UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR TÉCNICO

Digital Transformation Ontology

Silvia Bogéa Gomes

Supervisor: Doctor Miguel Leitão Bignolas Mira da Silva

Co-Supervisor: Doctor Flávia Maria Santoro

Thesis approved in public session to obtain the PhD Degree in

Computer Science and Engineering

Jury final classification: **Pass with Distinction**

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Título Digital Transformation Ontology

Abstract

Digital technologies are shaping and creating physical reality. The economy and society have been rapidly digitalized, introducing new habits, novel ways of living together, new cultures, new shapes for traditional businesses, and new types of businesses regularly. In this scenario, digital transformation has gained great research interest, even though the need for a common understanding of this concept is evident. The research problem addressed in this thesis is the lack of a proper conceptualization of digital transformation. This thesis proposes the Digital Transformation Ontology (DTO) to distinguish and represent organizational digital transformation concepts in an unambiguous way. Moreover, the ontology provides a domain-independent conceptual specification that can be able to guide digital transformation initiatives based on a solid conceptual foundation and a clear understanding of digital organizational transformation and related concepts. This thesis' three-tiered research methodology uses the inquiry strategy of design science methods as the first level to answer the thesis' research questions. SABiO methodology was adopted in the second level to develop the artifact. The third level describes the research methods necessary to fulfill the methodological strategy components' requirements. Two sub-ontologies—a Core Ontology of Organizational Transformation (COOT) to study organizational transformation and a Domain Ontology of Digital Transformation (DODT) to study a specific type of digital organizational transformation—comprise DTO to create a reference model representing the digital transformation paradigm. They have been applied in real-world case studies: COOT on a car rental company and DODT on a Portuguese government digital transformation project. The case studies´ results indicate that the proposed ontology for digital transformation was able to represent most relevant concepts of the initiatives analyzed which makes it a viable alternative for supporting such initiatives.

Keywords

Organizational Transformation; Digital Transformation; Digital Technology; Business Process Management Capability (BPM Capability); Ontology.

Título	Ontologia de Transformação Digital
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Resumo

As tecnologias digitais estão moldando e criando a realidade física. A economia e a sociedade foram rapidamente digitalizadas, introduzindo novos hábitos, novas formas de convivência, novas culturas, novas formas de negócios tradicionais e novos tipos de negócios regularmente. Neste cenário, a transformação digital ganhou grande interesse de investigação, ainda que seja evidente a necessidade de um entendimento comum desse conceito. O problema de investigação abordado nesta tese é a falta de uma conceituação adequada de transformação digital. Esta tese propõe a Ontologia de Transformação Digital (DTO) para distinguir e representar conceitos de transformação digital organizacional de forma não ambígua. Além disso, a ontologia fornece uma especificação conceitual independente de domínio que pode orientar as iniciativas de transformação digital com base em uma base conceptual sólida e numa compreensão clara da transformação organizacional digital e conceitos relacionados. A metodologia de pesquisa de três níveis desta tese usa a estratégia de investigação dos métodos da ciência do design como o primeiro nível para responder a essas questões de pesquisa de tese. A metodologia SABiO foi adotada no segundo nível para desenvolver o artefato. O terceiro nível descreve os métodos de pesquisa necessários para atender aos requisitos dos componentes da estratégia metodológica. Duas sub-ontologias—uma Ontologia Core de Transformação Organizacional (COOT) para estudar a transformação organizacional e uma Ontologia de Domínio da Transformação Digital (DODT) para estudar um tipo específico de transformação organizacional digital—compreendem a DTO criando um modelo de referência que representa o paradigma da transformação digital. Eles foram aplicados em estudos de caso do mundo real: COOT em uma empresa de aluguel de carros e DODT em um projeto de transformação digital do governo português. Os resultados indicam que a ontologia proposta foi capaz de representar os conceitos mais relevantes das iniciativas analisadas, o que a torna uma alternativa viável para apoiar tais iniciativas.

Palavras-chave

Transformação Organizacional; Transformação Digital; Tecnologia Digital; Capacidade de Gerenciamento de Processos de Negócios (BPM Capability); Ontologia.

To my loves:

Luiz Felippe, Luiza, and Henrique, sources of inspiration,

Iracema and Expedito, my first and invaluable professors.

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Table of Contents

List of Figures

List of Tables

Acronyms

BPM	Business Process Management
BUPi	in Portuguese Balcão Unico do Predio, which directly translates to Unique Registration of Building
COOT	Core Ontology of Organizational Ontology
COVER	Common Ontology of Value and Risk
DODT	Domain Ontology of Digital Transformation
DOOC	Domain Ontology for Organizational Change
DT&I	Digital Transformation and Innovation
DTO	Digital Transformation Ontology
EA	Enterprise Architecture
GIS	Geographical Information System
NIP	in Portuguese Número de Identicação do Prédio, which directly translates to Property Identification Number
SABiO	Systematic Approach for Building Ontologies
SLR	Systematic Literature Review
SMS	Systematic Mapping Study
UFO	Unified Foundational Ontology

Chapter 1

Introduction

This chapter provides an overview of the thesis by outlining the research problem identification and motivation, as well as the objectives and solution approach. It identifies the thesis' context and motivation, specifies the problem, targets the intended principal contributions while emphasizing the main results, and presents the publications. At the end of the chapter, this document outline is provided.

1.1 Overview

Since the 1990's, the IS (Information Systems) domain has added the competitive potential and role of IT (Information Technologies) to IT-enabled transformations (Bogea Gomes, Santoro and Mira da Silva, 2021). However, the traditional view of an IS as something that represents and reflects physical reality is increasingly obsolete. Instead, digital technologies are now creating and shaping physical reality (Baskerville, Myers and Yoo, 2020).

While the Internet has grown in popularity, the world has created a digital infrastructure that is relatively inexpensive and simple to use. This digital infrastructure is made up of computers, mobile devices, digital technologies, digital sensors, broadband network connections, and advanced application platforms (Fichman, Dos Santos and Zheng, 2014).

The digitalization of the economy and society has been fast. Digital infrastructure shapes the growing interconnectedness of people, organizations, and machines as the basis of the digital economy (OECD, 2017). The digital economy is introducing contemporary habits, novel ways of living together, new cultures, different shapes for traditional businesses, and new kinds of businesses (Bogea Gomes, Mira da Silva and Santoro, 2019). A survey of leading retailers showed that almost 64% considered digital innovation to be fundamental to their business, and 28% said it was at least very important (Hagberg, Sundstrom and Egels-Zandén, 2016).

The digital world shapes our experiences by seamlessly and inseparably interweaving the digital with the physical, creating (or helping to create) the physical environments in which we live. Some objects are purely digital (e.g., digital media such as photos and videos), while others, like the Internet of Things, have embedded computing capabilities in mundane everyday objects (such as a microwave and a thermostat) (Recker, 2021). Besides, the digital world blends personal and corporate IT environments and encapsulates the transformational effect of new digital technologies (Ismail, Khater and Zaki, 2017).

Digital transformation and innovation have directly influenced our society's relationships and forms of consumption. For Hinings, Gegenhuber and Greenwood (2018), digital transformation is the combined effects of one or more digital innovations that, by bringing novel actors, structures, practices, values, and beliefs, change, threaten, replace or complement existing rules within organizations, ecosystems, industries or field. In certain situations, transformation can result in innovation. In others, innovation can lead to transformation. Innovation usually refers to a creative spark and the first steps toward making something happen. On the other hand, transformation is the change process that leads to incorporating the innovation spark.

The World Wide Web connects many more digital objects (about 20 billion) than people (about 8 billion), and they influence what we do and how we live our lives. The digital infrastructure is part of many human experiences, such as planning holidays through automated recommender systems, choosing the modes of transportation using shared mobility service platforms, and engaging in physical activities in response to signals from wearable devices (Recker, 2021).

Uber[1], Airbnb[2], Facebook[3], LinkedIn[4], and eBay[5] are some examples of successful and highly valued organizations that have developed innovative digital business models. New entrants are arising from digital innovation, and existing organizations that have self-adapted to the digital age are growing fast in the market. Oswald and Kleinemeier (2017) affirm that in the next ten years, 40% of organizations indexed in Standard & Poor's 500 will cease to exist unless they keep up with technological trends. Furthermore, they observe that digital transformation directly impacts customer behavior and consumption forms.

This scenario has increased interest in digital transformation and digital innovation research. One way to confirm this subject's importance is to search Google Scholar as presented at (Bogea Gomes, Mira da Silva and Santoro, 2019). Documents with "digital innovation" or "digital transformation" in the title or anywhere in the text, first until 2009, and then in the period from 2010 to 2018, not including patents and citations, show a significant evolution in these two periods scenarios. Up to 2009, Google Scholar had indexed approximately 5890 papers with those two terms in their titles or anywhere in the text, of which only 1% (approximately 72 papers) had these terms in their titles. From 2010 to 2018, the number of publications was nearly eightfold - approximately 45032 papers were published. The proportion of papers with those two terms in their titles grew to approximately 8% of all papers (about 3502). From 2019 to the date of this research, in January 2023, at least eight times more papers (approximately 65500) have been published compared to the period up to 2009, with 21% of papers (approximately 13871) having these terms in the title. Figure 1.1 shows that the number of selected papers has increased year over year for the past fourteen years.

1.2 Motivation

New business models tightly integrated with digital platforms and infrastructures composed of new digital technologies have transformed the market in recent years. In contrast, large and well-established organizations with traditional business models have gone out of market. For instance, Kodak, once a behemoth in analog photography, neglected the transition to digital. Another example is Netflix that passed Blockbuster in transitioning from physical DVDs and video clubs to online digital content streaming (Aguiar *et al.*, 2019). Organizations are increasingly confronted with the need to respond creatively and adapt to changes in order to remain viable and develop sustainable competitive advantages (Bogea Gomes, Santoro and Mira da Silva, 2022a). Consumers' digital expectations and needs are constantly changing, as the digital world is constantly changing and new things are always coming up (Hinings, Gegenhuber and Greenwood, 2018). To keep up with or survive future competition,

[1] https://uberportugal.pt/portugal/

[2] https://www.airbnb.com.br/

[3] https://www.facebook.com/

[4] https://www.linkedin.com

[5] https://www.ebay.com

organizations may need to prioritize critical processes and move faster than competitors to reap the benefits of the digital (Kretschmer and Khashabi, 2020). Despite efforts to create a unified view of changes in the digital age, the terms digitization, digitalization, IT-enabled organizational transformation, and digital transformation have distinct meanings, although being frequently used interchangeably (Bloomberg, 2018; Verhoef *et al.*, 2021). The appropriate conceptualization of these terms is not yet consolidated, although some existing publications discuss their benefits and consequences (Bockshecker, Hackstein and Baumöl, 2018a).

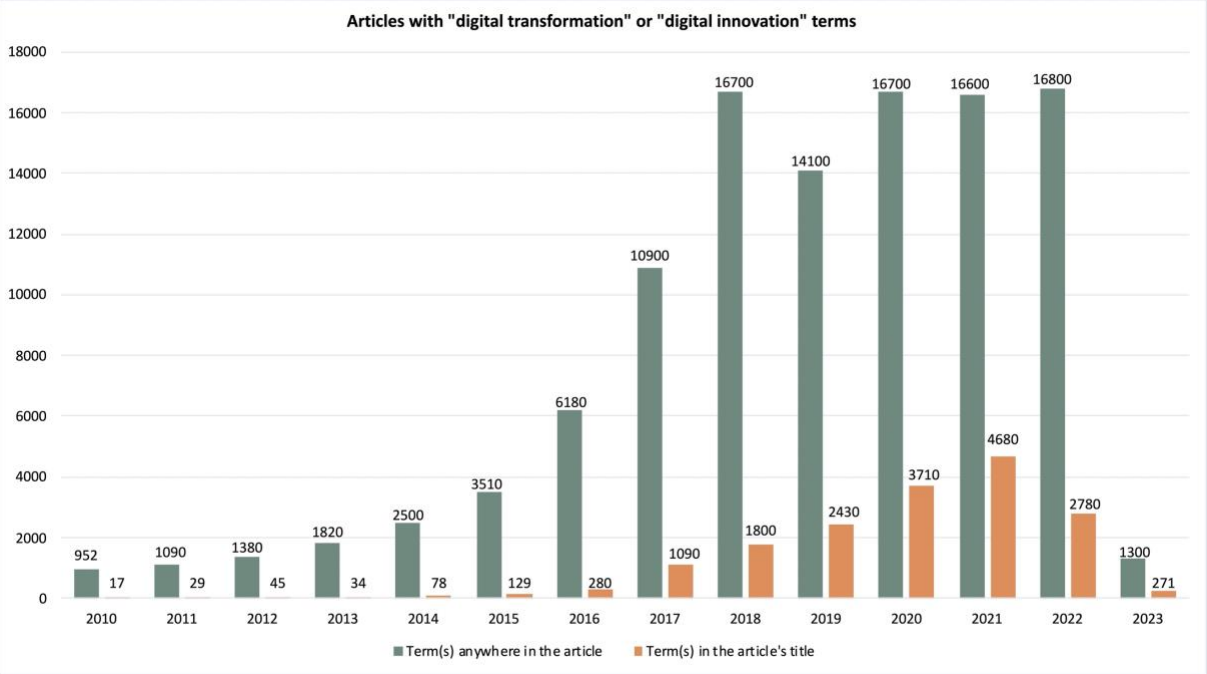

Figure 1.1. The terms DI and DT: title vs. anywhere in the papers.

According to Ismail, Khater and Zaki (2017), digital transformation is the process by which organizations combine multiple digital technologies to improve business performance by changing multiple business dimensions, such as the business model, customer experience and operations, while also affecting people and networks. It is a type of organizational transformation that changes societies and industries by the convergence of multiple new digital technologies enhanced with ubiquitous connectivity (Beverungen *et al.*, 2021). Organizational transformation is a type of organizational change that creates a new vision for organization (Porras and Silvers, 1991).

Furthermore, for Zimmermann, Schmidt and Jain (2020) digital transformation comprises digitally enabled products and services, processes, enterprise architecture management and decision-making, and includes capabilities, skills talent, culture, and entire value system, demanding for “an integration of approaches from different areas of information systems research”.

For Oswald and Kleinemeier (2017), digitization is defined as the process of converting analog to digital form, which is primarily driven and enabled by digital technology. Unlike digitization, digitalization does

not have a single, precise definition. For many authors, the automation of business processes characterizes digitalization. Digitization and digitalization are primarily concerned with technology, whereas digital transformation is not. Digital transformation has enabled both humans and artificial actors to be interconnected via multiple communication channels. This hyper-connectedness has made it possible to perform business processes in new and innovative ways, but it has also increased the complexity of managing them in line with corporate or societal objectives. This trend fundamentally changes the resources and capabilities that organizations and people require to manage business processes effectively. As a result, organizations need to re-evaluate themselves in order to build up the assets and core competencies required to remain successful in their industries (Beverungen et al., 2021). Ubiquitous digital technologies are driving organizations to embrace non-traditional digitally transformed business models. However, the research on digital transformation remains fragmented. The problem under study is transversal to the research areas (Chawla and Goyal, 2021).

1.3 Problem

Morakanyane, Grace and O'Reilly (2017) state that even though digital transformation has gained great research interest, the lack of common understanding of this concept is evident. There are various definitions or descriptions of digital transformation, resulting in the emergence of hype and buzzword in academic and practitioner literature. In contrast, more attention should be paid to what digital transformation is and how one should think about it (Gong and Ribiere, 2021). This term has been broadly used, even though it is hard to agree on a single definition. There are so many different definitions that it is possible to find overlaps. The main differences relate to the spectrum of application of changes and their beneficial implications for the organization (Aguiar *et al.*, 2019). When reviewing the literature defining digital transformation, definitions vary depending on perspectives and perceptions (Reis *et al.*, 2018).

Despite the ubiquity and visible impact of digital transformation in society, and this topic has gained great research interest, there is a lack of common understanding of the concepts related to it (Morakanyane, Grace and O'Reilly, 2017; Verhoef *et al.*, 2021). Besides, although the powerful impact of digital transformation has been widely discussed, it is still necessary to clarify what it is (Bloomberg, 2018). Moreover, it has been observed that current digital transformation concepts have a poor track record in supporting the analysis of the potential of digital transformation initiatives, designing them suitably, and implementing them within organizations (von Rosing and Etzel, 2020).

