



Revising IT Governance:

Towards an Alignment of IT Developments with
Security and Digital Transformation Concerns

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To my family, promoters, colleagues and friends

This work is dedicated to the significant pillars of my journey—my family, whose boundless love and unwavering support have been my guiding lights. Your encouragement has been the fuel for my academic endeavors, and I am profoundly grateful for the sacrifices you made to see me succeed. A special acknowledgment to my sister Zeinab, who stood by my side through every challenge and triumph. Your presence added immeasurable strength to my journey. To my esteemed colleagues, whose collaboration and camaraderie have enriched my professional life. Together, we faced challenges, celebrated victories, and created lasting memories that transcend the workplace. A special acknowledgment to my two promoters, Manuel Kolp and especially Yves Wautelet without whom I could not achieve this milestone. Your guidance, expertise, and unwavering support have been the cornerstones of my academic success. To my cherished friends, who shared both the joyous moments and the trials of this academic journey. Your friendship has been a source of strength and laughter, making the challenges more manageable and the successes more joyful. This dedication is a tribute to the collective efforts of those who believed in me—family, colleagues, professors, and friends. Your influence has left an indelible mark on my journey, and I carry your support with me as I embark on new endeavors.

With heartfelt gratitude,

Abstract

In an era marked by rapid technological evolution and Digital Transformation (DT), the imperative for organizations to integrate and leverage on Information Technology (IT) within their operational frameworks has never been more critical. The contemporary digital landscape, characterized by the pervasive adoption of online technologies and the rise of mobile connectivity, demands a reevaluation of traditional IT governance and strategic management practices. As businesses navigate through this complex environment, the role of conceptual modeling in enhancing the alignment between IT capabilities and business objectives emerges as a pivotal area of inquiry. This PhD explores how conceptual modeling can be adequately applied to address the multifaceted challenges and opportunities within IT governance, thereby facilitating a strategic recalibration of organizations in the digital age. At the heart of this exploration lies the recognition of the expanded scope of IT management due to the massive transition from desktop-based to mobile user needs, human-served to online AI customer support, on-premise to cloud-based infrastructures, and the diversification of IT services. This shift not only underscores the need for adaptive business models and regulatory compliance but also accentuates the significance of security, sustainability, and DT as critical components of IT governance. Due to this new environmental setting, the thesis argues that traditional approaches to conceptual modeling, while instrumental in decision-making processes, can reveal to be falling short in capturing the nuanced dynamics of contemporary IT governance. It advocates for the application of conceptual modeling techniques that can report on the complexities of organizational structures and induce a more profound alignment between technological innovations and strategic business objectives of various nature. Employing Design Science Research (DSR) as methodological paradigm, the thesis leads to the development and refinement of conceptual models aimed at addressing emergent domains within IT governance, such as IT security and DT. Through iterative design cycles and empirical studies across diverse industry settings, including healthcare and telecommunications, the research shows the relevancy and validity of newly developed frameworks. The thesis consequently shows the utility of a methodologically rigorous and iterative approach in crafting solutions that are both theoretically robust and pragmatically viable. By reimagining the application of conceptual models in the context of IT governance, the thesis describes paths for organizations to use IT as a strategic enabler of innovation and growth. In doing so, it provides a comprehensive framework for understanding and navigating the complexities of the DT journey, offering valuable insights and methodologies for future research and practice in the field.

Samenvatting

In een tijdperk dat wordt gekenmerkt door snelle technologische evolutie en digitale transformatie (DT), is de noodzaak voor organisaties om informatietechnologie (IT) te integreren en te benutten binnen hun operationele kaders nog nooit zo cruciaal geweest. Het hedendaagse digitale landschap, gekenmerkt door de wijdverspreide adoptie van online technologieën en de opkomst van mobiele connectiviteit, vraagt om een herbeoordeling van traditionele IT-governance en strategische managementpraktijken. Terwijl bedrijven door deze complexe omgeving navigeren, blijkt de rol van conceptuele modellering in het verbeteren van de afstemming tussen IT-mogelijkheden en bedrijfsdoelstellingen een cruciaal onderzoeksgebied te zijn. Dit proefschrift onderzoekt hoe conceptuele modellering adequaat kan worden toegepast om de veelzijdige uitdagingen en kansen binnen IT-governance aan te pakken, en zo een strategische herijking van organisaties in het digitale tijdperk te vergemakkelijken. Centraal in deze verkenning staat de erkenning van de uitgebreide reikwijdte van IT-management vanwege de enorme overgang van desktop-gebaseerde naar mobiele gebruikersbehoeften, van menselijke naar online AI-klantenondersteuning, van on-premise naar cloud-gebaseerde infrastructuren, en de diversificatie van IT-diensten. Deze verschuiving benadrukt niet alleen de noodzaak van adaptieve bedrijfsmodellen en naleving van regelgeving, maar ook de betekenis van beveiliging, duurzaamheid en DT als kritieke componenten van IT-governance. Door deze nieuwe omgevingssetting betoogt het proefschrift dat traditionele benaderingen van conceptuele modellering, hoewel instrumenteel in besluitvormingsprocessen, tekort kunnen schieten in het vastleggen van de genuanceerde dynamiek van hedendaagse IT-governance. Het pleit voor de toepassing van conceptuele modelleringstechnieken die kunnen rapporteren over de complexiteit van organisatorische structuren en een diepere afstemming kunnen bevorderen tussen technologische innovaties en strategische bedrijfsdoelstellingen van diverse aard.

Met behulp van Design Science Research (DSR) als methodologisch paradigma leidt het proefschrift tot de ontwikkeling en verfijning van conceptuele modellen die gericht zijn op het adresseren van opkomende domeinen binnen IT-governance, zoals IT-beveiliging en DT. Door middel van iteratieve ontwerpcycli en empirische studies in diverse sectoren, waaronder de gezondheidszorg en telecommunicatie, toont het onderzoek de relevantie en validiteit van de nieuw ontwikkelde kaders aan. Het proefschrift laat bijgevolg de bruikbaarheid zien van een methodologisch rigoureuze en iteratieve aanpak bij het ontwikkelen van oplossingen die zowel theoretisch robuust als pragmatisch haalbaar zijn. Door de toepassing van conceptuele modellen in de context van IT-governance opnieuw voor te stellen, beschrijft het proefschrift wegen voor organisaties om IT te gebruiken als een strategische aanjager van innovatie en groei. Hiermee biedt het een uitgebreid kader voor het begrijpen en navigeren van de complexiteit van de DT-reis, en biedt waardevolle inzichten en methodologieën voor toekomstig onderzoek en praktijk op dit gebied.

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Chapter 1

Introduction

1.1 Research Context and Meta-Research Question

In contemporary times, organizations are confronted with unparalleled challenges in integrating technology into their operations. During the 1990s and 2000s, the rise of the internet necessitated a fundamental re-evaluation of business models, leading to significant disruption in traditional supply chains. This era witnessed widespread disintermediation and the emergence of reintermediation strategies, which gave rise to powerful market entities, now collectively referred to as the GAFAs (Google, Amazon, Facebook, Apple). The present landscape, characterized by the ubiquitous adoption of online technologies — particularly through the widespread use of mobile devices — demands a reimagining of all business sectors, including those traditionally resistant to IT-driven innovation. The imperative now extends beyond merely considering whether a product or service could be offered online, or whether teams could operate virtually, or even whether certain intermediaries should be eliminated. The stakes are fundamentally higher, necessitating a profound redesign of products and services at their very core to unlock new dimensions of user value. This includes the development of intelligent assistants, the remote operation of local devices, real-time and distant customer support, and the exploration of metaverses. Such transformations are not optional but essential for ensuring the sustainability of businesses in this new era of possibilities.

In the current landscape, the scope of IT management has expanded significantly, encompassing a broader range of responsibilities than in the past. Previously, organizations primarily relied on on-premise infrastructures to support their internal software systems. However, the shift towards cloud infrastructures has led to a diversification of IT services and introduced the need for support across decentralized operators, clients, and edge-based devices. This evolution necessitates the development of optimal business models, the integration of new types of regulations, such as those related to sustainability, and addresses an array of security concerns that are more critical and fundamental than ever before.

These challenges are not solely the purview of management. Addressing security concerns, for example, requires significant investment and strategic

decision-making regarding prioritization. Consequently, new domains of IT governance and strategy have emerged as crucial aspects of governance. These include cloud computing, cybersecurity, sustainability, and the Digital Transformation (DT) itself. These areas demand a concerted effort to ensure that organizations can navigate the complexities of the modern IT environment effectively. This holistic approach to IT governance and strategy is essential for organizations aiming to thrive in this dynamic and increasingly complex digital era.

Conceptual modeling has traditionally been pivotal in enhancing decision-making processes at both governance and management levels. Yet, its deployment has largely been confined to broad contexts, rather than addressing the specific, nuanced domains of IT governance identified earlier. This gap presents an opportunity to employ conceptual modeling more effectively in these areas, aiming to achieve a deeper alignment between business objectives and IT capabilities. Conceptual modeling holds the promise of addressing several critical challenges. These include comprehending the complexities of organizational structures that increasingly encompass both IT and non-IT domains, identifying multifaceted opportunities for alignment, improving communication regarding new strategic objectives, aiding the strategic planning of operational initiatives, guiding adherence to regulatory standards, and enhancing overall decision-making processes.

The utilization of conceptual modeling in IT governance represents a pivotal shift towards a more nuanced and multifaceted approach to aligning technology with business strategies. By employing conceptual modeling, organizations are better positioned to navigate the complex and evolving challenges they face, achieving a strategic alignment that is adaptive to technological advances and regulatory changes. This leads us to the central research question of this thesis: *'How can conceptual modeling be applied to identify and address emerging domains within IT governance that significantly influence the long-term strategic positioning of organizations?'* Ultimately, this exploration seeks to understand how conceptual modeling can serve as a foundational tool in enabling organizations to harness IT not just as a support function but as a strategic driver of business innovation and growth.

1.2 Application of Design Cycle Research and Methodological Originality of the Thesis

To explore the overarching meta-research question and delve into the individual studies that constitute the backbone of this thesis, we employed a comprehensive suite of research methodologies, prominently featuring Design Science Research (DSR) as the methodological cornerstone across Chapters 2, 3, 4, and 5. The adoption of DSR, renowned for its effectiveness in navigating the exploration, creation, and validation of innovative solutions—be it methods, artifacts, or technological implementations—is especially pertinent to the intricate and dynamic field of conceptual modeling for IT governance. This research aims to construct

valuable tools for an array of stakeholders, including C-suite executives, strategy consultants, and governance decision-makers, thereby addressing a critical gap in the existing body of knowledge.

The iterative essence of DSR, characterized by cycles of Relevance and Rigor, serves as a fundamental strategy for identifying and tackling domain-specific challenges. Through these cycles, we have developed and refined artifacts designed to enhance the modeling of burgeoning areas within IT governance, particularly focusing on IT security and DT. These artifacts are intended to meet the evolving requirements of these emerging governance areas, thus embodying the thesis's innovative approach to conceptual modeling.

The methodological innovation of this thesis is further highlighted by incorporating two distinct design cycles in the development processes of the IT security governance framework (Chapter 2) and the DT reference model for strategic objectives (Chapters 3 and 4). This dual-cycle approach, enriched through the integration of new case studies, facilitates a rigorous process of empirical testing, refinement, and insight extraction. In both researches, the first design cycle applies the research within the healthcare domain, specifically in a hospital setting, laying the groundwork for IT governance frameworks that are responsive to the unique challenges of this sector. The second design cycle shifts focus to the telecom industry, offering a contrasting perspective with studies conducted within the Belgian context for IT security governance and an Asian context for DT governance. This transition not only amplifies the empirical robustness and adaptability of the developed frameworks and models but also showcases their broad applicability across varying organizational and cultural landscapes.

By employing a methodologically rich approach that weaves together multiple design cycles and case studies from distinct domains, this thesis makes a substantive contribution to the field of conceptual modeling research. It demonstrates the pivotal role of an iterative, evidence-based approach in crafting frameworks and models that are not only theoretically sound but also practically viable across diverse settings. Moreover, this work significantly advances our comprehension of IT security and DT out of a strategic approach, marking a methodological milestone in the application of DSR to the ever-evolving challenges of strategic alignment in the digital age. Through this comprehensive exploration, we not only contribute to the academic discourse on IT governance but also provide actionable insights and methodologies that future researchers and practitioners can apply in similar and related fields.

1.3 Structure of the Thesis and Individual Contributions in Answering the Meta Research Question

Chapter 2 entitled '*A Security-Aware IT Governance Framework*' introduces the SecureMoDrIGo framework, an enhancement of the previously developed Model-Driven IT Governance (MoDrIGo [252]) framework. Addressing the evolving

landscape of security concerns, SecureMoDrIGo integrates security concepts into the IT governance process. It guides the evaluation, direction, and monitoring stages, offering a multi-level security overview for informed decision-making. The contribution of Chapter 2 lies in providing a comprehensive framework that integrates security considerations into IT governance, thus ensuring that security is an integral part of the strategic IT service adoption process. Applied in a hospital's adoption of a Remote Patient Monitoring service, the framework is validated through expert opinions, showcasing its utility in strategic IT service adoption. This work has been done in collaboration with Yves Wautelet, Abigail Gongora Matus, Jamal El-Hachem, Samedi Heng, Konstantinos Tsilionis and Manuel Kolp; it has not been submitted to any scientific journal yet.

Chapter 3 entitled *'Towards Strategic Support and Guidance of the Digital Transformation: A Conceptual Model'* focuses on the critical aspects of DT within organizations. It emphasizes the misconception that adopting new IT technologies alone is sufficient for digitalization success. The research aims to enhance understanding among C-level executives by identifying and illustrating core DT concepts using conceptual modeling. The contribution of the paper involves proposing a framework that offers a high-level overview of the custom DT context, facilitating a systematic and integrated approach for organizations shifting from ad-hoc technology-driven approaches to systematic integrated strategies for DT. It underscores the importance of conceptual clarity and strategic vision in navigating the complexities of DT. The paper compares the proposed approach with existing conceptual modeling methods for DT, highlighting its novelty in focusing on governance-level understanding and interrelation of DT concepts, which is essential for C-level executives. This work has been done in collaboration with Yves Wautelet and Manuel Kolp; it has been presented at the first workshop on Enterprise Modelling for the Digital Transformation (EM4DT) on 24th November 2021 and published in PoEM Workshops proceedings of 2021.

Chapter 4 entitled *'Supporting digital transformation strategy formulation through a customisable set of objectives: conceptual model and expert opinions'* delves into the realm of Digital Transformation Strategy (DTS) formulation, addressing the common challenges of ad-hoc approaches without a cohesive global vision. Its contribution lies in presenting a conceptual model, shaped through a systematic literature review and refined by expert opinions, offering a generic, yet customizable, set of DTS objectives. This model serves as a foundational guide, empowering organizations to tailor their unique DTS effectively. The article further demonstrates the integration of this model into existing IT services development processes, ensuring alignment with the organization's overarching DTS objectives. This work has been done in collaboration with Yves Wautelet, Daan Dijkmans, Samedi Heng, Stephan Poelmans and Manuel Kolp; it has been published in the Enterprise Information Systems journal 18(3) by Taylor & Francis in 2024.

Chapter 5 entitled *'Customizing a Generic Digital Transformation Objec-*

tives Model onto a Telecommunication Company' delves into the challenges faced by organizations in establishing a DTS, particularly the difficulty in coordinating individual initiatives toward a long-term vision. In this chapter, we have built upon previous work that derived DT strategic objectives from literature and validated these through expert opinions. This chapter contributes by focusing on applying and validating the generic DT strategic objectives model in the context of a public telecommunication company. Through interviews with domain experts, the study identifies the prioritized objectives that guide the company's DT strategy formulation, emphasizing considerations such as government policies and human resources management. Critiques from interviewees include the model's limitations in recognizing the government's crucial role in managing a state-owned company. Some objectives also faced comprehension challenges among managers, highlighting areas for improvement in the generic model. This work has been done in collaboration with Ke Xu, Yves Wautelet, Konstantinos Tsilinis and Manuel Kolp; it has been presented at the 16th international workshop on Enterprise & Organizational Modeling and Simulation (EOMAS 2024) on 4th June 2024 and is published in Springer LNBIP proceedings series.

Chapter 6 entitled *'On the ability of novice modellers to identify, represent and trace tactical and strategic conceptual elements in business process and enterprise modelling'* explores Business Process Modeling (BPM) and its significance in aligning process improvements with an organization's business strategy. While commonly viewed as representing detailed daily work execution steps, BPM also serves to define broad process outlines and their impact on organizational strategy. As a contribution, the focus of this chapter shifts from the operational to the tactical and strategic perspectives, assessing the ability of novice modelers to represent business processes and trace their strategic impact. The study employs a quasi-experiment where subjects create Business Use-Case Diagrams for a complex case. Results indicate that the proposed quality assessment is effective, and cognitive style does not significantly impact the quality of representations produced by modelers. This work has been done in collaboration with Koen Heeren, Yves Wautelet, Stephan Poelmans and Manuel Kolp; it has been presented at 27th International Enterprise Design, operations and Computing Conference (EDOC) on 2nd November 2023 and is published in the Springer LNBIP Forum proceedings series.

Chapter 7 serves as a comprehensive reflection on the significant contributions made by the research, along with a candid exploration of its limitations and avenues for future work.

Part I

Supporting Business and Security Alignment through Strategy Formulation

Chapter 2

A Security-Aware Governance Framework

2.1 Introduction

One of the key issues within contemporary organizations, especially the ones heavily dependent on IT-intensive systems, is security. Indeed, security threats have a global impact on the organization and need to be envisaged from the governance to the management level and vice versa. Therefore, it is critical that organizations (which are mostly comprised of non-IT specialists) learn how to cope with IT security issues and address them strategically at the very top level [196]. In that aspect, Vellani [239] urges to start determining at a higher level of what needs to be protected, otherwise organizations run the risk of choosing and deploying incomplete and erratic security measures that might expose their IT assets to all sorts of vulnerabilities.

Envisioning IT security at the corporate level may require the laborious investigation of new ways of expressing its components for the sake of comprehension and clarity. However, making appropriate IT security configurations allows the critical assets of an organization to be protected which implicitly contributes to the setup of proper Business and IT Alignment (BITA) practices. Therefore, it is deemed necessary to first define a security vision (i.e. strategy) which is a formal statement of the overall security approach and objectives. The organization's business and security objectives can then be aligned with individual initiatives. Also, the security strategic objectives can be disseminated to the lower management levels. Then, the operational level can take charge of the task of identifying specific vulnerabilities, threats or risks to secure IT assets, and the organization as a whole [59]. Indeed, the work of incorporating security within the organizational strategy and implementing it through appropriate tactics is consonant with the work of defining and recognizing which IT assets are strategically vital to the organization and securing these through comprehensive measures [103].

The focus of this research is to propose a framework that provides a high-level security overview for more accurate decision making regarding asset-adoption. Thereby, the Research Question (RQ) driving the study is “*How can we determine and build-up a set of key elements relevant for understanding managerial impact on security of IT service adoption decisions taken at governance level?*”. In the process of answering this RQ, we should be able to demonstrate some of

the key concepts to govern the security of an organization and how can these be traced at management level for their further understanding, elaboration and work allocation. We should also be able to portray a way of using and extending an existing framework with these security-related concepts to provide for adequate governance and management-level representations.

Ultimately, this novel framework (called SecureMoDrIGo) can be used to assign security-related resources and effort onto most relevant areas when implementing the IT governance decisions at the management level (via the adoption of *Business IT Services* as defined in [252, 255]), leading to a security-aware organization. It extends the ontology of the Model Driven IT Governance (MoDrIGo) [252] framework to include relevant security concepts at multiple levels but also pinpoints how these concepts influence strategic decision making. To offer some background, MoDrIGo notably allows to “*represent an organization’s business and IT strategies in terms of strategic objectives*” [252] and to evaluate the impact of IT service acquisition decisions in terms of the business and IT alignment. MoDrIGo follows the three classical stages of IT governance processes, namely *Evaluate*, *Direct* and *Monitor*. This allows to analyze all of the IT services of the portfolio at different moments in time in order to determine their fit with the business and IT strategies [252]. The availability and behavior of IT services (or any sort of *strategic opportunities* [228] expressed in the form of services) are then adapted accordingly to the precise governance decisions on IT investments taken [228]. It should be noted at this point that this study is a complement to the one of Aghakhani et al. [75] negotiating the topic of risk representation at the strategic level. While the focus of the latter is on providing a high-level risk overview which helps organizations perceive and detect risks when pursuing their strategic objectives, the present research rather aims to help organizations successfully adapt a security strategy and assign the security-related effort within the IT services adoption process. It is destined to be used and understood by business executives that are not necessarily familiar with the technical approach and aspects of IT security.

The remainder of this paper is structured as follows: Section 2.2 focuses on the research paradigm and followed approach; In Section 2.3, we will explain the core add-ons of SecureMoDrIGo and how the framework is being primarily evaluated; Section 2.4 discusses the applicability and evaluation of the framework in the premises of a specific company. Afterwards, Section 2.5 is dedicated to the discussion. Threats to validity and related work are then discussed in Sections 2.7 and 2.8 respectively. Finally, conclusion is given in Section 2.9.

2.2 Research Methodology and Approach

Our followed methodology has its roots on the Design Science (DS) paradigm [93]. In that aspect, we propose a solution, in the form of a framework, for the identified lack in concrete ways of conceptualizing IT security issue at the governance level while allowing their dissemination and elaboration at the lower levels of the organizational matrix. The DS research approach dictates the elaboration of specific cycles such as the *Relevance*, *Rigor*, and *Design Cycles* for the establishment of DS artifacts. These are correspondingly instantiated

in subsections 2.2.1, 2.2.2 and 2.2.3 while the research protocol is visualized in Figure 2.1.

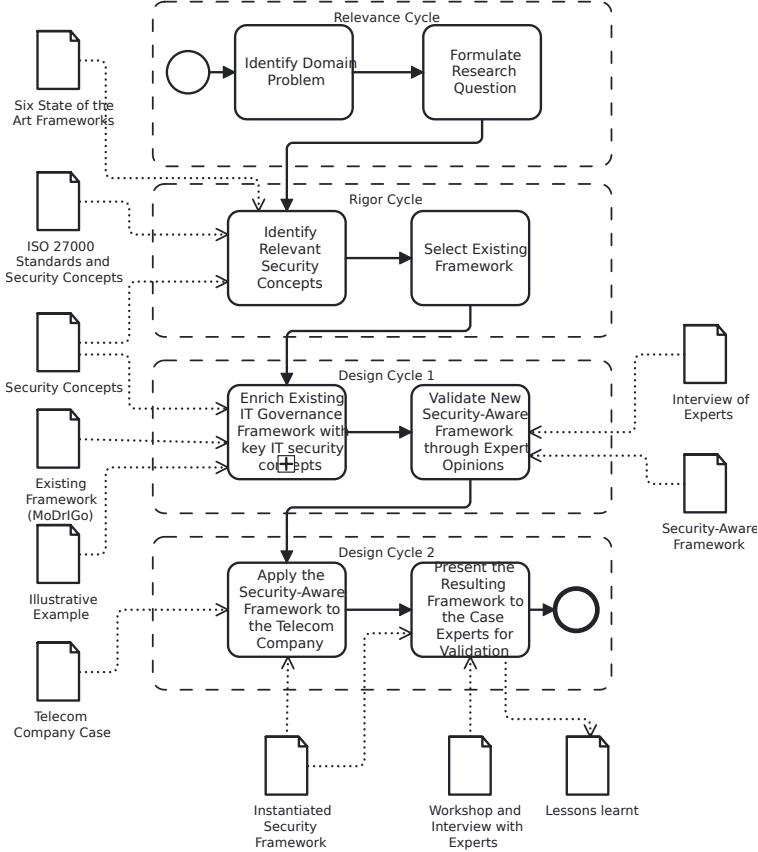


Fig. 2.1 Research Approach

2.2.1 Relevance Cycle

The relevance cycle focuses on the identification of the opportunities and/or problems in the application domain [93]. We currently identify a dearth in studies delving into the impact of incorporating security considerations into strategic deliberations on IT service adoption decisions. Indeed, while many security management frameworks exist (see for example the studies of [167], [2]), our framework is aimed to support governance and anchor to the management level rather than be a pure security management framework. Thereby, instead of focusing on IT security at the lower organizational levels (i.e. by managing specific and unconnected infrastructure threats), this study rather focuses on the representation of security aspects at the **governance level**. This is presently achieved by analyzing the state of adoption of internal *business IT services*. Indeed, the acquisition of new IT services have a very significant impact

on the organization's finances and are thus governance-level decisions. Since strategic objectives are implicitly supported by these IT services, failure in their proper adoption may lead to the non-fulfillment of the strategic objectives and, therefore, missing the sought long-run competitive positioning [227]. In this context, security concerns (that can respectively impact the services' adoption) become a matter of reference for the entire C-suite (so it is no longer a concern of the IT department only), since they are the ones needing to understand the security consequences of IT services acquisition on the entire organization and best allocate budgets.

2.2.2 Rigor Cycle

This cycle refers to the theories and/or methods used to ground the construction and the evaluation of the SecureMoDrIGo framework [93]. To reiterate, the latter is based on the MoDrIGo framework which has been previously validated in the study of Wautelet [252]. The relevance of MoDrIGo as the basis for this research has been already elaborated in the study of [75]; in a nutshell, its relevance is based on the comparison of six important criteria such as *service-driven*, *support for BITA*, *goal-orientated*, *socially-oriented modelling concepts*, *focus on IT development and deployment issues* and *support for security concerns*. A detailed description of these criteria can be found in Appendix A of this chapter which can be found in the online Appendix¹.

The establishment of SecureMoDrIGo has been based on the identification of relevant security concepts incorporated in the frameworks and ontologies described in the studies of (i) Naouar et al. [167], (ii) Agrawal et al. [2], (iii) Milcevic & Goeken [145], (iv) Parkin et al. [180], (v) Ramanuskait et al. [184], (vi) and Fenz & Ekelhart [61]. The selection of these frameworks/ontologies for our study has been based on their close approximation and compliance with ISO27000 [101], with the latter considered as one of the most fundamental and widely used series of standards in terms of providing guidelines for evaluating security [144]. To select the relevant security concepts from the aforementioned frameworks, the members of the research team performed individual screenings of the related papers to find the security concepts. Once the candidate security concepts were identified, these concepts were discussed among all the authors to reach unanimity. The final set of security concepts that were kept to enhance the MoDrIGo framework towards its security-conscious counterpart are analyzed in Section 2.3.

2.2.3 Design Cycle

Hevner [93] defines this cycle as the elaboration of the process to construct and evaluate DS artifacts, while Sonnenberg & vom Brocke [215] dictate that the actual process of establishing a DS artifact has to be performed by conducting consecutive design-to-construction and construction-to-evaluation sprints. In

¹The online Appendix can be found at: <https://data.mendeley.com/preview/gznyxgbz5c>

Table 2.1 How each of the most relevant IT security concepts is supported by the ontology-based ISO/IEC27000 standards/studies

	Studies					
	<i>Naouar et al. metamodel [167]</i>	<i>Parkin et al. ontology [180]</i>	<i>Fenz & Ekelhart ontology [61]</i>	<i>Milicevic & Goeken metamodel [145]</i>	<i>Ramanuskait et al. ontology [184]</i>	<i>Agrawal ontology [2]</i>
Concepts	Asset	Asset	Asset	Asset	Asset	Asset
	Threat	Threat	Threat	Threat	Threat	Threat
	Vulnerability	Vulnerability	Vulnerability		Vulnerability	Vulnerability
	Security Incident	/	/	Security Breach	/	Event
	/	/	/	/	/	Likelihood
	/	/	/	/	/	Risk
	/	/	/	/	/	Consequence
	Control	Behavioural Control	Control	Control	Countermeasure	Control
	Control Objective	/	/	Control Objective	/	/
	Requirement	Behavioural Foundation	Security attribute	Requirement	/	CIA
	Role	Role	Organization	Role	Organization	Organization
	Exploit	/	/	/	/	Objective
	/	/	Severity scale	/	/	/
	/	/	Control type	/	/	/
	/	/	Threat Origin	/	/	/
	/	/	Threat Source	/	/	/

that aspect, the process of establishing and evaluating the SecureMoDrIGo framework took the form of two such consecutive iterations (design cycles). These are shortly described below and extensively analyzed in Sections 2.2.3.1 and 2.2.3.2.

2.2.3.1 First Design Cycle

This cycle describes the enrichment process for the ontology of MoDrIGo with significant IT security concepts; then, a primary evaluation of the enhanced framework is performed. Table 2.1 lists the majority of the IT security concepts used by the six selected security frameworks mentioned in Section 2.2.2. Certain security concepts share identical naming conventions, while others exhibit variations across diverse studies, yet they converge semantically to represent the same underlying concept. For instance, the concept of *asset* is referred to as such in all studies; in contrast, the security property of assets is referred to as *requirement* in [167] and [145], *behavioural foundation* in [180], *security attribute* in [61], and *Confidentiality, Integrity and Availability* (CIA) in [2].

Table 2.1 portrays the concepts of *Asset*, *Threat*, *Vulnerability*, *Incident* and *Control* as predominant in the IT security literature. Other concepts, expressing a semantic equivalence, such as *Requirement* and *Role* are also frequently used by most of the aforementioned security frameworks. Finally, the *objective* concept seems also to be of importance since SecureMoDrIGo focuses on the governance level of an organization and organizational objectives encompass security objectives. While the concept of *strategic objective* is established within MoDrIGo, we reintroduce here the concept *security objective* to emphasize our focus on strategic goals specifically tailored to IT security. Overall, these seven security concepts (see Figure 2.2) are the ones used to enrich MoDrIGo and make it evolved into its security counterpart (SecureMoDrIGo). The concepts *severity scale*, *control type*, *threat origin*, *threat source*, and *exploit* are not selected since they cover risk (and not necessarily security-related) elements and are considered at a lower level of representation which does not match

the high-level of abstraction that SecureMoDrIGo targets. The case study of Hospital Saint-Romain, thoroughly elaborated in the work of Wautelet et. al. [252], serves as an illustrative exemplar showcasing the enrichment process that enhances the MoDrIGo framework towards its secure-aware counterpart. This enrichment process is thoroughly described in Appendix B of this chapter which can be found in the online Appendix. Following that process, the initial iteration of SecureMoDrIGo underwent a primary evaluation. This comprehensive assessment included in-depth interviews with subject matter experts to meticulously validate the framework’s efficacy and identify areas for refinement. The first desing cycle is fully elaborated in Section 2.3.

2.2.3.2 Second Design Cycle

This cycle describes a real-life case that has been used to apply and evaluate the first iteration of the SecureMoDrIGo, as received at the end of the first design cycle. Yin [275] describes a case study as any kind of empirical inquiry meaning to investigate a specific phenomenon within a real-world context. More precisely, the case refers to a security audit for a running service within a Belgian telecommunication and media organization, inquired by its C-suite. For privacy reasons, this organization will onwards be referred to as “Telecom company”. The running service referred to the registration process for an online streaming platform. We need to mention that the SecureMoDrIGo has not been applied upfront before the adoption of the online streaming platform; instead, the framework was applied in parallel to the operational activities of this online streaming platform. This concurrent implementation enabled a comprehensive evaluation of the framework’s efficacy in providing actionable security insights to the management level, and facilitating the seamless dissemination of these insights to the governance level. The framework was thus applied in a bottom-up fashion for this specific case.

Once the application of the framework was done, the security team of the Telecom company was interviewed in the context of a workshop in order to investigate whether the framework is ease to use, comprehensible, and can produce deliverables that facilitate the communication with C-level executives. Overall, the aim of the entire exercise was to investigate whether the produced documentation of the framework (i) contributes to the awareness of potential security concerns for the company, and (ii) motivates the C-level to take decisions in terms of enhancing security measures. This workshop session concluded with specific questions that were asked conjointly to C-level executives and the security team members, to evaluate the extend to which the framework has been of value for the organization; finally, they had to assess the understandability of its deliverables. To evaluate the quality, thoroughness, and practicality of these deliverables, the SecureMoDrIGo was compared against the security frameworks previously used/deployed within the company. Any feedback produced in this phase, was meant to be used to enhance the robusteness of the framework. The second design cycle is fully elaborated in Section 2.4.

2.3 Design Cycle 1: Building the Security-Aware MoDrIGo Framework

This section is divided in 2 major parts. Section 2.3.1 describes the elements of the SecureMoDrIGo metamodel (see Figure 2.2) while Section 2.3.2 describes an interview-driven process of primary evaluation of the framework.

