed with other methods can be used as input to the first two phases. For example, an organization's intentions can be modeled with an existing goal modeling method, such as 4EM (Sandkuhl et al., 2014). Table 23 and Figures 22 and 23 provide an overview of the phases and sequence of activities.

Table 23. Overview of the modeling procedure, its phases, and the elements used.

Phase	***Main actions***	***Model elements***
0: Foundation	Describe the basis for the analysis in terms of an identified capability.	Capability, outcome
1: Observation of context and intentions	Analyze the internal and external context in which the capability must function. Identify needs for change.	Context, monitored factor, KPIs, intention
2: Decision alternatives	Analyze the alternatives for capability configurations that address the need for change, including the needed resources and behavior.	Configuration, resource, behavior
3: Delivery of change	Understand what needs to be done in order to deliver the change in the form of a transition from the current capability configuration to a future one.	Change, change properties

The modeling procedure may be iterative, as a change has a potential impact on the capability and its outcomes, meaning that the foundation phase may be triggered again and the procedure may continue when necessary.

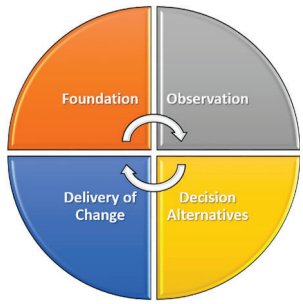


Figure 22. An overview of the phases in the KYKLOS modeling procedure.

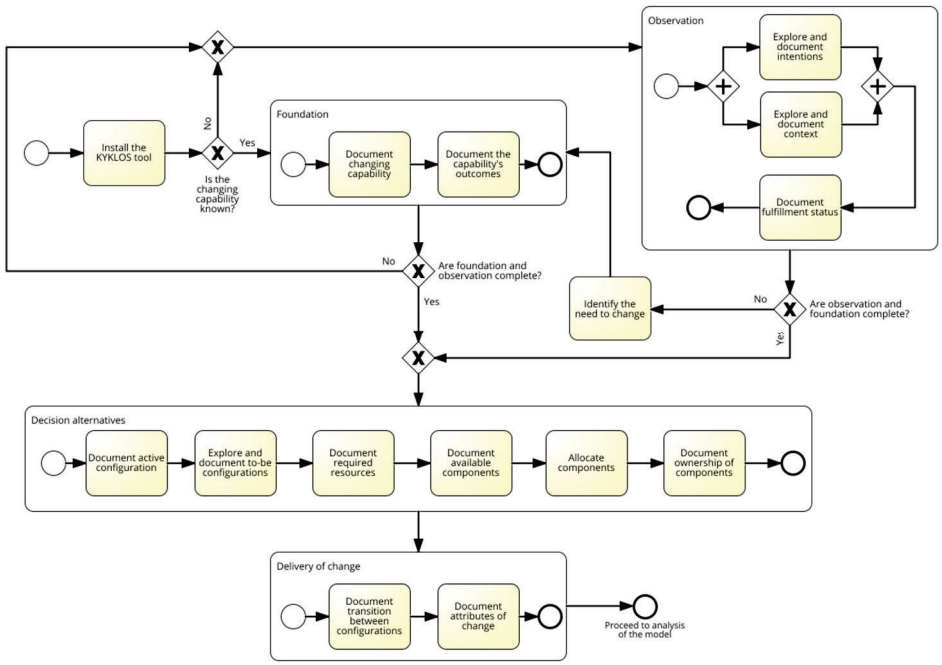


Figure 23. The sequence of activities in the KYKLOS modeling procedure.

A structured analysis of each phase is given below, including the input, objective, driving questions, description, output, modeling activities, tools, and contributors, and an example is given for each phase.

Foundation

Input The identified problem.

Objective. The identification of the capabilities that should be further analyzed. The identified capability and its outcome(s) are input into the KYKLOS model.

Driving questions. Which capability's potential changes should we analyze? What are the outcomes it produces?

Description. The starting point for the analysis is the noteworthy fact that even newly started companies have some form or idea of a capability. At the start of the analysis, it is often clear which organizational capability needs to be studied; in other cases, there are several methods for identifying and selecting the capability that should be analyzed in depth. For example, according to suggestions put forward by Sandkuhl and Stirna (2018a), the identification of capabilities can be based on goals, processes, or concepts. Another suggestion by Henkel et al. (2014) is to focus on the main capabilities of the organization, in other words, those providing value to external customers in terms of producing goods or services. The owner of the identified capability is also captured, along with its type according to the capability typology. This means that the user needs to document whether the capability is a main or supporting capability.