Thus, the research problem addressed in this thesis is the lack of a proper conceptualization of digital transformation. This thesis aims to clarify the digital transformation concept, identify which entities can be transforming in a digital transformation, define digital transformation and its related concepts and what are the expected outcomes of digital transformation, and their impacts to the organizations. This is the purpose of the research questions presented in Figure 1.2.

1.4 Solution Proposal

Although knowledge is considered a concrete organizational asset, it behaves differently than physical and natural resources. Instead of being bound to end like natural resources, knowledge can be replicated and expanded endlessly, enabling broad reuse and newness. The initiatives of digital transformation require increasingly the ability to manage knowledge, considering, for example, ways to map real world and integrate heterogeneous knowledge accurately.

RQ1. What is digital transformation?

RQ2. What can be transformed in a digital transformation?

RQ3. What are the characteristics of a digital transformation?

RQ4. What are the outcomes of a digital transformation?

Figure 1.2. The thesis research questions.

Any organization that wants to succeed in the digital economy must have an intellectual, comprehensive, and user-friendly system for managing knowledge reserves (personalization perspective), as well as a system for accessing knowledge and acquiring new knowledge (codification perspective). Organizations must learn how to manage their intangible assets, or knowledge, to compete successfully in their own market. Knowledge management is the process by which an organization collects, organizes, distributes, and analyzes its own knowledge about resources, documents, and human skills. The ability of an organization to use the hidden value of intangible assets is critical to its long-term prosperity and survival (Mizintseva and Gerbina, 2018).

Different communities use the term "ontology" differently (Guarino, 2005). In the information systems community, the term ontology is akin to the original definition given in philosophy ("a particular theory about the nature of being or the kinds of existents") (Guizzardi, 2005, p. 77). According to Guarino et al. (2009), Gruber originally defined ontology as an "explicit specification of a conceptualization" in 1993, and Borst defined it as a "formal specification of a shared conceptualization" in 1997. In 1998, Studer et al. merged these two definitions to define ontology as "a formal, explicit specification of a shared conceptualization," where conceptualization is "the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them."

Ontology engineering process mentioned in Guizzardi et al. (2015) says that modeling and representation approaches should be kept separate. To be more specific, modeling approaches should be used during the conceptual modeling phase of ontology engineering. On the other hand,

representation approaches could be used to make different implementations of a given ontology as a conceptual model.

This thesis aims to solve the research problem identified - the lack of a proper conceptualization of digital transformation - creating a reference ontology, grounded in UFO, to apply it to digital transformation conceptual modeling using the OntoUML modeling approach.

In this sense, there are essential questions to answer, such as the goals, characteristics, elements, and results of the digital transformation. Another critical issue which has not yet been addressed in the literature is the transformable entities in the various digital transformations. However, primarily, the questions of what and how to transform have not yet been satisfactorily answered.

Ontologies are increasingly being recognized as key enablers and critical tools for the digital transformation of knowledge management processes (Spoladore and Pessot, 2022). For example, Grigaliunas, Toldinas and Venckauskas (2017) developed an ontology for a transformation model in the domain of digital forensics. Javaid *et al.* (2017) proposed facilitating SMEs' digital transformation using enterprise ontologies and service blueprinting. Etymologically, *ont-* is derived from the present participle of the Greek verb *einai* (to be) and, thus, the latin word *Ontologia* (*ont-* + *logia*) can be translated as the study of existence.

The German philosopher Edmund Husserl coined the term Formal Ontology at the beginning of the 20th century as an analogy to Formal Logic. While Formal Logic is concerned with formal logical structures (e.g., truth, validity, consistency) independent of their veracity, Formal Ontology deals with formal ontological structures (e.g., theory of parts, theory of wholes, types and instantiation, identity, dependence, unity), i.e., with formal aspects of objects regardless of their nature. Since the term *ontology* was first used in a computer-related discipline (Mealy, 1967) apud (Guizzardi, 2005), it has been applied in a wide range of areas in computer science (Guizzardi, 2005).

The term *ontology* has a precise meaning in the information systems community, similar to the original definition given in philosophy: "a particular theory about the nature of being or the kinds of existents," a system of categories independent of language and state of affairs (Guizzardi, 2005). The term ontology in the computer and information science literature appeared for the first time in 1967 (Smith, 2004) apud (Guizzardi, 2005). However, a wide range of different artifacts with a spectrum of divergent characteristics have been referred to as ontologies.

These specifications range from simple catalogs containing, for example, the products sold by a company, through a set of text files, a glossary, a thesaurus, a collection of taxonomies, a collection of frames, to a lexicon of terms with natural language definitions (thesaurus) and formal logical theories (Smith and Welty, 2001) apud (Guizzardi, 2005). Models that describe domain-specific entities are used in these examples. While domain conceptualizations and, consequently, domain ontologies are established by the consensus of a community of users with reference to a material domain, a conceptual modeling language that can be used to express these domain ontologies must be rooted in a domain independent philosophically and cognitively well-founded system of real-world categories, i.e., a

foundational (upper-level) ontology (Guizzardi, 2005). A foundational ontology is a meta-ontology built on formal ontology theories developed in philosophy.

Guizzardi (2005) illustrates (see Figure 1.3) the relationships between a conceptualization, a language, a domain abstraction (representing part of some state of affairs in reality articulated according to the conceptualization) and a specification in the language which represents this domain abstraction.

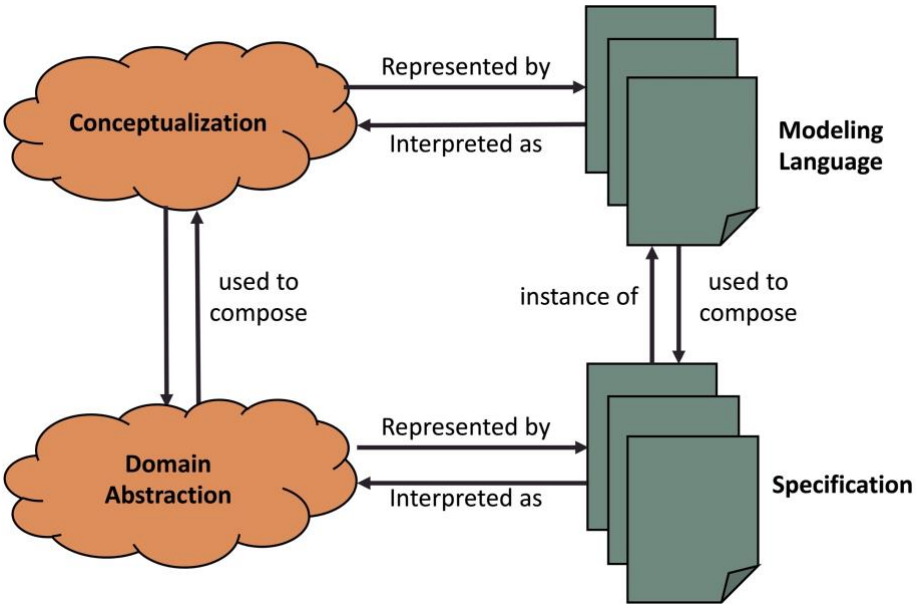

Figure 1.3. Relations between conceptualization, domain abstraction, modeling language and specification (Guizzardi, 2005)

1.5 Main Contributions, Goals and Results

The current thesis' goal is to provide a domain-independent conceptual specification to guide the development of digital transformation initiatives. It has a solid theoretical basis and a clear notion of what is a digital organizational transformation and its related concepts. Moreover, this thesis aims to use the conceptual specification to analyze real-world cases and verify the feasibility of consistently being a Digital Transformation initiative in the form of an ontology – the Digital Transformation Ontology (DTO).

The main goal of this thesis is to propose a "Digital Transformation Ontology" (DTO) as a conceptual model or a description that is not tied to any specific design or technological preferences to determine the organizational impacts of digital transformation. In order to achieve this goal, the following secondary goals are enunciated:

- represent what digital transformation is, the potential subjects of change in digital transformations, the characteristics of a digital transformation, and the outcomes of a digital transformation.
- contribute to the conceptual specifications that can be used to support understanding (learning), problem-solving, and communication among stakeholders about the digital transformation initiative's conception.

- provide a common basis of understanding the motivation to transform, the transformation strategy for change, business process management dimensions, and digital platform functioning.
- investigate the digital transformation process and the structure demanded by a digital transformation initiative as operational processes.
- investigate the organization's motivation to transform for strategy formulation.

1.6 Publications

During the research effort that culminated in this thesis, ten research papers were published, which are presented in Table 1-1, besides the research paper submitted (yet in review process) as presented in Table 1-2. The contributions of these papers are highlighted in the chapters they refer to.

Table 1-1. Papers published in the scope of this thesis.

Year	Type	Published Venue	Rank	Title	Chapter(s)
2019	Conference	28th International Conference on Information Systems Development (ISD 2019)	A[6]	Digital Innovation and Transformation: a quasi-systematic literature review	Introduction R. Background Related Work
2019	Conference	IEEE 23rd International Enterprise Distributed Object Computing Conference (EDOC)	B	A Reference Model for Digital Transformation and Innovation	Appendix B
2019	Conference	IEEE 23rd International Enterprise Distributed Object Computing Conference (EDOC)	B	Digital Transformation Capability Maturity Model Framework (First Author: Tomás Aguiar)	Introduction
2020	Conference	International Conference on Business Process Management (BPM Forum)	---	Digital Transformation from a Business Process Management Innovation: A Car Rental Case Study	Demonstration and Evaluation Appendix A
2020	Journal	International Journal of Information System Modeling and Design (IJISMD)	Q3	An Ontology for BPM in Digital Transformation and Innovation	R. Methodology R. Background Related Work Proposal Demonstration and Evaluation Appendix A

[6] CORE Computing Research and Education Association of Australasia 2018; ERA (Excellence in Research for Australia) 2023

Year	Type	Published Venue	Rank	Title	Chapter(s)
2021	Conference	27th Annual Americas Conference on Information Systems (AMCIS 2021)	A[7]	A Taxonomy for Digital Technology	Introduction R. Background Proposal
2021	Journal	ISACA Journal - Volume 1	----	Identifying the Practices of Digital Transformation Based on a Systematic Literature Review (First author: Tomás Aguiar)	Introduction
2022	Conference	International Conference on Conceptual Modeling (ER 2022)	A	An Ontological Analysis of Digital Technology (Short Paper)	R. Background Proposal
2022	Conference	PoEM Forum	----	Bibliometric Analysis of Business Process Capability	R. Background Proposal
2023	Journal	Applied Ontology	Q1	Towards A Core Ontology of Organizational Transformation	R. Methodology R. Background Related Work Proposal Demonstration and Evaluation

Table 1-2. Papers submitted in the scope of this thesis.

Year	Type	Submited Venue	Rank	Title	Chapter(s)
2023	Journal	Information Systems Frontiers (in review)	Q1	Digital Transformation Viewpoint in ArchiMate	Appendix B

1.7 Document Outline

The remainder of this thesis is organized as follows: Chapter 2 outlines the research methodology. Chapter 3 discusses background knowledge and presents the results of the literature review. Chapter 4 introduces related work. Chapter 5 describes the Digital Transformation Ontology (DTO) as artifact. Chapter 6 presents the artifact with application scenarios to demonstrate, evaluate and discusses the evaluation of the artifact proposed. Finally, Chapter 7 concludes this thesis with final remarks, the thesis's main contributions, limitations, the implications for research and practice, and prospects (see Figure 1.4).

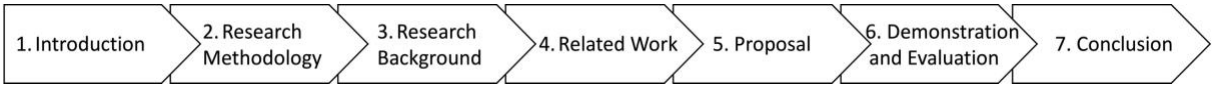

Figure 1.4. Thesis' chapter

[7] CORE Computing Research and Education Association of Australasia 2018; ERA (Excellence in Research for Australia) 2023

Chapter 2

Research Methodology

The strategy of inquiry used to answer a research question is called research methodology. Inquiry strategies include qualitative, quantitative, mixed, design science, and computational methods. These strategies specify how procedures in a research design should be carried out (Recker, 2021). The inquiry strategy of design science methods is used to answer this thesis' research questions.

This chapter describes this thesis' three-level research methodology (see Figure 2.1).

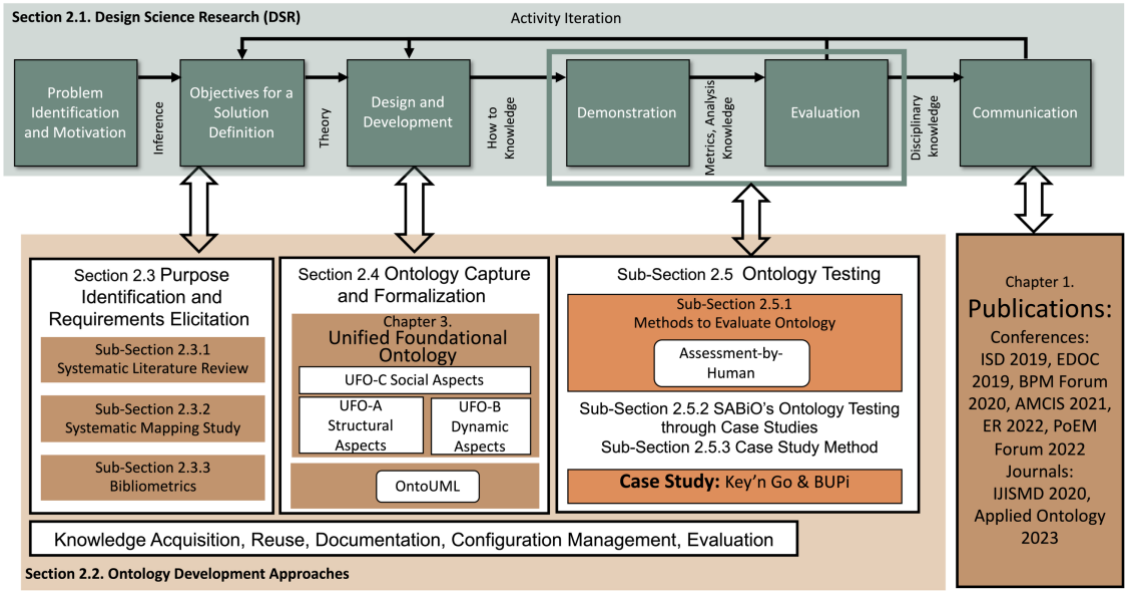

Figure 2.1. Methodological Approach (adapted from (Peffers *et al.*, 2007)).

The first level adopted is depicted in the Figure 2.1 and discussed in Section 2.1 - **Design Science Research (DSR)**. DSR is an approach in which the research answers relevant questions through the creation of artifacts, providing new information to the body of scientific evidence required for comprehending a real-life situation (Peffers et al., 2007; Wieringa, 2009; Recker, 2012, 2021).

The ontology is the artifact in this thesis. The development of the artifact was supported by SABiO methodology, as depicted in the second level of Figure 2.1 and discussed in Section 2.2 - Ontology Development Approach. This ontology development approach is introduced in Section 2.2. The ontology proposed is a reference ontology, as defined in SABiO (Section 2.3).

The third level describes the research methods necessary to fulfill the methodological strategy (Table 2-1).

Table 2-1. Three-level Methodological strategy approaches.