2.3.1 SecureMoDrIGo MetaModel

Figure 2.2 outlines the augmentation of the MoDrIGo ontology with the security concepts outlined in Table 2.1 and in accordance with the ISO27000 standard series. The security-related concepts are depicted within the dashed rectangle-shaped line, cloistered portion of the metamodel (the uncloistered portion represents the MoDrIGo ontology as detailed in [252]). In that figure, security-related concepts are classified based on their level of abstraction, with those marked in white associated with the governance/strategic level and those marked in other colour associated with the management level. These concepts are further elaborated based upon the description for the evaluation of the security threats for the adoption of the Remote Patient Monitoring (RPM) service in the case of the Hospital Saint-Roman (see Appendix D of this chapter in the online Appendix). The RPM service is part of the telemedicine services provided in the hospital, but all its security aspects had to be properly analyzed prior to any adoption decision taken at the governance level. While a detailed elaboration of the RPM evaluation is presented in Appendix B of this chapter (see the online Appendix file), the remainder of this section focuses on the fundamental security concepts that were deemed essential for enhancing the MoDrIGo ontology in conjunction with the RPM assessment.

1. *Security Objective*

Description: It represents an actor's strategic interest with respect to security. Security objectives are principally introduced to fulfill possible security constraints that exist in the system or are imposed to an actor [159].

Importance: Achieving strategic objectives of an organization is one of the important goals of our security model. Knowing what strategic security objective or interest (of an actor) needs to be fulfilled is therefore critical.

Illustration: In the meta-model, the security goal is represented as `Security_Objective` class.

Example: *In the case of the RPM service, “delivering health services through a safe and secure platform” is one of the security objectives that the Saint-Romain hospital is seeking to achieve. We can say that when using the asset “remote healthcare device”, using firewall sustains this security objective as it avoids the generation of false alarm (incident) which results from an attacker taking control of the device (threat). The latter can exploit the vulnerability of the remote healthcare device, which is “lack of proper documentation of the security posture of the device”.*

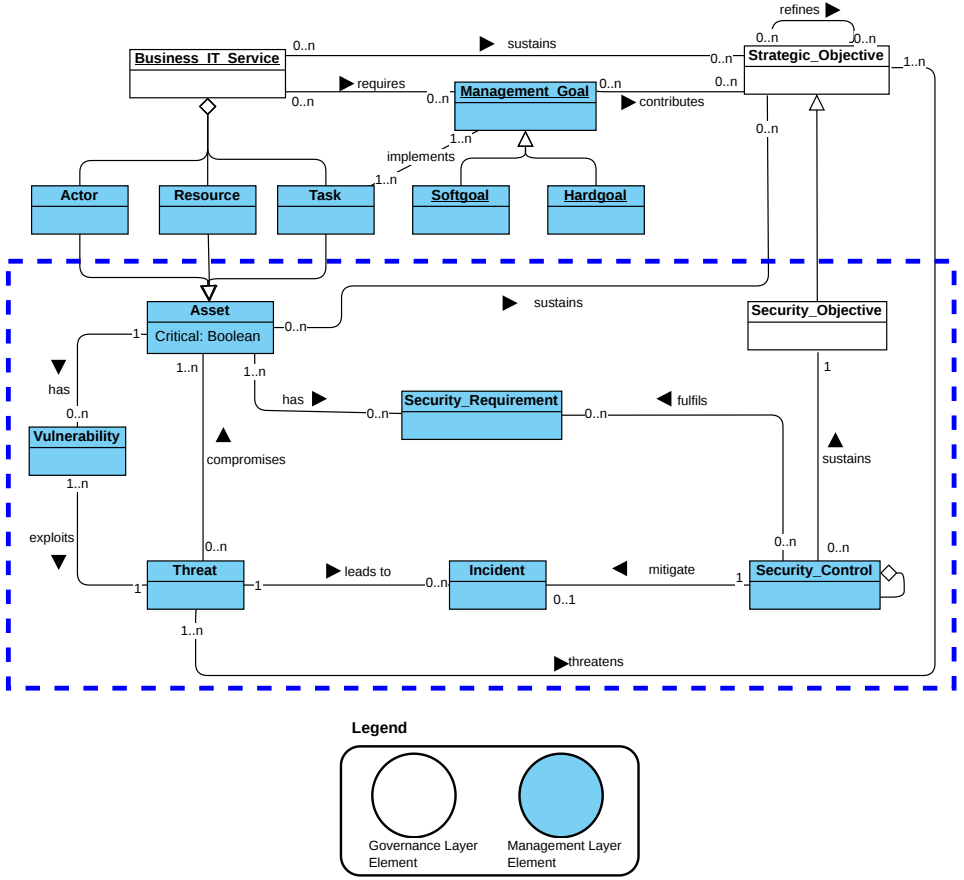


Fig. 2.2 SecureMoDrIGo Meta-Model

2. Asset

Description: Assets are anything of value such as people, property, and information [239, 145, 2, 145, 167]. Assets must be identified and documented prior to defining security measures [239].

Illustration: In Fig. 2.2, asset is represented as a class **Asset**. It is important to note that, in this study, we emphasize the fact that there exists four types of assets: *people*, *process*, *business-IT service*, and *resource*, represented as **Actor**, **Process**, **Business_IT_Service**, and **Resource** class respectively. Furthermore, each business-IT service is composed of people, process and resource.

Importance: We believe that this concept is at the core of our security study as it represents the value that deserves protection by the organization.

Example: *Nurses, doctors and admins are examples of human asset; hospital reputation, staff experience, and patient trust are examples of in-*

tangible property assets, innovation process, budget management processes, and crisis process are examples of tangible property assets and, finally, patient record and authentication credentials are examples of information assets. For the sake of traceability between the examples of the concepts, we take into account the asset “login credentials” which is a critical information asset which physicians use to log into the RPM system where patient history and report can be found.

3. *Security Requirement*

Description: Also referred to as property, attribute or constraint in other studies, a requirement is a security property of an asset such as confidentiality, integrity and availability [2].

Importance: We believe that this concept is important in the context of our research as it allows us to determine what about that asset is important to protect.

Illustration: In the meta-model, the requirement concept is represented as `Security_Requirement` class.

Example: *Login credentials should follow some rules such as not include personal information, using long and complex password, not be shared with anyone, etc..*

4. *Vulnerability*

Description: Vulnerability refers to the gaps or weaknesses that can be exploited by threats in order to gain unauthorized access to an asset be it hardware, software, firmware, medical devices, operating systems, people, network, and processes [239, 269, 145, 167].

Importance: Considering this concept for our research is of important value as it reflects the weakness of the organizational assets which should be controlled to avoid future exploitation.

Illustration: In Fig. 2.2, vulnerability is represented as `Vulnerability` class.

Example: *Choosing a “weak password” is among the vulnerabilities of “login credentials” which can lead to data leakage, ransomware, and phishing attack.*

5. *Threat*

Description: A threat is a potential incident or attack, which exploits the vulnerability of one or more assets and can harm an organization or a system [16, 145, 167, 2].

Importance: Knowing the weakness of an asset is important but it should also be clear what or who exploited the weakness of the asset. This allows further precaution within the organization.

Illustration: In the meta-model, Threat is represented as `Threat` class.

Example: *The “phishing attack and the following data breach” is an example of threat that can result from “lack of confidentiality” and “information exposure” resulting from using a weak password*

6. *Incident*

Description: An incident or an event is “*the combination of a threat and one or more vulnerabilities*” [55, 145]. It refers to “*an occurrence or change of a particular set of circumstances*” [2]. A thief entering a company building due to deficient physical access control, or a hacker exploiting weak awareness of the staff are examples of events.

Importance: We believe that keeping track of what happens in case an asset is exploited is a very important factor when modeling security and it allows to come up with proper countermeasures to control the current incident and avoid similar events in the future.

Illustration: In the meta-model, incident is represented as `Incident` class.

Example: *In case of phishing attack, user login credentials are exposed to the attacker (threat) and this may result in accessing patient’s vital data.*

7. *Security Control*

Description: Security controls (also called safeguard or countermeasure) are designed as means to improve security [55, 145] by modifying risk [2]. Security controls can be policies, processes, practices, devices, or other components or actions of the IS that act to reduce risks [55, 167]. Examples of security control include: firewall, backup procedure, building guard.

Importance: We consider this concept crucial to be included in our model as it allows to represent how an organization avoid or reduce risks and events and subsequently improve the protection of its assets.

Illustration: In the meta-model, security control is represented as `Security_Control` class.

Example: *The adoption of RPM in Saint-Romain can bring several threats among which is phishing attack resulting from using weak password. The materialization of such threat causes access to health protected data. To control such incident and to prevent similar future incidents, Saint-Romain uses multi-layer login protocol.*

2.3.2 Primary Evaluation of SecureMoDrIGo

This section describes the means for the primary evaluation of the SecureMoDrIGo framework. For that, we conducted in-depth, semi-structured interviews with five C-level managers. As seen in Table 2.2, their profiles varied with some of them being Chief Executive Officers (CEOs) of their respective companies and others being implicated in top-level roles in the domain of cybersecurity. Overall, we chose to perform semi-structured interviews since this form of data collection focuses on specific themes but can also grant access to the interviewees’ motivations in terms of explicating their behavior, attitudes, and beliefs corresponding to the topic currently under investigation [186].

The individual interviews were conducted either in person or online with the use of a known meeting platform, and each took approximately one hour to one hour and a half with twenty minutes of presentation. The interviews were

conducted following a structured process: first, a generic set of questions were asked individually to gather background information regarding the interviewees. The answer to these questions allowed us to become more accessible to the roles and expertise of the interviewees. Next, the framework was presented to each of the interviewees with the support of various forms of demonstration slides².

Following, we asked a set of questions centered around the quality of the provided information that the framework relinquishes. This allowed us to tap onto the interviewees' opinion and gather a primary set of remarks regarding the framework itself. A final set of questions were asked and these focused on security initiatives within the framework. This allowed us to evaluate and validate the security aspects of the framework and investigate its completeness, weaknesses, and potential benefits. The results of these interviews are described below and they are structured according to the major themes set by the questions.

Table 2.2 Information about the five interviewees

Interviewee	Role	Organization	Number of Employees/experts
Interviewee 1	CEO	Biotech sector providing medical solutions	60
Interviewee 2	Corporate Insurance and Risk Manager	The company develops, produces and distributes an extensive range of analog and digital imaging systems and IT solutions, mainly for the printing industry and the healthcare sector, as well as for specific industrial applications.	7500
Interviewee 3	Product Owner of Security Projects	Public social security institution that calculates and pays pensions.	2800
Interviewee 4	Software Security Expert	The organization provides technology innovation solutions	150
Interviewee 5	President and cofounder	An online platform that provides medical advice to bring patients and doctors into immediate contact. Active in France since 2014	35

Theme 1: Ease of use of SecureMoDrIGo. On a general level, the interviewees seem to notice that the framework offers simple and easy to understand visualization flows and this can be considered as one of its strengths. However, they do notice that such flows may be an oversimplification of the reality as organizations may occasionally exhibit very complicated structures that can be hardly fitted in any diagrammatic form. The fourth interviewee would have liked to see the framework embellished with some more security-related annotations such as *phishing*, *multi-layer login protocol*, etc., so that they can be understandable by high level managers and executives who are not familiar with such terms. The interviewee also raised some concerns with the scalability of the framework since if it is to be applied on complex examples, it will increase in size and this might hamper its ability to properly depict both

²These slides can be found in here: <https://docs.google.com/presentation/d/1kgMIpkn2NYNR3C0G35vsUUnmErwbd3KQ/edit?usp=sharing&oid=103100165128877675128&rtpof=true&sd=true>

the governance and the management-levels.

Theme 2: Importance of integrating the Governance and Management levels via the links provided by SecureMoDrIGo. The first, fourth, and fifth interviewees seem to agree on the importance of having a framework that disseminates security-related matters to the governance-level, as such matters are often crucial to the uninhibited function and performance of the organization on a strategic aspect. Indeed, the fourth interviewee acknowledges the (sometimes) severe knowledge gaps that most technical-level security frameworks offer to the top management. In that aspect, cybersecurity technicians are often forced to take actions in complete desolation of the impact of those actions on the strategic level of the organization. The interviewee adds that the cyclic mechanism of rolling-up and drilling-down in-between the governance and the management levels, clearly shows the link between the two levels and makes the dissemination of information fast and easily transmitted between strategy and operations. For the fifth interviewee, this link allows to raise security awareness in both levels, which is useful and necessary for the evaluation of the compatibility of a new IT service in both levels, prior to its adoption. However, the first interviewee notes that such a link will only be useful if the framework is applied on a long-term basis and some useful Key performance Indicators can be driven to evaluate the accomplishment of higher-level security goals.

Theme 3: Exhaustiveness of SecureMoDrIGo's identified security aspects. Most of the interviewees seem to agree that the framework covers all the necessary security concepts when taking into account the illustrative example of the RPM service of the Hospital Saint-Roman and its security concepts. However, the third interviewee decreed that the identified concepts seem to be exhaustive for the RPM service example but this does not guarantee that these elements will remain exhaustive in terms of uncovering strategic security concepts when applied to other cases. Interviewee 4 on the other hand, mentions that the security concepts are clear but to be able to be widely adopted, the framework needs to focus on all possible security issues while addressing the scalability of the models in complex cases. The interviewee added that the framework should also consider *mitigation plans* for management-level security concepts in terms of providing clear course of action when a threat or an incident happens. The fifth interviewee mentioned it would be interesting to be able to also see all the sub-level risks and indicators at the governance level. He also emphasized on the importance of defining *certainty* for each one of the security objectives at that level.

2.4 Design Cycle 2: Implementing and Evaluating the Secure-Aware MoDrIGo Framework

As briefly discussed in Section 2.2.3.2, the SecureMoDrIGo framework was employed to evaluate the security bearing of the registration process for the Telecom company's online streaming service. This service is included in the

company’s digital TV subscription plan and allows users to browse the latest movies and TV shows. Due to the processing of a multitude of sensitive customer data points, the Telecom company must continuously identify potential security threats that extend beyond the infrastructural level. A data breach could severely tarnish the company’s image, emphasizing the strategic importance of recognizing security vulnerabilities, and justifying the application of SecureMoDrIGo on that particular company.

The presentation of the following subsections follows a logical order. Section 2.4.1 explains the strategic objectives of the company; these constitute the aspired strategic trajectories into the futurity of the company. This section also shows a brief analysis of how these objectives can be rationally decomposed in their security-gnostic counterparts. Section 2.4.2 shows how security-related information analyzed at the management-level, in the form of a specific business IT service, can actually contribute to the production of new knowledge that can be used to create operational-level responses to tackle security risks; the knowledge that can be produced by analyzing the business IT service from a security point of view, can also be used to elevate tactical/operational-level insights to the governance level for a proper (re)evaluation of strategic-level opprobria that can harm the company in the long-term. Section 2.4.3 overviews the impact of the business IT services’ adoption on the evolved security ecosystem of the business strategy as an aggregation. Finally, Section 2.4.4 presents an ex-post evaluation of the entire SecureMoDrIGo framework by members of the security team within the Telecom company. The artifacts produced during the implementation of the framework were the main sources of analysis for the provision of this evaluation. It is important to emphasize that the framework’s artifacts, to be presented in the subsequent sections, were designed and crafted by the research team following their access to non-confidential internal sources detailing the governance and management-level processes and procedures of the Telecom company. The production of these artifacts was conducted through an iterative approach; this implies that initial draft versions were produced and subsequently validated by company representatives. The insights garnered during this phase were then incorporated and contributed to the finalization of these artifacts.

2.4.1 Security-aware Strategic-level Representation

Figure 2.3 shows the governance-level representation of the Telecom company via the use of SecureMoDrIGo focused on a specific root-level strategic objective. This representation has been established on the basis of interviews with various roles within the Telecom company as well as the in-parallel consultation of sources internal to the company describing generic and security-related strategic views. SecureMoDrIGo, following the example of the parent MoDrIGo framework, uses an Non Functional Requirements (NFR) diagram [42] to represent the generic strategic objectives of the organization (i.e., long-term business objectives releasing strategic value to the entire organization). Such NFR diagrams were originally used to represent Non Functional Requirements but have actually evolved to represent high level (very abstract) strategic objectives

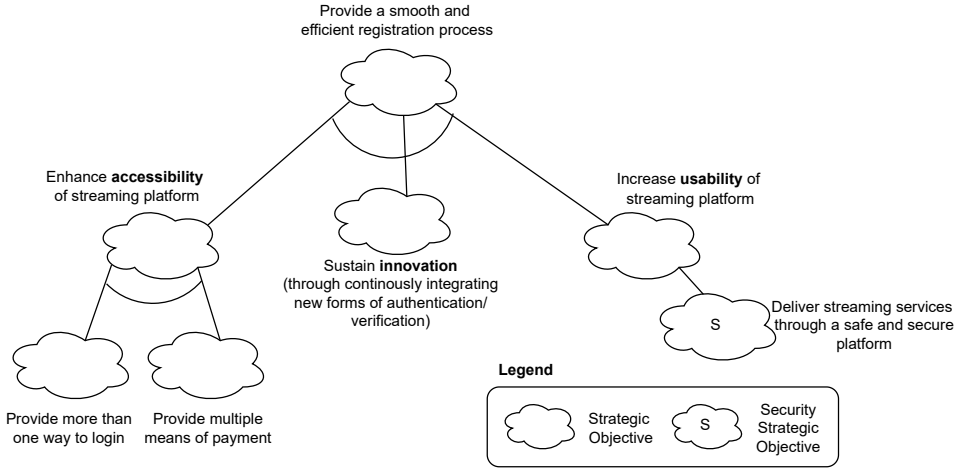


Fig. 2.3 SecureMoDrIGo's strategic-level representation

and trace the impact of functional developments (called operationalizations) on these kinds of objectives [228]. For the Telecom Company, one of the top-level strategic objective is to *Provide a smooth and efficient registration process* to their online streaming platform. This parent-level objective can be decomposed in several leaf-level sub-objectives, one of which is the *Increase usability of streaming platform*. The satisfaction of the latter depends on *delivering streaming services through a safe and secure platform*. The last one is a security objective that plays an important role for the fulfillment of the overall strategy of the Telecom company. Indeed, this security objective must be fulfilled to ensure that customer experience is maximized, therefore increasing the usability of the platform, and ultimately fulfilling the top-level strategic objective (i.e., provide a smooth and efficient registration process). We see here that having a clear definition of the term *security objective* at the strategic level is crucial because it enables businesses to identify the high-level security aspects of each strategic goal. Additionally, it enables the adoption of strategic decisions that are in line with the specified security policy.

2.4.2 Security-aware Management-level Representation

This section is meant to depict one way of implementing SecureMoDrIGo at the premises of the Telecom company to facilitate the identification of security concepts at the management-level, and to examine the potential impact of these concepts on the attainment of security strategic objectives. In that way, C-level executives can be empowered to (1) identify and anticipate threats and their potential future consequences, and (2) implement appropriate controls to mitigate these threats. In our case, management-level representations are being depicted by making use of the i* Strategic Rational Diagram (SRD) [277]. SecureMoDrIGo does not necessitate the use of a specific modeling notation to identify security-related concepts at the management-level. Nonetheless,

the i^* SRD is being used here because it provides a non-constrictive modeling notation to represent a tactical-level situation where the security-affiliated tasks of a multitude of individual actors (and the means for their realization) can be documented. Most important, the i^* SRD is able to provide links for studying the organizational impact of the adoption of a particular security concept on both the strategic and operational-level. In the first case, *means-to-end* relationships can identify how management-level tasks can be tied to hard-goals that have a clear definition of the way to achieve them (so the C-level is more likely to be committed towards their achievement). The use of *soft-goals* within the i^* SRD offers the chance of cascading such security measures in the operational-level by allowing the latter to define its own technological requirements on how to address some possible security issues contrived at a higher level.

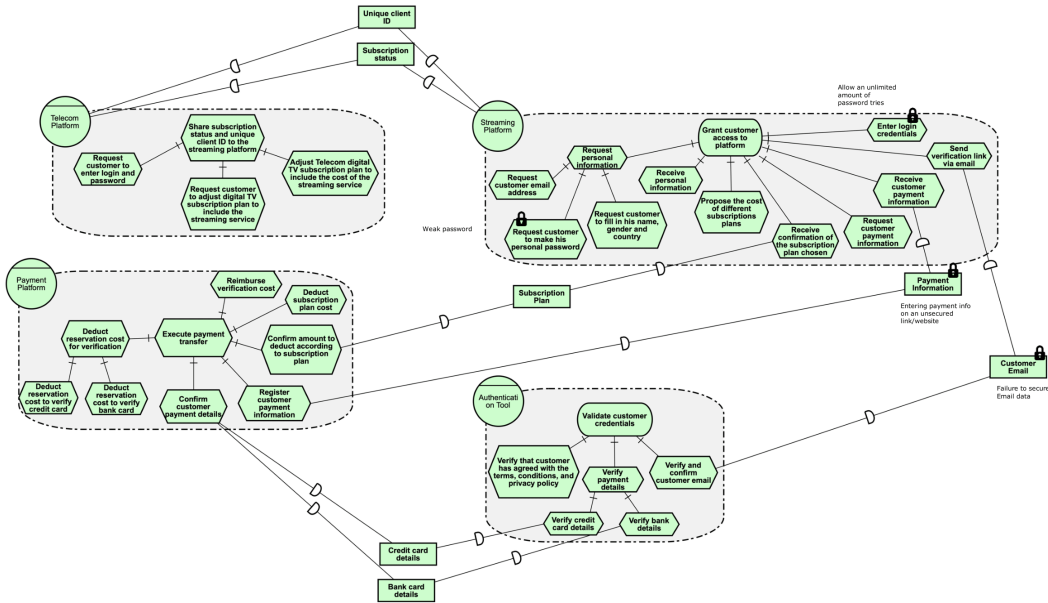


Fig. 2.4 Strategic Rational Diagram Representing SecureMoDrIGo's management-level representation

Figure 2.4 shows the registration process of the online streaming service as a Business IT Service that is provided by the Telecom company (the legend is shown in Figure 2.5). This service will be used here as the specific example of representing management-level elements tethered to security concepts (i.e., vulnerabilities, threats, required measures etc). To make it more clear, business IT services aim to fulfill, notably through the use of IT capabilities, the business needs of a specific organization; they are used to structure the global IT problem into the organizational modeling stage [252, 227]. In our particular example, there are two possible ways a client can register to the online streaming service: (1) If the customer already has a digital TV subscription plan with the Telecom company, then the customer can log in to a personal telecom account and adjust the digital TV subscription plan to include the cost of the streaming plan chosen.

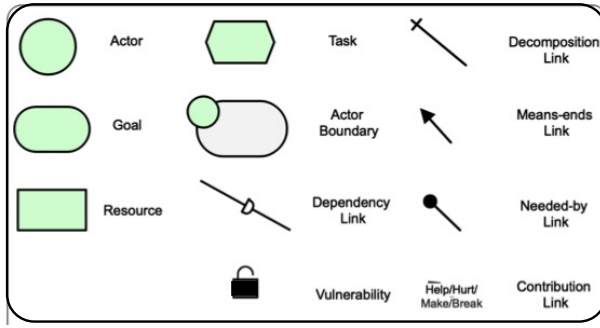


Fig. 2.5 Legend related to Figure 2.4

The cost of the streaming service is added to their digital TV subscription plan paid through a direct monthly debit system. A subscription status and a unique client ID are then shared to the streaming platform so that the customer can be granted access to use the streaming platform. (2) New customers are also able to register themselves to the streaming service. This registration process is done through the streaming platform which then requests the customer to fill in his personal information (customer email address, personal password, his/her name, gender, and country). The platform also requests the customer to agree with the privacy statement (accept the terms, conditions, and privacy policy), as well as request the customer to confirm his/her personal information. After the customer has confirmed his information, the platform sends an email to the customer wherein he/she clicks on a link and confirms that the email account is in fact his/her email address. The authentication tool then verifies and confirms this email address. Moreover, the platform offers 3 different subscription plans (the monthly, 6 months, or yearly plan). Once the customer has made his/her selection, the subscription plan screen is redirected to the payment page which can take place online.

We see that, at the management-level, the proper use of the Business IT Service requires the orchestration of activities of four main actors (*Telecom platform*, *Streaming platform*, *Payment platform*, and *Authentication tool*); these actors are indeed closely dependent on each other. The streaming platform is dependent on the Telecom platform to share the subscription status and unique client ID to the streaming platform, in order for the customer to gain access to the streaming platform. The payment platform is dependent on the streaming platform to receive the confirmation of the subscription plan chosen, so that the payment platform can confirm the amount to deduct according to the subscription plan. The payment platform is also dependent on the streaming platform (for the retrieval of customer payment information) and on the authentication tool (to verify corresponding payment details). After the payment details have been verified, the payment platform can confirm the customer payment information. Finally, the authentication tool is dependent on the streaming platform to send the customer a verification link to the customer's

email address. Once this has been done, the authentication tool can verify and confirm the customer email.

The aforementioned description of activities shows that there are four potential security concerns identified within the registration process of the online streaming service. These are: (1) *having a weak password*, (2) *allowing an unlimited amount of password tries*, (3) *entering payment information on an unsecured link/website*, and (4) *failure in securing email data*. This list of security vulnerabilities is not exhaustive. In fact, many more security concerns may exist, and these may occur at any given moment during the actor orchestration within the registration process. Due to space constraints, we will be drilling down on the first (see Figure 2.6) and third security vulnerability (see Figure 2.7) as they are considered the most precarious threats that can be successively associated to a specific performed task and utilized resource.

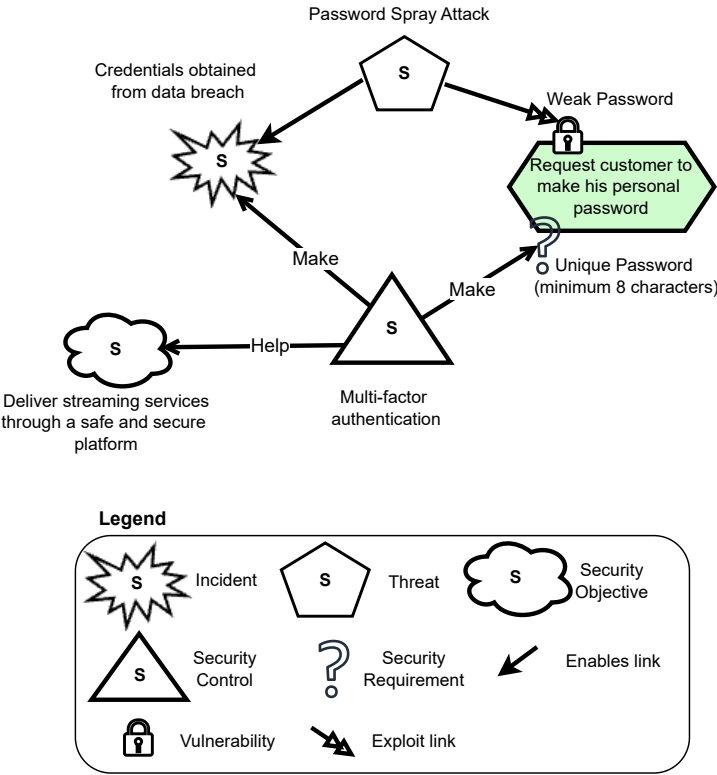


Fig. 2.6 Vulnerability diagram for the request customer to make his personal password task

Vulnerability associated to a task: The registration form requires the customer to make his/her personal password for his/her account. Providing a weak password is a vulnerability that can lead to potential security threats and incidents. As shown in Figure 2.6, when the customer provides a weak password (vulnerability), password spray attack (threat) can happen, which then leads to

user credentials being obtained (incident). To avoid the security threat enabling the potential incident, the Telecom company should put in place a multi-factor authentication system (security control). The security control put in place will help maintain the security requirement of request customer to make his personal password (unique password). A unique password consists of a minimum of 8 characters and must contain at least 3 of the 4 following characters: a lowercase letter, an uppercase letter, a number, and a special character. The security control also helps the Telecom company to achieve its security objective *deliver streaming services through a safe and secure platform*.

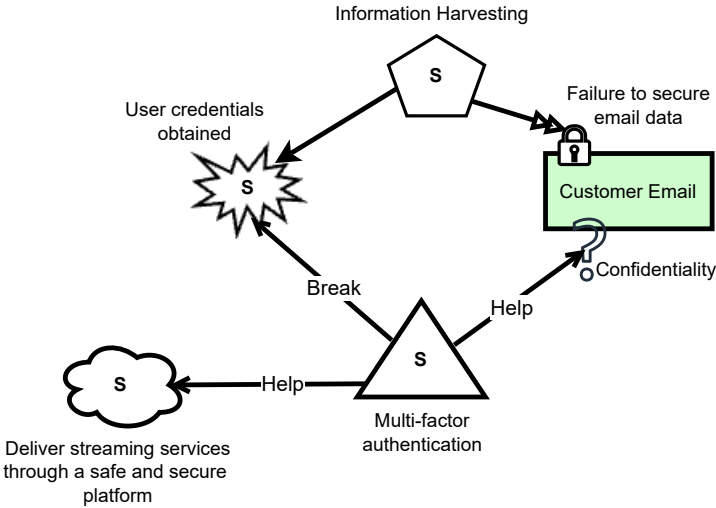


Fig. 2.7 Vulnerability diagram for the customer email resource

Vulnerability associated to a resource: After the customer confirms his/her email address, the email address is verified and confirmed by the authentication tool. The potential security concern of failing to secure email data relates to a security concern from the side of the service provider who is responsible for backing up email data (e.g., 3rd party cloud infrastructure). Failure to secure customer email data is a vulnerability that can lead to potential security threats and incidents. As shown in Figure 2.7, when the service provider fails to secure email data (vulnerability), information harvesting (threat) can happen, which then leads to the hacker obtaining user credentials (incident). A possible solution to counter such a security threat and to avert a potential security incident would be for the Telecom company to put in place a multi-factor authentication system (security control). Setting up some sort of enhanced security control, such as a multi-factor authentication, would help maintain the security requirement of customers to retain their email confidentiality.

The analysis of the aforementioned vulnerabilities, makes it possible to provide a visual link depicting the traceability of security concerns between the strategic and management levels. The traceability link is made evident through the representation of the security objective in Figures 2.6, 2.7, and 2.3. Having a

framework that can assist in modeling associated security requirements, threats, and controls in different levels of abstraction can help the governance board to optimize their strategic decision-making processes. For example, with the implementation of the SecureMoDrIGo, the C-level of the Telecom company has had in its disposal a way to make the connection as to how particular security issues identified at the management-level (by human resources having the technical knowledge to identify those) can help the entire organization to ensure that their *streaming services are delivered through a safe and secure platform* (so the framework can be the analysis platform for the provision of a cornucopia of technical solutions that aid the attainment of the security-aware strategic objective, as shown in Figure 2.3). By identifying the appropriate/correct security controls and requirements, governance board members will be able to have the knowledge necessary to make the most use of funds that have been set aside for security purposes.

2.4.3 Representation of the impact of the Business IT Service security analysis on Strategy

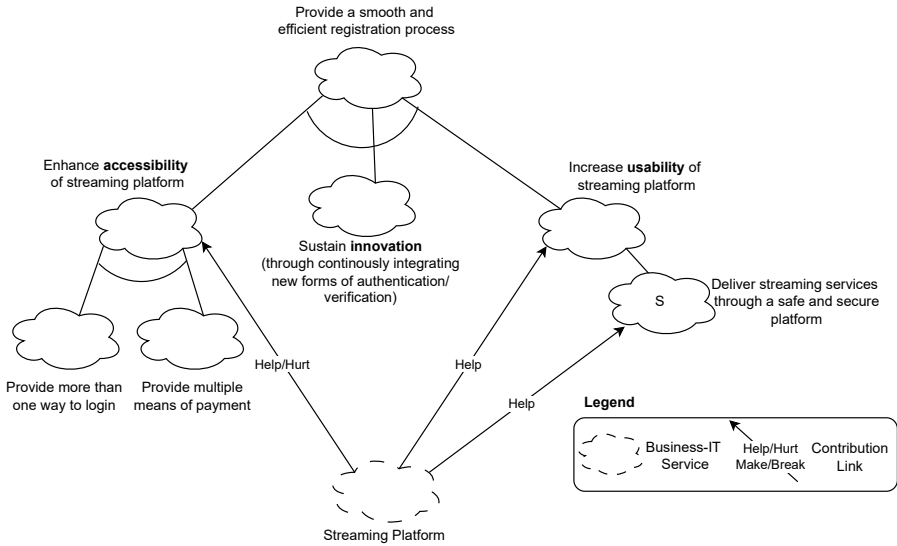


Fig. 2.8 Strategic-level representation enhanced with security

The knowledge extracted from the i* SRD allows us to determine the types of impact vestiges that the function of the streaming platform will have on the attainment of the strategic objectives of the Telecom company (in terms to security). For example, strengthening customer email data security by implementing a multi-factor authentication system, as previously discussed, will fortify the platform against potential email data breaches and ensure the platform's robustness in terms of privacy. Such type of security control augmentation, based on the analysis of vulnerability diagrams, would enable (**help**) the Telecom company to achieve its security (strategic) objective to

deliver streaming services through a safe and secure platform. In addition, implementing mechanisms that safeguard customer confidentiality and provide a more secure platform for their streaming services would be a crucial factor in positively influencing the overall usability of the platform. However, the introduction of these additional security controls, even if well-intentioned, could hinder user accessibility if not carefully designed. Thereby, the NFR diagram of Figure 2.3 can now be re-envisioned to include such contribution links. Figure 2.8 is the end-result of that process.