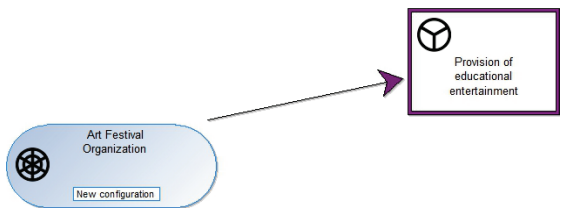
Output. An identified capability, and a brief description of its outcomes (what it achieves).

Modeling activities. The capability and its outcome(s) are input into the KYKLOS model and connected via relationship(s). In the case where there are relevant supporting capabilities, these should also be input into the model. At this point, the attributes of the capability need to be documented, which means that the name, owner and significance (main or supporting capability) should be input into the model using the notebook of the object.

Tools. KYKLOS software, e3value model (suggested in case of difficulty identifying the outcome)

Contributors. Modeling expert, domain expert

Example. From the Veria Arts Center case.



Observation

Input. Business intentions, capability context

Objective. The aim of this phase is to document the business intentions and the context, which are measured to assess the capability's performance.

Driving questions. Which external factors are relevant to the capability? Which internal goals should be fulfilled by the capability?

Activities. In this phase, the internal intentions and external context of the previously identified capability are analyzed. The context consists of elements that can be observed, have an effect on the capability, and cannot be controlled by the organization. These may be determined by identifying opportunities and threats as part of a SWOT analysis, or by conducting a broader PESTLE analysis. Existing context modeling approaches such as the one developed by Koç et al. (2016) can be used as a means of refining the context to give measurable items. The analysis of the internal intentions focuses on the intentions/goals of the organization that hinder or drive the capability. A goal model may be used for this analysis, for example, a 4EM goals model. During this analysis, the desire or need to change the given capability is captured in the KYKLOS model as intentions that are not fulfilled (for example, criteria for efficiency) or external context entities (for example, changes in legislation) that restrain the capability. The type of intention that is connected to the capability also determines the exact type of the capability, according to the typology given in Section 4.2.1.

Between context and intentions, it is recommended to prioritize what has been prioritized or discussed to a greater extent by the domain experts.

Output. The context is described as a set of monitored factors and the associated KPIs. The intentions are described as a set of intention elements. An important result is also the (set of) identified KPI(s) and intention element(s) that are currently not fulfilled by the capability, which comprise the identified need to change. It should be noted that if no need to change is identified, there is no point continuing the analysis of the changing capability. KYKLOS is applicable to each capability case up to this point in the analysis, but the succeeding phases are performed only when a change is needed.

Modeling activities. To model the context, a context container object is input into the model and named. The associated monitored factor objects are input to the context container and named, and their type is documented based on the proper PESTLE category. The KPIs that quantify these factors are input as KPI objects outside the container, and are associated with each relevant monitored factor via a relationship. Their names and values are also documented.

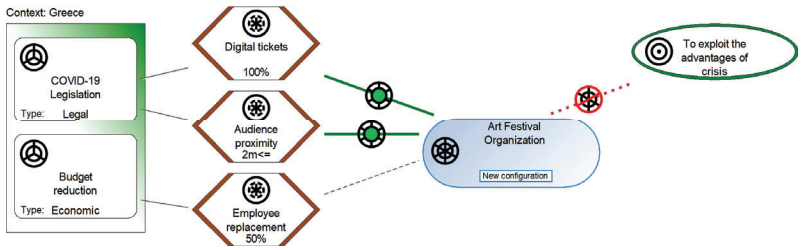
Intentions are input into the model as intention element objects. Their names and types (goal, problem or requirement) are documented in the Notebook, and this also affects their visualization. If one intention element leads to another, for example when a problem leads to a requirement, the objects are associated to each other via a relationship.

The fulfilled, unfulfilled, or unknown fulfillment status of KPIs and intention elements is visualized in different ways using lines and symbols (a solid green line and  , a dotted red line and , or a dashed black line, respectively).