Level	Section	Sub-Section
1	2.1 DSR	
2	2.2 The Ontology Development Approaches	2.2.1 The Ontology Development 101 Approach 2.2.2 SABiO
3	2.3 SABiO's Purpose Identification and Requirements Elicitation	2.3.1 Methods for Literature Review 2.3.2 Literature Review Phases (SLR and SMS) 2.3.3 Bibliometrics
3	2.4 SABiO's Ontology Capture and Formalization	UFO and OntoUML – presented in Chapter 3 Research Background
3	2.5 SABiO's Ontology Testing	2.5.1 Ontology Demonstration and Evaluation Methods 2.5.2 SABiO's Ontology Testing through Case Studies 2.5.3 Case Study Method

2.1 Design Science Research (DSR)

Design Science Research (DSR) is an approach in which the research answers relevant questions by creating artifacts and contributing new knowledge to the body of scientific evidence (Peffers *et al.*, 2007). DSR emphasizes the connection between knowledge and practice by showing that one can produce scientific knowledge by designing useful things (Wieringa, 2009). In this context, designed artifacts are essential in understanding a real-life problem (Peffers *et al.*, 2007).

The real world is changed to suit human purposes, to solve a practical problem, but to solve a knowledge problem, one acquires knowledge about the world without necessarily changing it. These two kinds of problems in design science are mutually nested, although their problem-solving and solution-justification methods are different. Practical problems call for a change in the world to better align with some stakeholder goals. Knowledge problems, in contrast, call for a change in our knowledge about the world (Wieringa, 2009).

The Design Science Research Methodology (DSRM) proposed by Peffers *et al.* (2007) is an approach that provides a commonly accepted framework for successfully carrying out DSR and a mental model for its presentation. This thesis is organized according to the DSR activities, as presented in Figure 2.2.

The DSR cycle begins with recognizing the problem (DSR - problem identification and motivation). Following that, it derives the goals of a solution from the problem definition and knowledge of what is possible and feasible (DSR - define the objectives for a solution). Next, the artifact is designed (DSR - development). The artifact is then demonstrated (DSR - demonstration) based on the functional specification, discussed (DSR - evaluation) in terms of its data, interpretation, and relationship to other works, and communicated (DSR – communication). After completing the first DSR cycle for an artifact proposal, the design can be refined and used in subsequent iterations and feedback cycles. It is worth mentioning that only two design cycles were performed so far at this stage of the research. Nevertheless, there are already sufficient results to be communicated.

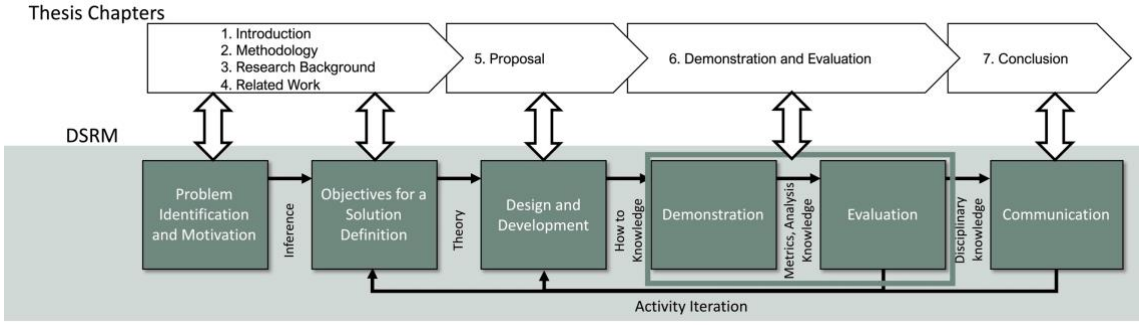

Figure 2.2. The thesis chapters related with the DSRM activities (Peffers *et al.*, 2007).

Design science research, emphasizing on design and artifacts, focuses on two research activities at its core: building (constructing the artifact) and evaluating (testing the artifact). Based on Hevner (2007), Recker (2021) stated that design science research is placed in a broader framework bounded by the practical environment and the available knowledge base at that point in time when examining how such artifacts can be developed and evaluated.

The environment defines the problem space in which the phenomena of interest reside. People, organizational structures, and existing digital information or communication technologies and infrastructures are all part of the environment in information systems research. For a specific artifact, the environment should establish why the artifact at the heart of the design science research is relevant to stakeholders in that application domain. Prior research and results from reference disciplines provide foundational theories, frameworks, instruments, constructs, models, methods, and instantiations for the design phase. The knowledge base provides the materials by and through which design science research is accomplished.

The results from the first design cycle for DTO proposal (Figure 2.3.) are presented in the Appendix A. The second cycle (Figure 2.4) is presented in Chapter 4.

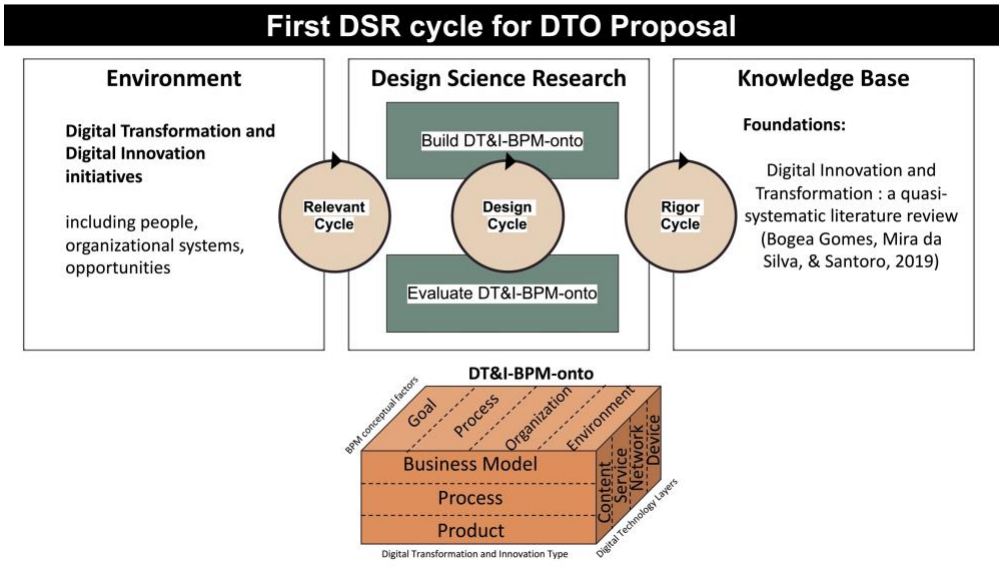

Figure 2.3. DSR framework for DTO Proposal – first cycle, based on (Recker, 2021).

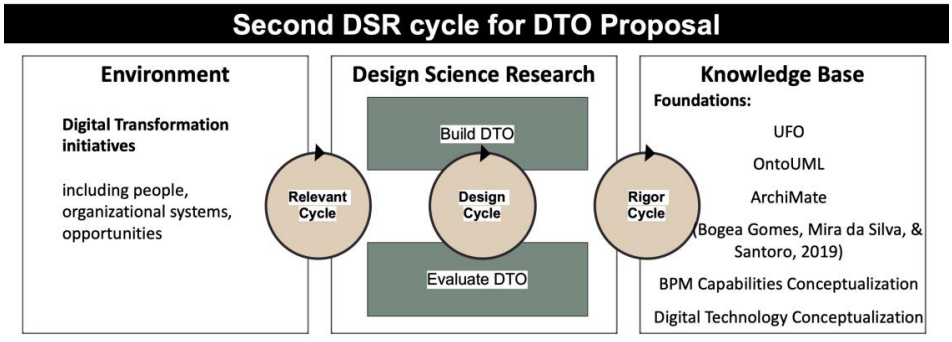

Figure 2.4. DSR framework for DTO Proposal – second cycle, based on (Recker, 2021).

The activities proposed in the Design Science Research Methodology (DSRM) (Peffers *et al.*, 2007) are briefly described in Table 2-2:

Table 2-2. DSRM activities (Peffers *et al.*, 2007)**.**

Activity	Description	Resources required include
Problem identification and motivation.	Define the specific research problem and justify the value of a solution. Justifying the value of a solution accomplishes two things: it motivates the researcher and the research audience to accept the results, and it helps to understand the reasoning associated with the researcher's understanding of the problem.	Knowledge of the state of the problem and the importance of its solution.
Define the objectives for a solution.	Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible. The objectives can be quantitative or qualitative, such as describing how a new artifact is expected to support solutions to problems not hitherto addressed. The objectives should be inferred rationally from the problem specification.	Knowledge of the state of problems and current solutions, if any, and their efficacy.
Design and development. (Create the artifact).	Such artifacts are potential constructs, models, methods, or instantiations (each defined broadly) or new technical, social, or informational resource properties. Conceptually, a design research artifact can be any designed object. This activity includes determining the artifact's desired functionality and architecture and creating the actual artifact.	Knowledge of theory that can be brought to bear in a solution, for moving from objectives to design and development.
Demonstration.	Demonstrate the use of the artifact to solve one or more instances of the problem. The demonstration could involve its use in experimentation, simulation, case study, proof, or other appropriate activities.	Adequate knowledge of how to use the artifact to solve the problem for the demonstration.
Evaluation.	Observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from the use of the artifact in the demonstration. It requires knowledge of relevant metrics and	Items such as comparing the artifact's functionality with the solution objectives from activity 2, objective quantitative performance measures such as budgets or items produced, satisfaction surveys, client

Activity	Description	Resources required include
	analysis techniques. Depending on the nature of the problem venue and the artifact, evaluation could take many forms.	feedback, or simulations. It could include quantifiable system performance measures, such as response time or availability. Conceptually, such evaluation could include any appropriate empirical evidence or logical proof. At the end of this activity, the researchers can decide whether to iterate back to activity 3 to improve the artifact's effectiveness or to continue with the communication activity and leave further improvement to subsequent projects. The nature of the research and the venue may dictate whether such iteration is feasible.
Communication.	Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as practicing professionals, when appropriate.	Communication requires knowledge of the disciplinary culture.

2.2 The Ontology Development Approaches

A Digital Transformation and Innovation Business Process Management Ontology (DT&I-BPM-onto) (Bogea Gomes, Santoro and Mira da Silva, 2020) was initially built following the Ontology Development 101 approach (Noy and McGuinness, 2001). The goal was to characterize processes and technologies working together to promote transformation.

In order to improve the artifact, both in terms of consistency and correctness, the Unified Foundational Ontology (UFO) (Guizzardi, 2005) is used as the foundational ontology and the Systematic Approach for Building Ontologies (SABiO) (Falbo, 2014) as the ontology development approach into the subsequent research steps. Different from the Ontology Development 101 approach, SABiO includes the conceptualization of the reference and operational ontologies as well as the development and support processes for the domain and core ontologies. The two methods for developing ontologies are then explained.

Ontologies encode knowledge and make them reusable at different levels. They are utilized by individuals, databases, and applications that require information sharing. Ontologies include a range of models of varying degrees of semantic richness and complexity (Obrst et al., 2003). This

thesis adopts a human-oriented approach, producing a conceptual model to transfer knowledge between humans.

2.2.1 Ontology Development 101 Approach

The methodologies proposed in the literature to support the ontological development, aim at the quality in the ontology specification process. Dahlem and Hahn (2009) compared sixteen methodologies for the development of ontologies based on 13 established criteria. Based on this work, the authors set down their main requirements for the choice of a methodology: be user-friendly; use a minimum necessary set of stages and concepts; use clear, unambiguous, and well-defined keywords and concepts; have developmental life cycle stages clearly identified and described in detail; be interactive, that is, offer the possibility to correct mistakes made in previous steps; highlight common mistakes and present ways to avoid them. As result, the "Ontology development 101: A guide to creating your first ontology" methodology proposed by (Noy and McGuinness, 2001). As a first iteration, based on Dahlem and Hahn (2009) work, 101 approach was selected to construct this thesis' first ontology. This methodology considers seven steps in the ontology development process, as depicted in Figure 2.5.

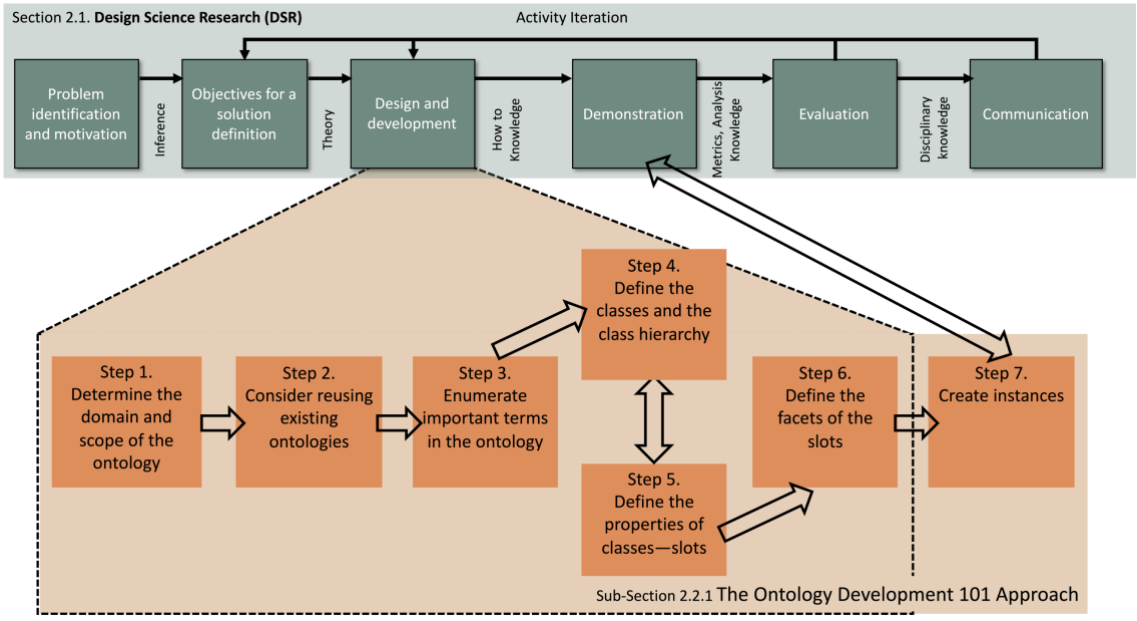

Figure 2.5. The Ontology Development 101 approach based on (Noy and McGuinness, 2001) integrated with DSR based on (Peffers *et al.*, 2007)

Its iterative process involves a formal explicit description of concepts in a domain of discourse (classes, sometimes called concepts), properties of each concept describing various features and attributes of the concept (slots, sometimes called roles or properties), and restrictions on slots (facets, sometimes called role restrictions).

The Ontology Development 101 methodology was proposed in 2001, and since then it has been widely used. According to a Google Scholar search on Nov. 10, 2019, more than 5900 documents cited this methodology. Since 2015, more than 1600 research documents cited it and, in this year

(2019) more than 260 articles citied it, including "Smart city ontologies: Improving the effectiveness of smart city applications" (Komninos et al., 2016) with 64 citations and "A product life cycle ontology for additive manufacturing" (Mohd Ali et al., 2019) with 24 citations.

2.2.2 Systematic Approach for Building Ontologies (SABiO)

The Systematic Approach for Building Ontologies (SABiO) (Falbo, 2014) supports the development of domain and core ontologies, as well as reference and operational ontologies. SABiO prescribes an ontology development process comprising five phases: (1) Identification of Purpose and Elicitation of Requirements; (2) Ontology Capture and Formalization; (3) Design; (4) Implementation; and (5) Testing.

However, since the ontology developed in this thesis is a reference ontology, SABiO's reference ontology development process was used, which involves three phases: (1) Identifying Purpose and Eliciting Requirements, (2) Capturing and Formalizing the Ontology and (3) Testing the Ontology. The Design and Implementation phases are specific to the operational ontology development process.

Moreover, SABiO considers five main supporting processes spanning the development process: Knowledge Acquisition, Reuse, Documentation, Configuration Management and Evaluation. The SABiO's phases and processes used in this thesis are briefly described in Table 2-3.

Table 2-3. Phases and processes used in this thesis based on SABiO (Falbo, 2014).