It is crucial to recognize that SecureMoDrIGo’s documentation serves as a guide to identify potential security concerns that should be elevated to the governance level, not as a rigid directive for addressing them. The framework is designed to stimulate innovative solutions and foster a culture of awareness. In the previous example, it would be considered a sound practice if the suggestion to implement multi-factor authentication emanated from the Telecom Company’s personnel, having carefully scrutinized the vulnerability diagrams provided by SecureMoDrIGo. In that sense, the documentation provided by the framework is comparable to the draft version of a contract that is cascaded from the governance level to management-level on what needs to be covered security-wise by management. Therefore, even if the security considerations described in the artifacts provided by SecureMoDrIGo (e.g., see Figures 2.6 and 2.7) do not alter the top executives’ choice to secure specific assets, the documentation may still serve as a guidance for the financial flows associated with the provision of extra IT security assistance that may be required in the short-term.

2.4.4 Framework Evaluation

After having employed SecureMoDrIGo on the particular registration process as a service for the Telecom Company, the framework’s produced representations were evaluated by conducting a workshop with three members of the security team of the Telecom company. Table 2.3 presents the characteristics of the workshop participants; once more, names are not given for the sake of confidentiality. The workshop presentation delved into the practical application of the framework for analyzing security vulnerabilities within the registration process for the online streaming platform. The NFR and i* artifacts played a pivotal role in this demonstration, effectively illustrating the framework’s capabilities in identifying and addressing potential security weaknesses. Overall, this ex-post evaluation was meant to grant us access to the existence of any possible ‘blind spots’ that may impede the proper implementation of the framework.

The main aim of the presentation was to investigate if the framework’s main elements (1) can easily be understood and (2) to investigate if the findings of the framework (management and governance diagrams) are useful in terms of cascading crucial information to C-level executives and (3) detect whether the produced representations of the framework contribute to the awareness of potential security concerns and assess whether this motivates the Telecom company to enhance security measures. Following the presentation, two sets of questions were asked. The first set was meant to query the overall structure and quality of the framework (i.e., *From a domain perspective, are there any issues*

found within the representation diagrams of the framework?, Are the diagrams clear and understandable?, etc). The second set was meant to yield insights regarding the easiness to understand and quality of the produced artifacts (i.e., in your opinion, are there any important security elements covered by the framework?, If yes, which ones?, If no, which elements do you think need to be represented within the management and governance level diagrams?, etc). The interview questions were asked in an informal manner in the form of conversation, following a semi-structured interview format. The latter allowed us to have some basic questions to start (and lead) the conversation, but the point was for the participants to have the time to reflect and answer freely on the matter. Given that the respondents' answers took the form of narrations, we used narrative synthesis [98]. Accordingly, we reviewed the recorded answers from the workshop participants multiple times to identify commonalities and/or points of differentiation in their answers. Points of convergence were transcribed to text and codified. Afterward, the codified version of the text was given a specific theme. Three themes were recognized and these are provided below.

Table 2.3 Information about the three interviewees

Interviewer	Role	Organization
Interviewee 1	Manager of Enterprise Security	Telecom company
Interviewee 2	Security Officer (in charge of onboarding projects into security assessment)	Telecom company
Interviewee 3	Security Officer (focus on security assessment, and threat modelling)	Telecom company

Highlights of the SecureMoDrIGo Framework: According to interviewee 1 and 3, the framework breaks down complex problems into something visual while at the same time transmitting valuable information to managerial audiences. Interviewee 1 recognizes the value of the produced documentation from the framework. He notes that there is much value to be gained from representing such a threat model exercise visually to managerial roles within the security environment. He goes on to then say that the drillable feature included within the presentation makes it evident as to how the potential security concerns identified within the i* SRD relate to their corresponding vulnerability diagrams. In terms of the latter diagrams, they are well understood and they were found the easiest to interpret. The security elements, links and terminology found within these vulnerability diagrams were the most comprehensive. The security team members see the significance in presenting and creating such graphs for C-level executives. In addition, Figure 2.8 was also clearly understood by the security team members of the Telecom company. General consensus held that the diagram effectively illustrated the business IT service's contribution to the attainment of security-conscious strategic objectives. This was achieved through a thorough examination of this service's security postulations, aided by the visual representation of the i* SRD. Overall, the security elements in the model were regarded to generic enough to be understood by non-technical professionals but, at the same time, covering particular security concerns that

specialists encounter.

Points of Attention for the SecureMoDrIGo Framework: According to interviewee 1, the framework is comprehensive, but it can become overwhelming when documenting complex procedures, processes, or services. He goes on to explain that the application of the framework might become very heavy for first time users and the knowledge needed to apply the framework onto a business process or service may become very extensive (having to understand the notations of i^* and using different applications to get the modeling done). Indeed, the i^* SRD was the most difficult artifact to read. The team members considered the diagram to be overly large, making it difficult to understand. Of course, the registration process of the internet streaming service platform is very extensive in nature and the security team members had only a short amount of time to properly analyze the diagram; this fact, in combination with their lack of prior knowledge in i^* notations exacerbated the comprehensibility of the diagram. In that aspect the team members remarked that they would need an extra role (e.g., a modeling consultant) to help them apply the framework. It was explained to them that the use of i^* is indicative and SecureMoDrIGo can be flexible enough to incorporate different modeling techniques to represent different concerns of the organizational matrix. However, interviewee 1, also noticed there is a large amount of background information about the current state of each of the levels of the organization that needs to be compiled before applying the framework (i.e., an extensive amount of knowledge needed to sufficiently understand the business IT service, to understand the possible vulnerabilities that can be linked to such a service and so forth). This might be an extra factor hindering the ease of use of the framework. Nonetheless, the interviewee does make clear that this extensive background knowledge is also needed for the threat modeling exercises that are currently in place for the Telecom company. Appendix E of this chapter (see online Appendix) provides a comparison between the SecureMoDrIGo framework and the security framework currently in place within the Telecom company.)

Formulated suggestions for improvement of the SecureMoDrIGo Framework: Interviewee 2 proposed a suggestion for enhancing the vulnerability diagrams' scalability. He noted that there is a current challenge in the industry whereby separate models are created to depict privacy, fraudulent, and security risks. He stated that by adding the risk categorization dimension and modeling the likelihood of these risks occurring can enhance the model's scalability. Interviewee 2 then concluded by saying that the risk element can easily be depicted within the model by a different security icon.

2.5 Discussion

We can now further discuss the main contributions provided by SecureMoDrIGo, which address our main RQ: *How can we determine and build-up a set of key elements relevant for understanding managerial impact on security of IT service adoption decisions at governance level?*. After having overviewed the

key security concepts that we can find in literature, we have enriched an IT governance framework (MoDrIGo) with these in order to further develop a vision of the alignment of security issues (encapsulated in IT services) to the business strategy but also to security objectives. While MoDrIGo classically addresses business and IT alignment of IT services through conceptual modeling, SecureMoDrIGo adds the identification of *business and IT risk alignment* into the same context. Indeed, the inclusion of Security Objectives allows to refine strategic modeling with some elements translating into qualitative aspects the risk appetite of the organization. Also, at management-level, the inclusion of vulnerabilities encapsulated onto classical management-level elements into the i* SRD allows to identify the points of attention related to security. Further, detailing these into a vulnerability diagram related to a particular element with the concepts of asset, security requirement, vulnerability, threat, incident, and security control allows to study/highlight the rationale of the potential impact onto the strategic risk (or business) objectives. All in all, this allows to aggregate the security related strategic impact of the business IT service adoption to furnish relevant and understandable documentation to the C-suite.

All of the instantiated diagrams overviewed in the method but the vulnerability ones have adopted the notation that was already adopted in previous works using these diagrams. The elements constituting the vulnerability diagrams' graphical representations have been adopted rather randomly and other choices could clearly have been made in order to associate the best fitting geographic form to each concept in line with the findings of Moody [153]. This however, remains another research that is left for future work and an experiment will be conducted with novice modelers to evaluate the best fitting graphical representations of the constituting concepts.

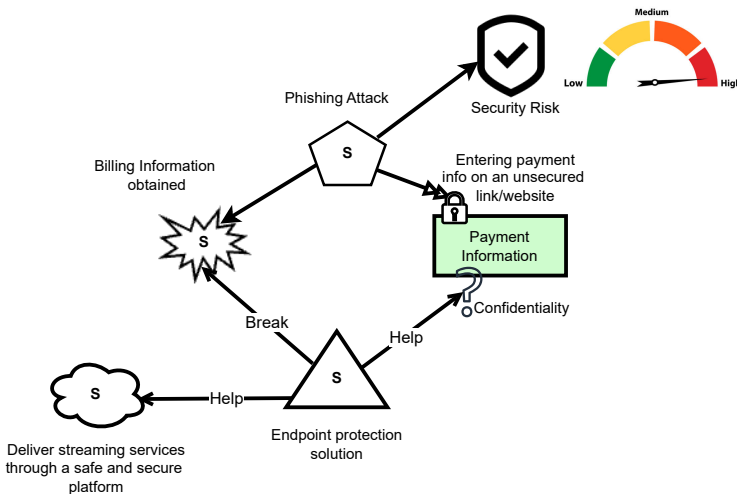


Fig. 2.9 Vulnerability diagram for the payment information resource enhanced with risk dimension

In terms of some recommendations for future work, we first point out the inclusion of the categorization of risk into the vulnerability diagrams and provide a brief estimation of the risk severity of each incident. Possible categorizations of risk include privacy, fraudulent or security risks. Indeed, having the capacity to demonstrate risk categorization within the vulnerability diagrams can contribute to significant added value because within the management-level artifacts of the framework, risk diagrams are often modeled separately from security threat and control diagrams. To be able to introduce the risk categorization icon into the vulnerability diagram, the definition of risk categorization needs to be agreed upon. In this context, risk categorization is defined as the classification of risk based on its nature, such as privacy, fraud, or security concerns. Consider the example shown in Figure 2.9; the phishing attack exploits the vulnerability, *entering payment information on an unsecured link/website*. For this instance, the threat (phishing attack) relates to a particular risk, that risk being the security risk. For this reason, the relationship between phishing attack and security risk is modelled as an enable link. The phishing attack enables a certain level of security risk. The severity of the security risk demonstrated in the example is HIGH. Users want to have a high-level guarantee that their billing information is protected and safeguard against pervasive external system attacks. Demonstrating this risk severity is of much added value because C-level executives can then easily visualize the severity of each vulnerability case and know which exact security controls need to be implemented first.

Second, we point out the need of implementing an integrated Computer-Aided Software Engineering (CASE) tool that allows the user to edit and construct governance-level diagrams and add security elements to management level diagrams. The CASE tool should allow the building and editing of vulnerability diagrams and include security elements within existing management and strategic level representations. This way of working ensures consistency and efficiency, as all produced documentation can be edited within one central application. The integrated CASE tool should allow the user to connect all the diagrams through hyperlinks. For instance, a user should be able to access the corresponding vulnerability diagram as soon as he/she clicks on the vulnerability lock within the strategic rationale diagram. The user should also be able to access the strategic-level representation enhanced with security diagram as soon as he/she clicks on the security objective found within the vulnerability diagram. This ensures traceability within the 3 diagrams. A benefit of integrating this feature into the CASE tool is that the application becomes more visual and interactive. When presenting the diagrams to C-level executives, the audience is more likely to become engaged as he/she can visualize how the diagrams are connected to each other, and more easily assess the contribution of each diagram to the organization. This was observed from the presentation that was given. The security team members were more inclined to listen and engage in discussion, due to the visual interactive features that connected the governance level and management level diagrams together. The integrated CASE tool should be generic enough to demonstrate all the possible incidents that can result from a particular security breach. Security team members of the Telecom

company believe that it would be of great value for all possible incidents to be listed as an output of the SecureMoDrIGo framework. They do not recommend that this list be portrayed within the vulnerability diagram but to add this list as an extra document to be provided alongside the vulnerability diagram. In this way, C-level executives can make note of which vulnerabilities lead to which particular incidents occurring, and then make note of how these incidents can properly be mitigated. The security team members do believe that it is effective to portray the most important incident on the vulnerability diagram (otherwise the diagram would become cluttered if all incidents were to be portrayed within the diagram). Therefore, they make the explicit suggestion of providing additional documentation.

We can point out that use of the Descartes Architect CASE tool [112] allows to have roll-up and drill-down the representations from the strategic representation to the SRD and to the vulnerability diagram. Using independent vulnerability diagrams allows to better scale the approach even if the CASE tool remains essential to properly ensure this.

Finally, SecureMoDrIGo can be applied within the three stages of the IT governance process which is explained in Appendix C of this chapter (see online Appendix).

2.6 The Interplay of IT Service Concepts vs Security Concepts

Although SecureMoDrIGo allows to highlight security concepts such as threats, it still requires to integrate quantitative metrics to quantify the risk. This would significantly enhance the comprehensibility and management of security when it comes to IT services adoption decisions. As an example of risk metrics that can be integrated into the SecureMoDrIGo framework, we can refer to likelihood and impact, which, if well integrated and calculated, allow the security team to determine security level, allocate resources and prioritize objectives [76].

Likelihood is about the probability that a given threat will exploit a vulnerability. The likelihood of a threat can be assessed using standardized scoring systems such as the Common Vulnerability Scoring System (CVSS) [138]. CVSS is intended to produce a numerical score to determine the severity of vulnerabilities and is based on coding vulnerabilities such as exploitability, attack complexity and open threats. Using the score provided by CVSS, organizations can prioritize vulnerabilities systematically and concentrate on the vulnerabilities that are most likely to be exploited [138].

Impact refers to the possibilities that an unlikely security event happens [76]. Examples include financial losses, loss of reputation, regulatory fines, and operational loss. Framework such as Fair [106] provides a methodological approach to quantify in financial terms, with entities having not to worry about the financial disaster that accompany security breaches.

The integration of quantitative metrics into SecureMoDrIGo can be implemented as follows:

- enhancing the vulnerability diagrams by incorporating CVSS scores and impact estimates in these diagrams in order to provide a clear visualization of risk level;
- including risk matrices and quantitative impact assessments in order to emphasize the strategic significance of addressing specific vulnerabilities;
- using governance-level artifacts such as quantitative risk assessments to inform decisions, which helps to security investments are in-line with business objectives and risk management priorities.

The integration of these quantitative metrics will provide SecureMoDrIGo with a more comprehensible and actionable security strategy that enables organizations to effectively manage and mitigate risks related to IT services.

2.7 Threats to Validity

Our presented study considers some threats to validity. In particular: A possible threat to the **construct validity** is that the modeling constructs are wrongly interpreted by the people applying the framework or reading the representations. Some concepts included in the method can then be used in an unintended way. To reiterate, the artifacts associated with the Telecom company case study were crafted by the research team, which collectively possess extensive modeling expertise. However, when security-related practitioners are required to apply the framework from scratch, the combination of clearly defined instructions in the form of workshops and the use of the Descartes Architect tool, which seamlessly integrates contextual information on employed concepts, can prove invaluable.

On the other hand, threats to the **internal validity** are mostly explicated as errors that occur during the knowledge acquisition process, so during the performed interviews. Such errors can inhibit the framework's modeling constructs to capture the correct representation of the perceived digital transformation priorities of the interviewees. To minimize the impact of such threats, it is pivotal to establish an interview questionnaire that contains a series of control questions that are meant to subdue traces of any subjective apperception of the interviewees. Indeed, the interview questions that were used within the study were established using an iterative process.

The **external validity** can be threatened by any circumstance that may jeopardize the application of SecureMoDrIGo in different contexts. In our case, we used the Telecom company as the main evaluation platform of the easiness to use and applicability of SecureMoDrIGo. The choice of the specific case might have influenced out results since we were able to implement SecureMoDrIGo in a company that already possessed a high-level of security awareness given their area of expertise which is related to the provision of online services. However, the security personnel in the particular company was not trained in applying modeling driven methods to identify security issues in the form of visual artifacts. And, even though the ability of novice modelers to understand

and create qualitative artifacts has been evaluated in other studies (see, for example, [240, 226]), we wanted to capture real-time data not only during the implementation of the Framework, but also by performing the ex-post evaluation of the framework by members of the Telecom company. We hoped that the latter would be able to yield insights regarding the harmonization of the general applicability of the framework. In any case, the framework is currently in a process of implementation by an external researcher (not related to the research team) on a different case. We wish to use the experiences and the data from this study (which is to be released in the form of a future communication) to create a roadmap that would lead in an uneventful implementation of the framework.

2.8 Related Work

There exist different sources in the literature dedicated to Risk Management (RM). The first family of sources focuses on RM standards such as the *ISO/IEC Guide 73* [45] which are documents typically containing general considerations about RM. They form the foundation on which domain-specific RM approaches are built. On the other hand, the second family of sources include (IS and IT) security standards such as *ISO/IEC 27001* [205], *Common Criteria* [100], and *NIST 800-27 Rev A* [220] / *NIST 800-30* [219]. These standards often encompass a section on security-specific terminology. The third family of sources involve RM methods. A representative subset of these methods include *EBIOS* [208], *MEHARI* [44], *OCTAVE* [4], *CRAMM* [47] and *CORAS* [247], which are mostly supported by software tools. The final family of sources consists of *security frameworks*. Whilst the previous family of sources were practitioner-oriented, these family of sources are rather research-oriented. In other words, they emanate essentially from the literature. *Moffet and Nuseibeh* [150] and *Haley et al.*, [84, 85] propose a framework with the aim to deal with security requirements. Moreover, *Firesmith* [67, 66] introduces a set of related information models and, based on them, provides the theoretical foundation underlying security and safety engineering [55]. With more than 200 practitioner-oriented RM methods as well as several academic security modeling frameworks available, selecting the most suitable approach is still a major challenge [55]. For this reason we will now focus on the identification and analysis of general frameworks allowing to represent the organizational context at multiple levels and see if they consider security aspects or if they can be enriched with them.

Conceptualizing information in security management allows to represent best practices and guidelines in terms of concepts and their relationships for effective reuse, exploitation, and comprehension of security standards within the organization [144]. Different studies already exist in literature with focus on security ontology/metamodel based ISO 27000 series standards. Among them, a recent study conducted by Naouar et al. [167] provides a model-based method for cybersecurity risk assessment that first depicts a semantic alignment of risk analysis concepts and the functional system modeling concepts, and second, represents security risk concepts and metrics. On the other hand, in the study conducted by Meriah et al. [144], they have provided a comparative analysis of six security ontology/metamodel-based on ISO/IEC 27000 series standards,

namely Parkin et al. ontology [180], Fenz and Ekelhart ontology [60], Fenz et al. ontology [61], Ramanuskait et al. ontology [184], Milicevic and Goeken metamodel [145], and Agrawal ontology [2].

There exists more than hundred IS security RM (ISSRM) standards and methods, which mainly incorporate process guidelines that help determine security objectives, identify vulnerable assets, and assess risks and also define and implement security requirements necessary to treat the risks. Although using these methods reduces the losses that might have been caused by security problems, but generally, they offer very little modeling support. They usually resort to ad hoc diagrams and informal documentation in natural language. This means that powerful abstraction mechanisms, automation and visualisation proposed by conceptual modeling techniques are underexploited [55]. This is in contrast with the Requirement Engineering (RE) literature where a number of modeling languages are featured and specifically dedicated to security-sensitive context. Some of the examples of such languages include Abuse Cases [137] and Misuse Cases [211], which extend Use Cases and focus on eliciting new threats and vulnerabilities that may be exploited by malicious actors; Secure Tropos [158, 80] is a formalization of i^* and Tropos; KAOS which is also extended to deal with security aspects and addresses security concerns by treating attacks as anti-goals [237]; Abuse Frames [124] derive from Problem Frames. The main advantage of these languages is that they address security issues during the early phases of IS development and therefore, allow enforcing security by *construction*. This is more efficient than doing it after the fact. Nevertheless, it turns out that these modeling languages lack constructs to properly sustain the governance level; in other words, they are frameworks for managing the risks once adoption decisions have been made or budgets have been allocated. As such, although these languages are useful when it comes to eliciting and modeling threats and their countermeasures, they are still largely incapable of addressing of being an aggregated and non-technical view of the organizational situation to top-level decisions. Other UML based methods such as SecureUML [127] and UMLSec [108] address security at the design level. Therefore, they do not focus on high level requirements as well as business assets.

2.9 Conclusion

In this paper we have enriched the MoDrIGo framework with security related concepts to build SecureMoDrIGo. The latter allows to visualize the impact of IT services adoption on security at governance level and, implicitly, highlight the business and IT risk alignment. Out of the operational aspects of security, the risk an organization is willing to take is part of its strategic policy; that's why the framework allows the representation of security objectives that are strategic elements depicting its approach and appetite in the field. Also, traceability with the management-level representations allows C-level executives to understand vulnerabilities onto tactical and operational-level elements and visualize their rationale (through the vulnerability diagram); this allows to put in place controls to mitigate these threats and thus protect the assets that may be compromised

by the threats. The main limitations of the framework are the fact that it in terms of management it documents the vulnerabilities without furnishing an operational implementation of the security requirements. Forward engineering abilities can here be developed. Future work also includes the development of Key Performance Indicators to quantify the risk-related performance of IT Services as well as the application on new case studies gain experience through its use.

Part II

A Strategic Approach to The Digital Transformation

Chapter 3

Towards Strategic Support and Guidance of the Digital Transformation: A Conceptual Model

In Chapter 2, we emphasized the importance of integrating security concepts into IT governance frameworks to enhance organizational resilience and protect critical assets. By enriching the Model Driven IT Governance (MoDrIGo) framework with security related concepts, we highlighted how organizations can better manage risks and ensure compliance with regulatory requirements. The robust security measures and governance practices discussed within Chapter 2 are foundational for any DT effort, as they ensure a secure and compliant environment in which digital initiatives can be executed.

3.1 Introduction

Digitally enabled organizations are supported by emerging digital technologies, which increasingly promise great opportunities for growth [128]. These digital technologies embrace ICT systems such as mobility, analytical systems, and virtualization and are integrated with back-office ICT in order to provide a holistic view of the digital organization [128]. Such initiatives are known as being part of the Digital Transformation (DT) of organizations and require them and their respective management to reflect on the process of implementation.

With the shift to digitalization, organizations cannot focus their behaviour and reflection only on the physical/traditional world [62]. Managers in any organization must be able to recognize and anticipate technology-enabled change, assess its potential and impact, and understand how to leverage digital technology in order to capture and create value for their organizations [62]. Successful management of an organization in a digital era requires rethinking the organizational strategy, business model, and key business drivers [62].

Studies show that implementing large-scale ICT-enabled change initiatives does not have a great rate of success across organizations [128, 10, 99]. The extensive and diverse literature on DT suffers from a missing common agreement on the exact definition of DT [250] and what it encompasses [263]. In order to address this gap, this paper aims to address key DT concepts and provide

a high-level overview of the custom DT context which will help organizations succeed in their DT journey. For that, we will present a framework that helps organizations recognise DT concepts and then instantiate this framework to the case of a digitally-enabled hospital to better understand its applicability.

The rest of this paper is structured as follows. Section 3.2 focuses on the research approach followed to carry out this research. Section 3.3 provides some background information about DT and the existing research on DT conceptual models. A running example is then provided in Section 3.4. Section 3.5 depicts the proposed DT framework. Finally, Section 3.6 and 3.8 provide a discussion and the resulting conclusion respectively.

3.2 Research Positioning and Objectives

3.2.0.1 Research Question

Being in the paradigm of Design Science Research (DSR) [93], this research has the aim to propose a solution to the problem of recognizing the necessary DT concepts in order to provide a high level view that helps executives, at the strategic level of any organization in different industries, transform their business with a minimum rate of failure. For that, this paper aims to address the following research question (RQ): *How can we represent through conceptual modelling the key DT-related concepts/elements that can be used at the governance-level to drive a successful DT?*

The artefact built through the DSR approach is a metamodel and is, once instantiated onto an organization, aimed to support strategic reasoning into organizations willing to have a structured DT approach.

3.2.0.2 Research Methodology

The metamodel is based on a literature review leading to a careful reading and examination of the identified sources and was validated on the basis of an internal discussion. The literature review indeed allowed us to identify the key contributions in the field of the DT. This was then followed by the overall study of the identified resources which led to the extraction of the key concepts. Each of the identified concepts were then discussed and validated based on the basis of a discussion among the authors of the paper. The metamodel is presented in Section 3.5. The latter provides an explanation of each of the identified concepts as well as the resources they were extracted from. The metamodel is then instantiated on a case (see Subsection 3.5.2) to better show the applicability of each of the identified concepts in the metamodel.

3.3 Related Work

3.3.1 The concept of DT

DT has become a buzzword in contemporary academic and practitioner conversations [86]. Furthermore, as to its strategic importance [213], DT is affecting and challenging managers and C-level executives across industries and contexts

(eg. [265, 10, 46, 22]). Moreover, the emergence of the Covid-19 pandemic have further urged organizations into action by increasing awareness regarding the need to accelerate DT [69].

According to the European Commission forecasts, one of the leading global trends to 2030 will be a *transformative industrial and technological revolution*. There are many definitions provided by business experts, academicians and government authorities. For example OECD [171] states that “*digital transformation refers to the economic and societal effects of digitization and digitalization. Digitization is the conversion of analog data and processes into a machine-readable format. Digitalization is the use of digital technologies and data as well as their interconnection which results in new or changes to existing activities*”. On the other hand, Bloomberg [28] explains that “*Digital transformation requires the organization to deal better with change overall, essentially making change a core competency as the enterprise becomes customer-driven end-to-end. Such agility will facilitate ongoing digitalization initiatives but should not be confused with them*”. For Verhoef et al. [241], DT is the way in which “*a firm employs digital technologies, to develop a new digital business model that helps to create and appropriate more value for the firm*”. Last but not least, according to Lucas et al. [129], changes driven by DT relate to changes in the relationship between the organization and employees and customers, adjustment to the business processes, and market condition. DT and the following business model innovations have basically changed customer needs and behaviour, disrupted many markets, and suppressed traditional firms [241]. Continuous changes in customer expectations and behaviour are forcing organizations to take the lead in the DT [164].

3.3.2 DT challenges and conceptual solution

To appropriately incorporate disruptive technologies, organizations must include the DT within their core strategy [87]. Westerman et al. [265] note that “*executives are digitally transforming three key areas of their enterprises: customer experience, operational processes and business models*”. According to Heavin and Power [87], there are major challenges of DT facing managers such as *priorities* (i.e. does increasing the efficiency of existing operations have more priority than focusing on the customer and their needs?) and *security vs accessibility* (i.e. managers must balance the sensitivity and importance of data with accessibility concerns).

Different opinions do exist among researchers about how DT should be supported [280]. Some studies emphasize the importance of focusing mainly on customers and their needs [206, 48]. Likewise, Bloomberg [28] states that “*digitization and digitalization are essentially about technology, but the digital transformation is not. Digital transformation is about the customer*”. Some other studies insist on importance of the fact that executives should support and initiate the incorporation of digital culture as well as the processes of organizational change [206, 78, 88]. In their study, Verina and Titoko [242] propose a conceptual framework to provide a deep understanding of DT concepts. Their

framework is based on three categories of DT in business, namely technologies, people, and processes and management. In another study, Chernbumroong et al. [40] propose a conceptual model of DT by focusing to deliver greater business outcomes for Thai SMEs. They also emphasize the three elements of people, process, and technology, and they consider the “people” element to have the most important role in DT process. Other studies have been addressing DT by focusing on the Covid-19 pandemic issues. For example, Muditomo and Wahyudi [160] present a conceptual model for small and medium-sized enterprises. In their study, they focus on DT drivers as well as strategic imperatives and DT milestones. They emphasize that external DT drivers such as digital competition, digital technology, and digital customer behaviour are the main triggers for DT.

3.4 Running Example: Digital transformation in Healthcare

As with many other industries, Healthcare has seen major benefits from DT with the adoption of new digital technologies helping to deliver high-quality, secure patient care and drive greater business efficiency. Electronic Health Records (EHR), Enterprise Resource Planning systems (ERP), digital imaging, e-prescription, are all among the digital technologies that have been integrated into the IT systems of many healthcare organizations [83]. Adopting technological innovations has primarily had an impact on the positioning of the patients and the internal processes within the healthcare system [116].

The rising relevance of the DT in healthcare became evident to both practitioners and scholars [189]. One of the DT services popular in the healthcare industry is Telemedicine. The latter traces back to the 19th century [14] and refers to “the delivery of [HC] services, where distance is a critical factor, by [...] using [ICT] for [...] treatment and prevention of disease and injuries, research and evaluation, and for continuing education of [HC] providers, all in the interests of advancing the health of individuals and their communities” [175].

To illustrate and understand different DT concepts within the healthcare industry, we take into account an evolution of the Saint-Romain hospital which is a fictive example but partially based on previously collected data presented in [257] and [252]. Let’s consider that due to the Covid-19 pandemic, the governance board decides to adopt a telemedicine service. Being able to identify the related DT concepts especially at the strategic level, Saint-Romain not only accelerates the adoption of telemedicine but also avoids possible adoption challenges. As such, the more guided and supported the hospital boards and executives become regarding the adoption of telemedicine, the more effectively they can survive in the digital world.

3.5 The proposed DT Conceptual Model

This section presents the identified DT concepts in the form of a metamodel. The main goal is to be able to recognise DT concepts especially at strategic

Concepts	Sources
<i>Customer</i>	Matarazzo et al. (2021) [134], Fitzgerald et al. (2014) [68], Berman (2012) [25], Lemon et al. (2016) [123]
<i>Customer Value</i>	Matarazzo et al. (2021) [134], Berman (2012) [25], Pereira (2017) [182]
<i>DT Service</i>	Wautelet (2019) [252]
<i>Technology Asset</i>	Ferreira et al. (2020) [62], Andriole (2017) [10], Sahu et al. (2018) [201], Henriette et al. (2015) [90]
<i>Market Demand</i>	Ebert and Duarte (2018) [57], Bharadwaj et al. (2013) [27]
<i>DT strategy</i>	Correani et al. (2020) [46], Kane et al. [110], Bharadwaj et al. (2013) [27], Morakanyane et al. (2020) [156], Hess et al. (2016) [92]
<i>DT Objective</i>	Wautelet (2019) [252]
<i>Business Model Technique</i>	Zott and Amit [283], Osterwalder and Pigneur [178], Weill and Vitale [261], Loonam et al. [128], Westerman, Bonnet, and McAfee [264], Myrthianos et al. (2014) [163], Parry et al. (2014) [181]

Table 3.1 DT concepts and the associated literature sources

level. As previously mentioned in Section 3.2.0.2, the metamodel is built on the identification of the key contributions in the field of DT. Table 3.1 shows each of the identified concepts as well as the sources from which these concepts were retrieved.

3.5.1 DT Metamodel

Based on the literature study, some of the important DT concepts are identified and described below. Each concept is illustrated on the case described in Section 3.5.2. The resulting metamodel is represented in Figure 3.1.

1. *Digital Service*

Description: A digital service is a coarse-grained functional element. It refers to the adoption of new digital technologies in order to sustain DT objectives and bring value [257, 252].

Illustration: In Fig. 3.1, a digital service will be an instance of the `Digital_Service` class.

Example: *Adoption of telemedicine is an example of a digital service in Saint-Romain.*

2. *Customer*

Description: One of the most important motivations for organizations to go through their DT, is *improving customer experience* [68]. “*The customer dimension concerns about the entire customer interaction journey with the organization through digital transformation*” [25, 123]. According to surveys, improving customer relationships is the area where organizations have the most success with digital technologies. Improving customer experience followed closely by customer-friendly ways of enhancing products and services, is one of the most prominent examples [68].

Illustration: In Fig. 3.1, a customer will be an instance of the `Customer` class.

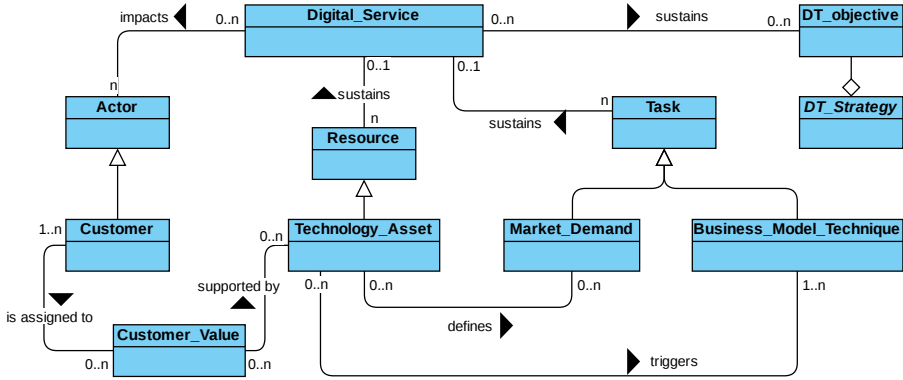


Fig. 3.1 Digital Transformation Metamodel

Example: In the context of Saint-Romain, customers are referred to as patients cared by the hospital. For that, to successfully transform, Saint-Romain executives must focus on improving patient experience.