Tools. KYKLOS software, 4EM Goals model (suggested) or other goal modeling approaches, PESTLE analysis (suggested) or any context modeling approach.

Contributors. Modeling expert(s), Domain expert(s)

Example. From the Veria Arts Center case.



Decision alternatives

Input. Changing capability, Need to change, Unfulfilled intention(s) and/or context factor(s)

Objective. This phase aims to explore the configuration of the capability and to examine potential changes to it.

Driving questions. What resources does the current capability consist of? What alternative capability configurations can meet new internal goals and external contexts? Which resources do we need to obtain in order for the new configurations to work? Which of these resources are available?

Activities. The configuration of a capability consists of a set of resources and behavior elements that result in a capability achieving its goals. A capability may have several configurations fulfilling the same goal, for example, the act of scanning tickets for attending an event may be performed by a machine (as a resource) or by a human (as an alternative resource). The detailed behavior concerning a configuration may be captured, for example, as a process model.

The examination begins with the active configuration, since this represents the as-is state of the capability. The resources that are allocated to it are captured in the model, along with the identified behavior in the form of processes. Resources may be tangible, for example equipment and goods, or intangible, such as knowledge. Following this, one or more alternative configurations are identified to fulfill the changes that are motivated by internal intentions or external contexts, along with their required resources. As a design activity, this requires domain experts to collaborate with modeling experts. During this activity, the KYKLOS model can be used to visualize the configurations.

An essential activity of this phase involves differentiating between required and available components (resources and processes). Whereas a configuration

consists of required resources and processes, the state of the configuration is active only when these resources are allocated to it. The tool was developed in such a way as to support this by visualizing the configuration as a container to which the components are considered to be allocated.

In this phase, an additional task is performed. Documentation of the owners of the capability and the components of the configuration enables the tool to visualize the internally and externally owned components, and motivates consideration of the organizational boundaries in terms of resources that imply additional costs.

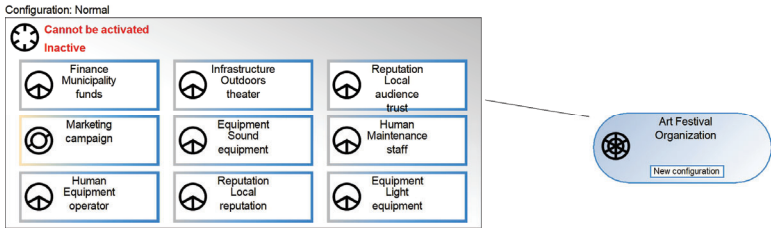
Output. A set of capability configurations that are connected to the capability via a relationship, their required (registered in the capability's notebook) and the available resources and processes (both contained in the configuration container).

Modeling activities. Initially, the different configurations of the capability that have been identified are input into the model as configuration container objects, and are associated with the capability via a relationship. This task can be performed manually or automatically, by pressing the 'New Configuration' button in the capability object. After naming the configuration using the required resources attribute in the notebook, all the resources, their names, types and quantities that are required for the realization of the capability are documented. Afterwards, a resource pool object is input into the model and all the resource objects that are relevant to the capability are put inside it. For each resource object, its name, type, quantity and owner are documented. The resource objects are then allocated to the configurations by moving them inside each configuration. The same task can be performed for the required processes, which are input into the model as process objects and allocated to configurations. The external components (resources and processes) that are used in the realization of the capability are identified using the 'Check component ownership' button in the resource pool container objects. The tool also automatically checks whether the existing resources in the model are adequate for activating a configuration of the capability. This is shown as a message at the top of each configuration object, stating whether it can or cannot be activated. In case where the resources required for activating a capability not only exist but are also allocated to the configuration, the configuration is considered active. Resources are reallocated by moving objects to a different configuration container. The tool's algorithms take into consideration the existence of resources and quantity of resources, and it is therefore advisable to avoid deleting resource objects from the model, but to reduce their quantity to zero instead, as the activity states of the configurations may show incorrect indications, even if the model fixes itself on the first time an object is moved.

Tools. KYKLOS software, 4EM Actors and Resources model or equivalent

Contributors. Modeling expert(s), Domain expert(s)

Example. From the Veria Arts Center case.



Delivery of change

Input. Decision to change, set of capability configurations

Objective. The purpose of this phase is to elaborate how the new capability configuration can be achieved. The active configuration that was modeled during the previous phase represents the as-is state, and the newly designed alternative configuration(s) represent to-be state(s). So, a description of the actual change (the transition between configurations) is then needed.