Development Phase	Description
Ontology Purpose Identification and Requirements Elicitation phase	This phase comprises four activities that occur in an iterative way, all of them involving the participation of the ontology engineer, domain experts and potential ontology users. Initially, it is necessary to identify the ontology purpose and its intended uses. Once they are defined, it is required to elicit its requirements. Ontology requirements, like software requirements, can be divided into functional and non-functional requirements. Functional requirements refer to the knowledge (content) to be represented by the ontology, and can be stated as competency questions, i.e., the questions that the ontology should be able to answer.
Ontology Capture and Formalization phase	The main goal of this phase is to capture the domain conceptualization based on the competency questions. SABiO suggests that concepts and relations in a reference domain ontology are analyzed in the light of a foundational ontology. Ontological analysis can be applied in several scenarios: portions of the ontology that are developed from scratch should be analyzed, as well as non-ontological and ontological resources to be reused. A foundational ontology must be selected for performing this task.
Ontology Testing phase	In SABiO, ontology test refers to the dynamic verification and validation of the behavior of the operational ontology on a finite set of test cases, against the expected behavior based on the competency questions. In this sense, SABiO's testing phase

	is competency questions-driven, and considers mainly black-box testing, although white-box testing can also be applied.
Support Process	**Description**
Knowledge Acquisition Process	Knowledge acquisition occurs mainly in the initial phases of the ontology development process. Conventional methods and techniques for knowledge acquisition and requirements elicitation applies, mainly those devoted to collaborative knowledge acquisition, such as brainstorming.
Reuse Process	Along the development process, many opportunities exist for reusing conceptualizations already established for the domain. Typically, these are the primary sources for reuse: existing domain ontologies, core ontologies, foundational ontologies, and ontology patterns. Existing ontologies for the domain can be totally or partially reused.
Documentation Process	Results from the ontology development process must be documented. Moreover, results from some support processes, such as evaluation, must also be documented. So, documentation is a process that must occur in parallel with the others.
Configuration Management Process	The primary documents proposed by SABiO and the source code of the operational ontologies must have their configuration managed. Thus, once approved, they must be submitted to Configuration Management, where they will be controlled at least concerning changes, versions, and delivery.
Evaluation Process	According to Falbo (2014) ontology testing is an evaluation process in reference ontology. SABiO's evaluation process comprises two main perspectives: (i) Ontology Verification: aims to ensure that the ontology is being built correctly in the sense that the output artifacts of an activity meet the specifications imposed on them in previous activities. (ii) Ontology Validation: aims to ensure that the correct ontology is being built, that is, the ontology fulfills its specific intended purpose.

Figure 2.6 illustrates the relationship between the DSR and SABiO methodologies developed for this thesis. Later in this thesis, the case study methodology and the publication strategy are discussed.

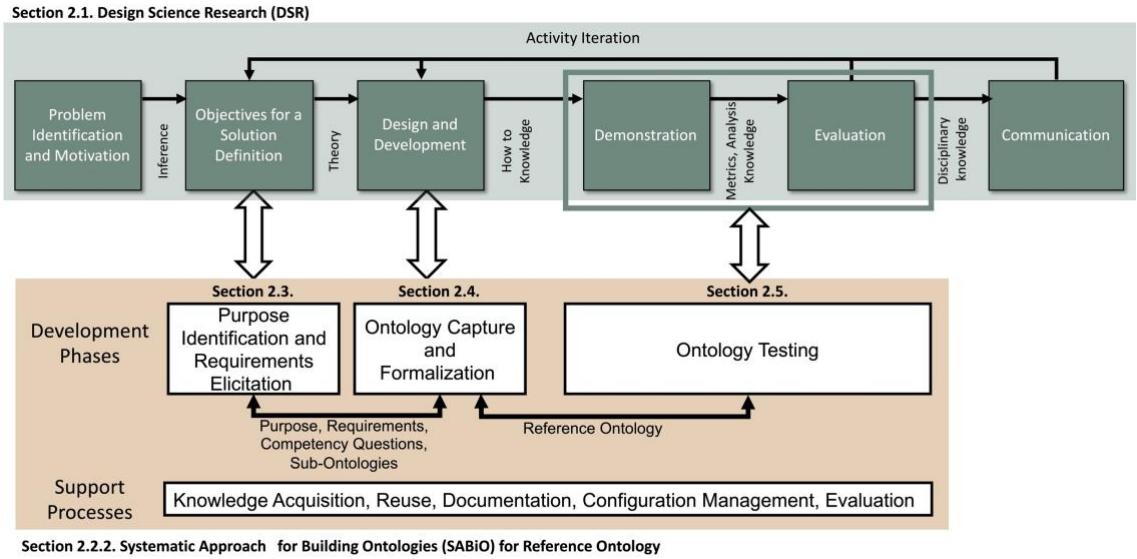

Figure 2.6. The correlation between DSRM and SABiO designed in this thesis.

2.3 SABiO's Purpose Identification and Requirements Elicitation

An essential part of conducting research is identifying extant research on the chosen theme to evaluate and make rational and scientific decisions (Kitchenham and Charters, 2007). Understanding the chosen theme's state-of-the-art involves summarizing the existing evidence, identifying gaps in current research, and providing an appropriate position concerning this theme. Systematic Literature Review (SLR), Systematic Mapping Study (SMS), and Bibliometrics are some research methods for a literature review.

2.3.1 Methods for Literature Review

The earlier research knowledge typically exists in research literature found in journals, conference proceedings, books, and gray literature. The SLR and SMS methodologies include three main phases: planning, conducting and reporting (Barn, Barat and Clark, 2017). They essentially differ in terms of their review design characteristics. SLR and SMS's research questions, search process, search strategy requirements, quality evaluation, and results (Petersen, Vakkalanka and Kuzniarz, 2015) differ according to the type of literature study.

According to these authors, the research questions in SMS are general, as to discover research trends. On the other hand, those of SLRs are more specific, as at aggregating evidence, and Bibliometrics is generally only limited by the boundaries of the topic analyzed. This main difference impacts the research process. The pursuit for SMS and Bibliometrics is based on a topic area (width), while specific research questions drive SLR (depth). In one topic area (width), various SLRs (depth) may be conducted.

Besides, the search requirements are less stringent for SMS, while in SLR and Bibliometrics, all available studies must be searched for. This also means that quality assessment is essential in SLR and Bibliometrics to determine the rigor and relevance of the primary studies, whereas in SMS, no quality assessment is needed. The outcome of an SMS is an inventory of documents on the topic area mapped to a classification. Hence, an SMS provides an overview of the scope of the area and allows one to discover research gaps and trends.

Bibliometrics also analyzes the scientific performance of articles, authors, institutions, countries, and journals based on their number of citations, to reveal the field's study trends through the analysis of keywords and to identify and cluster scientific gaps from the most recent publications. The differences between these three methods are summarized in a comparative table (see Table 2-4), with the characteristics for SLR and SMS cited from (Petersen, Vakkalanka and Kuzniarz, 2015) and those of Bibliometrics based on (de Oliveira et al., 2019) which analyze the same characteristics. Moreover, one additional characteristic is included: the goal.

Table 2-4. SMS, SLR and Bibliometrics.

About	Systematic Literature Review (depth)	Systematic Mapping Study (width)	Bibliometrics
Goal	To focus on gathering and synthesizing evidence.	To provide an overview or to structure a research area.	To identify paths and new directions in a topic of a research area.
Research questions	General. Aims at aggregating evidence, and hence a particular goal must be formulated (e.g., whether an intervention is practically useful in the industry).	Specific. Aims to discover research trends (e.g., publication trends over time, topics covered in the literature).	Limited by the boundaries of the topic analyzed. Aims at mapping the state-of-the-art and identifying research gaps and trends, applying quantitative or statistical methods.
Search process	Driven by specific research questions.	Based on a topic or research area.	Based on a topic area.
Search strategy requirements	All studies must be found.	Less stringent as only research trends are of interest.	All studies must be found.
Results considering the existing literature	Answers the research questions formulated.	Explores the subjects covered in the topic and trends.	Determines an array of significant indicators for measuring the bibliographic material.

2.3.2 Literature Review Phases (SMS and SLR)

The stages in a literature review are divided into in three main phases: **Planning**, **Conducting** and **Reporting** the review. The literature review starts with a **Planning phase** that confirms the need for the review and the research questions, besides defining a review protocol, including sources searched, search strategy, and the inclusion, and exclusion criteria. It represents the structure of the study. To support the literature review phases, the online tool Parsif[8] was used.

In the **Planning phase**, the search strategy string was elaborated regarding PICOC (Population, Intervention, Comparison, Outcomes, and Context). The Population in which the evidence is collected. The Intervention applied in the empirical study, i.e., which theme is under study? The Comparison to which the Intervention is compared. The experiment's Outcomes should be not only statistically significant but also significant from a practical point of view. The study Context must be defined as a comprehensive view of the population, including whether it is conducted in the academia or industry, in which industry segment, and the incentives for the subjects (Wohlin et al., 2012). Also, it must focus on the most relevant databases for the study area, such as Web of Science, EBSCO, Google Scholar, and Scopus.

Next, the **Conducting phase** involves the search and selection of literature, and the summarization of evidence. Each data extraction field has a data item and a value. The information for each item extracted is tabulated. The extracted strategies are grouped. The documents belonging to each theme are counted, and their sub-themes are identified. The sub-themes for the inclusion and exclusion process were known a priori. Validity classification schemes defined before are applicated (Petersen, Vakkalanka and Kuzniarz, 2015).

Finally, the **Resulting phase** focuses on specifying dissemination mechanisms and formatting the main report.

This thesis' first literature review was identified as a quasi-systematic literature review since it is an exploratory study designed to characterize a research area. No baseline is applied to compare the results obtained (i.e., the Comparison of PICOC was not done), as it aims to establish an initial knowledge baseline for future primary study comparisons. However, it continues to explore the methodological phases of protocol preparation and runs with the same rigor and formalism (Travassos et al., 2008).

2.3.3 Bibliometric Analysis Method

The concept of bibliometrics, or bibliometric analysis, was introduced by Alan Pritchard in 1969, growing exponentially since the advent of the Internet (Roig-Tierno, Gonzalez-Cruz and Llopis-Martinez, 2017). Bibliometric analysis is a discipline that applies statistical methods to evaluate developments and knowledge enhancements regarding a specific subject and to assess the scientific quality and influence of the distinct works and sources (Albort-Morant *et al.*, 2018). Its

[8] https://parsif.al/

application in a study's initial phase could ensure that relevant references to the literature are considered. In addition, it shed light on the literature gaps, which could substantiate the scientific demand and originality of the proposed study (de Oliveira *et al.*, 2019).

The bibliometric analysis is used to measure and compare the scientific output, research groups, institutions, regions, or countries using indicators based on the number of publications, the citations received, and the collaborations. Moreover, it could identify the most important or influential journals in a given field and monitor the evolution of a discipline or research subject over time (El Mohadab, Bouikhalene and Safi, 2020). This bibliometric analysis was conducted using the method stages based on (de Oliveira *et al.*, 2019), as seen in Figure 2.7.

Figure 2.7. Bibliometric analysis method stages based on (de Oliveira *et al.*, 2019).

Bibliometric methods utilize several tools to help researchers identify a relevant and current research problem. **Bibliometric indicators** could give more consistency to the research project since they use statistics from different bibliographic databases that differ in scope, data volume, and coverage. The **research project objectives and methods** could clearly and concisely illustrate the scientific gaps in the field with the development of the research project based on bibliometric analysis. The main objective of analyzing the gaps in the literature was to provide the researcher with ways to identify opportunities for exploring new relevant topics of a given field of research, as well as studies that had not been fully explored and which required the development of further studies to advance the state of the art of a particular theme (de Oliveira *et al.*, 2019).

2.4 SABiO's Ontology Capture and Formalization

This thesis proposal is an ontology grounded in the Unified Foundational Ontology (UFO) (Guizzardi, 2005; Guizzardi, Falbo and Guizzardi, 2008; de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011; Botti Benevides *et al.*, 2019). UFO is an axiomatic formal theory founded on contributions from Formal Ontology in Philosophy, Philosophical Logic, Cognitive Psychology, and Linguistics. UFO has been conceived as a conceptual modeling foundation.

UFO is the second-most used foundational ontology in conceptual modeling language, with the fastest adoption rate (Verdonck and Gailly, 2016). This study also demonstrates that OntoUML is one of the most popular ontology-driven conceptual modeling. UFO is structured into three modules; UFO-A (an ontology of Endurants) (Guizzardi, 2005), UFO-B (an ontology of Events) (Botti Benevides *et al.*, 2019), and UFO-C (Guizzardi, Falbo and Guizzardi, 2008; de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011) (an Ontology of Social and Intentional Entities). UFO-A and UFO-B are directly reflected in the modeling primitives of OntoUML, as well as in the constraints that govern the relations between these primitives. UFO-C has been built on top of UFO-A and UFO-B to systematize social concepts such as plan, action, goal, agent,

intentionality, commitment, and appointment, among many others. UFO-C, however, is represented as an OntoUML library with general categories that are later specialized by the corresponding domain-specific notions.

OntoUML is the UFO-based modeling language (Guizzardi, 2005). It is an extension of UML Class Diagrams whose meta-model conforms to the ontological distinctions and axiomatization of UFO (Guizzardi, 2005; Almeida, Falbo and Guizzardi, 2019; Fonseca *et al.*, 2019; Guizzardi *et al.*, 2021) OntoUML is the modeling language used in this thesis. In Chapter 3, Research Background, the UFO theory will be presented in the OntoUML language.

2.5 SABiO's Ontology Testing

2.5.1 Ontology Demonstration and Evaluation Methods

According to Brank, Mladenić and Grobelnik (2006), various ontology evaluation approaches have been considered in the literature for different evaluation types and purposes. They present the following categories of evaluation: (b1) those based on comparing the ontology to a gold standard ontology[9], (b2) those based on using the ontology in an application and evaluating the results, (b3) those involving comparisons with a data source (e.g., a collection of documents) from the domain to be covered by the ontology, (b4) those in which evaluation is done by humans who try to assess how well the ontology meets a set of predefined criteria as standards and requirements.

(Suarez-Figueroa, Kamel and Poveda-Villalon, 2013) also consider different approaches to help developers during the ontology evaluation process: (s1) comparison of the ontology to a "gold standard", (s2) detection of common errors from catalogues in the ontology, (s3) use of dimensions and criteria for describing the quality and goodness of the ontology, (s4) use of the ontology in an application and evaluation of the results, (s5) comparison of the ontology with a data source from the domain to be covered, and (s6) evaluation by experts who check the ontology against the requirements. In addition, according to those authors, ontology evaluation can be supported by natural language processing techniques.

(Walisadeera, Ginige and Wikramanayake, 2016) argue that there is no agreed method or approach to evaluate an ontology in the current literature. The choice of a suitable approach depends on the purpose of validation or evaluation, the application in which the ontology is to be used, and what aspect of the ontology one is trying to validate or evaluate.

[9] "gold standard" in the sense of comparing the syntax in the ontology definition with the syntax specification of the formal language in which the ontology is written (e.g. RDF, OWL, etc.) (Brank, Mladenić and Grobelnik, 2006)

A similar approach to the works of (Brank, Grobelnik and Mladenic, 2005) and (Suarez-Figueroa, Kamel and Poveda-Villalon, 2013) was taken as the basis to evaluate the coverage and precision criteria of COOT and DODT, that is, the ontology was used in an application and the results were evaluated.

2.5.2 SABiO's Ontology Testing through Case Studies

DSR demonstration focuses on applying the artifact to assess whether it is able to solve one or more instances of the problem (Peffers et al., 2007). SABiO ontology verification ensures that the ontology is being built correctly (Falbo, 2014). An assessment-by-human approach was used for the **verification**, confirming that the concepts and relations defined in DTO (COOT and DODT) were able to answer the competency questions.

DSR evaluation compares the objectives of a solution to observe the results from the use of the artifact (Peffers et al., 2007). SABiO ontology **validation** ensures that the correct ontology is being built (Falbo, 2014). A single-case study approach was used for the validation of each ontology: Keyn'Go® for COOT and BUPi for DODT.

SABiO's Verification aims to ensure that the ontology was built correctly, i.e., the artefact meets the competency specifications imposed at the outset. For verification, SABiO suggests checking whether the ontology meets its requirements during the Ontology Capture and Formalization phase. This can be done by indicating which ontology elements (concepts and relations) are able to answer each competency question formulated. , The use of the artifact to solve one or more instances of the problem is demonstrated. This is done by using internet data and literature about UBER (a successful disruptive public case) and ArchiSurance (an artificial case for ArchiMate testing).