3. Customer value

Description: To improve customer experience, a successful DT requires to take into account various business factors, among them *value proposition* [25]. The latter measures the value customers realize from consuming products and services of an organization. Moreover, it captures the total benefit the customer achieves through the consumption of the product or service, which satisfies their latent demand [182].

Illustration: In Fig. 3.1, a customer value will be an instance of the `Customer_Value` class.

Example: As explained previously, In Saint -Romain, customers are patients and the value brought to them through telemedicine includes “healthcare access from home”, “prescription delivery”, “rapid care”, “quality care”, etc.

4. Technology Asset

Description: Most transformational leverage are driven from tried-and-true strategic technology (e.g., customer relationship management software, ERP, etc.) and operational technology (such as networking and databases) [10]. Usually there are five aspects, namely (i) platforms, (ii) functions, (iii) infrastructure, (iv) applications, and (v) channels that have to be considered [201]. Technology assets are digital resources with the purpose to optimize and transform business activities [90].

Illustration: In the metamodel, a technology asset will be an instance of the `Technology_Asset` class.

Example: An example of the telemedicine-related technologies used by Saint-Romain include a platform for enhancing communication between healthcare providers, which increases diagnostic accuracy of some difficult

cases as well as improving the treatment results of critical or severe Covid patients with limited medical resources. A remote-monitoring tool - to better perceive the evolution of Covid disease - is another example of telemedicine-related technologies.

5. *Market Demand*

Description: Another business factor that can impact the success of DT is *market analysis* [27]. According to Ebert and Duarte [57] “*Disruptive companies explore the occupation gaps left by the market leaders*”.

Illustration: In the metamodel, a market demand will be an instance of the `Market_Demand` class.

Example: *With the raise in the number of people infected with Covid, Saint-Romain executives sensed the acceleration in the use of telemedicine platforms among healthcare organizations. To successfully transform, Saint-Romain must analyze the current and the future of the telemedicine market. As an example, knowing that patients need to buy their medicine after every televisit, it will be profitable for Saint-Romain executives (and more convenient for its patients) to integrate online pharmacy apps into the telemedicine service.*

6. *Business Model Technique*

Description: There is no widely accepted definition of the business model concept. According to Zott and Amit [283] business model is a “system of interdependent activities that transcend the focal firm and spans its boundaries”. On the other hand, Osterwalder and Pigneur [178] view this concept as a support “in articulating how the firm creates and captures value”. Finally, Weill and Vitale [261] describe it as a set of “roles and relationships among firm consumers, customers, allies, and suppliers”. Despite the differing views, there is a consensus amongst practitioners and scholars alike that a business model is an important tool in supporting the strategic choices of an organization [163, 181].

According to Loonam et al. [128], organizations seeking to deploy digital technologies in order to gain greater competitive advantages must also ensure that their business models are aligned respectively. In their study, Westerman, Bonnet, and McAfee [264] state that digital technology can drive five archetypes of business model reinvention, namely (i) substituting products and services, (ii) rethinking value propositions, (iii) re-configuring value delivery models, (iv) creating new digital businesses based on new products and services, and finally (v) reinventing the entire industry. In this study we will use the word *business model technique* to refer to these five archetypes.

Illustration: In the metamodel, a business model technique will be an instance of the `Business_Model_Technique` class.

Example: *As Saint-Romain is only willing to expand the use of technology in its business model, it will focus on reconfiguring its value delivery models so that it can provide online services during pandemic*

7. *DT Objective*

Description: A DT strategy is composed of fine-grained DT objectives [252]. **Illustration:** In the metamodel, a DT objective is represented as a class `DT_Objective`. As DT objectives are refinements of DT strategy, we used the aggregation link to model this in the metamodel.

8. *DT Strategy*

Description: According to Kane et al. [110], “*what separates digital leaders from the rest is a clear digital strategy combined with a culture and leadership poised to drive the transformation*”. Digital strategy refers to an organizational strategy formulated and executed through the leverage of digital resources to create differential value [27].

Illustration: In the metamodel, a DT strategy is represented as an abstract class `DT_Strategy`. The latter is an aggregation of DT objectives.

Example: *In the case of the Saint-Romain, their DT strategy is an aggregation of the following DT objectives: “increased value for patients”, “provide healthier future for individuals by providing access to mobile healthcare”, “improve employee and patient experience by removing paperwork, save time and cost”, “access to real-time patient information”, and “reach to remote areas and provide personalized healthcare with use of technology”.*

3.5.2 Model-based Representation of DT concepts

To better understand the DT concepts already presented in the metamodel (see Fig. 3.1), in this section we provide a respective instantiation, called “*DT Strategic Diagram*”, by considering the case of a digitally enabled Saint-Romain. The resulting representation is depicted in Fig. 3.2. Following the DT strategic diagram, we can see the important role of patient (customers of healthcare) and their associated values. For example, for patients, it is important to have *low care costs* or to be able to *easily communicate with their physicians*. Saint-Romain can provide value to the patients by adopting a new digital service, here *telemedicine*. The latter is operationalized through the deployment of a number of technology assets, namely *Real-time audio/video communication*, *store-and-forward*, and *remote patient monitoring*. While *real-time audio/video communication* provides patients with *better communication* and *receiving customized treatment plans*, *remote patient monitoring* supports patient values such as *good patient experience* and *reduction of time and cost in patient flow*. The telemedicine adoption is mainly defined by the analysis of the market and triggers Saint-Romain to come up with new techniques regarding its business models. For example, because of the Covid-19 pandemic, the healthcare market is pushing the healthcare industry towards more virtual ways of working. Based on such market demand, Saint-Romain decides to adopt telemedicine which triggers the hospital to reconfigure its value delivery models in order to provide online services to the patients especially during Covid-19 pandemic. Subsequently, the adoption of the new digital service will have an impact on the strategic objectives of the Saint-Romain, here, using telemedicine helps the

hospital to expand the use of technology to deliver services to patients as well as in remote locations.

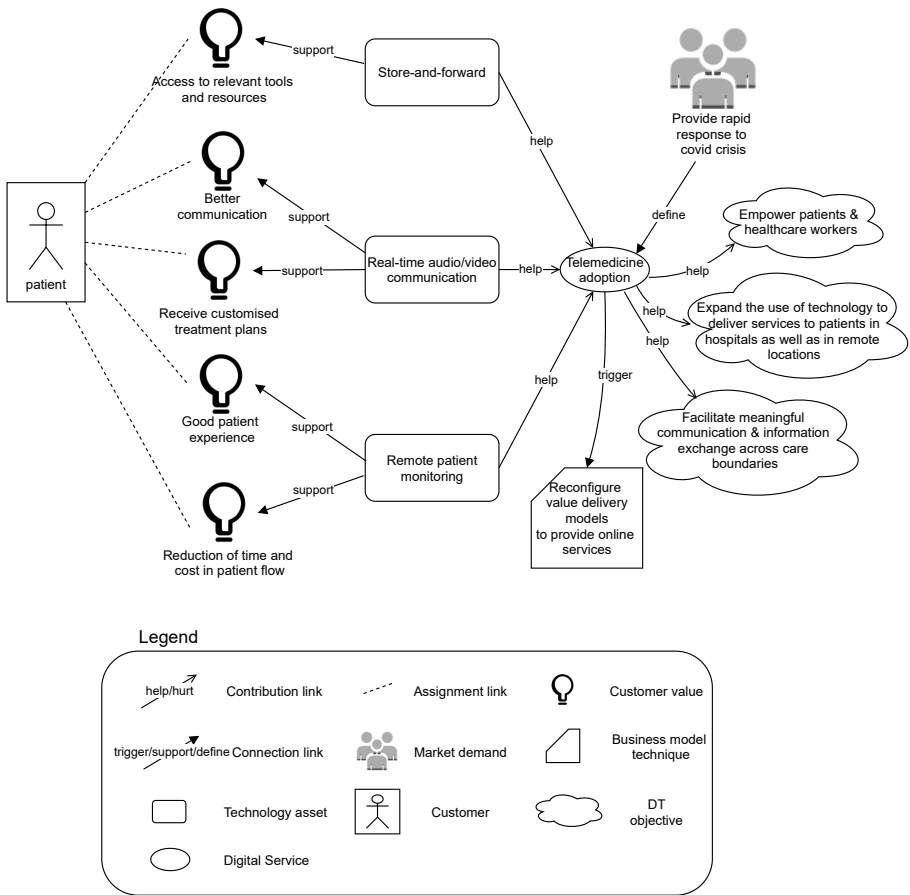


Fig. 3.2 Instantiation of Figure 3.1 - DT Strategic Diagram - case of a Digitally-enabled Saint-Romain

3.6 Discussion and comparison with other methods

With the provided metamodel our research allows executives to recognize important DT concepts as well as to see the impact of each of these concepts at the strategic level board decisions when it comes to the DT. On the other hand, instantiating the metamodel into a case study enables first, to represent each of the DT elements to emphasize its significant role when applied to an organization (here a healthcare) when it seeks to achieve DT, and second, to depict the possible impact each of these elements can have on each other. Finally, we can see how the adoption of new technologies affect the strategic objectives of an organization.

As previously mentioned in Subsection 3.3.2, similar studies exist with the focus on conceptual modelling. Some of these methods are listed below:

- **Muditomo & Wahyudi (2020)** [160]. Their conceptual support provides SMEs with a flow model that can describe decision-making steps in determining strategic imperatives and measurable DT milestones;
- **Verina & Titko (2019)** [242]. Their model focuses attention on factors enabling DT processes as well as on potential outcomes for business and society;
- **Udovita (2020)** [232]. Their method consists of identifying different dimensions of digital transformation that a firm can adopt in its DT process;
- **Heavin & Power (2018)** [87]. They provide a conceptual decision support guide for managers;
- **Rautenbach et al. (2019)** [185]. Their model aims to provide a diversified assessment toolset which helps organizations in enabling value-adding digital transformation by providing them a value equation for each digital dimension;
- **Chernbumroong et al. (2021)** [40]. Their model defines the states that enable digital transformation processes as well as the role and interaction of people.

Based on the analysis of each of the aforementioned studies and their respective methods, our approach entails novelty in that it makes use of conceptual modelling to help researchers and practitioners understand the many DT concepts that are required to be identified and understood by the top-level governance board of an organization as well as how these concepts are interrelated. We believe that to make DT operational, we should start from the governance level. Our framework helps C-level executives understand the requirements of DT and to identify its components.

3.7 Digital Transformation and Risk Management

Although there are many opportunities related to DT, it brings many dangers that can seriously jeopardize any organization. This can be anything from

cybersecurity threats and data breaches to regulatory compliance requirements and technology failures.

It is imperative to be cautious while working online, even high tech and digital working organizations are lagging behind in cybersecurity measures. Research by [187] also proved that the rate of cyber threat is growing every year, which requires cybersecurity to adopt practices to prevent actual data breaches and cyber attacks. Effective protections against cyber risks are implemented through integration of risk management in technical solutions such as firewalls, encryption solutions, as well as security awareness in the enterprises ([187]).

In a similar way, digital risk management gets even more sophisticated when it comes to compliance. The General Data Protection Regulation (GDPR) in the EU and the California Consumer Privacy Act (CCPA) in the US are just a couple of the many regulations that require a stringent level of data privacy and security.

Kshetri, in his earlier research [121] emphasized the need for regulation compliance as a means to reduce the legal and reputational consequences of data breaches, and non-compliance with privacy regulations.

Similar to cybersecurity and regulatory compliance, risk management of digital and technological services requires good technology governance. For example, Van Grembergen and De Haes [236] emphasize that IT governance frameworks help to integrate business and IT, to support IT executives align technology investments with overall business objectives, and provide a strong governance structure for the management of technology-related risks. Using governance frameworks like Control Objectives for Information and Related Technologies (COBIT) or Information Technology Infrastructure Library (ITIL) can help organizations to strengthen their abilities in managing risks growing resilient in digital disruptions [236].

Furthermore, adopting emerging technologies such as Artificial Intelligence (AI), blockchain, and the Internet of Things (IoT) introduces new risks and challenges for organizations ([274, 273]). Therefore, as organizations and leaders navigate through the jungle of digital technology project complexity, they must adopt a proactive risk management methodology if they plan to survive.

3.8 Conclusion

In this paper we proposed a framework to model DT concepts and reconstitute a DT situation into an organizational DT strategic diagram. For that we first built a metamodel to introduce the new concepts and the way they are interrelated and second, instantiated the metamodel into an illustrative example of a healthcare instantiation (i.e. Saint-Romain hospital). With the constructed metamodel and the DT Strategic Diagram, we answer the research question raised in Section 2. As emphasized by Kane et al. [110], *more than being a matter of technology, DT is about adopting a consistent digital strategy*. Therefore, to successfully transform, organizations or more precisely executives, should be aware of important digitalization concepts beforehand. Having a clear vision and digital strategy helps them achieve the required DT maturity. Moreover, based on our research, one of the most important concepts is *customer value* as

today customers are becoming more than ever digital-savvy and organizations should create products and services that meet customer value. To come up with such products and services and be able to create value, organizations need to reconfigure or reinvent their *business models* to define the required set of activities to create and capture value. For that, we consider the *business model* as another important DT concept. As of other important DT concepts, we can refer to *technology asset* and *market demand*. The analysis of the latter helps organizations in their adoption choice (i.e. which technology can help them survive in the market and avoid disruption) and sustain their strategic objectives.

Moreover, integrating a risk management perspective into discussions surrounding digital and technological services is significant. This perspective encompasses various dimensions, including cybersecurity, regulatory compliance, technology governance, and emerging technology risks. Organizations must address cybersecurity threats, ensure regulatory compliance, implement robust technology governance practices, and proactively manage risks associated with emerging technologies.

Despite the advantages of the presented framework in recognizing key DT concepts, the framework has the limitations to not consider security and privacy issues. Future work includes addressing the latter, which remain key factors (and a real dilemma in the case of healthcare [65]) when adopting new technologies.

Chapter 4

Supporting Digital Transformation Strategy Formulation through a Customizable Set of Generic Objectives: Conceptual Model and Expert Opinions

This chapter delves deeper into the practical challenges of formulating and implementing a DT strategy within specific organizational contexts. It extends the discussion on strategic objectives introduced in Chapter 3 by providing a framework for their application and validation in real-world scenarios.

4.1 Introduction

The growing digitalization of products and services has significantly transformed existing business models, corporate structures, and entire industries. Such developments call for an active transformation of systems and processes through redefinition of the organization's strategy, mission and structure in order to stay competitive [38]. A Digital Transformation Strategy (DTS) serves as a response to the challenges of managing digital initiatives and related infrastructure [89]. It aims to coordinate, prioritize, and implement the Digital Transformation (DT) efforts of an organization as well as to govern its journey to achieve the desired (digitally transformed) future state [136]. Its scope spans beyond the digitalization of resources and involves the transformation of key organizational and structural aspects, the use of advanced Information Technology (IT) or value creation aspects including key products and services, the combination of social aspects with technological devices [139], resulting in adjusted or entirely new business models [110].

DTS formulation remains an ongoing area of research, which results in an immature literature and inadequate understanding [147]. More precisely, there is still a conflict among perspectives, frameworks, conceptualizations, and definitions of a DTS [37, 92, 136, 165]. Specific organizational guidelines on how to formulate, implement and assess DTS are still vague and both practitioners and managers continue to lack knowledge regarding the development and implementation of such a strategy [31, 37, 49, 92]. This lack has been recognized

as one of the key reasons why only a limited number of organizations have been successful in implementing DT plans [31, 92, 136]. On the other hand, we believe that the lack of conceptual foundation within existing research corresponds to another breach into literature. Strong foundation would allow to dispose of a common understanding of the DTS terminology which is required to carry out a DT exercise. The advantages of conceptual models in strategy formulation have been discussed in [73, 256]. Models, and especially goal modeling languages and frameworks, are generally perceived as an efficient way to enable coordination among the involved stakeholders in the course of DT. They provide agreement, commitment, and shared understanding which are needed to build up a DTS, assess the current state of the organization and its context, and determine the ideal (digitally enabled) future state [235]. The aim of this research is to address the aforementioned study gaps by building a conceptual model to represent a *set of interrelated strategic objectives* to be achieved when conducting a DT. Such an approach provides an in-depth understanding of what to pursue in a DTS and its underlying processes and activities. This would help top managers identify the correct levers to master DT.

The focus of this research is to build a tool that provides a good understanding of the scope of action of an organization that seeks digitalization. This is achieved by considering DT as a strategy rather than a technology. For this, the main research question this paper is answering is: *“How to build and validate a generic conceptual (goal) model covering all of the DT strategic objectives that can be instantiated onto a specific organization to support its DT strategy formulation?”* Our research is based on the precepts of the Design Science (DS) paradigm which has the aim to propose a solution to the problem raised by the research question. The main contribution of this paper is the conceptual model of the DT strategic objectives. The relevancy and exhaustiveness of these objectives, as well as the strengths and weaknesses of the approach are evaluated through expert opinions. This leads to an enhanced version of the representation. The rest of the paper is structured as follows. Section 4.2 provides some background information about DTS, its formulation and the role of conceptual modeling with this regard. The context of the research including the application of DS through the relevance, rigor and design cycles is then given in Section 4.3. Section 4.4 provides a detailed explanation of the SLR process and the resulting generic DT strategic objectives reference representation. Subsequently, this section provides a validation of the representation using expert opinions. This results in a enhanced model for which the applicability is provided in Section 4.5. Afterwards, a discussion of the results is given in Section 4.6. Following that, Section 4.7 depicts the threats to the validity. Finally, Section 4.8 concludes the paper.

4.2 Background

4.2.1 The Emergence of the Digital Transformation Strategy

The DT involves changes in value creation arising by the adoption of digital technologies and business models. It can take various forms from new ways

of supporting the customer experience to new forms of production and manufacturing like digital twins [17]. This requires organizations to reorganize their objectives and identify possible new revenue streams that can derive from digitally enhanced customer interactions, products, and services [92, 136]. DT strategies receive increasing attention. Their scope span across product transformation and internal process optimization. It can also involve the use of disruptive technologies to enforce collaboration [13]. For organizations responding to digitalization, DT strategies provide a blueprint to digitally transform both their internal processes and value offerings [136, 207]. Given their scope and a purpose, DT strategy differs from an IT one [39, 222] and Digital Business Strategy (DBS) [27, 172]. An IT strategy is understood as organizational perspective on deployment and management of IS [39], and the set-up of plans for operationalizing IT in organizations. Although the IT strategy belongs to corporate governance, it is usually not considered as being a part of the business strategy but rather seen as something that needs to be distinguished separately [39]. On the other hand, a DBS seeks to consolidate business and IT strategies by addressing the issue of business and IT alignment. In this scenario, the role of IT strategy is changing from being primarily functional to becoming more integrated with the organization's corporate strategy [147].

While DBS comprises a digital business perspective including IT's possibilities for business models, products, and services, it does not provide any transformational insights in the course of a company-wide DT. In other words, it does not provide a framework, roadmap, or guidelines for the transformation phases which are pivotal for the desired future state [90, 92, 136]. As such, the concept of DTS [37, 92, 212] was introduced to coordinate, prioritize and implement an organization's DT efforts with the aim to govern its journey to achieve the desired (digitally transformed) future state [136]. It refers to broader transformation and change in processes, customers, products, services, and process models. A DTS could enhance the fusion of the IT and business strategies and provide transformational guidelines to reach the future state of the organization, and finally, it sets out the basis for future organizational restructuring [147].

4.2.2 Formulating the DTS

The transformative impact of digital technologies on almost all aspects of the inner and outer environment of an organization has highlighted the importance of formulating a DTS in many pre-digital firms across traditional industries [195]. Numerous strategic decisions need to be taken considering changes in customer interactions, organizational culture, management and finance, as well as technology. Fostering an organizational-wide coordination mechanism, organizations should develop a strategy which could ensure that they are on the right path to transformation [165, 243]. However, how such a strategy can be generated remains an open question [37].

Extant studies on DT strategies can be classified into two streams [282]. The first stream considers strategies as an object of study and identifies components constituting DT strategies and, from this, deduces a roadmap for their

formulation (e.g., [136, 194, 207]). For example, Kahre et al. [109] discuss a number of prominent organizational preconditions for DTS formulation such as *change in the understanding of IT, appropriate organizational structuring, leadership and accountability, dynamic capabilities*, etc. The second stream pursues the practice-turn in strategy research [266]. It seeks to understand how DT strategies emerge from strategizing (e.g., [23, 36]). The DT framework by Matt [136] provides a holistic approach for the development of an organization-wide DTS. It claims that, independent of the organization or industry, DT strategies have certain elements in common, which can be assigned to four dimensions. Every DT endeavour should be structured along these four key dimensions: *the use of technologies, changes in value creation, structural changes, or financial aspects*. These four dimensions have been addressed and explored by scholars such as [92] for diversified media companies, [268] for medium to large scale insurance companies, and [223] for SMEs. Mitroulis and Kitsios [146] extend these strategic dimensions by introducing *change in customer experience* as the fifth dimension. They emphasise that the evaluation of a DTS depends on four factors namely, *customer focus, digital innovation performance, employee performance, and financial performance* [147].

4.2.3 Modeling Aspects of the Digital Transformation Strategy

Models are used to describe a system: they reflect a certain group of components, their relationships, and properties that are essential for the scrutiny and control of the system [245]. Treating the organization as a system, it is possible to apply the same methods used for studying and managing these to in turn manage organizations [73]. Model-driven development allows to define and specify the scope of a system; when using such a development approach, it is possible to start from a high-level system representation [252]. This is especially the case when building strategic-level representations which is the aim of this study.

The principal challenge in modern strategic management is the important degree of complexity, uncertainty, and volatility of the environment in which decisions take place [74] and the ability of firms to adapt quickly is the most significant competitive advantage [191]. Classical strategizing methods are no longer relevant in the era of a rapidly changing world. However, expanding them through a variety of flexible techniques such as conceptual modeling enriches the strategizing process [73]. Conceptual modeling formally describes some of the aspects of the social and physical world around us with the aim of understanding and communication [162]. Conceptual models should represent *constructions* of future reality [70]. They are a prerequisite for successfully designing and planning complex systems. This is because conceptual models are a medium to foster communication among different stakeholders such as the users [70], and empower them. Moreover, models are required to evaluate different strategic options [278].

Prior researches have focused on conceptual frameworks and models that evaluate the readiness of DT and can help organizations and practitioners better conceive the process of tracking and achieving DT within an organization, among them [170] (digital innovation strategy framework), [136] (digital trans-

formation framework), [24] (digital reinvention framework) and [248] (digital orchestra framework). The review, gap analysis and comparison of some of these frameworks are provided in different studies such as [169]. Other studies are explicitly focused on strategy building and modeling [115, 278]. Korachi and Bounabat [115] proposes a framework for DTS building and provides specific guidelines to help organizations formulate, implement, and monitor their DT strategies. However, their framework is only based on IT governance and lacks additional digital strategy dimensions and concepts. On the other hand, Yucel [278] presents a generic model for modeling and evaluating the DTS. It represents the many dynamics that a DTS involves and should be considered while formulating such a strategy. Moreover, it provides the possibility to evaluate the effectiveness of a given DTS while developing it. However, their model lacks conceptualization and validation. Inspired by the ideas from the aforementioned frameworks especially the one provided by [136, 170, 278], we will develop our conceptual representation made of DT objectives typically found in organizations.

4.2.4 Aligning the business with the DTS through Enterprise Architecture

Bernard [26] defines Enterprise Architecture (EA) as *the analysis and documentation of an enterprise in its current and future states from an integrated strategy, business, and technology perspective*. EA indeed focuses on creating and maintaining a holistic and strategic view of an organization. It involves the analysis, design, planning, and implementation of the structure, processes, and systems within an enterprise to ensure that these align with the organization's goals and objectives. It considers both the current state of the organization's IT landscape and its desired future state. EA is implemented through the use of various languages, one of the best known being Archimate [122]. It can be applied in various contexts and also to conduct a DT [12].

EA can definitely help with the alignment of a DTS within an organization especially if the latter is expressed in the form of goals or objectives. More specifically, it can help through:

- **Alignment Mechanisms:** EA provides a structured framework for mapping business goals and objectives to IT capabilities. It helps identify how different digital initiatives and technologies can contribute to achieving specific DT objectives. By analyzing the organization's current state and desired future state, enterprise architects can align the various components of the EA (business processes, data, applications, and technology infrastructure) with the defined DT goals or objectives;
- **Strategic Planning:** EA helps in creating a strategic roadmap for DT. It assists in evaluating the impact and feasibility of different DT initiatives and prioritizing them based on their alignment with business objectives. By understanding the dependencies and interrelationships between various IT systems, enterprise architects can identify the most effective sequencing and timing of DT projects to achieve the desired objectives;

- **Technology Evaluation and Selection:** EA provides a framework for evaluating and selecting the appropriate technologies and solutions that align with the organization's DT objectives. By considering factors such as scalability, interoperability, security, and integration capabilities, enterprise architects can recommend the best-fit technologies to support the desired transformation. They can also evaluate the existing IT landscape, identify any gaps or redundancies, and make recommendations for optimizing and rationalizing the technology infrastructure;
- **Process Optimization:** EA helps to identify opportunities for process improvement and optimization as part of the DT journey. By analyzing current business processes, enterprise architects can identify bottlenecks, redundancies, and inefficiencies. They can then propose changes or re-designs to streamline processes, improve agility, and enhance customer experience. The alignment of processes with DT objectives ensures that the organization's operations are optimized to support the desired outcomes;
- **Governance and Risk Management:** EA provides a governance framework to manage risks associated with DT initiatives. By establishing standards, guidelines, and policies, enterprise architects ensure that DT projects align with regulatory, compliance, and security requirements. They help identify and mitigate potential risks, such as data privacy, cybersecurity, and data management, thereby ensuring that the DT journey progresses smoothly and securely.

In a nutshell, EA can play a crucial role in aligning DT objectives within an organization. It provides a structured approach to strategic planning, technology selection, process optimization, and risk management, enabling organizations to effectively transform their operations and achieve desired outcomes.

The adequate integration of the DTS objectives as an artefact to effectively drive the DTS within an organization using EA as an alignment method nevertheless remains out of the scope of the paper. A custom method can be engineered around our artefact using a generic high-level approach by a digital business architect as proposed in [270]. Its integration into Archimate could also be further studied.

4.2.5 IT Development Perspective

4.2.5.1 The NFR Framework

As said, the aim of the paper is to build a generic representation of the DTS objectives typically found in organizations in the form of a conceptual model. The latter can then be customized/instantiated to specific organizations. This conceptual model uses the formalization of the Non-Functional Requirements (NFR) framework [42]. Traditionally, the NFR Framework serves as a qualitative method to bridge the gap between NFR-related concepts and the design of software systems that encompass these concepts. The primary function of this framework is to model NFRs and their corresponding implementation methods,

ultimately leading to a comprehensive documentation of decisions regarding their implementation.

The choice of using the NFR framework was made in order to be dispose of an artifact (the DT strategic objectives represented through a conceptual model) that is compliant with this well-known notation. Besides, it is easily understandable and can be further used for the evaluation of IT adoption in the context of the DT. The use of the framework that is made in this article is pretty basic. We indeed simply use it as a goal decomposition structure in the form of NFR operationalizations. The latter type of elements has been chosen because all of the DTS objectives that have been identified are expressed in a functional manner (as elements to be implemented). Using the NFR framework nevertheless remains relevant because even if the DT objectives are expressed functionally, a lot of technological adoption that is made will only partially contribute to their achievement. Similarly their full achievement always only remains limited in time since the dynamic business context makes their achievement continuously subject to change. Another choice than NFR (like for example KAOS [238]) could have been made with very few impact on the artifact's presentation. Ultimately, we need a basic formalism to express a goal decomposition in the form of a tree whatever it may be.

Within the NFR framework, operationalizing goals are noted as bold clouds, while lines connecting these represent their interdependencies. When, in order to achieve a higher operationalizing goal, one or several sub-goals need to be achieved, an 'AND' refinement structure is used. The NFR framework uses a line to represent such a situation, the parent goal is connected to the children goals and all of these lines are connected through a partial circle structure. Through the use of this decomposition hierarchy, we explicitly highlight how the DT objectives in the parent level-nodes are refined through lower-level ones.

4.2.5.2 Integration of the DT Strategic Objectives Representation in an IT Development Life Cycle

The MoDrIGo framework [252] uses conceptual modeling to support the IT governance process especially for business and IT alignment evaluation when adopting IT services. Typically, an IT services' adoption decision is supported in MoDrIGo, by the evaluation of their alignment with the business and IT strategies. Since the latter are represented using the NFR framework, we can flexibly integrate the DTS representation instantiated to an organization when an IT service adoption needs to be evaluated. The DT objectives from a specific organization can, using MoDrIGo, be cascaded to the management level in order to evaluate the impact of the organizational change due to an IT service adoption on them. Also, the StrataMoDrIGo framework [228] offers a refinement of MoDrIGo to integrate IT developments (IT services but also each type of development having a significant impact on the organization's resources) in a quick and agile fashion. The refinement mechanisms work the same way and DT objectives can also be cascaded at management level for impact analysis. So the work performed in this paper to build-up a DTS model in the form of objectives can, once instantiated to a specific organization, be directly used for IT adoption

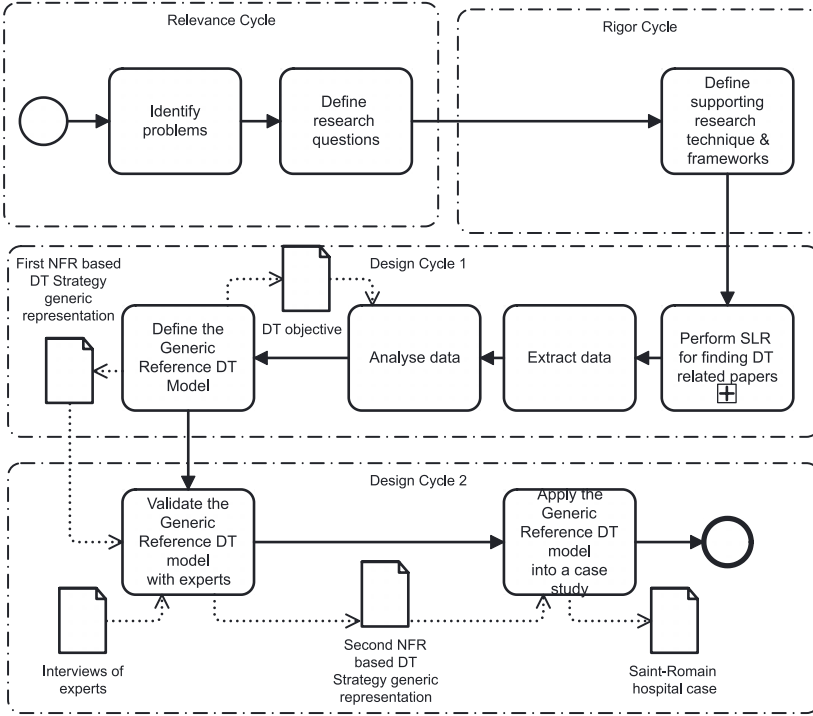


Fig. 4.1 Research Protocol

evaluation by plugin in the MoDrIGo and StrataMoDrIGo methods. This way we dispose of a tool for business and DT alignment evaluation at governance level when deciding on the adoption of new IT. This however remains optional and the contribution of this paper can be seen as a standalone effort that can be used independently by organizations conducting their IT developments to support the DT in another manner.

4.3 Research Approach and Method

Being in the paradigm of DS Research [93], we aim to bring a solution/enhancement, to the known problem of sustaining an organization willing to set-up a DTS. To this end, we build-up a generic set of DT strategic objectives from the literature that embraces all of the potential of the DT and can be instantiated/tailored to any organizational context. To answer the research question mentioned in the introduction and, based on the DS research cycles defined in [94], we will communicate an analysis of the *relevance cycle*, *rigor cycle*, and *design cycles* in sub-sections 4.3.1, 4.3.2 and 4.3.3 respectively.