Driving questions. What transitions between capability configurations can be made? What properties does the change itself have? For example, does it need to be performed at a fast or slow tempo, etc.?

Activities. The main activity is the addition of changes to the KYKLOS model, in the form of associations between pairs of configurations. There are no restrictions on the changes between two to-be configurations. This situation may represent a planned sequence of future changes.

A change can be designed with different properties; for instance, its tempo may be slow or fast. It is therefore necessary to design a change capturing all its properties, and in particular the eight properties identified in our previous work (see Table 24 and the StateMachine diagram in Section 4.2.1). In practice, these properties relate to dichotomies that can be used to gain a better understanding of how the change should be delivered. As an example, the magnitude of the change can be indicated using the change stride, and it can be documented as revolutionary with a tempo during the delivery of the change (relative to other changes in the model) that is slow.

Table 24. Properties of change (adapted from Paper 8).

Property	Dichotomy	Description
1. Control	Emergent – Planned	A planned change occurs due to planned, deliberate and conscious actions, while any other case is an emergent.
2. Scope	Adaptation – Transformation	An adaptation is an adjustment of existing capability, whereas transformation is a deeper change in a capability, or a new capability.

3. Frequency	Continuous – Discontinuous	Frequency refers to how often a similar change needs to occur; for example, a case that involves following consumer trends requires continuous change.
4. Stride	Incremental – Revolutionary	When a change is incremental, it can be implemented is a series of small steps. A revolutionary change entails a relatively large change performed all at once.
5. Time	Long – Short	Time refers to the duration needed to implement a change.
6. Tempo	Slow – Quick	Tempo is related to time, and deals with the speed with which the actions of the change succeed each other.
7. Desire	Desirable – Undesirable	Desire refers to a change being welcome or unwelcome to an organization, for example, as an identified opportunity or threat.
8. Intention	Intentional – Unintentional	Intention refers to a deliberate and conscious change that an organization intended, regardless of planning and desire.

It should be noted here that only the active configuration is related to the existing context and intentions that have been observed. From a modeling perspective, the contextual and intention elements in the model are only relevant to the configuration that is active at that given moment in time. Any delivered change that activates a new configuration may trigger and motivate a new observation phase. In practice, the context and intention elements are updated, and a new modeling iteration is started.

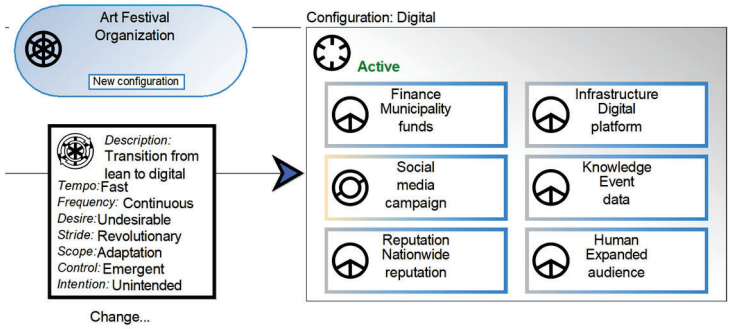
Output. A set of changes in the form of transition relationships between capability configurations. Each change is documented by identifying its properties. Adding these outputs results in a complete KYKLOS model.

Modeling activities. Having decided on the transition between capability configurations, the last modeling activities in the tool consist of capturing the change. This happens by adding transition relationship(s) between the relevant configurations. The notebook for the transition includes its name and all the relevant attributes that can be documented in the model. Visually, the transition can be minimized to a line or expanded to depict its main attributes in the table. This is achieved using the 'Change details' button located below the connecting line.

Tools. KYKLOS modeling software

Contributors. Modeling expert(s), Domain expert(s), Change project owner(s)

Example. From the Veria Arts Center case.


Art Festival Organization
New configuration
Description: Transition from lean to digital
Tempo: Fast
Frequency: Continuous
Desire: Undesirable
Stride: Revolutionary
Scope: Adaptation
Control: Emergent
Intention: Unintended
Change...
Configuration: Digital
Active
Finance Municipality funds
Infrastructure Digital platform
Social media campaign
Knowledge Event data
Reputation Nationwide reputation
Human Expanded audience