SABiO's Validation, on the other hand, aims to ensure that the right ontology was built, i.e., the ontology fulfils its specific intended purpose. The methodology suggests that potential users evaluate whether the ontology suits their intended uses to demonstrate that the reference ontology can represent real world situations. In this thesis, data from a real case is used to instantiate the ontology (in line with (Duarte *et al.*, 2018)). The artifact is evaluated by using two successful real case. (1) InterRent®, a subsidiary of Europcar, a global car rental company, reimagined its business by proposing a digital innovation business model called Key'n Go®. It is a successful digital transformation case because InterRent® significantly increased its Net Promoter Score (NPS) by digitizing an end-to-end process, generating a new product called Key'n Go®. (2) BUPi (in Portuguese Balcão Unico do Predio, which directly translates to "Unique Registration of Building) is a Portuguese government platform for identifying, mapping, and understanding the Portuguese territory, intending to simplify land registration through the use of a digital environment and based on the principles of a single point of contact and citizen involvement. It is a work in progress. It will implement a new Portugal land registry digital process by creating a unique Property Identification Number (NIP) using a single digital platform that

combines an integrated and interoperable process and data between all the Portuguese government institutes involved in Portugal's land registry.

2.5.3 Case Study Method

A case study consists of a detailed investigation of one or more organizations, or groups within organizations, intending to provide an analysis of the context and processes involved in the phenomenon under study. Case studies are tailor-made for exploring new or less understood processes or behaviors. An important advantage of case study research is the opportunity for a holistic view of the process (Meyer, 2001).

The case study method is an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not evident, when using multiple sources of evidence (Yin, 1992). The information is gathered from a few entities (people, groups, and organizations) though there is a lack of experimental control. This research methodology adds to existing knowledge by being based on a previously established theory, if such exists, or contributes to the building of a theory (Runeson and Höst, 2009).

One type of research methodology does not fit all purposes (Runeson and Höst, 2009). Purpose can be exploratory, descriptive, explanatory, and concept improving types. The main difference between case studies and other qualitative designs such as grounded theory and ethnography is that a case study uses theory or conceptual categories that guide the research and analysis of data (Meyer, 2001).

The case study methodology was originally used for exploratory purposes. However, it is also used for descriptive purposes. Available types of research perspectives are positivist, critical and interpretative. An interpretative case study attempts to understand phenomena through the participants' interpretation of their context. Data collected in an empirical study may be quantitative or qualitative. Its conclusions are based on a clear chain of qualitative or quantitative evidence collected from multiple sources in a planned and consistent manner. The qualitative case study methodology enables researchers to explore complex phenomena within some specific context (Rashid *et al.*, 2019).

Triangulation is essential to increase the precision of empirical research, taking different angles towards the studied object and providing a big picture. Four different types of triangulations - data, observer, methodological and theory triangulation - may be applied. Hence, a case study will never provide conclusions with statistical significance. On the contrary, many different pieces of evidence are linked together to support a solid and relevant conclusion.

Besides, the research process may be characterized as fixed or flexible. Case study is a flexible type, coping with the complex and dynamic characteristics of real-world phenomena. There are four significant process steps to be taken when conducting a case study (Runeson and Höst, 2009): case study design and planning, data collection, data analysis and reporting.

Case study has already been amply promoted as an evaluation tool. Evaluation is a particular type of research aiming at assessing and explaining the results of demonstrations, which are projects or programs operating in various real-life fields (Yin, 1992).

Chapter 3

Research Background

The foundation for developing and evaluating the Digital Transformation Ontology (DTO), a reference model representing the digital transformation paradigm, is presented in this Chapter.

The first step of the thesis was a systematic mapping study (SMS) aimed to identify the main concepts and constructs that contribute to conceptualizing digital transformation and digital innovation (Section 3.1). As a result, it mapped the notions of organization, digital, and transformation as central points of this thesis. Its concepts and characteristics are presented in the following sections. The organizational transformation, a type of organizational change creates a new vision for organization (Porras and Silvers, 1991) (Section 3.2). Organization represents a collection of people organized together into a community or other social, commercial or political structure (Binder and Clegg, 2007) (Section 3.3). Digital transformation is a type of organizational transformation that changes societies and industries by the convergence of multiple new digital technologies enhanced with ubiquitous connectivity (Beverungen *et al.*, 2021) (Section 3.4).

The information technology incorporation into business processes is not enough to allow organizations to be innovative and remain competitive in the Digital Age (Brocke, Zelt and Schmiedel, 2016); instead, it is essential to identify relevant contexts for the adequacy of the Business Process Management (BPM) approach. The BPM and Digital Innovation are joint directions for organizations to change and improve (Van Looy, 2015). Digital transformation is about digital technology as well as processes. The characteristics and concepts of Digital Technology, a type of digital object (Faulkner and Runde, 2009, 2011, 2013, 2019), have a technical identity mediated by its structure, social function, and component parts, which include one or more bitstrings (Bogea Gomes, Santoro and Mira da Silva, 2022b) (Section 3.5). BPM is a systematic approach to overseeing work to ensure consistent outcomes and take advantage of improvement opportunities. BPM manages chains of events, activities, and decisions that add value to the organization and its customers, referred to as processes (Dumas *et al.*, 2018) (Section 3.6). BPM capabilities are the basis for maturity models that address how capabilities can be develop along an anticipated, desired, or logical path (Kerpedzhiev *et al.*, 2020) (Section 3.7).

Section 3.8 introduces the Unified Foundational Ontology (UFO) and the UFO-based modeling language OntoUML. Section 3.8.1 summarizes UFO-A (an ontology of Endurants). Section 3.8.2 explains UFO-B (an ontology of Events). Section 3.8.3 describes UFO-C (an ontology of Social and Intentional Entities). Section 3.9 describes the COVER ontology, which defines the value notion utilized in this thesis.

Figure 3.1 presents the core conceptualization of each section, representing the main contributions of that section to the thesis.

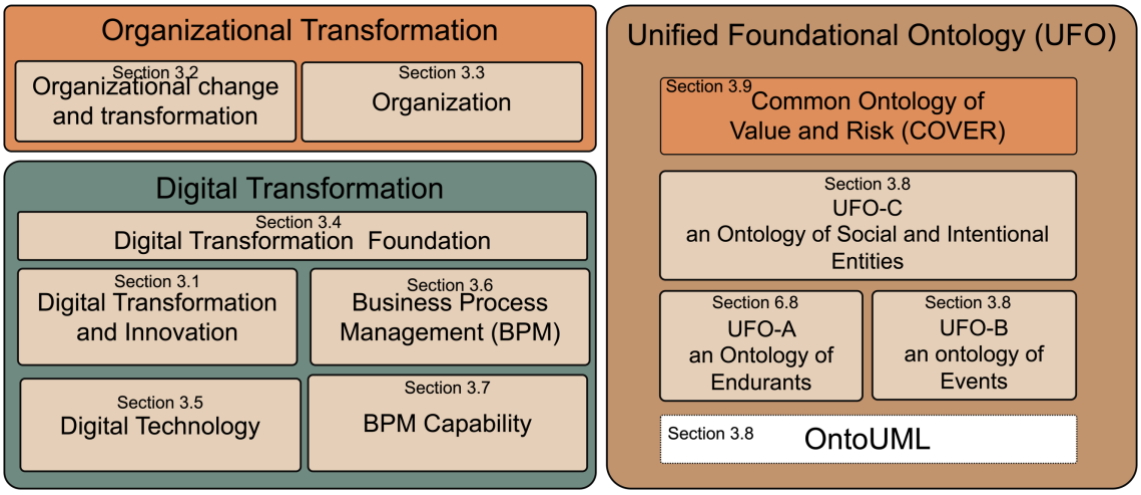

Figure 3.1. The thesis development foundation.

3.1 Digital Transformation and Innovation

Digital transformation and **digital innovation** are becoming increasingly popular in academic fields. The contribution to this field started with a Systematic Mapping Study (SMS) (Bogea Gomes, Mira da Silva and Santoro, 2019) about the main concepts and constructs that contribute to conceptualizing digital transformation and digital innovation. The context of the investigation was academic and industrial publications.

The **SMS Planning Review Process Phase** serves as the study's structure. It outlines the study objectives and research questions. This SMS should aid in comprehending digital transformation and innovation definitions. The related research question is *What constructs contribute to the conceptualization of digital transformation and digital innovation?* For that, the search string specified includes the terms "concept", "definition", and "construct", "strategy" (associated with a general notion or idea), "model", "ontology", and "new" to identify the papers sought.

The intention is to collect documents describing successful cases (those that added value). In addition, it would like to know what research has already been conducted on the topic, which is why it included the terms "systematic review" and "systematic literature review", generating the SMS's final search string:

> *Title:("digital transformation "OR "digital innovation ") AND Abstract:((systematic AND review) AND (concept OR ontology OR definition OR model OR new OR value OR strategy OR success OR construct))*

A thorough search of relevant literature reviews, case/experience reports, and papers involving concepts/definitions, business processes, and conceptual models/ontologies was conducted to understand what other researchers in this field have already developed. However, we did not consider papers that lacked concepts with their meanings and definitions, were not written in English, or could not access their full text.

• Inclusion Criteria: Cases / Experiences; Concentration on Business Process; Concentration on Concepts / Definitions; Concentration on Conceptual Models / Ontologies; Literature review.

• Exclusion Criteria: Duplicate document and lack of full text; Not written in English; Not access Referenced article (only citation).

ACM Digital Library, IEEE Digital Library, Scholar Google, Science@Direct, Scopus, and Springer Link were selected as the most pertinent databases for the BPM and Information Systems (IS) disciplines. The search was restricted to the title, abstract, and keywords; the publication year was not a factor. It included theses, technical reports, journal articles, and conference papers.

The search string was created and run in the **SMS Conducting Review Process** according to the rules of each source. As a result, 733 papers were found from various sources. It identified 150 duplicates in the subsequent step. The 583 abstracts were read to pre-select and accept the 76 documents that fit the topic scope, as presented in Table 3-1. Then, the papers were sorted according to their similarities and applied the inclusion criteria to start analyzing the results.

Table 3-1. Number of papers selected by criteria.

Accepted		Rejected	
Literature review	13	Full text not available	19
Focus on concepts / definitions	18	Not written in English	1
Focus on conceptual models / ontologies	18	Out of scope	483
Cases / Experiences	10	Referenced paper (only citation)	4
Focus on Business Process	17	Total	507
Total	76		
Duplicated		Total	150

The 76 documents were examined for conceptualizations, meanings, and definitions of digital transformation and innovation. Then, it ended up with 56 articles to work on. With these 56 articles selected, I started identifying the constructs that contribute to conceptualizing digital transformation and digital innovation. Figure 3.2, depicts this procedure based on pre-processing techniques for text mining (Vijayarani, Ilamathi and Nithya, 2018). These authors define text mining as discovering helpful information from text documents, also called knowledge discovery in text (KDT) or knowledge of intelligent text analysis.

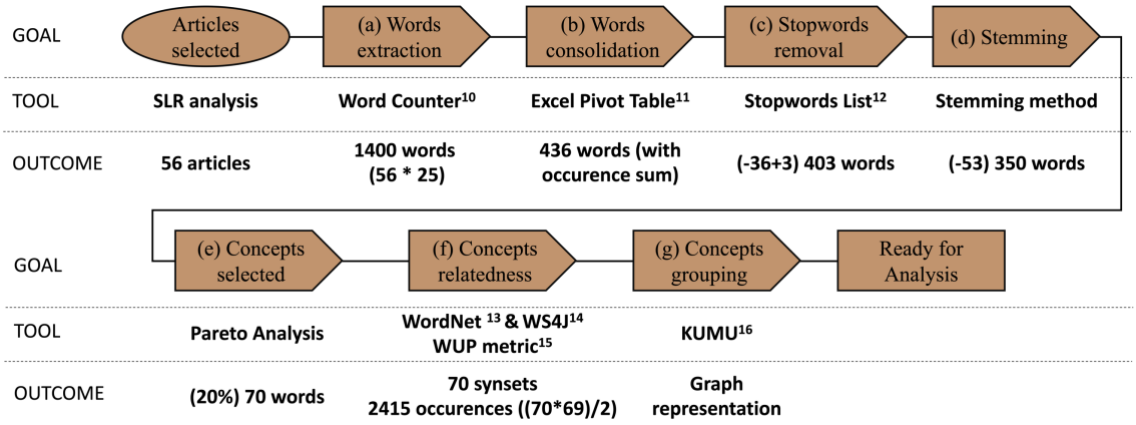

Figure 3.2. The preprocessing for constructs analysis based on (Vesti *et al.*, 2017).

(a) Words extraction - A list of the first 25 words that most appear in the texts (the minimum number of words offered) were selected, because the more words selected from each text (50, 100, ...), the bigger the set of words is highlighted, and the result could be dispersed. So, for each of the 56 papers, the Wordcounter[10] presented the 25 most used words and how often each of the 25 words appeared in the paper. It resulted in a list of 1400 words (56 papers * 25 words) and the number of occurrences in each paper.

(b) Words consolidation - As expected, some words appeared in more than one paper. So, the 1400 words were consolidated in a list of 436 different words that appeared in the 56 papers (using excel Pivot Table[11]), with the sum of the number of occurrences that each word appeared in all 56 papers.

(c) Stopwords removal - Stop words (or stopwords) are the most common words in a language. There are some lists of stop words used by natural language processing (NLP) tools. Although the Wordcounter had excluded the "link words" before, it is not enough. Additionally, the stopwords were removed from the 436 different words list, using the Long Stopword List[12] (as for example, able, home, see). Also, the words Digital, Innovation, and Transformation were removed, because they are the universe of our research and mandatory in the title of the research query. As an outcome, 36 stopwords were eliminated. However, three words classified in the list of stopwords were maintained as for this study should not be considered as stopwords: information, new and value.

(d) Stemming - According to Vukšić, Ivančić and Suša Vugec (2018), the purpose of this method is to remove various suffixes, to reduce the number of words, to have accurately matching stems. It is used to identify the root/stem of a word. Words that do not have the same meaning should be kept separated. So, the words set to identify roots or stems were analyzed. Root cases were found, such as regard / regarding / regards, result / results, and so on; and also, equivalent cases, such as, etal / et-al, R&D / research and others. Moreover, e-mails site addresses, and trademarks, like Amazon, Google, Apple, and ThyssenKrupp were found. Vukšić, Ivančić and Suša Vugec (2018) consider that one of the stemming purposes is reducing a word different grammatical forms like its noun, adjective, verb, and adverb. This study transformed all the words that are not a noun to its noun equivalent (e.g., manage to management, develop to development) to allow the comparison at the next step.

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[10] https://wordcounter.io/

[11] "A pivot table is a table of statistics that summarizes the data of a more extensive table (such as from a database, spreadsheet, or business intelligence program). This summary might include sums, averages, or other statistics, which the pivot table groups together in a meaningful way" (source: https://en.wikipedia.org/wiki/Pivot_table).

[12] https://www.ranks.nl/stopwords

(e) Concepts selected - In this step, the Pareto diagram were used, a well-known column chart, which orders the words by occurrence frequencies, from highest to lowest. It supported the prioritization of the words by taking into account the Pareto principle (80% of the consequences come from of 20% of the causes). This case considered 20% of words that occur more times in the 56 papers. In Table 3-2 can be observed in the total, 350 words occur 36616 times. The 20% of words that occur most frequently (70 words), has the sum of occurrences (27135 occurrences) that represent 74% of occurrences. Moreover, 80% of the remaining 279 words represent 9381 occurrences (26%). So, Pareto's Principle fits well in this case.

Table 3-2.Words organized in the Pareto's Principle.

	Word	Sum of # occurrences	% of occurences
20%	70	27135	74%
80%	280	9481	26%
Total	350	36616	

Table 3-3 contains the 70 words list with their total number of occurrences in the 56 papers.

Table 3-3. Seventy Words List classified in #occurrence descending order.