Figure 4.1 depicts this research protocol. Following the three aforementioned cycles of DS research, the research protocol is designed as follows: first we identify the problem and formulate the research question (relevance cycle). Then, in the rigor cycle, we define the research approaches (SLR, interviews,

case study, etc.) and their details as well as the conceptual framework to represent the DT strategic objectives (i.e. NFR). Afterwards, in design cycle 1, we conduct an SLR to identify the relevant DT related papers and define the frameworks to support the representation. This includes defining the search string, keywords, the digital libraries used to make the research, and the process of paper selection. To collect a comprehensive set of papers, we combined both a classical SLR [111] with a forward snowballing sampling [271]. While the former allows to identify key contributions in the field of the DT and strategy formulation, the latter uses the resulting papers as the start set to identify papers that were not previously discovered by the classical SLR. We then extract data from the selected papers and analyse it. This results to the identification of the DT strategic objectives which are then used to build the reference representation. The latter is then validated, in design cycle 2, based on semi-structured interviews from experts in the field of DT, which leads to the extension of the generic representation. Finally, still as part of the same cycle, the updated/extended representation is applied onto an illustrative example leading to the teaching of some lessons.

4.3.1 Relevance Cycle

The *relevance cycle* covers the identification of problem/opportunities in the application domain [94]. Here, we identified the need for a generic guideline or framework that can provide organizations with a way of formulating/building up a DTS. Moreover, the guidance should be made in a way that it can be used in the context of an IT development in order to study the alignment of new developments of significant importance with the DTS. So, once instantiated, the guidance provides a concrete anchoring within an IT development method to be able to immediately evaluate the actual alignment of (new) IT development/deployment with the considered DT strategic objectives.

4.3.2 Rigor Cycle

The *rigor cycle* refers to the methods/theories used to ground the construction and assessment of our generic conceptual representation [94]. This section summarizes the used research techniques, methods and frameworks.

To come up with the building of our DS artefact, we conducted a hybrid search strategy or more precisely, an SLR [111] complemented by guidelines on snowball sampling [271] which, according to [157], have better performance compared to conducting any of them alone. This allowed us to identify a set of generic interrelated DT strategic objectives on the basis of peer-reviewed documentation. All the details of the SLR process are furnished in Section 4.4.1. Later, the DT strategic objectives are represented and structured using the NFR framework. As said in Section 4.2.5.1, NFR has been chosen because it furnishes a convenient framework for the decomposition of goals in this context. Moreover, we can mention its use in the rigor cycle because a complete formalization of NFR has been built-up in [42]. The research thus uses a state of the art framework for presenting the DT strategic objectives in the form of a conceptual model (we call it here a representation of generic DT strategic objectives).

For the validation of the representation, semi-structured interviews with managers and consultants were conducted. These qualitative research interviews attempted to gather new, exploratory information from the interviewee's perspective who have personal experiences, attitudes, perceptions and beliefs related to the DT concept [53]. These interviews encouraged the identification of refinements or alternatives to the first NFR-based representation. The interviews sought to evaluate the different DT strategic objectives and find possible improvements. Within the semi-structured interviews, the interviewees were asked to rate the DT strategic objectives in terms of importance (from the most to the least) and, if applicable, propose additions or modifications. In the interviews, background information related to the interviewees and the DT was also asked. The last section of the interviews concerned the possible use of the representation in practice, addressing ease of use, practicality and its completeness in general. The interviews were aimed at managers and consultants, specialized in and knowledgeable about the strategic aspects of DT and what it encompasses. Each interview was initially allocated 60 minutes. While most interviews concluded within this or a larger time-frame (see section 4.4.4), a few experts had to cut their sessions short due to external commitments. In such cases, we made sure to prioritize the core topics and questions. We believe that despite these constraints, the interviews provided rich and valuable insights, although in a few instances, we had to omit some supplementary elements. The interview questions and the way they were conducted are provided in Appendix A of this chapter in the online Appendix file¹.

The results of the interviews were analysed using NVivo software for qualitative coding. The codes used depended on the corresponding question to which the answers were given. Aspects mentioned by interviewees that did not belong to their respective questions were coded thematically as described by Saunders et al. [204]. To provide this information, it was first necessary to transcribe the interviews. These interviews were transcribed using intelligent verbatim with the essential parts accurately transcribed. This analytical process ensured that the essence of the interviews was captured and consequently ready to be analyzed.

On the basis of the transcribed data, an underpinning of the importance of each DT strategic objective could be made and we wrote up the considerations to be made for each objective. These considerations included practical approaches or viewpoints to be held or made, suggested by the interviewees; they also included pathways or suggestions for future research. It also included considerations to be made concerning the structure, content and practicality. Out of the interviews, all of the DT strategic objectives that could be packaged as such were extracted. Very operational or implementation-related elements have also been brought forward by some interviewees but were judged out of scope of the strategic representation; in other words, representing them would lead to introduce elements on an inadequate level of abstraction and

¹The online Appendix file can be found at : <https://data.mendeley.com/preview/gznyxgbz5c>

consequently to a non-justifiable complexity (and in the end even a formally wrong conceptual model). Out of the interviews data, when elements were identified as potentially relevant DT strategic objectives, they were brought forward by the researcher in charge of the interviews and further discussed among the co-authors. If it could be abstracted to a DT strategic objective and consensus on this was found among the research team it was included in the new version of the representation. In gauging the agreement among the experts, we did not use a formal metric to quantify the level of consensus. However, when differences in opinions were spotted, we conducted follow-up discussions to understand the underlying reasons and worked collaboratively to reach a consensus or to document the range of perspectives. Location of inclusion within the representation was also discussed among researchers until a consensus was found. The newly proposed DT strategic objectives were added and alterations were thus made to the initial representation after consideration, ultimately suggesting an improved version.

4.3.3 Design Cycle

In the *design cycle*, the generic DT strategic objectives representation model is effectively constructed and evaluated. We more formally distinguish two design cycles in the research conducted in this paper. The first design cycle includes the construction of the model out of the SLR and its representation using the NFR framework. The second design cycle includes the validation and extension of the representation, the determination of its strengths, and shortcomings through expert opinions collected by interviewing experts. This step allows us to provide a better appraisal of the contribution. Then, we illustrate the applicability of the enhanced representation by instantiating it to the Saint-Romain hospital already used in previous work tackling strategy representation through conceptual models ([257],[252]). Further lessons are learned from this second design cycle.

4.4 Designing the Generic DT Strategic Objectives Representation

This section presents the detailed research process followed to build the generic DT strategic objectives representation. Subsection 4.4.1 focuses on the SLR process conducted to retrieve relevant articles. Subsection 4.4.2 provides the way data is extracted from the retrieved articles. The analysis of the extracted data is provided in Subsection 4.4.3. Finally, based on the list of the DT strategic objectives retrieved from the analysed data, the representation is built and its validation is provided in Subsection 4.4.4

4.4.1 Systematic Literature Review for DT

Figure 4.2 shows the SLR process in the form of a workflow. The forward snowballing subprocess is depicted in Figure 4.3.

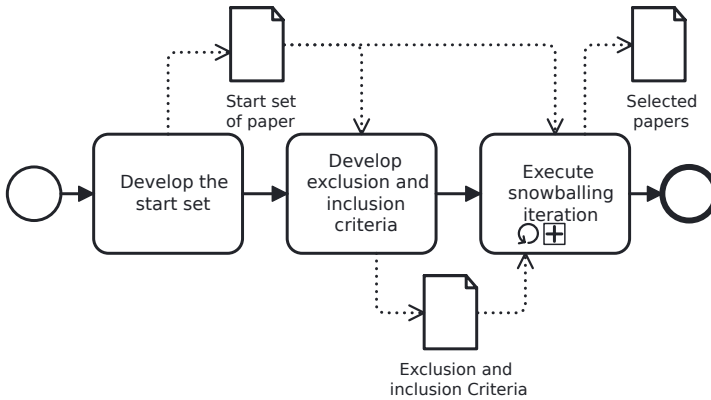


Fig. 4.2 The SLR Process

A detailed explanation of each of the aforementioned steps is provided in the following subsections.

4.4.1.1 Develop the Start Set

The first step is to identify a start set of papers for executing the forward snowball sampling. To this end, the following criteria are used to develop the start set:

- The selected papers are from different authors;
- The selected papers are from different publication years;
- At least one selected paper provides a review and a research agenda on the DT;
- At least one selected paper describes the critical success factors of the DT;
- At least one selected paper describes DT issues and challenges;
- At least one selected paper contains a previous attempt at using conceptual modeling to formulate the DTS.

In addition to Google Scholar, we looked in other digital libraries such as Scopus, Web of Science, IEEEExplore, ACM Digital library, SpringerLink, and ScienceDirect. Also, we made specific search into journals and conference proceedings listed in Table 4.1.

Following the guidelines to conduct snowball sampling, we used Google Scholar to identify and locate the articles to fulfill the aforementioned criteria for the start set to reduce bias [271]. The keywords “digital transformation”, “digital transformation strategy”, and “strategy formulation” were used to identify and form the initial set of articles from Google Scholars (search strings

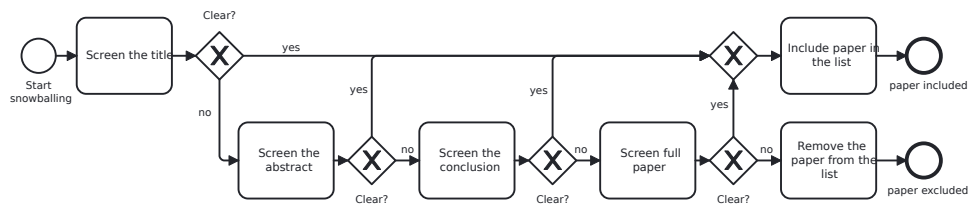


Fig. 4.3 The Forward Snowballing Process

Table 4.1 Journals and conference proceedings used for SLR.

Journals	MIS Quarterly, MIT Sloan, Manag. Inf. Sys., Journal of Information technology (JIT), Information Systems Journal (ISJ), European Journal of Information Systems (EJIS), Journal of Strategic Information Systems (JSIS), Information Systems Research (ISR), Journal of Management Information Systems (JMIS), Journal of the Association for Information Systems (JAIS)
Conference Proceedings	Hawaii International Conference on System Science (HICSS), International Conference on Information Systems (ICIS), Americas Conference on Information Systems (AMCIS), Mediterranean Conference on Information Systems (MCIS)

1 = digital transformation AND strategy formulation; search string 2 = digital transformation strategy AND strategy formulation) before the application of Wohlin’s recommendations. “Search string 1” and “search string 2” were searched separately and based on both search strings, a preliminary list of thirty papers was selected. Only the first ten pages (each page showing ten results) of search results were considered for the examination of relevant studies. The resulting preliminary set was selected based on the previously listed criteria as well as after reading the articles. Afterwards, all authors reviewed the preliminary set and based on a consensus, nineteen articles were chosen to be in the final start set. Tables 4.2 lists the nineteen studies along with the related citations of each of the articles.

Table 4.2 Start set of snowballing protocol

N°	Article	Related citations
1	Roadmap for digital transformation: A literature review [280]	[3]; [131]
2	Digital business transformation and strategy: what do we know so far [102]	[95]; [147]; [40]; [81];
3	Digital transformation strategies [136]	[192]; [209]; [128];
4	Implementing a digital strategy: Learning from the experience of three digital transformation projects [46]	[216]
Continued on next page		

Table 4.2 – continued from previous page

N°	Article	Related citations
5	Options for formulating a digital transformation strategy [92]	[189]; [37]; [5]; [23]; [183]; [79]; [82]; [21]
6	Challenges for digital transformation: towards a conceptual decision guide for managers [87]	[279];
7	Digital strategy and digital transformation [136]	[126]; [200];
8	Understanding digital transformation: A review and a research agenda [243]	[207]; [244]; [198]; [32]; [161];
9	A framework for a strategic digital transformation [281]	[225];
10	From digital business strategy to digital transformation-how: A systematic literature review [30]	[233]; [190];
11	Conceptualising digital transformation in business organisations: A systematic review of literature [155]	[221]; [177]; [242]; [77]
12	Components of a digital transformation strategy: A south African perspective [133]	[20]
13	Conceptual review on dimensions of digital transformation in modern era [232]	[149];
14	Critical success factors of digital business strategy [97]	[173]; [197]; [18]; [1]; [179]; [91]; [71];
15	Understanding digital transformation strategy formation: Insights from Europe's automotive industry [36]	[218]; [41]; [217]; [284]; [130]; [135]; [202]; [43]; [96]; [199];
16	Survival in the digital age: A framework for formulating a digital transformation strategy in SME [223]	[224];
17	Digital organisational transformation issues, challenges and impact: A systematic literature review of a decade [132]	[203]; [104];
18	Determining digital transformation success factors [156]	[107]; [8]; [210];
19	Digital transformation: a review, synthesis and opportunities for future research [166]	[114]; [35]; [11]; [148];

4.4.1.2 Developing Exclusion and Inclusion Criteria

At this step, we developed inclusion and exclusion criteria and applied them on articles found during the snowballing process.

Inclusion Criteria. We selected papers that: 1) are written in English; 2) are published from 2013 to 2021. The choice of this time span lies in the fact that DT is a subject that is still under research and thus apt to change. We thus, base our research to studies starting from 2013; 3) discuss digital strategy formulation; 4) discuss different aspects of digital strategy (e.g. [49]); 5) are published in well-known journals and conferences as well as research centers such as Deloitte, Capgemini consulting, McKinsey Quarterly, MIT Sloan and Harvard business review; 6) discuss DT roadmap, guidelines, drivers, enablers, success factors, best practices, barriers and challenges that could lead to strategy formulation and modeling (i.e. it is possible to drive relevant DT objectives from these papers).

Exclusion Criteria. Papers not meeting the aforementioned criteria are excluded. Other exclusion criteria include papers that: 1) focus on DTS execution and implementation or technical aspects; 2) do not belong to computer science; 3) have no full text available; 4) are not peer reviewed.

4.4.1.3 Executing Snowballing Iterations

We applied the inclusion and exclusion criteria to the start set using forward snowballing (identifying citing articles). Google Scholar was used for this purpose. Each of the nineteen articles in the start set was primarily read in order to understand it. Afterwards, we conducted forward snowballing where the papers citing the nineteen papers in the start set were evaluated. Microsoft Excel was used to keep track of forward snowballing procedure. That is, the authors, title, and the publication forum were extracted for each of the selected articles. Every new iteration was noted in a new Excel worksheet. This allowed to have a proper traceability of the articles. We identified 76 studies through the snowballing protocol. Four iterations were required before reaching saturation. The final inclusion of the papers was based on the full analysis of the paper. Iteration one covered the start set and resulted in 52 citations. Iteration two yielded to 18 cited papers and iteration three resulted in 6 cited papers. Finally, no new citations could be found from the fourth iteration. Note that we only follow the forward procedure of the snowball sampling. Although we base our study on the time span of 2013 to 2021, we believe that DT is an emerging and dynamic concept and that the breadth of the area addressed by this paper is rather small. Therefore, it is more relevant to rather consider citations which include studies belonging to recent years. The retrieved articles were then used to identify a generic set of interrelated DT strategic objectives required to build a DTS. In what follows we will explain how the extraction and the analysis of data took place.

4.4.2 Extracting Data

To structure the representation, we extracted a set of DT strategic objectives from the literature by looking at their frequency of appearance. Table 4.3 is an illustration of the analysis of the retrieved articles. It captures the occurrences of each of the identified DT strategic objectives in the articles. These and the list of the articles from which they are identified are provided in Appendix B of this chapter in the online Appendix file.

Table 4.3 DTS Objectives and their occurrence in the literature

	Key DT Objective	Number of Related Articles
Strategic Changes and Digital Maturity	Agile Mindset, Organizational agility, Agile IT	44
	Risk-taking, risk and Technology Appetite	34
	Dynamic/digital Capabilities	32
	Digital Roadmap	11
Changes in Value Creation	Customer Behaviour Analysis	55
	Operational Efficiency	35
	Digital and Traditional Offerings Alignment	8
Changes in Organizational Structure	Transformational Leadership	43
	Digital Skill set and Mindset	36
	A Separate Digital Unit	17
Financial Constraint		20

4.4.3 Analysing Data

Based upon further discussion and consensus, we clustered the identified set in four main (root) DT strategic objectives that could be further decomposed into more concrete (leaf-level) DT strategic objectives, and decided to include them in the representation. The clustering is repeated for each of these leaf-level DT strategic objectives until we reached a decomposition tree. The structuring process has been realized by the research team. The DT strategic objectives were each discussed, appraised in abstraction and related through the decomposition mechanism. Each DT strategic objective structure was discussed until a consensus was found. It was also supposed that the expert opinions could provide relevant feedback on this further in the validation process. No quantitative metrics were ever associated to the DT strategic objectives which would implicitly have led to distinguish more important and less important objectives within the generic model. Indeed, no information extracted from the SLR could be exploited in such a way and, the fact of using multiple sources for distinguishing the DT strategic objectives makes any assignment of value and comparisons in importance (possibly leading to a ranking) totally impossible. The analysis of the selected articles provides us with a list of crucial DT strategic objectives briefly explained hereafter (see Appendix B of this chapter in the online Appendix for an in-depth description of the leaf-level objectives.).

- **Develop a Digital Roadmap.** According to Chanas et al. [37], one of the building blocks to formulate a DTS is a bottom-up approach. The

idea is to use a digital roadmap that is developed by deriving digital innovation projects for an organization's main lines of business [37]. A firm's main product line plays a crucial role in its DT, because one of the key aspects of DT is to incorporate digital technologies into products [92]. To develop their digital roadmap, organizations should evaluate their digital maturity, including evaluating the capability and compatibility of their IS [115] to see if they are able to exploit and explore new technologies. Moreover, they should evaluate and prioritize their digital ideas and define their vision and strategic direction. Based on the conducted SLR, *develop a digital roadmap* can further be split into more concrete DT strategy objectives. These include “*developing and evaluating digital maturity*”, “*defining board's vision and strategic direction*”, “*evaluating capability and compatibility of IS*”, and “*evaluating and prioritizing digital ideas*”

- **Identify Structural Changes.** This DT strategic objective refers to the changes made to the organizational processes, structures and skill sets that are necessary to exploit and cope with new technologies. Based on the conducted SLR, *identify structural changes* is further divided into the following DT objectives: “*foster transformational leadership*”, “*foster digital skill-set and mindset*”, and “*establish a DT unit*”.
- **Evaluate Financial Ability.** According to Hess et al. [92], one of the key dimensions associated to DT is *the ability of organizations to finance the DT endeavor* as well as its need to take action in response to a struggling core business. Organizations should carefully plan the structural changes that are brought by their DT in order to leverage digital technologies for their benefit without forgoing financial constraints [243]. Likewise, Matt et al. [136] argue that all other DTS dimensions can only be transformed after taking into account *financial aspects*. These include an organization's urgency to act due to a diminishing core business as well as its ability to finance a DT endeavor. Organizations already under financial pressure might not be able to consider external ways to finance a transformation [136].
- **Identify Possible Changes in Value Creation.** From a business perspective, using new technologies often means changes in value creation [136]. For that, it is important to consider the impact of DT strategies on firm's value chain, meaning how far the new digital activities deviate from the traditional core businesses. More deviations offer more opportunities to expand the current products and services portfolio but on the other hand require stronger need for different product-related and technological competences [136]. When investigating the DT, size and value focus are considered as crucial dimensions. Size impacts every type of transformation. Moreover, the main product line of an organization will most likely play a key role in its DT since one of the key aspects of the DT is integrating digital technologies into products [92]. Achievement of such objective requires organizations to follow, analyse and anticipate customer behaviour, identify processes that can be enhanced by digital

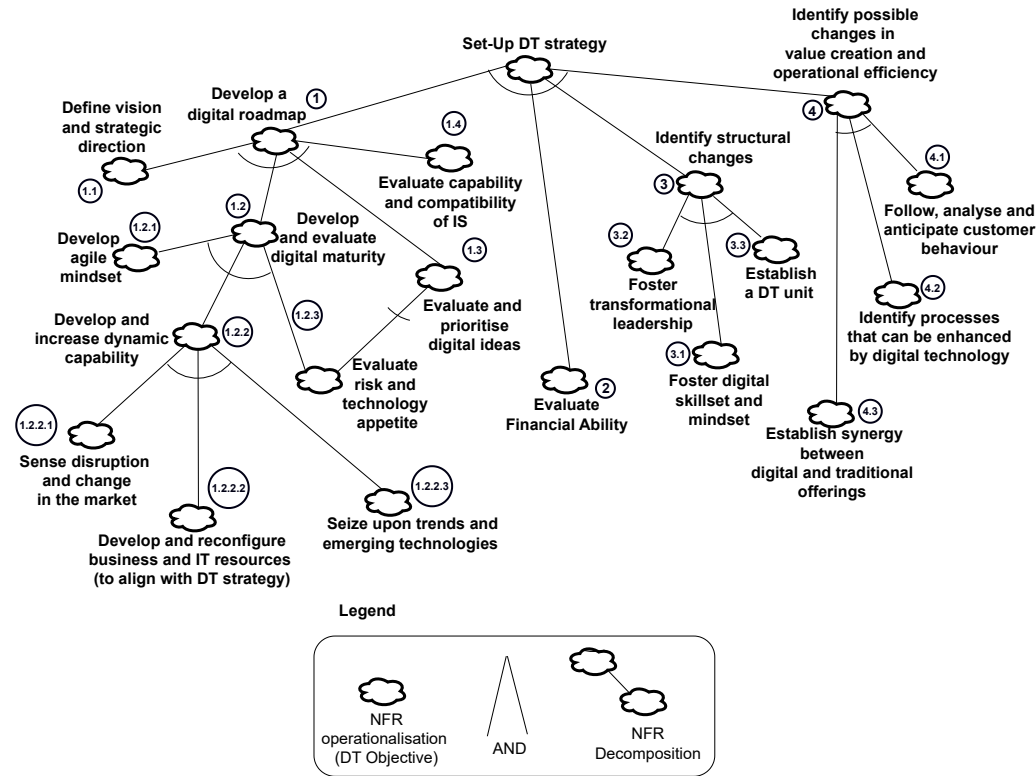


Fig. 4.4 The identified DT Strategic objectives represented in the form of NFR Decomposition.

technology and the establish synergy between digital and traditional offerings. Based on the conducted SLR, this DT strategic objective can further be split into sub-objectives “*Identify processes that can be enhanced by digital technology*”, “*follow, analyse and anticipate consumer behaviour and expectations*”, and “*establish synergy between digital and traditional offerings*”.

Figure 4.4 shows the application of the NFR framework to the identified DT strategic objectives. The four main strategic objectives are represented by numbers 1, 2, 3 and 4. Using the decomposition link, these are further decomposed into more concrete DT strategic objectives that are required for them to get fulfilled. For example, *evaluate and prioritise digital ideas*, *define vision and strategic direction*, *develop and evaluate digital maturity*, and *evaluate capability and compatibility of IS* are all sub-objectives that are required to be achieved in order to fulfill the DT strategic objective *develop a digital roadmap*. Likewise, to fulfill the sub objective *evaluate and prioritise digital ideas*, we

need to check how much risk the organization is willing to take for it and what budget it wants to dedicate to such digital idea.

4.4.4 Validating the Generic Reference DT model

The aim of this section is to evaluate the completeness of the generic model presented in Figure 4.4. For that, we conduct in-depth semi-structured interviews with managers and consultants specialized in strategic aspects of the DT.

The interviews were conducted individually via online conferencing software such as Skype, Microsoft Teams, or Zoom. The number of interviewees was six. The information about the interviewees is provided in Table 4.4. As such, six semi-structured interviews were held during March and April 2022. These semi-structured interviews were drafted, inspired by the Interview Protocol Refinement (IPR) framework as presented by Castillo-Montoya [34], to ensure the questions asked aligned with the research question and inquiry-based conversations were held.

Table 4.4 Interviewee Information

	Age	Highest obtained degree	Current position	Industry	Years of experience in DT
<i>Interviewee 1</i>	26	Master's Degree	Senior Consultant	Consulting	2 1/2
<i>Interviewee 2</i>	56	Master's Degree	Business Transformation and Change Management Executive	Consulting	25
<i>Interviewee 3</i>	26	Master's Degree	Strategy and Management Consultant	Consulting	3 3/4
<i>Interviewee 4</i>	50	Master's Degree	IT Director - Business Project Leader	Pharmacy, medical & consumer products	7
<i>Interviewee 5</i>	35	Professional Bachelor's Degree	CIO	Social services	13
<i>Interviewee 6</i>	39	PhD	Digital Transformation Lead	Education	10

These interviews ranged in duration from 00:51:40 to 01:29:53, with an average of 01:01:40, excluding the unrecorded parts. Initially, interviewees were searched for in the researchers' networks. After, potential interviewees were searched for through LinkedIn, in which case a contact request was sent, followed up by a personal message if the request was to be accepted. This personal message inquired the potential interviewee of who the research team was, the purpose of the study, and its goals. The personal message with its information allowed the potential interviewees to assess whether they were fit

to answer the questions and provide insights. Practical information concerning the interviews was also given there, together with an invitation to participate in the interview. If accepted, a PDF document was sent at least one week beforehand, containing an explanation concerning the DT strategic objectives representation. Before the interview, its purpose, goals and duration were verbally repeated. Confidentiality was also ensured and consent to record was asked to the interviewees. They were then shown the representation and were asked if everything was clear; they were encouraged to notify the interviewer immediately whenever anything was unclear.

During the interviews, the DT strategic objectives representation was shown through screen sharing, allowing the interviewees to situate the elements and follow clearly. The interviewees were attentively listened to as to understand and comprehend their opinions and perspectives. Prompt questions were asked whenever appropriate. When there was time left after the interview, the interviewees were asked to provide feedback. Due to time constraints, not every question of the protocol was always addressed.

Based on the interviews, the most important structural improvements occur in Branch One; the adapted model differentiates between an internal assessment perspective and an external assessment perspective. This distinction allows an organization to better delineate the objectives. The adapted model distinguishes between the assessment of the infrastructure and IT departments in order to refine the concept of IS. The need to strategically align was also added to this branch.

A people ability objective has been added; although this objective is listed under Branch Three, it is necessary to revisit this position in the future. This revisiting is necessary as the interviewees indicated its importance several times and it seemed necessary to make this a separate branch. Nevertheless, the generic DT representation as well as the one provided by Matt et al. [136] was taken into account, and it was thus decided to add it under Branch Three. In Branch Four, the adapted representation emphasizes on creating new flows of value entirely due to digital technologies. Two objectives were changed. DT unit was changed to DT entity and synergy between digital and traditional processes was added complementary to synergy between digital and traditional offerings.

A detailed explanation of the main findings regarding each of the branches of the model as well as a list of general shortcomings is provided in Appendices C.1 and C.2 respectively (see online Appendix).

By considering and analyzing the interviewees' feedback, we suggest an adapted model of the generic DT strategic objectives conceptual model in Figure 4.5. The numbers (beside each cloud) allow to track changes between the initial representation and the one updated through experts' feedback.

In a nutshell, six new DT strategic objectives are added to the generic representation, namely *Analyse Organizational Context and Environment* as a sub-objective to *Developing a Digital Roadmap*, *Evaluate Capability and Compatibility of Infrastructure* and *Evaluate Capability and Compatibility of IT*

Departments as sub-objectives to *Developing and Re-configuring Business and IT Resources*, *Develop and Evaluate Strategic Alignment* as a sub-objective to *Developing and Increasing Dynamic Capability*, *Evaluate and Increase People Ability* as a sub-objective to *Identifying Structural Changes*, and finally, *Identify New Methods of Value Creation* as a sub-objective to *Identifying Possible Changes in Value Creation and Operational Efficiency*. On the other hand, two of the existing DT strategic objectives are modified, namely, *Establish a DT unit* is replaced by *Establish a DT **Entity***, *Establish synergy between digital and traditional offerings* is replaced by *Establish synergy between digital and traditional **processes** and offerings*. The clouds in dotted line represent the objectives that have been *added* after the DT strategic objectives representation has been adapted. On the other hand, the DT strategic objectives that have been only modified after the adaptation of the generic model, are represented by clouds with dashed line. Furthermore, for the sake of tracing these objectives once the model is applied to a case (see Section 4.5), they are labelled with alphabets from A to H.

The detailed description of the added and modified objectives is provided in Appendix D of this chapter in the thesis Appendix document

4.5 Applying the Generic Reference DT Model

In this section, we illustrate the applicability of the improved DT strategic objectives representation (of which the generic version was presented in Figure 4.5) by instantiating it onto a hospital case. Based on the collection of three expert opinions that result from the work of these experts on the Saint-Romain hospital case in the context of [257], the instantiated representation is built and presented in Figure 4.6.

As depicted in Figure 4.6, DT strategic objectives are represented either with solid line, dashed line or dotted line. This facilitates the traceability between the generic and instantiated versions. Figure 4.6 indeed contains DT strategic objectives that have been:

- instantiated from the generic DT strategic objectives representation to the hospital case. So these are the instantiated version of the same elements. These DT strategic objectives are associated with the same numbers represented in Figure 4.5 in order to be easily traced. For example, the DT strategic objective *Seize upon trends and emerging technologies* in Figure 4.5 corresponds to its instantiated version *Examine key trends and their applications in clinical practice* in Figure 4.6 (both enumerated by number 1.2.2.3). Furthermore, the DT strategic objectives that have been added or modified in Figure 4.5 are represented with dotted or dashed line respectively. For example, the DT strategic objective *Evaluate patient and workforce attitude towards the new technology* in Figure 4.6 is the instantiation of the DT strategic objective *Evaluate and increase people ability* in Figure 4.5. On the other hand, the DT strategic objective *Ensure scientific rigour and evidence-based support through R & D and innovation*

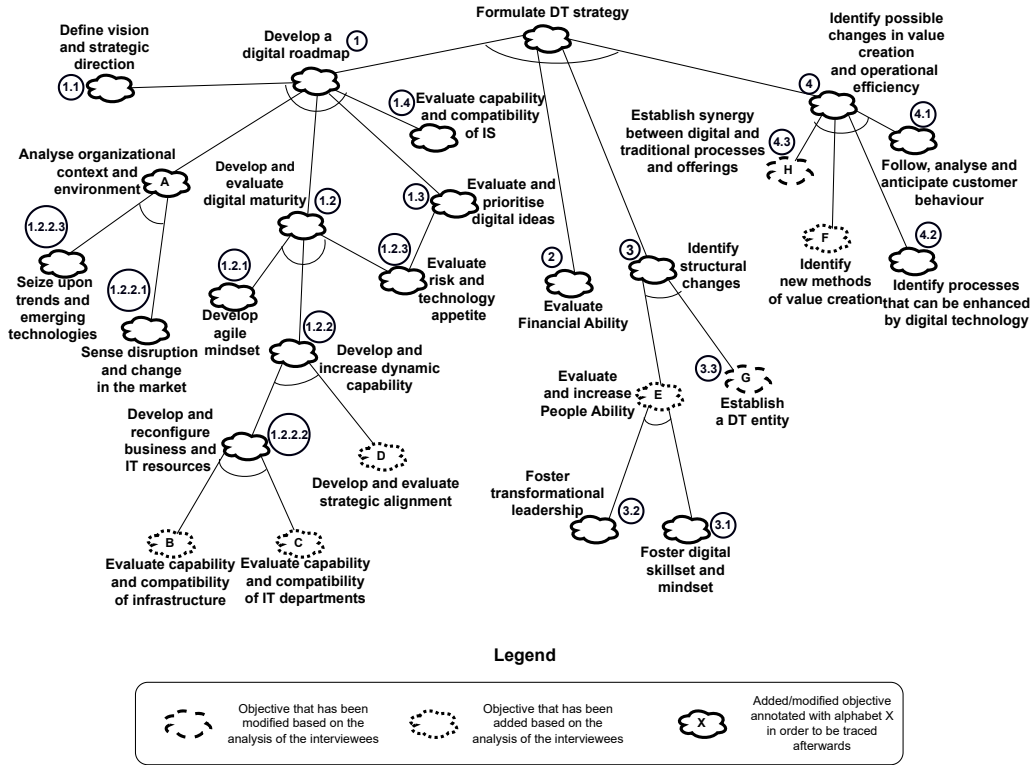


Fig. 4.5 Adapted DTS NFR Decomposition Representation

entity is an instantiation of the DT strategic objective *Establish a DT entity* in Figure 4.5;

- DT related strategic objectives that are case/domain specific. We have identified some DT strategic objectives that are important in this case but have no generic declaration. For that these have been added to Figure 4.6. These DT strategic objectives are represented with grey clouds. For example, based on the Saint-Romain hospital case, the DT strategic objective *Facilitate meaningful communication and information exchange across care boundaries* is considered important and is missing in Figure 4.5. For that it is added in the instantiated diagram.

Consequently, based on Figure 4.6, we can discuss the importance of the following five main DT objectives in the context of the hospital:

- Manage necessary changes to clinical services to deliver value.* Before going for a solution, the hospital should identify the problems that have

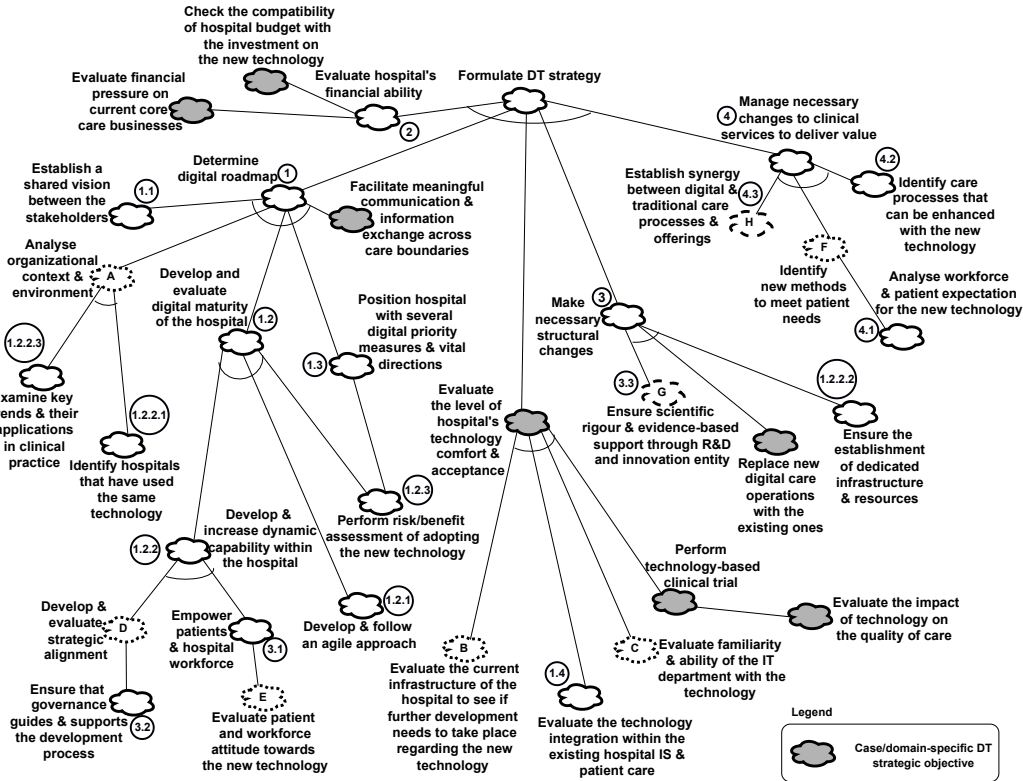


Fig. 4.6 DT strategic objectives representation for the Saint-Romain case

the priority to be tackled. Comparing the *current* and *after* DT situations of the hospital provides with a proper gap analysis and agenda for digitalization. This primarily results from assessing the patient expectation, current state of care business models and operations as well as how they can be enhanced using digital technologies. For example, Saint-Romain looks for new technologies to improve the efficiency and effectiveness of care delivery. Such improvement requires identifying those technologies that enhance patient and caregiver participation, and replace common work-flows within episodic care. Moreover, integration of a particular technology into clinical practice (e.g. mHealth) may lead to the introduction of new models of care (e.g. virtual care and telehealth). Therefore, such assessments help the hospital decide about new sources of revenue resulting from digitalization, the scope of their future business, and the extent to which they should diversify their business into the digital world considering patient health;

- *Determine digital roadmap.* The hospital should have a clear roadmap that can guide it in the DT journey. This requires facilitating communication

and information exchange across care boundaries, evaluating the digital maturity of the hospital, establishing shared vision among the stakeholders, analysing the hospital's context and environment and, finally, analysing the priority of the hospital regarding the digital technologies;

- *Evaluate the level of hospital's technology comfort and acceptance.* The hospital should evaluate its level of technology comfort (e.g. is CEO familiar with the new technologies, etc.) and its IT capability. Moreover, it is essential that the hospital evaluate its approach to using digital technologies. For that it should evaluate the role of the IT department as well as evaluating how innovative and proactive it is in its approach towards digital technologies. For example, in order to keep up the new technology, the hospital should be prepared for significant interoperability challenges as well as effective integration and utilization of the related technological initiatives;
- *Make necessary structural changes.* The hospital should decide about specialized know-how or new competencies that it needs to acquire as well as identifying the type of operational changes it expects beforehand. This requires setting up environments that support R&D which helps the hospital evaluates the impact of new technologies on healthcare cost, quality, and outcomes. For example, matching the use of care management and resource to the intensity of care and follow-up is an accelerator for optimizing clinical workflow. This requires aligning the objectives of administrator and clinician for how new technologies integrate to patient care and other requirements such as financial, personnel-related and technical factors that determine the functionality and usability of new technology;
- *Evaluates hospital's financial ability.* Since financial factors are one of the main barriers to technology adoption within Saint-Romain, it should have a proper analysis of their financial investment before deciding to transform its business. For example, it should know if the existing care businesses already enforce financial pressure on the hospital. Also, it should check if it is able to invest on new technologies with respect to its budget.

Instantiating the representation helps understanding to what extent the generic is tailorable to a case study.

4.6 Discussion

This section first provides a discussion about the use of the enhanced DT strategic objectives representation from a practical perspective.

4.6.1 Instantiating the Generic DT Objectives Representation within an Organization: Process Perspective

The process of instantiating the generic DT Objectives Representation to a specific organization can be further discussed. Globally the prescribed process

can be described as follows. First of all, domain expertise/knowledge needs to be gathered in order to better understand the specifics of the organization onto which it is being applied. Such knowledge is gathered through a discussion with middle and C-level managers. Relevant roles are not at all limited to IT-related functions but all of the departments/functions of the organizations need to be questioned. The most straightforward is to explain each DT objective individually to the relevant roles and obtain feedback on how this applies to the target organization. Global insights onto the DT approach and ideas are also relevant to collect. Second of all, a workshop can be conducted, with the entire C-suite for final validation. Typically the results are presented at first in their entirety and, after, each instantiated DT strategic objective is discussed within the group until agreement.

4.6.2 Using the DT Strategic Objectives Representation for Alignment Evaluation when Developing or Adopting IT

As seen in the paper, the generic DT strategic objectives representation as well as its instantiation on a case are making use of the NFR framework. Besides the advantages of NFR or similar representations allowing to clearly depict strategic objectives' hierarchy and parenting, its application also allows to have, through the instantiated representation, a brick that can be flexibly inserted into existing methods for Business and IT Alignment. Indeed, the representation as documented in the context of the DT identifies and customizes the objectives that need to be supported in the context of the DT but, so far, no concrete method is provided to evaluate IT developments at the light of this DT strategic objectives representation. Two methods that use NFR at strategic level to express the business and IT strategies, and allow to study the alignment of new developments with these strategies do nevertheless exist, namely MoDrIGo [252] and StratAMoDrIGo [228].

As discussed within the first part of the paper, the DTS is often seen as independent of the business strategy but also of the (classical) IT strategy. MoDrIGo is more limited than StratAMoDrIGo since it is service-oriented and only considers the development of new Business IT Services. The latter are services packaged to support organizational business processes and require the use of various kinds of IT technologies among which software and people for the support [255]. Each new Business IT Service considered for development and/or adoption can be evaluated at the light of the support it brings to the business and IT strategies in the basic framework but the same can easily be done with the DT strategic objectives instantiated out of the model provided as a contribution of this paper. Since MoDrIGo is meant as an IT governance framework focusing on the business and IT alignment issue (which is one part of IT governance), a new service development or adoption evaluation can now be made at the light of the contribution it brings to our representation. This gives additional information to the C-level people evaluating and deciding for it.

Similarly, StratAMoDrIGo can also use the instantiated NFR representation for the evaluation of new strategic opportunities. Strategic opportunities are all kinds of IT that involve a significant number of organizational resources

(enough to require a governance-level decision). It is thus much broader than only Business IT Services. Indeed, StratAMoDrIGo is made to support strategic agility and is more flexible than MoDrIGo in terms of IT development or adoption evaluation with respect to its alignment with the business or IT strategy. Again, the DT strategic objectives alignment evaluation with a particular strategic opportunity can be made flexibly in the existing framework. An example with a very limited, ad-hoc and generic DT strategic NFR representation is provided in [229]. The same kind of analysis can be made from the contribution made in this paper for a valuable analysis.

4.6.3 Discussion based on Expert Opinions

The analyzed and synthesized findings indicate that although the interviewees often agreed with the importance of a DT strategic objective, some of them were still received critically. It also appeared that not every objective was equally clear or that the interviewees did not interpret them similarly. The findings outlined above suggest what considerations should be taken when effectively approaching a DT strategic objective or how the importance of it may depend on the context in which the organization finds itself. Perceptions were also detailed in the interview results as well as the context in which the interviewees situate DT to create a clear overall picture of the manifestation of the DT. The findings obtained by this research contribute to a clearer understanding regarding how practitioners of DT perceive the DT strategic objectives representation, while it also confirms the importance of these objectives, although their perceived importance varies. Considerations to be made concerning its content, structure and whether it would be useful in practice were also outlined.

Concerning the practicality of the model, two interviewees pointed out the absence of sequence (or order) in the DT strategic objectives given. The representation was created as a structured set of reference objectives to be pursued but not as a roadmap to be applied. As such all of the DT strategic objectives are important but will not be pursued within the same order or with the same amount of effort in each organization. As a general rule, the achievement of objectives furnishing the highest value (see [228]) need to be privileged. Similarly, different DT strategic objectives are pursued in parallel and the deployment of new IT solutions will contribute to the achievement of certain DT strategic objectives and not others. The model should thus not be seen as a cookbook or a sequence of DT strategic objectives to be fulfilled successively. It should rather be seen as a reference from which the organizational instance is achieved over time, with objectives treated in parallel but with various effort even though sequential increments are made at once particularly when new IT solutions are adopted. Also, by nature, the environment is dynamic and the DT strategic objectives are never achieved once and for all but should be reexamined over time.

4.7 Threats to Validity

4.7.1 Construct Validity

In the field of software engineering, construct validity is concerned with whether one can justifiably make claims at the conceptual level that are supported by results at the operational one [214]. In this research, it translates into the understanding of the concepts for their instantiation onto practical elements.

In line with this, a threat to the construct validity would be that the DT strategic objectives are incorrectly interpreted within the construction of the generic representation by the research team or by practitioners customizing it to their organizational purpose. As a result, the artefact would be used in a way not corresponding to what it is intended to be used for. In this research, the instantiation of DT strategic objectives to build the generic representation was made by the first author of the paper but systematically reviewed and discussed with 2 senior researchers also author of the paper. Similarly, the tailoring/instantiation of the generic model onto the Saint-Romain case study was made by the first author under the supervision of 2 senior researchers of which one is very familiar with the specific application domain. Every misinterpretation has been debated while building and applying the artefact. Globally, the threat has thus been mitigated by discussing the representations in meetings or workshops with experts in modeling and domain specialists.

4.7.2 Internal Validity

The internal validity pertains to the process of acquiring knowledge, specifically focusing on the objectivity of the perspectives collected. Within the application of our framework, the internal validity concerns the objectivity of the observers (thus the researchers) within the knowledge acquisition process. The latter could, while going through literature or gathering expert opinions, relate their own opinion rather than on what they strictly find in literature or what experts relate. This could then result in an inaccurate model. This threat has been mitigated by the cross checking of several researchers onto the goals found in literature and the expert opinions. Concretely, the research objectives have been found out by the first author but the retrieval process and documentation has been systematically shown and discussed with the other authors. Similarly, the interviews have been realized by the third author but their faithful transcription also allowed a discussion and cross checking with the other authors.

4.7.3 External Validity

External validity is the degree of support for the generalization of an ‘architectural explanation’ to a theoretical population [267]. The DT strategic objectives representation model has been made to be as exhaustive and representative as possible in terms of objectives inclusion and representation. Of course some objectives might be missing and some will sooner or later be out of date and new ones will appear. The SLR should to some extent be renewed regularly to deal with this reality. To some extent the choice of the keywords when performing

the SLR could also play a role in the identification of the DT strategic objectives. A broader set of keywords would intuitively lead to the inclusion of a broader set of papers and vice-versa. We nevertheless aimed to identify the most relevant literature and tried to build a consistent sample of reference papers through the use and control of cross referencing. Also the ability of practitioners to select the relevant objectives as well as their ability to use them in the context of the alignment with new technologies with a broader framework might be subject to issues. Experiments must nevertheless be conducted to evaluate the ability to apply goal-based modeling in various contexts with inexperienced modelers. Results show that with some guidance from the beginning, the process can be realized pretty easily (see the example of [240]).

4.8 Conclusion

The primary objective of this paper was to build a conceptual reference model to help organizations formulate a DTS. The study of this model helps to answer the research question raised earlier in this study “*How to build and validate a generic conceptual (goal) model covering all of the DT objectives that can be instantiated onto a specific organization to support its DT formulation?*”

The artefact is built by first identifying a set of generic interrelated DT strategic objectives through an SLR and, second, by showing how we can make use of such a generic representation. By conducting a thorough and logical SLR, relevant aspects regarding DT and DTS were addressed and further elaborated. This way, a clear description of DT and what it implies/encompasses was given. It allowed a proper understanding of strategizing DT and why it is vital to formulate such a strategy. The different building blocks and methods regarding the construction of the generic DT strategic objectives representation were further developed to understand how the artefact was constructed and how it originated.

Afterwards, we conducted semi-structured interviews to assess the strengths and weaknesses of the generic reference representation, and to identify its deficiencies by asking about the perceived importance of each objective concerning a DT journey as well as the completeness of the representation from the perspective of top managers and consultants specialized in strategic aspects of DT. Moreover, its shortcomings were specified by inquiring about possible alterations to be made and demanding elaboration whenever such alteration was made or whenever an aspect was unclear. Targeted questions about its completeness and its applicability allowed identifying new DT strategic objectives and discussing the representation’s realism to deploy in an organizational context. The conduction of the semi-structured interviews resulted in the adapted generic representation. Finally, to show the applicability of the latter, we instantiated it to the Saint-Romain hospital case. This allowed us to fine tune the adapted artefact and suggest a pattern to ease its applicability. The tree needs to be considered as a dynamic construct that will evolve in time. The DT is constantly taking new forms and reinventing itself, for keeping its relevance the tree needs to keep up with this evolving reality.

Baskerville et al. [19] point out that the output of DSR is an artefact but also the design of some new knowledge; the latter can possibly also lead to a theory. As pointed out earlier, within our research, the DSR-specific artefact is the produced generic DT strategic objectives representation that can be customized to specific organizations. Next to this, we argue that the research also produces new knowledge that cannot be raised to the level of a theory but nevertheless concretely contributes to the body of knowledge in DTS. Through the collection and consolidation of DT strategic objectives obtained from the SLR, validation by experts, and the identification of objectives not previously documented but highlighted by these experts, we consolidate fragmented knowledge essential for the execution of a comprehensive DTS. The research process as a whole thus contributes to the body of knowledge in DTS.

We can nevertheless point to some limitations of our DT objectives model (so the DSR artifact that was build within this research), these are:

- although there are already many important strategic aspects present in the model to guide an organization on its DT journey successfully, some aspects need to be clarified upon. More precisely, the interviewees did not always agree with all of the existing DT strategic objectives so that they need clear guidelines on what is meant by the objective and how it concretely translates when applied;
- the conceptual representation lacks practicality. The content of the representation was generally well-received but practitioners need clear guidelines about how it should be used to deliver its full potential;
- the most prominent weakness of the representation is that its practical application needs to be reflected upon to address the shortcomings accordingly.

Despite its important contribution to the DT body of framework, the artefact can thus still be improved. More guidance for (i) its instantiation on particular organizations and (ii) its use once instantiated can be developed to better support researchers and practitioners willing to use it. More specifically, best practices for the instantiation of the generic representation perhaps tailored to specific sectors or industries would be welcome. A basic approach for this was given in the paper but it should be further developed and formalized. Similarly, providing case studies on the use of the model when adopting new IT solutions would also show the practicality of its use to the scientific and industrial community. Through the instantiation and the use of the representation, it can also be improved and further refined. It can then gain maturity through its application.

Chapter 5

Customizing a Generic Digital Transformation Objectives Model onto a Telecommunication Company

This chapter complements the former chapter by proposing the customization of the strategic objectives for the Digital Transformation (DT) and implementation within the context of a real life case study in the field of Telecommunication. Together, chapters 4 and 5 provide a comprehensive framework for understanding, strategizing, and executing DT initiatives in today's dynamic business landscape.

5.1 Introduction

Many organizations approach their Digital Transformation (DT) in an ad-hoc manner. In order to evaluate each technological initiative alignment within the context of the organization's DT, a clear DT Strategy (DTS) should nevertheless be set-up at governance level. Within the range of initiatives destined to help in this process, 4 have proposed to assemble all of the classical DT strategic objectives found in literature, unify them into a generic set of DT strategic objectives later evaluated through expert opinions. This generic set of DT strategic objectives is here applied onto an Asian telecom company. The latter is state-owned so directed by the national government; this specificity deeply impacts the governance. The DTS and its alignment with individual initiatives is explored using the specified model; data is collected through domain expert interviews before and after the instantiation of the generic model.

5.2 Background and Related Work

5.2.1 The Generic DT Strategic Objectives Model

In Chapter 4 we have introduced a generic DT strategic objectives model which is a goal-oriented conceptual model made of DT strategic objectives found in literature and pointed out by experts. This model is aimed to be instantiated onto a specific organization in order to support its DTS formulation. The

model is presented using the NFR framework [42] using a decomposition of operationalization elements which allows to see them and their hierarchy in an exhaustive manner. This provides a good understanding of the scope of action of an organization that seeks digitalization. Figure 5.1 presents the generic model. The latter is composed of 4 main branches, each being a strategic objective that is refined into sub objectives: The first branch is focused on *developing a digital roadmap*; the second branch is focused on *evaluating financial ability*; *identifying structural changes* is what the third branch is focused on; finally, branch four focuses on *identifying possible changes in value creation and operational efficiency*.

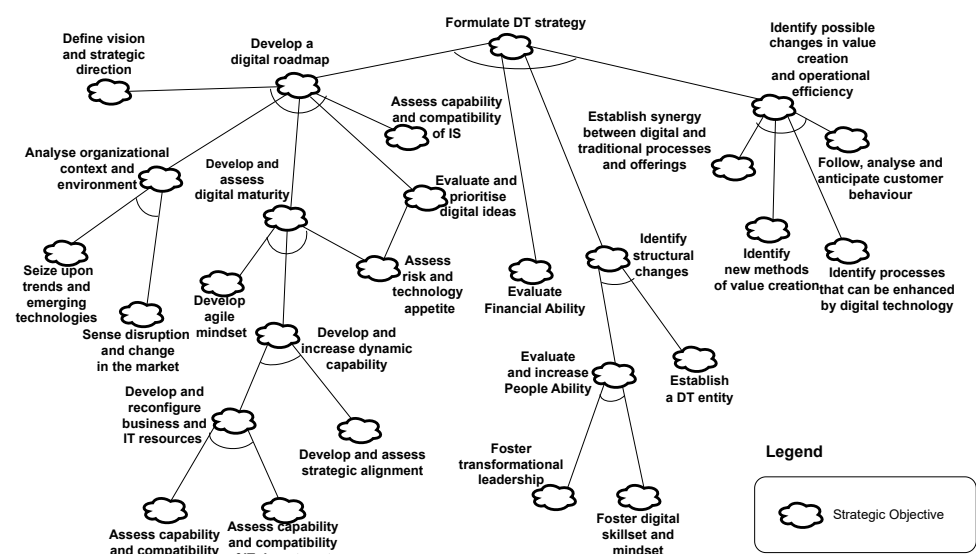


Fig. 5.1 Digital Transformation Strategic Objectives: Genetic Model

5.2.2 Related work

Existing research on DT strategies can be grouped into two main categories [282]. The initial category views strategies as a focal subject, pinpointing the components that make up DT strategies and deriving a blueprint for their creation (see, for instance, [136, 194, 207]). For instance, the work by [109] highlights several essential organizational prerequisites for DTS design, such as *change in the understanding of IT*, *appropriate organizational structuring*, *leadership and accountability*, and *dynamic capabilities*. The second category adopts the practice-oriented perspective in strategy research [266], aiming to explore the emergence of DT strategies from the strategizing process (examples include [23, 36]). The DT framework proposed by [136] outlines a comprehensive method for crafting an all-encompassing DTS. This framework posits that irrespective of the organization or sector, DT strategies share certain commonalities that span four primary dimensions. Any DT initiative should be organized around

these pivotal dimensions: *the use of technologies, changes in value creation, structural changes, and financial aspects*. Noteworthy contributions exploring these four dimensions come from researchers like [92] focusing on varied media companies, [268] for mid to large insurance firms, and [223] concerning SMEs. Moreover, [146] enhances these strategic dimensions by introducing *change in customer experience* as a fifth key dimension. They underscore that a DTS's assessment rests on four pillars: *customer focus, digital innovation performance, employee performance, and financial performance* [147].

Previous studies have delved into conceptual models and frameworks designed to gauge the readiness for DT. These tools assist organizations and professionals in understanding how to monitor and achieve DT within their entities. Examples include the digital innovation strategy framework by [170], the digital transformation framework by [136], the digital reinvention framework by [24], and the digital orchestra framework by [248]. Comprehensive assessments, gap identifications, and comparisons of several of these models can be found in works like [169]. Some research is devoted specifically to the creation and modeling of DTS [115, 278]. The work by [115] introduces a framework for DTS construction, offering detailed guidelines that aid organizations in devising, executing, and supervising their DT strategies. Nonetheless, their model predominantly rests upon IT governance and does not incorporate broader DTS dimensions or concepts. Conversely, [278] unveils a universal model to model and evaluate a DTS. This model portrays the varied dynamics intrinsic to a DTS and highlights elements crucial to its formulation. It also grants the capability to assess a DTS efficacy during its development stage. However, it falls short in terms of conceptual depth and validation.

5.3 Research Approach and Method

Being in the paradigm of Design Science Research (DSR) [93] and following-up on the previous study on building a Generic DT Strategic Objectives representation, this research has the aim to further validate the results through the use of a case study. For that, this paper aims to address the following Research Question (RQ): *What are the strengths and weaknesses of the use of the generic DT strategic objectives model proposed in Chapter 4 to support an Asian telecommunication company in formulating its DTS?*

Figure 5.2 situates the research described in the current paper within its broader context. It indeed extends previous research through a new custom Design Cycle (DC). The research activities in the light grey zone of the figure have been performed and published previously and the ones in the white one constitute the contribution of the present paper. As said in the background section, in Chapter 4 we have built up a generic set of DT strategic objectives out of literature (see DC1 in Figure 5.2). Then, they validated this first representation through expert opinions leading to an enhanced version of the DT strategic objectives (see DC2 in Figure 5.2). Also, still in DC2, the proposal was applied on the case of a hospital going through its DT. The latter case can nevertheless not be considered as a full case study so there is more space for application to extend the validation process and learn more lessons from

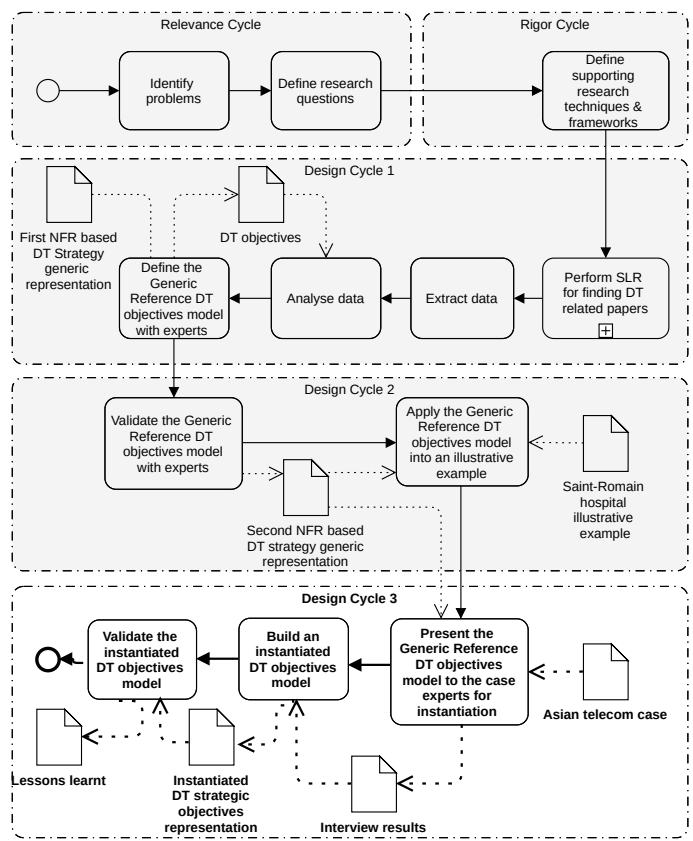


Fig. 5.2 Research methodology updated by adding a new Design Cycle for validation objectives

application; this is the purpose of this paper. Indeed, we introduce here the so-called DC3.

Within DC3, **which is the contribution of the present paper**, the latest (generic) DT strategic objectives representation, outputted from DC2, is applied onto the case of an Asian telecom company going through its DT. The overall approach firstly consisted in the collection of domain knowledge (through interviews) in order to determine the objectives that were relevant for the organization and tune them to this business context. Out of these interviews, an instantiated version of the DT strategic objectives representation was built. The latter representation was then presented to the interviewees and explained. These domain experts were then asked to evaluate the applicability and completeness of the model as well as possible implementation flows. Out of the application and instantiation process new lessons were learned and highlighted.

We followed a structured process for conducting the interviews. We indeed conducted in-depth semi-structured interviews with three C-level senior man-

agers of the company. These interviews were conducted between April and May 2022 via online platforms such as Skype and Wechat. All three managers were interviewed twice. Table 5.1 presents the age, the highest degree, the role, and the seniority years of each of the three interviewees. The first set of interviews was focused on the information regarding the interviewees and their knowledge regarding DT. This allowed us to gather information about the background and the expertise of each of them as well as gathering the necessary inputs for the instantiation of the generic conceptual model respectively. Based on the discussion of this first set, an instantiated representation was built. The latter was then presented to the interviewees during the second set of interviews. Subsequently, the interviewees were asked to describe the implementation of each of the branches of the model within their company, and validate the relevance of the generic objectives to their case, and find out the completeness and potential improvements of the instantiated generic representation model with regards to their case. The first set of the interview took 54 to 69 minutes, while the second set took 16 to 24 minutes. The analysis and discussion of the result is then done with the help of Nvivo, a software aimed to analyze qualitative research results.

Table 5.1 Interviewee Profile

	Age	Highest degree	Position	Seniority (years)
Interviewee 1 (I1)	46	Master	Manager of the DICT department	17
interviewee 2 (I2)	37	Bachelor	Manager of the B-end department	14
Interviewee 3 (I3)	53	EMBA	Vice general manager	20

5.4 Results

5.4.1 Preliminary Interview Round: Domain Knowledge Collection

The interviews began by a brief description of the in place DT implementation and DTS at the telecom company. According to the interviewees, the company has divided its business into four ends: 1) C(customer)-end grouping individual customers who purchase traditional services such as mobile devices and mobile subscriptions; 2) B(business)-end grouping offerings destined for businesses and governments and including digital-enabled services such as smart city, cloud- based system, IoT-related products, etc.; 3) H(home)-end with 5G-enabled offerings for families such as Wi-Fi 6 and smart TV; 4) N(New)-end combining services such as videos, gaming, sports streaming, etc. The C-end being the most traditional part for a telecom firm, the company’s ambition in the digital era is to increase the proportion of the other three ends in its overall income. According to I3, “*Currently, the C-end and H-end count for about 70% of our revenue and the B-end counts for merely 20%. Our ambition is, in*

the coming three years, the B-end and H-end will count for above 60% of our revenue, with C-end being stably developed. This requires us to reconfigure our resources including humans, infrastructure, structure, processing, in order to tackle the challenges brought by the digital transformation.” I1 added an example of such reconfiguration: “Our change in recruitment policies is an example. In the past, we brought in the graduates mainly as salespersons or customer service operators. Now, the majority come in as IT engineers.” I2 also added: “At the telecom company, we talk about ‘digitally intelligent transformation’. This means we’ll be transformed from a pure telecom company to a digital service provider, from resource-driven to innovation-driven development, from traditional to cloud-enabled production processing.”

5.4.1.1 Branch One: Perform Financial Investment Analytics

According to I1, *“The first thing to consider in financial aspect is the financial increase that digital transformation will potentially bring us. We need to consider when the B-end and H-end will reach the break-even point and it’s based on this analysis that we plan the allocation of financial and other resources.”* He validated the two sub-objectives and added *“the impact of digital transformation on our current core business, which is the C-end businesses, is definitely taken into account when performing financial analytics.”* Interviewees 2 also confirmed the two sub-objectives, however, believed that *“the financial ability isn’t a barrier: our financial performance and potentials are excellent and we’re in the right time to do the right thing.”* I3 approved this and added *“from one side, the government has pointed us as the leader of the digital economy and we receive very strong support from the state; from the other, our company is among the most profitable in the world and we have strong confidence on our financial ability.”*

5.4.1.2 Branch Two: Develop a Digital Roadmap

According to all three interviewees, the *social-economic environment* is the very first thing to be considered, which is not included in the model as a sub-objective. As mentioned by I1 *“We firstly analysed our external environment. It’s important to know that the whole society is being transformed digitally and if you don’t follow you’ll fail behind. The DT is a consequence of the nation’s economic development. As a state-owned company, we ought to respond to the nation’s advocacy and we have the responsibility to act as a leader.”* Finally, I2 added *“the digital roadmap of the telecom company is closely tied with the five-year plan of the government.”* The sub-objective *“Prioritize digital ideas”* was mentioned by I1 during his description of digital roadmap development. Other interviewees also agreed on this sub-objective. I2 added that to achieve such objective, they engaged external partners from Europe in this process to optimize the evaluation and prioritisation of digital ideas. The three interviewees emphasized the importance of the sub-objective *“Align stakeholders’ objectives”*. I1 said that *“our biggest shareholder is the state and it’s our mission to safeguard the state’s assets.”* Regarding the customers and employees, I2 said that *“the quality of service is one important aspect of our DT strategies and we constantly*

communicate the values we may bring to our clients to get their satisfaction towards what we're doing. Besides, motivation of our employees' enthusiasm and support is also important to consider.". Finally, I3 said that: *"what the individual shareholders care most is the value of their stock. We gained their support because our stock is upvalued during the past years."*

Concerning the assessment of digital maturity, all managers emphasized its importance when setting a digital roadmap. According to I3 *"The telecom company has very strong R&D capacity and agile mindset. Since this century, it's constantly recombined its resources into new offerings to adapt to changing environment. R&D is part of our gene."* I2 added *"it's important to know where you're right now to set the objective you want to achieve by digital transformation. We've certainly assessed the gap between our current situation and the objective stated by the government"*. Moreover, he suggested that this should be considered as a separate branch, as *"that's where we analyse the most when we formulate our strategies"* and because *"it makes the whole branch too complicated because the point related to digital maturity alone has 4 layers! If one objective has too many underlying dimensions, it's too difficult to be comprehended and implemented."* Finally, I1 explained that *"the digital roadmap we developed is closely related to the assessment of our digital maturity. We're currently working on three core digital activities: 'connection, algorithm and empowerment'. These three aspects were proposed based on our digital maturity: we have 90 million customers, making us the largest telecom operator in the world. Our huge customer base allows us to build a gigantic connection network, which is the foundation stone of the 'algorithm' and 'empowerment'."* When discussing the assessment of risk appetite, the opinions differed. For I1, assessing risk appetite is a valid point. According to him, the telecom company has different risk appetite as a function of the business ends: *"we can accept more risks for N-end businesses because these are the domains that we were not familiar with and thus we need more experiences. However, we expect more stability at C, H, and B-ends businesses because they are where most of our revenue comes from."* Interviewees 3 held opposite opinion by saying that: *"risks are not something considered by us. As a state-owned company, we must follow what's ordered by the government, who in turn provides us with the support we need and bears all the risks. We are totally different from private companies: we ought to be the pioneer in the digital economy and provide all the necessities for the digital transformation of the whole society."*

Regarding develop and increase dynamic capability, all interviewees confirmed that such objective is crucial when assessing digital maturity and when the fostering of dynamic capability requires the improvement of people agility. Interviewees 1 and 2 confirmed that within the company, there is this regular formation of digital knowledge that is given to the entire company, from high-level leaders to employees. According to I2: *"we have an established formation system across the company. For the employees, everyone is expected to follow online courses on digital technologies such as cloud, big data and IoT. After the courses, you need to take a test and obtain a certificate in digital transformation knowledge. For the high-level leaders, we need to follow one week's formation at our partner university, during which professors and experts from reputed*

universities and institutions are invited to give us courses.” For I3, the fostering of dynamic capability asks for intensive competition among employees and leaders. He added *“at our branch, hundreds of people are eliminated each year due to their lack of skills necessary for the digital transformation and even high-level leaders are included. At the same time, a great number of young graduates specialising in IT and management are recruited to replace less-skilled employees. The competition is fierce: if you cannot follow the path, then you are out.”* When it came to the evaluation of the organizational context and environment, all managers confirmed its importance when developing a digital roadmap and also the relevance of the refinement including *“Sense disruption and change”* and *“Seize upon trends and emerging technologies”*. Concerning the Market disruption, I1 claimed that the core activities of *“connection, algorithm and empowerment”* is a disruptive ideology and it is also served as their strategic direction. Regarding the emerging technologies, I2 pointed that 5G and other digital technologies fit into this category and should certainly be taken into account in their DTS formulation. As for the development of vision and strategic direction, all interviewees pointed this objective as important to achieve in the development of the digital roadmap. Regarding the *“Organisation-wide communication”*, the three interviewees confirmed that the implementation of digital technologies requires communication but the flow of the communication is mainly top-down, meaning that it’s the high-level leaders who mandate their decisions. Finally, for I3 this objective was ambiguous and less important at a state-owned company: *“the employees and local branches are expected to follow what’s mandated by high-level organisations and there is no room for negotiation.”*

5.4.1.3 Branch Three: Identify Structural Changes

All interviewees approved the importance of the structural changes in setting DT strategies and the first thing they pointed out was the *establishment of a DT unit*. I1 mentioned *“the department that I’m in charge of is an example of the structural change because it’s established to aid digital transformation”*. I2 shared the opinion and added *“we’re working on improving the proportion of employees with IT background in the organisation. On the internal side, we’re training employees to improve their digital knowledge. Externally, we’re adjusting our recruitment policy to bring in graduates of this field.”*

As for the reconfiguration of business and IT resources, all the interviewees confirmed that such objective is part of the structural changes. According to I1, they are reconfiguring these resources to support B and H-ends businesses, which is the direction of their DT. I3 added that the resources are also reconfigured into other industries such as agriculture, medical service and aeronautics which were traditionally not part of the telecom company’s expertise.