Word	# occur	Word	# occur	Word	# occur	Word	# occur
business	2203	study	459	ecosystem	212	open	128
technology	1452	design	416	architecture	197	culture	119
model	1424	case	399	component	195	experience	119
newness	1360	information	385	employee	190	impact	116
organization	1111	bank	377	market	189	evaluation	112
service	1035	firm	367	layer	180	offer	111
customer	1012	change	363	support	171	path	110
value	894	knowledge	344	field	170	information technology	107
company	814	resource	317	theory	162	manufacture	107
product	791	network	303	recombination	157	capability	106
process	784	platform	296	review	150	focus	106
management	766	literature	271	actor	148	project	106
digitization	661	mobility	261	physical	142	activity	102
user	530	artifact	253	cluster	133	channel	101
development	522	industry	241	practice	133	definition	101
strategy	504	work	240	provide	131	institutional	101
data	494	expert	221	social	131	mature	101
system	493			framework	128		

(f) Concepts relatedness - Aiming to analyze the relationship between these 70 words, semantic measures were used. According to Adhikari *et al.* (2015), semantic measures are widely used to assess the semantic relationship closeness between elements (informally, how a word A is related to a word B). Besides, the authors consider two types of semantic measures: similarity and relatedness. Semantic similarity "considers only taxonomical relationships for measuring the

semantic strength between two concepts, e.g., rafting and water polo both are similar because both are water sports." While the semantic relatedness "considers taxonomic and nontaxonomic relations (e.g., meronymy, functionality, cause-effect, etc.) between concepts, e.g., food poison and stomach pain both are related. Food poison is the cause of stomach pain." Summing up, in general it can say that words' similarity means how close to be synonyms the two words are. In the other hand, words' relatedness characterizes a larger set of potential relationships between words, which means several types of relationships. For instance, antonyms have a higher relatedness (they essentially belong to the same semantic type) but low similarity (they are not very similar at all). This work focuses on the semantic relatedness between two concepts.

I chose Princeton's English WordNet 3.0 lexical database[13] to measure the semantic relatedness between the concepts selected in the papers,. Wordnet is an online Knowledge Base thesaurus that groups words together based on their meanings. "Nouns, verbs, adjectives and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations". Besides, the WS4J (WordNet Similarity for Java)[14] was selected for measuring semantic similarity/relatedness between the words identified using the Wordnet. From the semantic relatedness/similarity metrics available in WS4J, the WUP relatedness metrics was selected to analyze the relationship between the concepts, because it calculates the relatedness metric by considering the depths of the two synsets in the wordnet taxonomies, along with the depth of the LCS (Least Common Subsumer)[15].

The LCS of two concepts A and B is "the most specific concept which is an ancestor of both A and B". For instance: a car is an automobile, and an automobile is a vehicle; a boat is a vehicle; vehicle is an object. In this case, "automobile" is the parent (and also ancestor) of "car", while "vehicle" is an ancestor of "car". "Vehicle" is also an ancestor of "boat". In this case, the LCS of "boat" and "car" is "vehicle", since it is the most specific concept which is an ancestor of both "boat" and "car". Note that while "object" is a common subsumer of both "boat" and "car", it is not the least, since there is still a child of "object" (in this case it's "vehicle") which is also a common subsumer of both "car" and "boat". "Automobile" is not the least common subsumer since it's not an ancestor of "boat". Each of the 70 words has their correspondent synset identified, using the common meaning of the words in the papers' text.

The next step was comparing each of the 70 selected synset in WordNet with the other 69 synsets, generating a list 2415 occurrences (not 4830, since the concept order does not matter

[13] https://wordnet.princeton.edu/

[14] http://ws4jdemo.appspot.com

[15] https://stackoverflow.com/questions/18629469/what-is-least-common-subsumer-and-how-to-compute-it

in this case). This list of 2415 occurrences have as attributes the synset 1, the synset 2, and the Degree of Relatedness between these two concepts, using WUP metric.

(g) Concepts grouping - In this step, Kumu[16] software which is considered as "a powerful data visualization platform that helps organize complex information in interactive relationship maps" was selected to analyze this network. The data (the 205 connections of the 70 elements with the relatedness metric greater than 60%) was imported into Kumu software.

Kumu has four chart layouts: System, Stakeholder, SNA (Social Network Analysis), and Custom. Each of them has a different goal. The SNA type was identified as the more adequate for this thesis, as "the template lets you identify key influencers, power structures, funding flows and more". The Graph generated by Kumu, considering the words and their connections with relatedness more than 0.6, is presented in Figure 3.3.

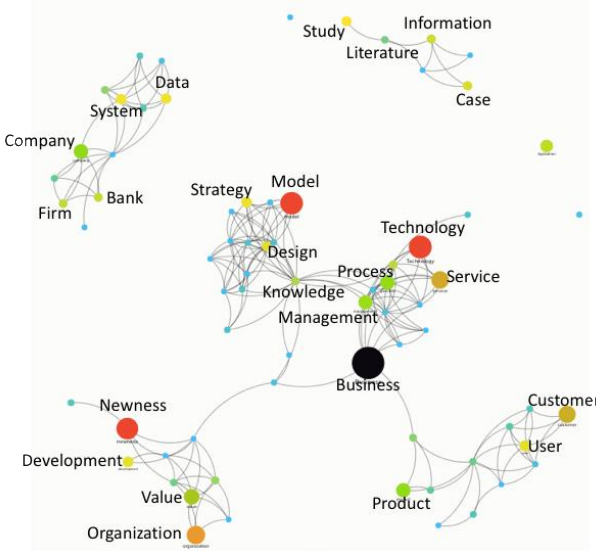

Figure 3.3. Graph Visualization considering connections with relatedness more than 0.6.

From now on, the analysis was done using the synset path, from the root until the word. For instance, the word business, has 10 synsets in the synset path selected. The synset #2 was selected as the meaning of the word business used in the papers, that means:

> S: (n) commercial enterprise, business enterprise, business (the activity of providing goods and services involving financial and commercial and industrial aspects) "computers are now widely used in business"

And the synset path is:

> [1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < psychological_feature#n#1 < event#n#1 < group_action#n#1 < transaction#n#1 < commerce#n#1 < business#n#2

[16] https://kumu.io/

[2] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < psychological_feature#n#1 < event#n#1 < act#n#2 < group_action#n#1 < transaction#n#1 < commerce#n#1 < business#n#2

Following the same rationale, it consolidated the words by their synset path (see Figure 3.4), but detailing more, it could map the graph in two levels: the cluster level (Figure 3.5) and the construct level (Figure 3.6). It uses construct meaning as “concept, conception, construct (an abstract or general idea inferred or derived from specific instances)” and cluster meaning as “a group of several similar things”. Both definitions were derived from WordNet.

newness#n#1	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < property#n#2 < age#n#1 < newness#n#1
computer_architec	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < property#n#2 < constitution#n#4 < structure#n#2 < computer_architecture#n#2
resource#n#2	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < quality#n#1 < asset#n#1 < resource#n#2
focus#n#3	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < quality#n#1 < comprehensibility#n#1 < clarity#n#1 < focus#n#3
mobility#n#1	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < quality#n#1 < mobility#n#1
organization#n#5	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < quality#n#1 < regularity#n#2 < orderliness#n#1 < organization#n#5
value#n#2	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < quality#n#1 < worth#n#2 < value#n#2
activity#n#2	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < state#n#2 < activity#n#2
development#n#7	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < state#n#2 < condition#n#1 < improvement#n#3 < development#n#7
maturity#n#2	[1] *ROOT*#n#1 < entity#n#1 < abstraction#n#6 < attribute#n#2 < state#n#2 < maturity#n#2

Figure 3.4. Synsets and their paths.

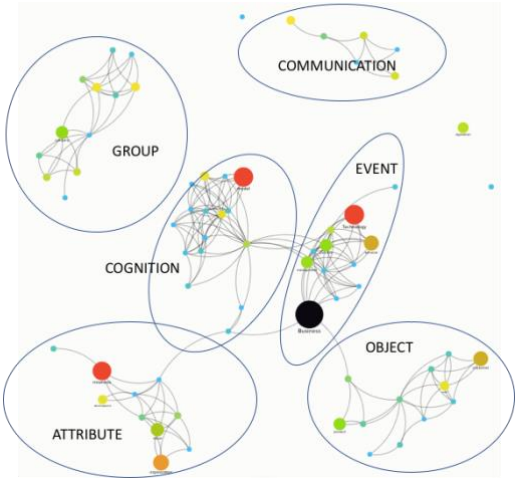

Figure 3.5.Cluster Level of Graph Visualization.

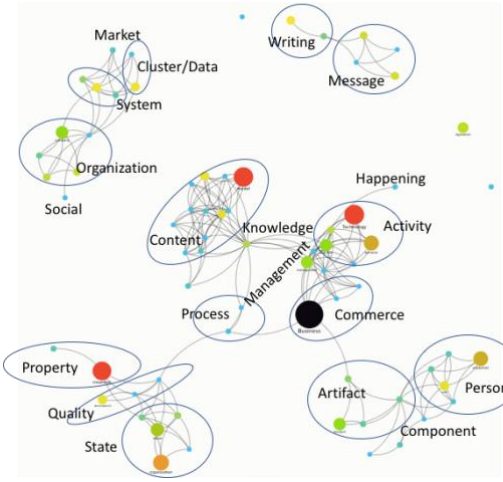

Figure 3.6.Construct level of Graph Visualization.

This study identified as Clusters: Group, Communication, Cognition, Attribute, Event and Object. The Group and Communication are independent Clusters, but Cognition (result of learning and reasoning) and its Attributes are associated with the Object through the Event. The Constructs identified from the Clusters are detailed in Table 3-4.

Table 3-4. Clusters and Constructs identified.

CLUSTER	Construct	Definition (in WordNet)	Main characteristics (from 70 Words associated)
ATTRIBUTE		S: (n) attribute (an abstraction belonging to or characteristic of an entity)	
	Property	S: (n) property (a basic or essential attribute shared by all members of a class) "a study of the physical properties of atomic papers"	newness; computer architecture
	Quality	S: (n) quality (an essential and distinguishing attribute of something or someone) "the quality of mercy is not strained"--Shakespeare	resource; focus; mobility; organization (as system synonym); value
	State	S: (n) state (the way something is with respect to its main attributes) "the current state of knowledge"; "his state of health"; "in a weak financial state"	activity; development; maturity
COMMUNICATION		S: (n) communication (something that is communicated by or to or between people or groups)	
	Message	S: (n) message, content, subject matter, substance (what a communication that is about something is about)	information; offer; definition; case
	Writing	S: (n) writing, written material, piece of writing (the work of a writer; anything expressed in letters of the alphabet (especially when considered from the point of view of style and effect)) "the writing in her novels is excellent"; "that editorial was a fine piece of writing"	study; literature
GROUP		S: (n) group, grouping (any number of entities (members) considered as a unit)	
	Collection	S: (n) collection, aggregation, accumulation, assemblage (several things grouped together or considered as a whole)	cluster, data
	Market	S: (n) market (the customers for a particular product or service) "before they publish any book they try to determine the size of the market for it"	
	Social	S: (adj) social, societal (relating to human society and its members) "social institutions"; "societal evolution"; "societal forces"; "social legislation"	
	Organization	S: (n) organization, organisation (a group of people who work together)	firm; industry; institution; company; bank

CLUSTER	Construct	Definition (in WordNet)	Main characteristics (from 70 Words associated)
	System	S: (n) system, scheme (a group of independent but interrelated elements comprising a unified whole) "a vast system of production and distribution and consumption keep the country going"	system; ecosystem; network
COGNITION		S: (n) cognition, knowledge, noesis (the psychological result of perception and learning and reasoning)	
	Capability	S: (n) capability, capableness, potentiality (an aptitude that may be developed)	
	Culture	S: (n) culture (the attitudes and behavior that are characteristic of a particular social group or organization) "the developing drug culture"; "the reason that the agency is doomed to inaction has something to do with the FBI culture"	
	Support	S: (n) support (something providing immaterial assistance to a person or cause or interest) "the policy found little public support"; "his faith was all the support he needed"; "the team enjoyed the support of their fans"	
	Content	S: (n) content, cognitive content, mental object (the sum or range of what has been perceived, discovered, or learned)	theory; experience; model; framework; design; strategy; information_technology; field
	Layer	S: (n) level, layer, stratum (an abstract place usually conceived as having depth) "a good actor communicates on several levels"; "a simile has at least two layers of meaning"; "the mind functions on many strata simultaneously"	
	Process	S: (n) process, cognitive process, mental process, operation, cognitive operation ((psychology) the performance of some composite cognitive activity; an operation that affects mental contents) "the process of thinking"; "the cognitive operation of remembering"	evaluation; review
	Open	S: (n) open, surface (information that has become public) "all the reports were out in the open"; "the facts had been brought to the surface"	
EVENT		S: (n) event (something that happens at a given place and time)	

CLUSTER	Construct	Definition (in WordNet)	Main characteristics (from 70 Words associated)
	Activity	S: (n) activity (any specific behavior) "they avoided all recreational activity"	practice; process (synonym of procedure); provision; technology; project; service
	Management	S: (n) management, direction (the act of managing something) "he was given overall management of the program"; "is the direction of the economy a function of government?"	
	Commerce	S: (n) commerce, commercialism, mercantilism (transactions (sales and purchases) having the objective of supplying commodities (goods and services)	business; manufacture; channel
	Happening	S: (v) happen, hap, go on, pass off, occur, pass, fall out, come about, take place (come to pass) "What is happening?"; "The meeting took place off without an incidence"; "Nothing occurred that seemed important"	change; recombination
OBJECT		S: (n) object, physical object (a tangible and visible entity; an entity that can cast a shadow) "it was full of rackets, balls and other objects"	
	Person	S: (n) person, individual, someone, somebody, mortal, soul (a human being) "there was too much for one person to do"	actor; expert; user; customer; employee
	Path	S: (n) path, track, course (a line or route along which something travels or moves) "the hurricane demolished houses in its path"; "the track of an animal"; "the course of the river"	
	Component	S: (n) component, constituent, element (an artifact that is one of the individual parts of which a composite entity is made up; especially a part that can be separated from or attached to a system) "spare components for cars"; "a component or constituent element of a system"	
	Artifact	S: (n) artifact, artefact (a man-made object taken as a whole)	artifact; product; work; platform

Analyzing the **CLUSTERS** (in bold uppercase) and **Constructs** set (in bold) identified from the papers selected, it could observe that **Digital Innovation & Transformation** is an **EVENT,** i.e., **Happening**, related to **Commerce**, **Management** and other **Activities**. Its **OBJECT is** taken by **Persons** who act in a **Path**, generating **Artifacts** and their **Components**. Its **ATTRIBUTES** are

characterized by newness and computer_architecture **Properties**, oriented to **Qualities** such as mobility and value, and **State** of Development, Maturity and Activities. The **COGNITION** is a fundamental element in this journey, it is **Open**, covers several **Layers**, and it is intensive in **Knowledge, Content** and **Process**, that **Supports** the new **Capabilities** development or the adequacy of existing ones, and also the **Culture** change. DI&T should be evaluated as a **GROUP**, a unit, analyzed as a **Collection** of clusters and data, in which the **Market**, the **Social** aspect, the **Organization** and the **System** (or the ecosystem) are central parts. The **COMMUNICATION** through messages/texts take place between the **GROUP**s and **OBJECT**s.

The literature agrees with that direction, as for Yoo, Henfridsson and Lyytinen (2010), Innovation is related to changes in thinking, products, processes or organizations. It is defined as the new elements' introduction or an old elements' new combination generating useful novelty (clusters **COGNITION** and **GROUP**). It may also refer to incremental or radical changes. (Sandhu, 2018) present Digital Revolution, Digital Business Transformation and Business Digital Transformation like Digital Transformation synonyms. For Morakanyane, Grace and O'Reilly (2017), Digital Transformation is "an organizational strategy formulated and executed by leveraging digital resources to create differential value" and they complement affirming that Digital Transformation is the integration of digital technologies into business processes (clusters **ATTRIBUTE**, **COGNITION** and **GROUP**).