Regarding the *new source of revenue* and *replacing traditional business models with digital-enabled ones*, all interviewees confirmed the importance of these objectives. However, they all pointed out that the idea that these two objectives do not contribute to refining the objective of *identifying structural changes* but rather to the objective *identify possible changes in value creation*

and operational efficiency located in the fifth branch of the representation. As for the replacement of the traditional business model, I1 mentioned that: “we start proposing many kinds of cloud-based services to the C-end users as a substitute for traditional services such as instant messages, voice-calls, etc. This is a shift of our business model”. I2 added “in the past, we provided business customers with physical equipment. What we’re offering more and more is integrated ICT solutions rather than materials alone.”

5.4.1.4 Branch Four: Identify Possible Changes in Value Creation and Operational Efficiency

According to I1: “in the past, customers needed to go to sales points to purchase services or recharge their accounts. But with the digital technologies, they’re able to do everything online and that brings them convenience.” I2 added “the integrated cloud-based solutions help B-end customers reduce their cost and makes system update easier for them.” Moreover, in response to how the identification of new methods of value creation was satisfied, I2 confirmed the objective of “Follow, analyse and anticipate customer behaviour”, while I1 added “the customer needs should also be guided as sometimes their needs would never be created without intentional guidance”. Moreover, I3 added “as a state-owned company, government policy is the priority we should consider. To identify what values we should create, the government report is important because it says where the state investments will go and that’s the direction we should follow.”

Regarding the objective establishing synergy between digital and traditional processes and offerings, all interviewees agreed that this objective should be considered at this branch. I1 mentioned that: “we gave customers the choice between on-line web site and off-line sales points to compensate the disadvantages of each side. I think that’s a kind of synergy.” I3 added “we call it ‘scale-based value creation’: we benefit from the loyalty of our customer base thanks to the traditional businesses to propose our digital services that will create more values for them. The synergy can at the same time benefit current traditional core businesses: “when we get in contact with a company, we not only propose the digital offerings that we’re famous for but the traditional ones such as internet and mobile devices.” I2 emphasised that same applies for H-end businesses by saying that: “when a customer orders family-related products such as WiFi and broadband internet or simply calls for a repair, we’d at the same time propose them digital smart offerings.”

5.4.1.5 Branch Five: Assess the Level of Organisational Technology Comfort and Acceptance

All interviewees confirmed the importance of the assessment of capability and compatibility of infrastructure and IS. However, I3 emphasized that “the assessments of technology comfort or acceptance are not relevant because the cloud-based technologies facilitate in a great deal the digital transformation of all levels” and also because “when your hierarchy or the government mandates it and gives all the support you need, you have no choice but to transform, despite your comfort or acceptance.” I1 added “concerning the infrastructures, we

evaluate its capability to be cloud-enabled. The same thing for IS: we evaluate its capability to be 'smart' thanks to digital technologies.”. According to I2, “before developing 5G services, we surely assessed its compatibility and its impact on 4G, which is our current core businesses.”

Regarding the assessment of IT department, all interviewees confirmed this objective. I3 mentioned that: *“based on our assessment, we adjust our recruitment direction to make sure that the IT department has sufficient ability.”*. I2 and 3 had the same opinion. Regarding the *prototyping*, interviewees 1 and 2 emphasized the importance of this objective. I1 explained that *“one example is the family gateway that we designed for our H-end business. It’s a digital-enabled new product that connects all the home appliances. With all the digital technologies in hand, we made a lot of efforts in prototyping in order to improve its performance.”* I3, however, held a different opinion regarding B-end businesses, *“it’s difficult to prototype when you deal with businesses and governments because all we offer is based on their customized needs. As the products are highly customized, all we can do is to improve our core technologies.”* Finally, I2 described what should be modified at this branch: *“first, you need to know if your infrastructures and IS can be cloud-enabled; then, the assessment of IT department is done to know if we have enough ability; finally, we prototype the products with all the digital technologies.”*

5.4.2 Instantiated DT Strategic Objectives Representation

As described in Section 5.3, the first set of interviews resulted in an instantiated representation of the DT strategic objectives; the latter is depicted in Figure 5.3. In this representation, modified and added objectives are highlighted in different colours. As it can be seen in Figure 5.3, most of the objectives in Figure 6 are relevant and can be directly instantiated into our case study, such as *“Recognize new sources of revenue through digitalisation”* which was instantiated into *“Identify new sources of revenue enabled by B, H, and N-ends businesses.”*.

The blue clouds represent the objectives that have been modified after the examination of the interview results in Section 5.4.1. The objective *“Assess and develop digital maturity”* was refined as one main branch of the highest level objective; this modification was made due to two aspects: a) as mentioned by I1 and 2, the assessment of digital maturity is one of the priorities at the telecom company in DTS formulation; b) the separation of this objective from the objective *“Determine digital roadmap”* reduces the layers of the model and facilitates its comprehensibility and application. *“Align stakeholders’ objectives”* was instantiated into *“Align stakeholders’ interests”*, as when speaking of this point, most of the interviewees referred to the upvaluation of the stock price and the improved service provided for customers, instead of their objectives. Furthermore, as suggested, the objectives *“Replace traditional business models with new digitally enabled ones”* and *“Recognize new sources of revenue through digitalisation”* were refined as sub-objectives of *“Identify possible changes in value creation & operational efficiency”*. Moreover, the objective *“Follow, analyse & anticipate customer behaviour”* was modified into *“Analyse, anticipate and guide customer needs”*, as I1 suggested that some of the customers would

never come true without a proposed guidance. Finally, the objective “*Assess the level of organisational technology comfort & acceptance*” was replaced with “*Assess technology compatibility*” as I3 rejected the idea that the acceptance should be evaluated because “*it is mandated by high-level organisations and you have to follow it despite your comfort or acceptance*”.

The red clouds stand for objectives that did not exist in the generic model but were relevant in the case of the telecom company. The objective of “*Analyse social-economic environment*” was added as the prioritised sub-objective of “*Determine digital roadmap*”. This is because this objective was mentioned by all the interviewees as the first dimension to consider when setting digital objectives. The objective was refined into “*Analyse strategic direction on the national level*” and “*Analyse macro-economic situation*”. The former is prioritized in this refinement as the company’s vision is closely tied to the vision of the country. The objective “*Evaluate financial increase potentials*” was suggested by Interviewees 1 and 2 as one crucial aspect of “*Perform financial analytics*”. The objective “*Analyse government investment directions*” was added as a refinement of the objective “*Identify new methods of value creation*” according to the suggestion of I3 that the telecom company’s value should be created where state investments on digital transformation go. Finally, the objective “*Assess IT department capability*” was refined into “*Evaluate recruitment policy*”, which reflects the idea of the interviewees that workers with expertise in digital domains are valued and unskilled workers will gradually be eliminated.

5.4.3 Post Interview Round: Evaluation and Validation of the Instantiated DT Objectives Representation

5.4.3.1 Content of the Model

Interviewees 1 and 2 approved the completeness and conformity of the model to the actual company situation. I3, however, did not consider the assessment of digital maturity as a separate branch. He says “*you can consider it, but it’s not equally important as other aspects. Mature or not, every industry and company will finally follow the digital path, as it’s a strategy at the national level. Even if you aren’t mature enough now, you’ll finally get used to it.*” Regarding the analysis of the social-economic environment, I1 added “*even though it is refined into two aspects: the analysis of the macro-economic situation and the strategic direction on the national level, it’s important to notice that the national strategic vision, especially the ‘Five-year Plans’, is closely tied with the macro-economic situation of the country. They can’t be done separately because the two are complementary.*”. Concerning the point of analysing government investment directions, I3 added “*what we analyse in particular is the white books who clearly state the industries that will be invested and supported, and that’s the direction we should go.*”

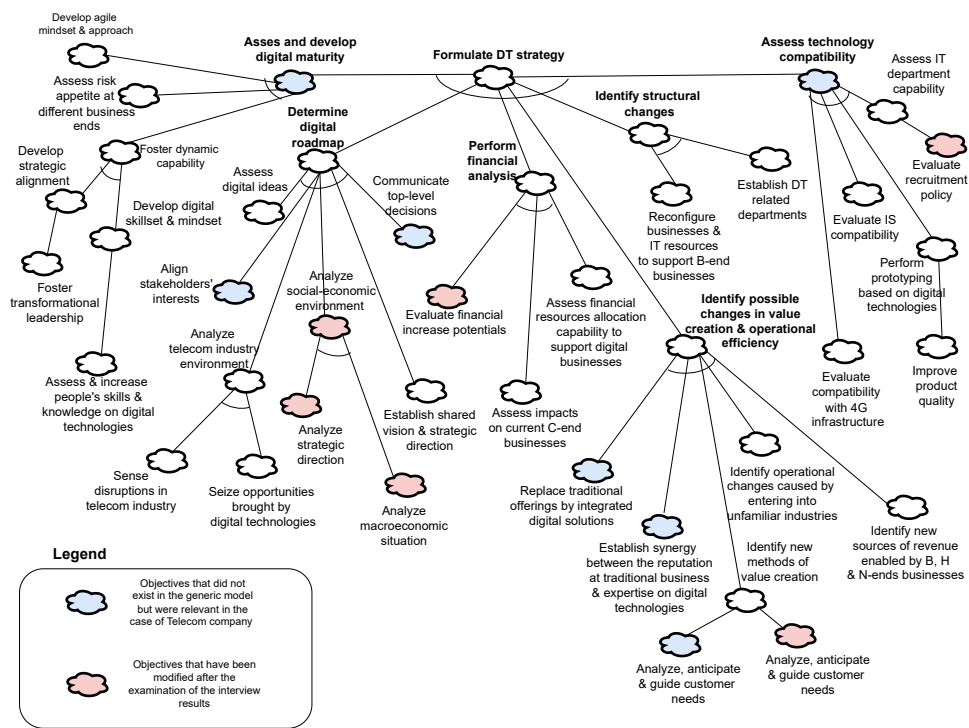


Fig. 5.3 Asian Mobile DTS NFR Decomposition Representation

5.4.3.2 Applicability, Advantages, and Shortcomings

Here, we asked the interviewees to evaluate the model’s ease of use and its usefulness in formulating a DTS. I1 approved the applicability of the model and thought that the model follows the right logic that should follow a DTS decision-maker and thus can be used as a checklist. According to I2 the reality is much more complicated and challenging than what the model encompasses, but the usage of this model definitely eases the tasks and makes everything clear and sorted. Moreover, he adds that it is necessary to understand, beyond what the model explains and which specific measures should be taken to achieve each goal. However, for I3 the model is too complicated and “at the telecom company, DT is more straightforward than what the model shows: we follow the direction of the country and we adjust the strategy whenever it’s inappropriate. What’s more, it’s difficult to say that if this model works for a company like the telecom company, it’ll work for other companies: the scale and the financial ability are totally different.”

As for the advantages of the model, all managers referred to its completeness. I2 explained that “for those companies who have little knowledge of DT, this model is very useful as it tells you all the aspects you should consider when formulating your DTS.” He added “how? If the model is destined for providing

a methodology, then it should be clearer what should exactly be done regarding each point.” According to I1, the model failed to show its internal logic between different points and the flow of the structure is still unclear. He suggested that *“perhaps you can give each point a weight and use this model to score a company’s DTS completeness”*. I3 had the same opinion by saying that: *“I can’t see from the clouds what’s important and what’s not. For me, a model is clear only when is straightforward and tells where the focus should be.”*

5.4.3.3 Steps for the Implementation

Each interviewee was asked to propose an order within the six branches of Figure 5.3. I1 suggested the following order: *assessing the digital maturity, developing a digital roadmap, identifying structural changes, identifying changes in value creation and operational efficiency, performing financial analytics, and assessing technology comfort and acceptance*. I2 proposed the order as: *performing financial analytics, assessing digital maturity, developing a digital roadmap, identifying changes in value creation and operational efficiency, assessing technology comfort and acceptance, and ending up with identifying structural changes*. Finally, I3 gave his order based on the 5 branches excluding the assessment of digital maturity: *“the first is to develop a digital roadmap. The second is to perform financial analytics. The last one is the structural changes. The rest two aspects are in-between and equally important.”*

5.5 Discussion and Threats to the Validity

The instantiated DT strategic objectives representation helps to clearly identify the priorities that should be considered by the company in formulating the organization’s DTS. These prioritized objectives entail the analysis of the government policies and the adjustment of human resources management. The digital-enabled offerings of the telecom company encompass cloud-based services and solutions, 5G networks, family smart technologies, etc. Also, it has proposed innovative ideologies that are disruptive to the whole industry. The positions of these offerings and ideologies about DTS formulations and their relationships are illustrated by the decomposition. Besides, the conceptual model suggests that the formulation of DTS entails top-level decision-makers carefully evaluating the resources and taking into account the stakeholders’ interests.

According to the interview results, some aspects of the model are criticized by the interviewees. The most frequent critics from the three interviewees consist in the generic model’s failure in recognizing the vital stake that the government has in the management of a state-owned company. Our findings suggest that, due to the nature of the company, the formulation of the telecom company’s DTS has a close relationship with what is stated by the government. Although confirmed by the interviewees as pertinent, some objectives were suggested to be less crucial than what was shown in previous studies. From the financial aspect, the telecom company has excellent financial performance and is among the most profitable companies on the planet. Meanwhile, the strong support from the government constitutes a significant part of its financial

resources. These factors led to the fact that the assessment of its financial allocation was judged as less important by the managers when implementing the DT. Meanwhile, the strong financial capability improved the company's risk tolerance and thus the assessment of the risk appetite was also suggested as less important.

Despite the positive appraisal of the interviewees regarding the completeness and accuracy of the instantiated model, its practicality and the clarity were still questioned. Some objectives were not fully comprehended despite our detailed explanation, such as the financial allocation ability which, to a certain extent, entails the meaning of assessment of impacts on current core businesses. Moreover, there was an overlap within the interviewees' understanding of different objectives whose differences are still ambiguous, such as the notion of *evaluating people ability* and *assessing IT department* which all refer to people's skillset. Also, during the interactions with the interviewees, we also realised that sometimes the model is limited in accurately describing the DTS formulation of a large corporation which deals with diversified businesses. For example, "Perform prototyping" was proved to be relevant in the C-end but not the B-end business due to the different level of customisation. It appeared that the lack of clarification on the horizontal relationships between objectives within the same refinement jeopardized the interviewees' appraisal of the model's applicability. It was also stated that the weight of each objective should be carefully evaluated, which is essential for its application in a real organisational context, because that will facilitate the comprehension of managers and clarify where the focus should be. Furthermore, our findings suggest that the clarification on the specific measures that should be taken regarding each objective appeared to help improve the applicability of the model. In addition, we can conclude that, although stated differently by the three managers, the evaluation of financial ability, the assessment of the digital maturity, and the development of a digital roadmap remain the priorities within the telecom company's DTS formulation.

At this point, some threats to validity are considered according to the prescriptions of Wohlin et al. [272] and Wieringa [267]. In particular, threats to the **construct validity** take the form of modeling misappropriations within the suggested framework which may lead to various implementation woes. To counter the impact of such an effect, the interviewer has allotted enough time before the start of each interview to explain each branch of the framework as well as providing information for its corresponding parts and significations. On the other hand, threats to the **internal validity** are mostly explicated as errors that occur during the knowledge acquisition process, so during the performed interviews. Such errors can inhibit the framework's modeling constructs to capture the correct representation of the perceived DT priorities of the interviewees. To minimize the impact of such threats, it is pivotal to establish an interview questionnaire that contains a series of control questions that are meant to subdue traces of any subjective perception of the interviewees. Indeed, the interview questions that were used within the study were established using an iterative process. Finally, threats to the **external validity** impede the generalization of the findings of the present study to other contexts. The implementation/instantiation of the framework has been presently conducted

in a highly hierarchical organization where DT strategic objectives are mostly identified at the strategic-level and communicated top-down. This may have facilitated the implementation of the framework given that the interviewees were occupying senior-level positions. Notwithstanding, in its basis, the framework is targeted at a population of such roles that can identify, structure, formulate, and communicate DTS in their respective organizational contexts. However, to curve any residual selection bias, future work will make use of a broader representation sample.

5.6 Conclusion

Within the present paper we have evaluated a framework previously introduced in the scientific literature using a case-based approach. Concretely, we customized a generic DT strategic objectives model to the case of an Asian telecom company. This case study strongly differs from the previous ones in the sense that the organization is state-owned so that the government has a large stake in its governance. The generic DT strategic objectives model encompasses many different aspects that need to be pursued in DTS formulation. Its objectives decomposition classification helps top-level managers identify the internal dependency between different objectives. Moreover, the instantiated representation helps organizations have a long-term overview of the goals they have to achieve through DT and address the challenges caused by the ongoing development of digital technologies. For instance, the telecom industry is subject to constant disruptions. Managers prioritized the analysis of the government policies and the adjustment of human resources management as priority objectives.

Part III

Feasibility of Strategic and Tactical Modelling for Novice Modellers

Chapter 6

On the ability of novice modelers to identify, represent and trace tactical and strategic conceptual elements in business process and enterprise modeling

While chapters 2 through 5 delve into various aspects of strategic modeling, with Chapter 2 focusing on security and Chapters 3 to 5 concentrating on DT, this chapter evaluates the ability of novice modelers to create effective strategic models. Being able to successfully produce strategic models, this would indicate that novice modellers can ultimately produce such models and effectively apply them in both security and DT contexts.

6.1 Introduction

A *Business Process (BP)* refers to the set of activities and tasks whose aim is the production of an output which brings value to the customer [9]. While BP representations are typically associated with operational execution, their representation can also be envisaged in a more aggregated fashion in order to model complementary dimensions to their pure operational flow. For differentiating functions, their careful IT support can indeed become an important tool to both create and maintain a competitive advantage as it plays a key role in a firm's daily operations and customer support. Packaged as IT services themselves part of the information system, software can support and automate custom business process execution [252].

The human component in both the creation and the understanding of BPs has been and continues to be a topic where much research is done [15, 64, 52, 174, 231, 230]. As humans are prone to error and typically struggle with abstraction, errors during the modelling process could easily happen [231], which can cost both significant amounts of time and money in a software development process [29]. This is especially a significant issue when non-expert (i.e. novice) modelers are involved in projects [9]. Since there are a lot of 'moving parts' (i.e. large amounts of textual (interview-based) descriptions provided) when it comes to modeling business processes, the way a person gathers and processes

information, could conceivably play a role in their ability to produce high quality BP modeling. There is a limited number of studies regarding the link between the modeler's modeling style and BP model quality. This is especially the case when it comes to higher abstract levels (so non-operational). This paper will focus on the ability of novices on producing qualitative models at strategic level. To this end, we overview what quality elements could be applied to evaluate such representations, we conduct an experiment based on a real life case with master-level students in Business Information Management (BIM) at KULeuven campus Brussels with a basic training on software modeling to overview their performance in such representations. For this, we evaluate their performance on the basis of standard elements present in the case and a reference solution made by an expert; we also overview if the cognitive style of subjects has an impact on their performance. It could indeed be reasonable to hypothesize that the way someone gathers and analyses information (e.g. when presented with a business modeling exercise and a complex textual description) has a real effect on the output they create in the form of the quality of a produced model [54] especially for non-experienced modelers. This way of gathering and processing information can then be operationalized by their cognitive style. This paper thus aims to answer two research questions: RQ1: *"How successful are novice modelers in producing tactical and strategic conceptual elements representations and ensuring their in-between traceability when compared to an expert solution?"* and RQ2: *"Does the cognitive style of a novice modeler have an impact on the quality of their produced tactical and strategic-level business process models?"*

6.2 Background and Related Work

6.2.1 Strategic and Tactical Modeling using the Business Use Case Model

According to Casadesus et al. [33], a business model *"refers to the logic of the firm, the way it operates and how it creates value for its stakeholders"*. They also define strategy as *"the choice of business model through which the firm will compete in the marketplace"* and tactics are referred to as *the residual choices open to a firm by virtue of the business model it chooses to employ*.

Goal-oriented requirements models can be used to model strategic and tactical objectives. These models are more geared towards 'why' and 'what' questions instead of 'who', 'what' and 'how' in the operational layer. Models such as i* [276] and KAOS [50, 238], semantically rich and suitable with this regards. However, they are not widely adopted in a business setting [254]. Based on the literature, the *Unified Modeling Language (UML)* [234] is by far the most industry adopted modeling notation. The Rational Unified Process (*RUP*) is a well known customizable and iterative software development process framework originally created by Rational Software and now maintained by IBM. The RUP aims to guide practitioners through the effort of software development with the help of a series of guidelines, artifacts etc. [249]. The RUP effectively acts as a guide on how to use UML. Specifically the *Business Use-Case Model (BUCM)* which is specified in the RUP documentation [105] is of interest as it can be used

to represent both the strategic and tactical layer. BUCM is presented in the Rational UML Profile for business modeling, which is an extension of the UML use case model by adding business semantics [105]. It is defined as “*a model of the business goals and intended functions*” [105] and is valuable to anyone who aims to understand how the business interacts with its environment.

The BUCM consists of several elements. The *business goal* (*BG*) is defined as a certain business requirement that has to be satisfied which allows the planning of the activities of the business [249]. It represents the strategic abstraction level and can be further abstracted as the *business objective* (*BO*). The main difference between the two is that BGs can be measured by key performance indicators, while a BO is too abstract to do so. A BG thus refines a BO [105]. An example of this would be the BO of sustainable management, which is then refined in the BG of ‘*reduce waste management by 20%*’. The *Business Use-Case* (*BUC*) represents the tactical level in the BUCM and is defined as “*a set of business use-case instances, where each instance is a sequence of actions a business performs that yields an observable result of value to a particular business actor*” [105]. BUCs are essentially BPs that involve both stakeholders in and outside of the business and focus on the value provided to these stakeholders and the business [249, 105, 259]. *Business actors* (*BA*) and *business workers* (*BW*) are connected to the BUCs and can be comprised of humans or software systems. The BA role is placed outside of the business but interacts with it through BUCs. A typical example is a customer. The BW plays a role inside the business and takes part in the BP that make up the BUCs (e.g. a procurement department employee). Both are linked to BUCs that they interact with through association links, indicating a relationship between the two [249, 105, 259].

6.2.2 Traceability and levels of abstraction

Traceability is defined in the RUP knowledge base as “*the ability to know and recognize that a particular model or code at any abstraction level, derives from something else, at a higher level of abstraction*” [249]. Traceability between different models allows for consistency [259], aids in determining whether or not projects are consistent with the given specifications and facilitates changing requirements during software development [249]. The levels of abstraction are typically divided into:

- **The Strategic Level** is the highest level of abstraction and provides an answer to the ‘why’ questions posed during development. It indicates general direction and long term strategy through goals and objectives of the organization or project. Additionally, it is important as it provides a good oversight or context for all stakeholders involved and facilitates the communication [152, 260]. Weske [262] also identifies the BGs as long term objectives and the business strategy as an overarching plan to reach those goals. In the context of this research, the strategic level will be modeled by means of the BUCM, allowing the use of BOs and BGs.
- **The Tactical Level** provides and answer to the ‘what’ and ‘who’ questions posed during development. The tactical level models the BP and

resources that are available to the organization which will be used to achieve the BOs and BGs in the strategic level. It also shows how the different processes and roles interact with each other and provides an organizational view [151, 152]. This level could be modeled by means of use-case diagrams as defined by UML, but in the context of this research, the tactical level will be modeled by means of the BUCM, allowing the use of BUCs;

- **The Operational Level** concerns specific tasks performed in realization of the (business) use cases or processes in the tactical level. This level answers the ‘how’ question and models the specific tasks for each stakeholder [151, 152]. UML and BPMN [246] are most often used for the modeling of this level.

6.2.3 Modeling Quality Framework

The measurement of quality of conceptual and BP models remains a significant topic. Different guidelines, frameworks, and standards have been proposed over the years with the objective of measuring or improving model quality. Unfortunately, there is a lack in generally accepted way of measuring model quality especially at the strategic level [52]. In general, BP models should incorporate requirements of all stakeholders, be consistent (i.e. ensure traceability between models) and facilitate communication [152].

Quality of BP models can be hard to define and many different definitions are proposed [63]. In the context of this research paper, quality will follow the interpretation of Dzepina & Lehner [56], equating the term of quality with the ‘suitability for use’. They also state that “*To assess or evaluate quality, the assessors judging the quality (novices or experts in process modeling) as well as the intended purpose of the process model, need to be considered. Otherwise the same model can be understood in various ways, depending on who is evaluating it and for which purpose it is intended*” [56].

Despite the existence of different frameworks, there is still no generally accepted universal way of measuring BP model quality [52, 188]. Finding suitable quality metrics can be challenging as researchers often use different definitions for quality and quality metrics [52]. A recent systematic literature review by De Meyer & Claes [51] combined recent literature on process model quality in their own *Comprehensive Process Model Quality Framework (CPMQF)* and found no less than 39 quality dimensions and 21 quality metrics used in various research papers to measure process model quality.

One of the modeling frameworks that is often discussed in research papers specifically addressing process modeling quality is SEQUAL [51]. The main idea behind it is that since models are essentially statements being made in a language, semiotic (or linguistic) quality properties can be applied to them to evaluate said models [117, 118, 125]. The framework is based on sets of statements, each representing different aspects of modeling. This include the *goals of modeling* (G), the *language extension or syntax* (L), the *domain* (D) of the modeling context, the *externalized model* (M), the *knowledge of stakeholders* (K), *social actor interpretation* (I) and *technical actor interpretation* (T).

These statements can then be compared in relation to each other in order to define the conceptual modeling quality of a certain model on different levels [120, 125, 168]. However, the framework has some shortcomings. Usually it is hard for participants to make reliable quality evaluations based on the statement sets and thus, there are raising concerns about the reliability of such a quality evaluation [154]. Also, according to Krogstie et al. [120], it is likely only feasible to measure the syntactic quality level objectively, as other measures rely on participant opinions and are thus hard to evaluate objectively.

These different levels of quality can be divided up in *physical quality*, which relates to *how well the modeler was able to externalize their domain knowledge in the model and how well the reader of the model can understand it*. The *empirical quality* indicates the *comprehensibility of the model* (e.g. the layout). The *syntactic quality*, which relates to *whether all the elements in the model use the correct syntax of the modeling language*. This could for example be checked by the formula dividing the set of statements in the M by the set of statements that apply by the correct syntax rules of the L. The semantic quality relates to the elements in the model being correct and relevant to the problem (aka validity) and whether the model contains all elements that would be correct in the context of the problem (aka completeness). The perceived semantic quality relates to the actors model interpretation and domain knowledge. Pragmatic quality indicates whether or not the reader of the model understands it. The social quality relates to the agreement on the model between different actors and finally the organizational quality relates to whether or not the original goal of modeling is actually fulfilled [119, 120, 168].

While the original SEQUAL framework serves as the basis for many variations and extensions, several shortcomings of the framework were identified. Moody et al. [154] trained participants of their experiment in the application of the framework, but found that it was hard for participants to make reliable quality evaluations based on the statement sets explained earlier and thus raising concerns about the reliability of such a quality evaluation. Krogstie et al. [120] added to this that it is likely only feasible to measure the syntactic quality level objectively, as other measures rely on participant opinions and are thus hard to evaluate objectively. They add to this that this would be a challenge for basically any framework trying to measure objective quality measures beyond the syntactic level [120]. In the context of this research and the case that will be given to respondents, the semantic and syntactic quality measures are the most relevant and feasible to measure. Specifically the semantic validity and correctness will be measured, as well as the syntactic correctness of the modeled BUCM elements. This paper will focus on the SEQUAL modeling framework as it is often discussed in research papers specifically addressing process modeling quality [51].

6.2.4 Modeler Experience Impact on Modeling Quality and Cognitive Style Index

Traditionally, conceptual models including BP models are made as an interplay between the domain expert and a system analyst (an expert in modeling tech-

niques) [72]. Typically, unlike system analysts, domain experts have higher, detailed knowledge of the domain but often, slight powers of abstraction beyond that knowledge. Recently, BP modeling projects have expanded to company-wide initiatives in which novice modelers are increasingly active. The trend towards a growing involvement of novice modelers in process modeling projects results in various quality issues [193]. Recent studies reveal considerable weaknesses of process models from practice with reference to understanding and error probability [142, 141, 143, 140, 188]. The way someone gathers and analyses information (e.g. when presented with a business modeling exercise and a complex textual description) has a real effect on the output they create in the form of the quality of a produced model [54]. Within this study, we will experiment the ability of novice modelers in producing qualitative business models.

The CSI, designed by Allinson & Hayes [7] is a 38-item self-report questionnaire that allows a straightforward way of measuring ones cognitive style. Every question is oriented towards the intuitive or analytic style and respondents simply have to respond whether they agree or disagree with the statements proposed. If they do not lean either way, they indicate that they are uncertain. Two points are given depending on the polarity of the question and a total of 76 points are able to be scored. Respondents can then be grouped into one of the five categories of cognitive style, depending on where they find themselves on this scale [6].

People on the left side of the scale are considered to be intuitive (0-28) and the people leaning towards intuitive are considered quasi-intuitive (29-38). The adaptive category sits in between the intuitive and analytical categories (39-45) and indicates the ability to adapt to the situation, expressing qualities of both extremes. People leaning towards the analytic category are considered to be quasi-analytic (46-52) and the analytic category finds itself on the right side of the scale (53-76) [6]. The difference between intuitive and analytic is based on left and right brain theory [176]. The right side of the brain relates to the intuitive side of the CSI scale and to feeling-based judgements and open ended, creative approaches to problem solving and a global perspective. The left side of the brain relates to the analytic side. It relates to reasoning, attention to detail and analytical people prefer a methodical approach to problem solving [7, 231].

It can definitely be argued that both intuitive and analytical minded modelers have their place in an information systems development context. The interesting fact about this divide between intuitive and analytical is that it could be argued that due to intuitive people being better at seeing the 'big picture', might have an easier time to produce strategic BP models in particular as they allow a higher level of abstraction. However, in the context of this paper and the experiment that will be conducted, the hypothesis is that analytical respondents should have an easier time following the case instructions, are better suited to analyze the complex textual description and ultimately produce a higher quality model. This hypotheses will be tested in the paper.

6.3 The Experiment

6.3.1 Experiment Design

The experiment took place in a physical setting and respondents were given a general introduction as to what was to be expected. The attendance for the experiment was not obligatory and thus students were incentivized to attend by offering a maximum of 1,5 bonus points on their final grade for their *Business Process Management and Integrated Software Systems* course (BPMISS). A half point was to be earned by simply attending and completing the entire experiment, whilst an extra point could be earned by creating a high quality model. Students were expected to need two hours to complete the entire experiment, however if needed could take longer if they wanted to.

Before starting the modelling experiment, students received the CSI questions to fill in part 0. In part 1, students were surveyed about their occupation, educational background, age and gender as well as their familiarity with UML, the business modeling discipline of the RUP and the BUCM. In part 2, respondents were provided a theory section concerning the RUP/UML BUCM which detailed all the necessary constructs, to be used as a reference while solving the TransLogisTIC case depicted in the next section. The whole experiment including part 1, part 2 and part 3 can be found in Appendix C of this chapter¹. Subjects were expected to have some basic knowledge of the BUCM as it was part of the course curriculum for the BPMISS course where some theoretical background was given. Also, all students had followed and passed a course about UML during the preceding semester. However it was to be expected that the majority of students would not actually have created a BUC diagram by themselves based on a complex textual description at that stage of the academic year. Because of this, a top-down approach with six steps was provided during the explanation of the BUCM constructs to give the respondents guidance as to how to approach the creation of a BUC diagram. The following steps were: (i) *Identify the BO(s) and BG(s)*; (ii) *Identify the BUCs (and which BG they support)*; (iii) *Identify the business actor instances*; (iv) *Identify the business worker instances*; (v) *Identify the relationships between the different components*; (vi) *Bring everything together in a diagram*.

Following the theoretical examples based on the RUP/UML profile for business modeling, a small example case called ‘Knitting shop’ was provided solved following the same six steps provided above. A physically drawn solution was provided as well. To end part two, respondents were surveyed about the clarity and understandability of the theory section.

6.3.2 TransLogisTIC case

The modeling exercise was provided by one of the authors and is based on a real life case he has been working on. Respondents were given the following introduction: “*You’re hired as a business analyst working for a consultancy*

¹The online appendix can be found at: <https://data.mendeley.com/preview/gznyxgbz5c>

firm. You are currently working on a project, for which you're asked to model the strategic and tactical elements of the organization's business processes on the basis of the following textual description. You need to model these levels using the BUCM. A summary of all elements (modeling constructs and links/relationships) that are needed is provided for you to use as a reference when modeling (see part 2)."

The case revolved around the TransLogisTIC project relates to an organization adopting new IT system for managing its outbound logistics processes. Respondents were given a two-page long textual description further clarifying the project to be represented. The first page of the project description mainly included information about the BOs and goals (i.e. the strategic level). The second page of the description provided more information about business actors and workers involved in supply chain process and the BUCs they were involved in (i.e. the tactical level). The complete textual description can be found in Appendix C. In consistency with the top-down approach provided in the theory part, respondents were given steps that can guide them through modeling a high quality BUCM. These steps were: (i) *Identify the BO(s) and BG(s) from the point of view from TransLogisTIC*; (ii) *Identify at least 2 BOs and or goals which are not explicitly stated in the text, but are relevant in the context of the case (also include these in the drawing of your model in step 6)*; (iii) *Identify the BUCs (and which BG they support)*; (iv) *Identify the business worker(s)*; (v) *Identify the business actor(s)*; (vi) *Identify the relationships between the different components*; (vii) *Bring everything together in a diagram*.

To end the experiment, respondents were surveyed about the clarity of the case instructions, the perceived difficulty of modeling and finally their perceived ease of use and usefulness of the BUCM method.

6.3.3 Data Collection through Variables

6.3.3.1 Modelers' Background

The first questionnaire of the experiment informed about the modeler's demographic characteristics and familiarity with modeling. Students were asked what their primary occupation was at the time of the experiment (*occupation*), what their educational background was (*edu*), their age (*age*) and gender (*gender*).

6.3.3.2 Familiarity with modeling

This was then followed by questions inquiring about the familiarity with the UML (*fam_UML*), familiarity with the business modeling discipline of the RUP (*fam_BMRUP*) and finally the familiarity with the BUCM (*fam_BUCM*). Responses were recorded by means of a five-point Likert scale ranging from 1 to 5. With (1) 'Not at all', (2) 'Slightly', (3) 'Moderately', (4) 'Very' and (5) as 'Extremely'. The coding of this Likert scale is the same for every subsequent subsection.

6.3.3.3 Clarity of theory

After reading through the provided theory regarding the creation of a BUCM and the ‘Knitting shop’ example, respondents were asked to what extent certain concepts were clear to them. Responses were recorded by means of a five-point Likert scale ranging from 1 to 5. The questions inquired after the clarity of BOs (*clarity_BO*), BGs (*clarity_BG*), BUCs (*clarity_BUC*), business actors and workers (*clarity_BA* *clarity_BW*), association and dependency links (*clarity_association*; *clarity_dependency*) and finally the clarity of the provided example case (*clarity_example*).

6.3.3.4 Model Quality and Evaluation Metrics

As discussed earlier, several levels of quality are commonly used to perform quality assessment of conceptual models. In the context of this research and its limitations, the quality assessment of the produced BUCMs will be mainly focused on the semantic quality goals of *validity* and *completeness*. This means that the models will be graded based on whether or not the elements in the model are correct and relevant to the problem proposed in the TransLogisTIC case and whether or not the models show a sufficient degree of completeness compared to all the model elements that would be considered relevant and correct. Additionally, the proper notation of the language extension was graded in the form of checking for any illegal links between the modeling constructs (e.g. connecting a BA to the BO) as a measure of syntactic correctness or quality.

In order to have a representation of a model that is considered to be complete, a reference diagram was used as recommended by España et al. [58]. This reference was furnished by Yves Wautelet (see Appendix D), an expert in the context of the modeling notation and case. It is important to note that there is not one single correct model, however for the purpose of this research the reference diagram is considered to be correct and complete provides a high quality solution to the case. Having such a reference allowed the subject’s answers to be graded in a consistent way.

Six semantic quality metrics were used to grade the models. The correct identification of the BO (*BO_identification*), the BGs (*BG_identification*), the BOs or goals which were not explicitly stated in the case but would be relevant in its context (*BOBG2_identification*), the BUCs (*BUC_identification*), the links between the BUCs (*BUClinkstoBG*), the business actors and workers (*BABW_identification*) and finally the syntactic metric in the presence of any illegal links between the elements (*Links_illegal*). As mentioned earlier, different interpretations of the case could result in different but equally correct solutions of the case. As a result, respondents could identify more elements in their diagram than there were present in the reference one. More points than the reference diagram would have had could be obtained by providing the elements that are correct and relevant in the context of the case. This would, however, prove to be exception rather than rule.

Regarding the BOs, BGs, BUCs and BWs, a point was given for every single correctly represented element (meaning it had the right description and was

modeled correctly). Alternatively, a partial score of a half point was given when the modeled element was considered to be correct but not specific enough, overlapping with other elements or when for example a BA was correctly identified but modeled as a BW. The assessment of every single element on a separate basis was done to provide a more detailed score of the modeled elements. As the case proved to be quite complex, using a more course grained method of scoring (e.g. giving zero or one when all use-cases were identified) would likely result in extremely low scores across the board as most respondents would likely not be able to replicate the completeness of the reference model. For the assessment of the links between the BUCs and BGs and the presence of illegal links a score was given on one, again with the possibility of receiving partial points. Partial points were for example given when most links were present and correct but some obvious connections were clearly missing or when arrows between elements were pointing the wrong way.

When applying this scoring method to the reference model, a total of 29 points were achievable with a higher score indicating a more complete, correct and thus higher quality model. A problem with simply summing up the points of all the variables was that certain elements like the BAs and BWs would be proportionally too large. To create a global score on 10 that properly measures the modeling of the strategic and tactical levels, the different scores of every variable were thus divided by the scores of the reference model, creating scores for every variable on 1 (or slightly more if respondents managed to be more complete than the reference model). This then allowed the application of weights that made more sense and could put more importance on the BOs, goals and use-cases, as these are really the core of the BUCM. Finally, the scores were then converted to a score on 10 (*Quality_score*). An overview of the weights applied can be seen in the table below.

Table 6.1 Weights of scoring variables

Metrics	Weights
BO Identification	5.5%
BG Identification	22%
BO/BG2 identification	5.5%
BUC Identification	33%
BUC links to BG	11%
BA/BW Identification	11%
Illegal Links	11%

To add validity to the assumption that the total quality score is actually an appropriate indicator of model quality, an additional expert review score (*Expert_review*) of subject's awareness was provided by Yves Wautelet. Each model was independently graded, with a strong focus on correct interpretation and consistency in the models, **not** making use of the reference diagram. A correlation analysis was conducted between the quality score and expert review score with the assumption that if the calculated quality score actually is a good indicator of quality, it should also be highly correlated with the scores given by an expert reviewer.

6.3.3.5 Clarity of case instructions

Once the respondents finished the drawing of their model, they were asked to what extent the case instructions were clear (*case_instructions*) and to what extent the description of the TransLogisTIC case was clear (*case_description*) once again by means of a five-point Likert scale ranging from 1 to 5.

6.3.3.6 Perceived ease of modeling

The perceived difficulty of modeling the different components that make up the BUCM was also surveyed. On a five-point Likert scale respondents were asked to indicate how easy they found the modeling of BOs (*ease_BO*), BGs (*ease_BG*), BUCs (*ease_BUC*), links between BUCs and BG (*ease_BUCtoBG*), business actors and workers (*ease_BA*; *ease_BW*) and identifying the relationships between components (*ease_relationships*).

6.4 Results

The following two hypothesis are proposed as a basis for the experiment: *H1: If the proposed quality score is a suitable measurement for the model quality, then it will be strongly correlated to the score given by an expert reviewer. H2: Analytical modelers will achieve higher quality scores, compared to intuitive and adaptive modelers, because it is easier for them to follow the structured experiment approach and they are able to process complex information more easily.*

6.4.1 Respondents' profile

6.4.1.1 Background

All 29 respondents (12 females and 17 males) indicated that their main occupation was *student*. When asked about their educational background or highest previous degree, nine respondents indicated having an academic bachelor in business administration with two other respondents having an academic bachelor in business engineering. Five respondents already obtained a master degree with two specializations in digital marketing, one in management and 2 master degrees were unspecified. Twelve students indicated having a professional bachelor with specializations in accountancy & tax (1), business & IT (1), marketing (2), financial management (1), teacher math & economics (1), event management (2), international entrepreneurship (1), logistics (1), office management (1) and two unspecified degrees.

6.4.1.2 Familiarity with modeling variables

As to be expected, not a single student considered themselves to be extremely proficient in any of the three variables presented. The familiarity with the UML is indicated to be at least moderately to very high for 89.7% of respondents with only 3 respondents (10.30%) indicating they were slightly familiar with the UML. Three respondents (10.30%) indicated not being familiar with the

business modeling discipline of the RUP at all. The familiarity with the BUCM is moderate overall with 62% of respondents indicating being moderately or very familiar. Eleven respondents (37.90%) claimed to be only slightly familiar with the BUCM.

6.4.1.3 Cognitive style of the respondents

Following the theory presented by [7], 31% of the respondents are intuitive, 34.50% of them adaptive and 34.50% are analytic. Moreover, females are deemed to be more analytical than males. Allinson & Hayes [6] state that this difference in cognitive style between male and female students does occur more often, but tends to reverse when students graduate and enter the workforce.

6.4.2 Analysis of the Representations

6.4.2.1 Individual Quality Metrics

This section is focused on the discussion of quality metrics. First, the descriptive statistics are discussed and an analysis per metric between the different cognitive style groups is made. Following this, a correlation analysis of the global quality score and the score given by the expert reviewer is performed which is then followed by testing if any significant differences exist in the quality scores between the different cognitive style groups. This is shown in Table 6.2.

In a nutshell, regarding the strategic level and identification of the BO, respondents did quite well with a mean of 0.62, indicating that the average respondent got the BO at least partially right. Identifying BGs proved to be a much more difficult task with a mean of 2.09. This means that of the seven BGs that were present in the textual description, respondents on average only managed to model slightly over 2 goals. For most respondents this was the result of confusing the objectives with goals, resulting in overlap of the two metrics. When presented with the question to model two BOs or BGs not explicitly in the text (BO/BG2 identification), respondents managed to find, on average one BO or BG that was relevant and correct in the context of the case. When looking at the tactical level, the modeling of the BUCs produced

Table 6.2 Individual Quality Metrics

	Min	Max	M	SD
BO identification	0	1	0.62	0.42
BG identification	0	6	2.09	1.57
BO/BG2 identification	0	2	0.97	0.84
BUC identification	0	11	4.86	3.65
BUC links to BG	0	0.5	0.17	0.24
BA/BW identification	1	10	6.47	2.87
Illegal links	0	1	0.85	0.36

divergent results. On average respondents managed to model about half of the possible use-cases, however some people did not manage to model a single BUC, whilst other respondents managed to identify 11 BUCs. Linking BUCs

to the correct BGs proved difficult as well. Not a single respondent managed to appropriately link their BUCs and BGs. Respondents tended to either draw their links either too fine-grained or course-grained, or simply made clearly false connections. Identifying the different BAs and BWs proved to be the easiest for respondents. The average respondents identified an average of 6.47 BAs and BWs. Finally, most respondents successfully avoided to draw illegal links (e.g. connecting a business actor to a BO). Most errors were made by either not providing a direction to the links between constructs or simply missing links, causing for example a BUC to not be connected to anything in their model.

Table 6.3 Descriptive statistics quality metrics by cognitive style category

Cognitive Style	Intuitive		Adaptive		Analytic	
	M	SD	M	SD	M	SD
BO identification	0.61	0.42	0.55	0.44	0.70	0.42
BG identification	1.22	0.97	2.40	1.82	2.55	1.54
BO/BG2 identification	0.83	0.93	0.95	0.86	1.10	0.77
BUC identification	5.22	3.27	4.40	3.94	5.00	4.00
BUC links to BG	0.05	0.17	0.25	0.26	0.20	0.26
BA/BW Identification	6.61	2.40	5.95	3.01	6.85	3.31
Illegal Links	0.89	0.33	0.90	0.32	0.75	0.42

Table 6.3 shows the quality metrics by their respective cognitive style category. A notable difference in the ability to identify the BGs can be seen between the analytical respondents ($M = 2.55$, $SD = 1.54$) and intuitive respondents ($M = 1.22$, $SD = 0.97$). Another remark is that connecting BUCs to the correct BG clearly did not go well for the intuitive respondents ($M = 0.05$, $SD = 0.17$).

In the following subsections the specific variables retained from the different parts of the experiment are specified. The complete experiment can be found in Appendix C, a complete list of variables can be found in Appendix B.

6.4.2.2 Total Quality Score

Because simply adding up the scores attained for every separate quality metric would result in certain metrics having too much weight (e.g. the identification of business actors and workers would make up 8 ‘easy’ points of the maximum attainable 29 points), every score was divided by the amount of elements that were present for every metric in the reference model. This then allowed for the usage of weights to be applied to the different metrics and the conversion to a total quality score on 10. Next to this global score, an additional ‘expert review’ of student’s representations score was provided by Yves Wautelet. The use of an expert reviewer can help immensely in assessing the quality of a model [58] and is routinely used in practice. While the calculated total quality score based on the provided quality metrics relies heavily on the semantic quality metrics validity and completeness, the score provided by Wautelet focused more on consistency and correctness of the models. Subsequently, it could be argued that if the correlation between both quality scores is high, it adds reliability

and validity to the total quality score variable as a measurement for the quality of the produced representations.

Table 6.4 Descriptive statistics of total quality score and expert review score. Note that N=29, scores on 10.

	n	Total quality score		Expert review	
		M	SD	M	SD
All respondents	29	5.11	2.30	5.04	2.16
CSI 3 categories					
Intuitive	9	4.87	1.42	5.39	2.23
Adaptive	10	5.08	2.86	4.35	2.37
Analytic	10	5.37	2.53	5.40	1.93

The minimum and maximum for the total quality score were respectively 0.3 and 9.31. For the expert review score this was respectively 1 and 8 out of 10. In Table 6.4, the means and standard deviations are presented for both all the respondents between the three cognitive style categories. When looking at the means of the total quality score between the three cognitive style categories, a slight slope in average score is noticed. Analytic respondents ($M = 5.37$, $SD = 2.53$) scored slightly higher on average than adaptive respondents ($M = 5.08$, $SD = 2.86$) which in turn scored slightly higher than the intuitive respondents ($M = 4.87$, $SD = 1.42$). While this initially looks promising and to be a first indication of support for our second hypotheses, the same cannot be said for the expert review scores. Both the intuitive and adaptive respondents score more than a point higher on average compared to the mean of the adaptive respondent ($M = 4.35$, $SD = 2.37$).

Table 6.5 Pearson correlation analysis total quality score, expert review score and CSI score. Note that N=29, CSI score on scale of 0 to 76. Quality scores on scale from 0 to 10. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$

Variables	(1)	(2)	(3)
(1) Total quality score	1.000		
(2) Expert review score	0.793***	1.000	
(3) CSI score	0.017	0.002	1.000

As can be seen in Table 6.5, the Pearson correlation between the total quality score and expert review score can be considered to be strong and positive ($r = 0.793$, $p < .001$). No significant correlation was found between the two quality scores and the CSI score. This confirms H1.

With both the KS and SW normality tests indicating that the total quality score variable follows a normal distribution, a one one-way ANOVA test can be performed to test whether there is a significant difference in the mean quality scores between the three cognitive style groups. The test revealed that there is no statistically significant difference in quality score between the three different cognitive style groups ($F(2, 26) = 0.105$, $p = .900$).

Two more tests were performed in search of a possible significant effect between groups, this time making use of the cognitive style variable with two categories and the expert review score. First, an independent samples t-test was conducted to compare the total quality score for both intuitive and analytic respondents. No significant differences were found ($t(27) = 0.501$, $p = .621$) in scores for intuitive respondents ($M = 5.34$, $SD = 1.69$) and analytical respondents ($M = 4.91$, $SD = 2.79$).

Because the KS and SW normality tests indicate that the expert review score does not follow a normal distribution, a KW test can be used to test the expert review scores between the three different cognitive style categories. The results of the KW test ($H(2) = 1.534$, $p = .464$) indicate that the expert review scores do not differ significantly based on the modelers cognitive style either.

After conducting the above tests, H2, which stated that analytical modelers should have significantly higher scores than their intuitive and adaptive counterparts cannot be confirmed.

6.5 Discussion

To test the capability of the novice modelers to produce tactical strategic business process models, an experiment was conducted with 33 students of the master in BIM at the KU Leuven campus in Brussels. Two RQs were set-up:

RQ1: *“How successful are novice modelers in producing tactical and strategic conceptual elements representations and ensuring their in-between traceability when compared to an expert?”*. We can point out that there was some diversity in the ability of novice modelers to effectively produce a valid diagram but that, on average, the score was positive. Also, the proposed method of quality assessment for the produced models correlated strongly with the scores given by the expert reviewer. This indicates that the quality assessment could be deemed appropriate for its purpose.

RQ2: *“Does the cognitive style of a novice modeler have an impact on the quality of their produced tactical and strategic-level business process models?”*. To answer this, it was hypothesized that analytical modelers would be more capable than intuitive and adaptive modelers at producing a high quality model, as a result of being better at gathering and processing complex information and being more at comfort with a methodical, logical approach. The analysis of the data shows that there is a significant difference in the perceived clarity of the experiment case description, as analytical modelers found the TransLogisTIC case description to be more clear than intuitive modelers. However, based on the findings, the significantly higher perceived clarity of the case description that the analytic respondents had did not result in a higher quality of their strategic level BP models compared to their intuitive counterparts.

This section presents the threats to the construct, internal and external validity as presented in [272].

6.5.0.1 Construct Validity

The choice of the case can impact the results. TranslogisTIC is a rather advanced case with information furnished in natural language, this with the fact that students are not familiar with industrial work environments can impact the quality of their representations. The results did nevertheless not show too many issues in the modeling process and a total of 5 preliminary tests involving qualitative interviews were made with PhD students in conceptual modeling to envisage the feasibility and pinpoint the potential problems.

6.5.0.2 Internal Validity

The total paperwork furnished to the subjects was up to 5 pages for the CSI questionnaire, 6 pages for the case description and the questions and 8 for the experiment itself. A documentation and survey of this size can lead to fatigue with subjects finally trying to simply fill-in rather than trying to furnish their best possible answer. This was dealt with through: i) applying correctional penalties for guessing; ii) improving the subject's motivation by the possibility of gaining an additional bonus point on the basis of their performance for a course related to conceptual modeling they were following in the second semester of the training (in the context of which the experiment was organized).

6.5.0.3 External Validity

The group of respondents that took part in the experiment is composed of students only. While originally 33 respondents took part in the experiment, only 29 cases were ultimately available to analyze due to two respondents not being able to produce a representation and two cases containing missing values in the collected data. The sample size for this research is considered to be extremely low and any (in)significant results should be interpreted carefully as they could and probably should be considered to be unreliable. A second limitation concerning the group of respondents was the fact that every respondent was a student from the same master degree program in business information management, with presumably the same modelling background knowledge. If this experiment was conducted with business professionals, it could very well be that the results of both the business process model quality and modelling experience were significantly different.

6.6 Conclusion

Business process modelling has become of vital importance for organizations to run their everyday operations and as a way of pursuing or maintaining their competitive advantage. In the context of information systems development, high quality business process models allow for the effective visual representation of requirements and facilitate communication between the different stakeholders present. The highest abstract level, the strategic one concerns itself with the 'why' question during development. It indicates the long term objectives and goals of the organization or project and allows businesses to see whether their

strategy matches their business processes. The tactical level concerns the ‘what’ and ‘who’ and represents the core business processes used to achieve the business goals. The operational level concerns the ‘how’ and represents the individual tasks performed in realization of the business use cases. Traceability between these three levels is important, as it ensures quality and consistency when requirements change during the software development process.

Many different reasons could cause the design of low quality models. One of these factors, rarely discussed in existing literature is the cognitive style of the modeler creating the model. The cognitive style is defined as way a person gathers, processes, evaluates and organizes the data available. As such, it could be conceived to have a real impact on the creation of business process models. The cognitive style can be measured by the CSI, which divides modelers into five categories, depending on how intuitive or analytic they are perceived to be. It is hypothesized, in this research, that analytical respondents would be more capable of producing high quality models as a result of paying more attention to detail and preferring a structured, methodical approach to dealing with complex descriptions.

To test whether the cognitive style had an effect on the quality of produced strategic business process models, an experiment was conducted. There were no significant differences between the familiarity of modelling between the three cognitive styles and all respondents were considered to be slightly to moderately familiar with modelling in general. The clarity of the theory provided, the perceived ease of modelling the case, the perceived usefulness and ease of use of the BUCM method all did not differ significantly between intuitive, adaptive or analytical respondents.

The main conclusions from this analysis are threefold. First, the proposed method of quality assessment for the produced models, correlated strongly with the scores given by the expert reviewer. This indicates that the quality assessment could be deemed appropriate for its purpose. Second, there was a significant difference found between the perceived clarity of the case description between intuitive and analytical respondents. The analytical respondents found the case description to be more clear. This, however, did not result in any significant difference in the quality of the models that were produced by analytical respondents compared to intuitive respondents, nor in any difference between the three categories. In conclusion, the effect of cognitive style on the quality of produced strategic-level business process models did not present itself in this research, however due to the caveat of limited sample size, definitive conclusions should not be drawn and further research regarding this topic should be pursued.

We can finally point out that strategic modeling in business process representation is a complementary view that can be built-up and proposed by development teams even without an in depth knowledge in such modeling aspects or strategic management. When adequate tools are taught, representations supporting solutions that can be understood and measured in value by a larger group of stakeholders than software professionals and end users only can be built.

Part IV

Conclusion

Chapter 7

Conclusion

7.1 Contributions

The IT industry has undergone profound transformations over the last decade, driven primarily by the widespread adoption of mobile technology and the emergence of innovative approaches to enhance customer engagement throughout the purchasing and service journey. These advancements have not only revolutionized customer experience but also redefined the execution of an organization's core and differentiating processes, with mobile technologies playing a pivotal role. The omnipresence of IT has exerted a significant influence on the infrastructure and technologies underpinning customer service delivery, necessitating a reevaluation of traditional approaches to IT governance and management.

As IT systems become increasingly distributed, cloud-based, and reliant on the Internet of Things (IoT), the challenge of ensuring their security intensifies. The complexity of safeguarding such a dispersed IT landscape underscores the need for a strategic perspective on IT security. This requires the C-suite to possess a comprehensive understanding of the security landscape to make informed decisions regarding security-related acquisitions, budget allocations, and overall security strategy. In essence, IT security must be envisaged not merely as a technical issue but as a strategic imperative, integral to the organization's broader strategic objectives and governance.

Parallel to the challenges in IT security, the Digital Transformation (DT) journey itself demands strategic consideration. The shift towards digital-centric business models and operations necessitates a clear understanding of the strategic objectives underlying DT efforts. This strategic alignment ensures that digital initiatives are not only technically viable but also closely aligned with the organization's long-term goals and competitive positioning.

This thesis has endeavored to address these complex challenges by exploring the role of conceptual modeling in enhancing IT governance, with a particular focus on IT security and DT. Through the development and refinement of conceptual modeling frameworks, this research has provided valuable insights into the strategic management of IT security and the governance of DT initiatives.

These models serve as tools for the C-suite and other decision-makers, offering a structured approach to navigating the intricacies of the digital landscape and aligning IT initiatives with strategic business objectives.

The rapid evolution of the IT industry and the corresponding shifts in customer expectations and service delivery mechanisms underscore the need for a strategic approach in these new domains. The challenges of IT security and DT are emblematic of the broader shifts occurring across the industry, necessitating a reimagined approach to governance that is both strategic and adaptable. This thesis has contributed to this reimagining by demonstrating the utility of conceptual modeling in addressing emerging domains to be supported in IT governance. By providing frameworks for understanding and addressing these challenges, this research underscores the importance of strategic alignment in ensuring the long-term success and competitiveness of organizations in the digital era. This leads us back to the foundational inquiry of this research, framing the meta-research question that has guided this exploration: *'How can conceptual modeling be applied to identify and address emerging domains within IT governance that significantly influence the long-term strategic positioning of organizations?'*

Within this thesis, we have explored the utility of conceptual models, interwoven into comprehensive frameworks, to articulate and navigate the myriad elements central to strategic modeling. These elements encompass generic and custom strategic objectives, operational tasks (and their support or lack thereof for strategic objectives), stakeholders, their rationales, and their interdependencies. Through the diligent application of these models, we have introduced and elaborated on several key contributions:

- **SecureMoDrIGo:** This innovation extends the Model-Driven IT Governance (MoDrIGo) framework by incorporating essential security concepts, culminating in SecureMoDrIGo. It leverages conceptual models to: (a) delineate the security impact of IT service adoption at the governance level, and (b) map the flow of security concepts between governance and management tiers, facilitating bidirectional traceability. SecureMoDrIGo equips organizations with enhanced capabilities to mitigate threats and safeguard critical assets, all while advancing their strategic objectives. Its efficacy is demonstrated within a leading Belgian telecommunications company, with expert evaluations underpinning its validation.
- **DT Strategic Objectives Representation:** This contribution outlines a generic set of prominent DT strategic objectives, derived from a systematic literature review and honed through expert feedback. Organizations can harness this representation as a benchmark for crafting their bespoke DT strategic objectives. An application of this model within a Belgian hospital illustrates its potential for integration into existing IT development processes, ensuring that new software initiatives are in harmony with the organization's DT ambitions.

- **DT Conceptual Framework:** This framework endeavors to crystallize the core concepts of DT through conceptual modeling. It furnishes stakeholders, especially board members requiring a lucid vision and robust transformation support, with a mutual understanding of the DT landscape. This high-level perspective aids organizations in navigating their digitalization endeavors, encouraging a transition from sporadic, technology-led efforts to a more structured, holistic approach to DT.

In addressing the meta-research question, it becomes evident that the frameworks delineated above, all rooted in conceptual modeling, tackle various facets of the query. They underscore the vital role of conceptual modeling in bridging the gap between strategic intents of IT security and the DT and the operational execution.

As we finish this thesis, it prompts a reflective inquiry into the potential synergy among these frameworks, particularly in mitigating risks intrinsic to DT. Combining SecureMoDrIGo's emphasis on security within IT governance, the strategic objective representation's guidance for DT initiatives, and the DT Conceptual Framework's overarching view, offers a holistic strategy to confront DT challenges. This amalgamation could pave the way for a comprehensive risk management approach, one that not only anticipates and mitigates risks but also aligns with the strategic, operational, and security imperatives of the DT. Such an integrated framework would not only fortify an organization's DT journey against prevalent and emerging risks but also ensure that the journey is strategically coherent, operationally sound, and secure. This combination of frameworks offers a proactive solution to the changing digital world, marking a big step forward in helping organizations find their strategic place in the digital age. It provides a clear and detailed answer to the main research question that has driven this study.

7.2 Limitations

Each chapter in this thesis addresses certain unique constraints that could pose specific threats or challenges to the smooth progress of each research approach. However, if we take a step back and look at the bigger picture, we can identify some overall limitations. Recognizing these limitations can help us improve the work presented in this thesis. To be more specific:

- We focus on the strategic aspect of IT governance but do not envisage other aspects such as compliance for example;
- There has not been the development of a specific Computer-Aided Software Engineering (CASE) tool to back up the methods proposed. A tool that supports the customization of models and assists in applying these methods in a cohesive way is essential for fully realizing their potential value;
- While the frameworks have been tested with real-life cases and expert feedback has been collected, introducing new case studies would be beneficial. New applications do constitute new design cycles often leading to

fresh insights requiring adjustments or fine-tuning of the frameworks and their implementation steps;

- Experience in software modeling and notably the i* framework is necessary to properly understand and apply these frameworks. As a result, the frameworks might not always offer the best support to those who are new to software modeling. Exploring ways to simplify the use of these frameworks could make their benefits more accessible while reducing the effort needed for modeling.

7.3 Future Work

Looking forward, future work could involve refining and extending the conceptual models to address emerging challenges in IT governance. Further case studies and empirical testing in different industry sectors could provide valuable insights into the applicability and scalability of the proposed frameworks. Additionally, the integration of feedback from a broader range of domain experts and stakeholders could enhance the robustness of the models.

The thesis that has been presented in this document lays a foundational work for the integration conceptual modeling to support the governance of IT security and the digital transformation. The exploration of SecureMoDrIGo and DT strategic objectives representation provides significant strides toward bridging the gap between strategic intent and operational execution within the domain of IT governance. However, the journey does not end here. The path forward suggests several avenues for future work, aiming to expand the horizons of this research and address the limitations identified. Future research directions include:

- **Broader Scope of IT Governance Considerations.** Future work could explore other critical aspects of IT governance beyond the strategic focus, such as compliance, risk management, organizational structures [113] and the integration of ethical considerations in IT practices. This expansion would offer a more holistic view of IT governance, ensuring that organizations are not only strategically aligned but also compliant and ethically sound in their operations.
- **Enhancing Integration with IT Management for Services Design and Development Planning.** A critical direction for future work involves the enhancement of the integration of the developed frameworks with IT management, focusing not only on software architecture design but also on IT services development planning (see for example [258, 251]). This effort would seek to bridge the gap between the strategic governance models developed in this thesis and the practical aspects of IT service development and deployment. The objective would be to create a more seamless and symbiotic relationship between governance frameworks and the day-to-day management of IT services. Key elements of this future work could include the development of methodologies for IT service lifecycle management that align with the governance frameworks to support the entire lifecycle of IT

services, from inception and development to deployment and maintenance [253]. This approach would ensure that IT services are developed with strategic alignment from the outset and maintained in accordance with governance principles.

- **Development of a Computer-Aided Software Engineering (CASE Tool).** The creation of a CASE tool to support the application of the proposed frameworks would significantly enhance their practicality and ease of use. Such a tool would facilitate the customization of models, automate aspects of the modeling process, and provide a cohesive platform for applying the methods outlined in the thesis, thereby extending their reach and utility. For such a purpose, an interesting option would be to further develop the DesCartes Architect CASE tool [112] that supports and integrates NFR, i^* and other frameworks already.
- **Incorporation of Additional Case Studies.** Engaging in new case studies across varied industries and geographical locations would enrich the research with diverse perspectives and challenges. Each new application represents an opportunity for a design cycle, potentially revealing insights that necessitate the refinement or adjustment of the frameworks and their implementation methodologies. This iterative process is crucial for ensuring the relevance and adaptability of the models to a wide range of contexts.
- **Enhancing Accessibility for Novice Modelers.** Considering the specialized knowledge required to effectively utilize the i^* framework and the conceptual models developed in the thesis, future research could focus on simplifying these tools. Making the frameworks more accessible to those with limited experience in software modeling would democratize the benefits of strategic IT governance modeling, reducing the barriers to entry and potentially broadening the impact of this research.
- **Integration and Synergy Among Frameworks.** A promising area for future work lies in the integration of SecureMoDrIGo, DT strategic objectives representation, and the DT Conceptual Framework into a unified, comprehensive risk management approach. This integrated framework would address not only the security aspects but also the strategic, operational, and competitive challenges of digital transformation, offering a coherent strategy for navigating the digital landscape.

By addressing these areas, future work can build upon the foundation laid by this thesis, continuing to advance the field of IT governance and ensuring that organizations are well-equipped to navigate the complexities of the digital age.

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