(Bohnsack *et al.*, 2018) concluded that Digital Transformation is a process organized into three building blocks - Determinants, Process and Outcome. For them, each building block has its own organization (clusters **OBJECT**, **COGNITION**, **GROUP** and **COMMUNICATION**). Ismail, Khater and Zaki (2017) described the different Digital Transformation perspectives found in the literature. They represent them in concentric circles, where the outermost circle is related to the Digital Era perspective, followed respectively by the Social / Economic, Industry / Ecosystem, Network, Company / Institutional perspectives and finally, the innermost circle is related to the Individual (clusters **EVENT**, **ATTRIBUTE** and **GROUP**).

Concerning the relationship between the terms Digital Transformation and Digital Innovation, Hinings, Gegenhuber and Greenwood (2018) observe that "Digital Transformation comes from the combined effects of several Digital Innovations bringing - for organizations, ecosystems, industries or fields - novel actors, structures, practices, values, and beliefs that change, threaten, replace or complement to existing rules (clusters **GROUP**, **OBJECT**, **COMMUNICATION** and **ATTRIBUTE**).

Digital transformation changes societies and industries fed by the convergence of multiple new digital technologies enhanced with ubiquitous connectivity with the intention of reaching superior performance and sustained competitive advantage by transforming multiple business dimensions (Beverungen *et al.*, 2021). Although often used interchangeably, digitization, digitalization, and digital transformation account for interdependent but different phenomena.

Digitization describes the transformation of information into a digital representation. It has produced the emergence of the **digitalization** paradigm, which has made information technology

(IT) pivotal for competitiveness and customer satisfaction. Digital technologies connect people, things, and locations to generate and analyze large amounts of data. Digitization and digitalization merge to become **digital transformation**, which alters communication and interactions between all stakeholders and reshapes the current economic, social, and landscape (Fischer *et al.*, 2020).

Digital transformation transforms strategically the activities, processes, competencies, and business and organizational models. Reflecting on the effects of digital transformation in organizations helps to understand their potential transformations in directing and interacting with people (Arbaiza, 2018). Merely incorporating digital technologies is not enough to allow organizations to be innovative and remain competitive in the digital age (Brocke, Zelt and Schmiedel, 2016). Customer experience, operational processes, and transformation of business models are the three main affected areas of digital transformation, as pointed out by (Arbaiza, 2018). To provide valuable outcomes, technology needs to be properly used in combination with clearly articulated objectives and processes (Van Looy, 2017).

This study aimed to identify key concepts and constructs for digital transformation and innovation. However, it became evident that it was necessary to investigate additional ones as the next steps of the thesis.

3.2 Organizational Change and Transformation

A literature review was conducted (Bogea Gomes *et al.*, 2023) to identify research works on conceptualization and modelling of organizational transformation phenomena. The literature findings were collected, classified, and synthesized. This thesis is concerned with studies that investigate the difference between the terms: organizational transformation and organizational change; the concepts, constructs, conceptualizations and definitions of these two terms, and the conceptual models, ontologies, strategies and theories used to represent or explain them.

The literature review was conducted based on the guidelines provided by (Kitchenham and Charters, 2007; Boell and Cecez-Kecmanovic, 2015). The following sources were selected for this search: ACM Digital Library, AISeL, EBSCO (includes IEEE Xplore Digital Library, Science Direct and Emerald Insight), Scopus, Google Scholar, and Springer Link. All studies are limited because a search string binds them. The search string included all variations of the terms related to organizational transformation and organizational change. Anyway, some works might be left out of the analysis, albeit potentially relevant to the domain at hand. The main findings from the literature review are presented as follows.

Organizations' environments have been changing rapidly for them to survive and prosper (Binder and Clegg, 2007). Organizations themselves are increasingly executing complex transformations, such as mergers and splits, chain redesign, sharing and sourcing, and the rationalization of products, processes and systems (Op't Land and Dietz, 2012). Thus, organizations require a broader definition to incorporate, as a single autonomous legal entity, the collaborative relationships outside its boundaries demanded by globalization, outsourcing and virtualization.

The topic of organizations and their transformations is not new. (Porras and Silvers, 1991) studied organizational change as an intentionally planned response, which can be classified into two general types: organizational development and organizational transformation. Organizational change can be planned or unplanned; it can also be revolutionary (organizational transformation) or evolutionary (organizational development). Most planned organization changes are evolutionary regarding an organization's day-today adaptations (Burke, 2017).

In this thesis, organizational transformation or revolutionary change (also referred to as disruptive, strategic or radical change) as directed primarily to create a new vision for the organization (Porras and Silvers, 1991) was investigated. Several different categorizations for organizational changes are described in the literature.

(Hernaus, 2008; Purchase *et al.*, 2011) differentiate change-related practices, for example, by their level of impact, scope, speed, focus, structure, and nature. These classifications are not exhaustive, and they intertwine with each other. The change approaches differ conceptually in content (what changes) and process (how the change occurs). Specifically, (Purchase *et al.*, 2011) specify what transformation means by illustrating the contrasting levels of significance or the extent of the desired changes and the impacts of such changes from three perspectives – as a response to radical changes in the economic, market, or social environment; a fundamental alteration of context; and a step change in performance – as criteria for distinguishing transformation from other more modest forms of change.

Moreover, it is interesting to observe that every organization is a "world" with a particular view that influences what its members see and let in from the world outside. To some degree, this view inadvertently or deliberately selects what is shared, sometimes explicitly, sometimes implicitly (Sheldon, 1980). It can justify why the same transformation is successful in one organization and not in another with similar characteristics (such as belonging to the same market segment and having similar products or services).

Another approach to distinguishing transformation is the modification of context. For Rouse (2005), enterprise is used as a synonym for 'organization'. Thus, enterprise transformation occurs at least partly driven by the external context, i.e., the economy and markets. The economy affects the markets, which, in turn, affects enterprises. The enterprise system is constituted by its input, output, state, and work processes. The concept of "state" is central to the theory of enterprise transformation. Other important constituents of an enterprise state include market advantage, brand image, employee, and customer satisfaction. This author proposes that enterprise transformation is concerned with changes that substantially alter an organization's relationships with one or more key constituencies, e.g., customers, employees, suppliers, and investors. Transformation can involve new value propositions regarding products and services, how they are delivered and supported, and how the organization provides these offerings.

Although organizational transformation had become a central theme for researchers from various fields, given the large volume of publications and their various scopes and objectives, to the best of our knowledge, those are the most recent publications that state the problem of the lack of

conceptualization (Rouse, 2005; Purchase *et al.*, 2011). For instance, according to Rouse and Baba (2006), the motivation for organizational transformation can be stated in terms of value deficiencies, work processes, decision making and social networks. Thus, they elaborate on two broad and complementary perspectives on transformation: the technical problem to be solved and the behavioral, social context and mechanisms of transformation, to contrast them and raise important issues concerning what to measure, how to collect data, and what tools are needed to model and manipulate these findings.

While Zivkovic, Puvsara and Zivkovic (2011) established that beyond the technical and social-technical perspectives, organizational transformation also needs to be supported by an appropriate process, as it involves all the organization's components, such as organizational culture, structure, strategy, management style, systems, personnel skills and shared values. However, the course of the change process depends on the content of the organizational changes. Moreover, the contents of organizational changes depend on the organization itself and the chosen business model. Besides, for Zivkovic, Puvsara and Zivkovic (2011); Burke (2017), in a constantly changing world, the organization is an open system that affects the environment and is affected by it. For example, Zivkovic, Puvsara and Zivkovic (2011) related organizational changes like mergers, takeovers and changes in ownership structure to the organization's age and size, its leader, business strategy and technology. However, it is crucial to remember that organizations are increasingly interconnected with other organizations located in different parts of the world, which also influence their new ways of creating value, including for their customers and partners (Keen and Qureshi, 2006). Furthermore, the characteristics of these organizational changes may also change (Zivkovic, Puvsara and Zivkovic, 2011).

According to Ismail, Khater and Zaki (2017), the work on the transformation of organizations can take its starting at an external, internal, or holistic point or yet a combination of them: externally, for example, when the focus is on enhancing the customer experience, eventually altering its entire life cycle; internally, for example, affecting business operations, decision-making and organizational structures. Moreover, all business segments and functions are affected holistically, often leading to entirely new business models. Some internal and external factors can motivate an organization's competitive transformation strategy towards obtaining sustainable competitive advantages (Ismail, Khater and Zaki, 2017) and designing new value propositions. For Porter (1996), competitive strategy is about being different in the following sense: it means deliberately choosing a different set of activities to deliver a unique mix of values different from those of rivals; by choosing the way to compete, a company makes organizational priorities clear.

A business model can transform an organization through a fundamental statement of direction and identity. However, a business model is not a strategy (Keen and Qureshi, 2006). The business model design is a schema of the organization's critical resources, transactions, and value proposition. A business model describes how an organization creates, delivers, and captures value (Bock, Warglien and George, 2020). A business model is a hypothesis about who the customers are, what they value, and how they will make money by delivering that value. The

business model is a narrative that must be stated and helps mobilize leading stakeholders, including investors, customers, suppliers, and other partners. These and other authors study business model design and organizational transformation because, despite the numerous practice-based approaches to business model design, there needs to be a greater understanding of why and how business models change.

(Linz, Müller-Stewens and Zimmermann, 2017) argue that most established organizations have fine-tuned their business models to stay aligned with environmental changes, but these authors have yet to question their type of business model. Even though organizations understand their business models from the inside out, sporadic changes and external trends pressure stable business models. The competition in innovation has shifted from technological and process innovation to business model innovation because start-ups, niche players and small and medium-sized businesses with relatively limited investment have the means to challenge established players.

(Hernaus, 2008) offers examples of transformation support frameworks. These transformation models generally comprise strategy, work processes, structure, management processes, reward systems, people competencies strategy, technology, business processes, people, management system, social system, behavioral system, critical competitive factors, culture, structure, internal economy, methods and skills, measurement instruments and reward systems.

3.3 Organization

The following section was developed using the concept of organization proposed in UFO, which characterizes an organization as a type of social agent. The focus was not on re-defining the concept of organization itself; it was used to better understand the notion of organizational transformation. In practice, it became apparent that organizational transformation frequently happens in parts of the organization, not holistically across the entire organization. UFO's organization concept serves as a basis to enhance the comprehension of organizational transformation. The focus was explore ontology literature to expand this concept.

Organizations can be brought into existence (along with their parts, i.e., organizational units) by one particular type of normative description recognized by an organization and termed the organization’s body of norms. The organization’s body of norms is the case with so-called constitutive norms (Almeida and Cardoso, 2011). An organizational structure may also include roles, which define tasks, responsibilities, and required skills for a position (Frank, 2011a; Scheer, 2012; W3C, 2014).

In Artificial Intelligence domain, there is currently interest in creating artificial agents’ societies (Bottazzi and Ferrario, 2009). It results in an increasing transformation of certain human agent positions into artificial ones in the digital transformation domain. Therefore, it is essential to define what an artificial agent is. An artificial agent is a non-human and non-legal entity to which true legal responsibility cannot be ascribed. An artificial agent may also perform certain actions in an

organization. Organizations are created by physical and social agents but can be sustained by both physical, social, and artificial agents (Bottazzi and Ferrario, 2009).

The literature is not consensual about the differences between enterprise and organization. For Bottazzi and Ferrario (2009), enterprises and organizations are different concepts. Enterprises can be considered a special kind of organization. For example, a non-profit institute is an organization, but it is not an enterprise. Nevertheless, for the European Commission (2003) (Binder and Clegg, 2007), an enterprise represents a collection of people organized together into a community or other social, commercial, or political structure. This thesis refers to the enterprise as a type of organization according to Bottazzi and Ferrario (2009).

For W3C (2014), a formal organization is recognized in the world at large, with associated rights and responsibilities (as a corporation, charity, government or church), particularly, in legal jurisdictions (W3C, 2014). In contrast, an informal organization is an interconnected social structure that determines how people work together. An informal organization (e.g., a special interest group) can be formed within a formal organization.

An organization can be composed of organizational units, which means that an organization can comprise other organizations (sub-organizations). Sub-organizations are in some way associated and hierarchically ordered. Sometimes, a sub-organization can be regarded as standalone: a legally recognized business may be part of a larger group or holding company.

The W3C Organization Ontology (W3C, 2014) represents explicitly the organizational role that the person fulfils (e.g., the W3C ontology models the responsibilities associated with the function). An agent's situation fulfilling that role within an organization is then expressed through instances of the membership relationship. The concept of Post represents a position in the organization that may or may not be currently filled. Posts enable reporting structures and organization charts to be represented independently of the person holding those posts. Posts can report to other posts. Therefore, a post can exist without someone holding it. In contrast, a membership represents a relationship between a particular person (agent) and the organization and does not exist unless an agent partakes in the relationship. A post can have an associated role. An organizational structure comprises organizational units and their relationships. The elementary organizational unit, which cannot be further decomposed, is called a position.

In conclusion, Table 3-5 provides a comparison of the definitions and highlights points in common among them, the literature seems to agree that an organization can act as a social agent. Thus, this thesis assumes the following definition: an organization is a Social Agent (Section 3.8.3 - UFO-C), which comprises a collection of agents organized together into a community (or other social, commercial, or political structure, regardless of its legal form). These structures include partnerships or associations regularly engaged in collective activities, with some common purpose or reason for existence that goes beyond those of the set of agents involved in it. An organization could be a single integrated organization or a collection of inter-organizational partners.

The various concepts of organization in the literature were analyzed, according to (a) (Guizzardi, 2005), (b) (Binder and Clegg, 2007), (c) (Guizzardi, Falbo and Guizzardi, 2008), (d) (Bottazzi and Ferrario, 2009), (e) (Almeida and Cardoso, 2011), (f) (de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011), (g) (Frank, 2011b; Scheer, 2012), (h) (W3C, 2014).

Table 3-5. Organization conceptualization in the literature.

An organization….	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**
is a complex entity linked to a group of people;				O			
can constitute and regulate complex activities that otherwise could not be accomplished;				O			
is not a group;	O			O			
has some common purpose or reason for existence beyond the set of people belonging to it;							O
can act as an agent, regardless of its legal form, including partnerships or associations with regularly engaged economic activities;	O			O			
is a type of Social Agent that involves people and other agents and facilities with an arrangement of responsibilities, authorities and relationships;	O					O	
can bring itself into existence, along with its parts, which are organizational units, by one particular type of Normative Description;					O		
is an organizational structure that comprises organizational units and their relationships;							O
also includes roles, which define tasks, responsibilities, and required skills to a position;							O
can have artificial agents also perform certain activities initially				O			

3.4 Digital Transformation Foundation

In recent years, nearly every market segment has widely implemented initiatives to adopt new digital technologies and capitalize on their benefits. The degree of experimentation and adoption of new digital technologies in an organization is closely related to the degree of strategic renewal (Kretschmer and Khashabi, 2020). The digital world interweaves the digital with the physical, shaping our experiences seamlessly and inseparably, including a new digital culture. Organizations are increasingly confronted with the need to respond and adapt to changes creatively to remain profitably viable and develop sustainable competitive advantages (Bogea Gomes, Santoro and Mira da Silva, 2022a). Indeed, the potential impact and scale are so significant that faulty and imperfect transformation can harm organizations' competitiveness. To keep up with or survive future competition, organizations may need to prioritize critical processes and move faster than competitors to reap the benefits of the digital (Kretschmer and Khashabi, 2020). Despite efforts to create a unified view of changes in the digital age, the terms digitization, digitalization, IT-enabled organizational transformation, and digital transformation have distinct meanings, although being frequently used interchangeably (Bloomberg, 2018; Verhoef *et al.*, 2021).

With the advent of the Internet, information from analog records has been disintermediated from books, teachers, universities, libraries, institutions, and various authorities. Information from analog records contained in was duplicated, modified, distributed, and shared with minimal transaction costs. The digitization of information and its disintermediation from the physical representation of information permit users to act independently of the information's origin or creator. Access to information and the ability to trade and create commerce have vastly improved (Caradonna, 2020). There are numerous examples of enterprise digitization today, as there have been for decades. For instance, digitizing handwritten or typed text is an example of digitization, or yet digitizing music, image, and video. However, it is essential to remember that information, not processes, is being digitized.

Unlike digitization, **digitalization** does not have a single, precise definition (Bloomberg, 2018). For many authors, the automation of business processes characterizes digitalization. Digitalization progresses in phases. The initial phase, in which single operations or processes are automated. The middle phase, during which related processes are automated and linked together. Multiple systems that supported business processes and information flows are partially integrated into the third and most complex phase (Savić, 2020). Digitalization marks the fourth revolution by providing the means to convert 0s and 1s into meaningful values for easy consumption. It supports the improvement of specific processes (Vrana and Singh, 2021).

According to (O'Leary, 2022), digitalization includes business models in addition to business processes. To this author, "digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business." An organization may embark on a series of digitalization projects, ranging from process automation to computer retraining, that necessitate cross-functional organizational change and the adoption of digital technologies (Beverungen *et al.*, 2021).

Because so many scholars have different interpretations, providing a single definition of digitalization is difficult. However, there are some areas where these various interpretations overlap. Most decisions are based on altering organizational processes and creating new business models. Digital technologies have the potential to influence how people work and fundamentally alter an entire business model. Furthermore, scholars agree that digitization is the only way to achieve digitalization. Nonetheless, scholars concentrate on various aspects of the definition (Kusters, 2022).

While digitization and digitalization refer to processes in which organizations use digital technologies to work more quickly and efficiently, digital transformation progresses even further. Consumer expectations and behaviors have been fundamentally altered due to digital transformation, putting pressure on traditional organizations, and disrupting numerous markets. Major external factors driving digital transformation are identified (Verhoef *et al.*, 2021). It requires a complete organizational transformation, with digital technology implementation being a minor component. Only organizational change can result in improvement from this implementation. As a result, businesses and economies are becoming more intertwined. These interconnections help

to support the idea of a more globalized world economy. Digital transformation is more about people than technology (Kusters, 2022).

Adopting and using digital technologies enable and empower employees while also assisting in transforming organizational culture. Internal support is critical for making real progress. Furthermore, the organization must implement customer-centered changes. Digital transformations can divide IT and business functions, significantly resisting change. Aligning people, processes, organizational structures, and culture are critical for fundamental changes (Verhoef *et al.*, 2021).

Observing digital transformation from the product development perspective, (Vrana and Singh, 2021) emphasizes the enabling of collaboration and connectivity. The smartphone is a well-known example of this type of digital transformation. It is important to note that the smartphone does not enable digital transformation but facilitates it. The internet's connectivity and apps created an entirely new ecosystem, altering our lives. Information is digitized, processes are digitized, and businesses are transformed digitally. Each one is necessary for the next to be completed. It is critical to remember that digitization and digitalization are primarily concerned with technology, whereas digital transformation is not. Change is at the heart of digital transformation (Kusters, 2022).

In summary, the information is digitized, the processes and roles that comprise a business's operations are digitalized, and the business and its strategy are digitally transformed. Each is required but not sufficient for the next, and most importantly, digitization and digitalization are primarily concerned with technology, whereas digital transformation is not. The focus of digital transformation is the customer demands.

The business context drives digital transformation, besides influences and are influenced by the competition. Competition motivates digital transformation. It is changing dramatically due to these new digital technologies. Moreover, due to the digital revolution, consumer behavior is changing. Consumers are shifting their purchases to online stores, and digital touchpoints are essential in the customer journey, affecting both online and offline sales (Verhoef *et al.*, 2021). The environmental context depends on the business market segment characteristics as competitive environment level and environmental uncertainty level. The organization context depends on the organization's characteristics (Brocke, Zelt and Schmiedel, 2016).

For Wessel *et al.* (2021), transformations are driven by the influence of the current environmental and organizational contexts. Moreover, according to them, the organizational transformation could be a digital transformation or an IT-enabled organizational transformation depending on how digital technology, value propositions, and organizational identity interact in these processes. Organizational identity is a shared understanding of what the organization is and what makes the organization different from others (Obwegeser and Bauer, 2016).

In Digital transformation, the organizational identity is transformed and digital technology leveraging the new value proposition. An organization is represented by its organizational identity.

The sequential processes of articulating a vision (ideals and goals); delineating organizational identity boundaries, searching for a meaningful identity; comparing past and present experiences to make sense of the new organization; and arriving at a consensual identity (of what the organization will become and engaging in opportunities); interacting with the recurring of negotiating identity claims; achieving optimal distinctiveness (similar to using best practices but different from creating competitive advantages); performing liminal actions (such as trying out new behaviors and working in new ways); and accepting legitimizing feedback (receiving validation from external stakeholders) all contribute to the formation of an organizational identity (Gioia *et al.*, 2010). Digital technology is central to redefining value propositions in digital transformation, leading to a new organizational identity. On the other hand, IT-enabled organizational transformation entails using digital technology to support an existing value proposition, implying that an organization's existing identity is reinforced. Technological change can manifest as either a source of digital threat or a source of digital opportunity, kick-starting digital transformation or IT-enabled organizational transformation processes (Wessel *et al.*, 2021). Digital as a concept requires a new logic of thinking about technology (Baiyere, Salmela and Tapanainen, 2020; Baskerville, Myers and Yoo, 2020; Wessel *et al.*, 2021).

Business models are successful solutions for organizations to create value. These authors suggest combinations of business models to design strategies for new and existing businesses. Business models are proven strategy-building blocks. They are abstract representations of an organization's strategy, rooted in its competitive environment, to deliver customer value. An organization's strategy is unique to it. A business model is an abstraction of strategy. In contrast, a business model simplifies an organization's strategy. Multiple organizations could use the same business model. Likewise, a set of one or more business models can represent an organization's strategy. Each business model captures an essential insight into creating economic value, which can be combined to create more complex models and strategies (Seddon and Lewis, 2003).

Digital transformation is enabled by one or more digital innovations for that organization. Digital innovations are both the basis for, and the outcome of changes embodied in or enabled by digital technologies. Digital innovation can be a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT. Digital product innovations are significantly new products or services, from the perspective of a particular community or market, that are either embodied in IT or enabled by IT. Moreover, a business model in general is built on top of a digital innovation (Bogea Gomes, Santoro and Mira da Silva, 2021).

Bloomberg (2018) defines digital transformation as a customer-driven strategic business transformation that necessitates cross-functional organizational change. Initiatives typically include multiple digitalization projects, but achieving a fundamental transformation necessitates the organization dealing with change more effectively overall. Digital transformation cannot be accomplished through the execution of isolated projects. As an organization becomes completely customer-driven, change is a core competency. Digital transformation occurs not only in

businesses but also in industries and society. Business models and work cultures are evolving, and in the end, an organization employs numerous digital technologies in various parts of the organization and its business activities (Kusters, 2022).

3.5 Digital Technology

A literature review and a taxonomy-development approach were conducted (Bogea Gomes, Santoro and Mira da Silva, 2021) in order to investigate and organize the preliminary discoveries about digital technology conceptualization. Considering that digital transformation has become necessary for businesses to grow and remain competitive in the market (Butt, 2020), researchers and practitioners need to ground digital technology models for the digital transformation initiatives in solid concepts. Thus, based on the review and theory development framework of (Leidner, 2018), this thesis synthesized the research on technology in digital transformation concepts, analyzed the assumptions implicit in this previous research, and laid a foundation for developing a taxonomy in the context of digital transformation: its characterization, its roles/impacts, and the digital platform and ecosystem components, aiming a better understanding of digital technology in digital transformation research. The main findings from the literature review are presented as follows.

3.5.1 Digital Technology main Concepts within Digital Transformation

Although the evolution of digital infrastructures has occurred gradually, it has been inexorable. Technologies are used in daily activities, for both personal and professional purposes in both organizational and non-organizational contexts (Yoo, Henfridsson and Lyytinen, 2010). The term digital technology allows distinguishing a new wave of technologies with similar fundamental characteristics like cloud, wearables, devices, mobile, social media, business analytics, Internet of things (IoT) and Artificial intelligence (Sedera and Lokuge, 2019) (Brown and Brown, 2019) (Arbaiza, 2018) (Berger *et al.*, 2020).

Digital technological development has largely augmented the diversity, quantity, and complexity of computational systems, requiring more adaptable systems that are capable of self-adapting to the environment in which they operate. The current abundance of storage, processing, and display virtually qualifies any device connected to the Internet as a network-enabled device (NED). Sensors and identification devices provide real-time information to enrich virtual-world applications, allowing changes in real-world objects to be reflected in virtual environments (Alberti, 2013).

Two significant trends make digital technologies transformational for industrial production: cost reduction, wider diffusion, and the combination of both, allowing new types of applications (OECD, 2017). (Sedera and Lokuge, 2019) consider that digital technology provides better capabilities for organizations to face hyper-competitive dynamic markets. The use of digital technologies allows

organizations to generate new forms of revenue and business value, providing transformational effects on processes (Ehie and Ferreira, 2019).

The (OECD, 2017) categorized digital technology into three broad **types**: **digital technology enablers**, **digital systems integrators**, and **application technologies**. The digital technology enablers (big data, internet of things, and cloud computing) provide the backbone that allows for the digital transformation of industrial production under the digital systems integrators (simulations, artificial intelligence, and cyber-physical systems). The industry's main productivity effects are likely to unfold through the application technologies (3D printing, autonomous machines, and human-machine integration) (Ehie and Ferreira, 2019).

The digital world shapes our experiences by seamlessly and inseparably interweaving the digital with the physical. The digital world formed a new digital culture where mobile devices are connected to ubiquitous information systems in the cloud, the Internet of Things (IoT), and digital sensors that monitor nearly every movement made. Consequently, the digital world is becoming more and more integrated into the physical world (Baskerville, Myers and Yoo, 2020). Some objects are purely digital (e.g., digital media such as photos and videos). Others, like the Internet of Things, embed computing capabilities in mundane objects (such as a microwave and a thermostat) (Yoo, Henfridsson and Lyytinen, 2010). Digital objects acquire new affordances that were not previously available, changing user experiences and traditional industry boundaries (Yoo *et al.*, 2012). Digital objects are those whose **component parts** include one or more bitstrings. The set of digital objects, therefore, can include individual bitstrings, but it generally refers to a far broader category of objects, usually **hybrids**, in which bitstrings are combined with various types of material and nonmaterial components (Faulkner and Runde, 2019) .

Digital technologies make physical products, services, and processes **programmable**, **addressable**, **sensible**, **communicable**, **memorable**, **traceable**, and **associable** by embedding them with **software-based digital capabilities**. Digital technologies' characteristic attributes such as availability, accessibility, scalability, ease-of-use and ease-of-deployment, distinguish them from other technologies e.g., information technology, and allows them to advance the developments of many successful organizations, such as Uber, Airbnb, and Alibaba.com.

In information systems, as in other disciplines, novel products and services are derived from the combinations of existing components. Digital innovation is the outcome of the recombination of a set of digital resources in both design and use (Henfridsson *et al.*, 2018). Based on recombination, new things are created by combining existing things in new ways. (Hund, 2021) developed a typology of four different types of recombination. The first three types of recombination (**knowledge, structural, component**) focus on **design recombination** (producer-side), while the fourth type, **use recombination,** considers the opportunity for users to take organizational offerings and recombine them in unforeseen ways.

Knowledge recombination can be defined as novel combinations of knowledge elements (knowledge, concepts, expertise) to produce new knowledge. **Structural recombination**, which are change in organizational entities (e.g., units, divisions), is reorganized by merging, absorbing,

or forming a new one by combining existing units. **Component recombination** are new combinations of components, or new relationships between previously combined components. **Use recombination** concern how the properties of digital technology enable users to recombine digital resources while using them.

Digital technology actively shapes the physical world and fuses the digital and the physical worlds. It creates or helps to form the physical environments in which we live (Baskerville, Myers and Yoo, 2020). For example, citizens are using mobile technology, social media and other technology-enabled innovative solutions to enhance their participation in city governance (Alawadhi *et al.*, 2012). Due to ever-shorter innovation cycles and growing competitive pressure, organizations are increasingly forced to exploit the full potential of these digital technologies (Ismail, Khater and Zaki, 2017).

Three **digitalization waves** are distinguished by their types of digitalized object: information, community and value. The **digitalization of information** is represented by the Internet's availability and digitization of information. Information has been disintermediated from books, institutions, and authorities of all sorts and multiplied, altered, shared, and distributed with fewer transactional costs. The **digitalization of communities** emerged with social media. It allowed a physical decentralization and digitalization of communities by mapping them and their interaction digitally. The digitalization of value (here renamed to **digitalization of asset**) appeared with the introduction of blockchain and distributed ledger technologies. With the advent of blockchain technology, it is possible to keep track of data changes, digitize currencies, and create a decentralized network to map and transfer cryptocurrency independent of trusted third parties.

In all the three digitalization waves, there exists two relevant and similar **wave elements**: **decentralization** and **intermediation**. The first phase of the digitalization wave is the physical disintermediation of the object. The second phase is the decentralized use. Then, the pendulum swings back, bringing a centralized use of the object based on a business model built on top of the digital innovation (Caradonna, 2020).

The **layered modular architecture** extends the modular architecture of physical products by incorporating four loosely coupled layers of **devices**, **networks**, **services** and **contents** created by digital technology (Yoo, Henfridsson and Lyytinen, 2010). The **device** layer can be further divided into a physical machinery layer (e.g., computer hardware) and a logical capability layer (e.g., operating system). The logical capability layer provides control and maintenance of the physical machine and connects the physical machine to other layers. The **network** layer is similarly divided into a physical transport layer (including cables, radio spectrum, transmitters, and so on) and a logical transmission layer (network standards such as TCP/IP or peer-to-peer protocols). The **service** layer deals with application functionality that directly serves users as they create, manipulate, store and consume content. Finally, the **content** layer includes data such as texts, sounds, images and videos that are stored and shared. The content layer also provides metadata and directory information about the content’s origin, ownership, copyright, encoding methods, content tags and geo-time stamps.

Digital technology refers to ICTs possessing three fundamental properties: the **homogenization of data**, **reprogrammability** and **self-referentiality**. The functions of digital artifacts are malleable and can be changed dynamically. Digital technologies are **reprogrammable,** as their functions are malleable and can be changed dynamically. Digitalization permits the **homogenization of data** as digitalized data can be stored and transmitted irrespective of its content type by any devices with computing capabilities. Digital technologies can be **self-referential** as digital innovations are both the basis for and the outcome of changes embodied in or enabled by digital technologies (Tai, Wang and Wang, 2019).

The characteristics of digital technology pave the way for a layered architecture (Service, Content, Network and Device), and this is perhaps best exemplified by the Internet. The layers manifest two critical separations: (1) between device and service because of **reprogrammability**, and (2) between network and content because of the **homogenization of data**. The four layers represent different design hierarchies. Designers can pursue combinatorial innovation by gluing components from different layers using a set of protocols and standards to create alternative digital products. Combined with the rapid diffusion of personal computers and the Internet, the layered nature of digital technology has brought unprecedented levels of generativity (Yoo, Henfridsson and Lyytinen, 2010).

The **generativity** is the overall capacity of digital technologies to produce unprompted changes driven by large, varied and uncoordinated audiences. It refers to unanticipated outcomes produced by interactions with digital technologies, embodied in several ways. With the **convergence** affordance, digital innovations can be enabled by putting together either previously separated user experiences or digital capabilities with physical products based on digital technologies (Tilson et al., 2010) apud (Tai, Wang and Wang, 2019). Due to the generativity and convergence affordances of digital technologies, digital innovations in product, process and business models are likely to occur concomitantly (Tai, Wang and Wang, 2019).

3.5.2 Digital Technology's Roles and its Impacts in Digital Transformation

Digital innovations are both the basis for, and the outcome of changes embodied in or enabled by digital technologies (Yoo *et al.*, 2012). Digital innovation is a **product**, **process**, or **business model** that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT. **Digital product** innovations are significantly **new products or services**, from the perspective of a particular community or market, that are either embodied in IT or enabled by IT (Fichman, Dos Santos and Zheng, 2014).

Among the important effects of digital transformation are the take-up efficiency and the proportion of people that uses digital services as online banking (eBanking) and online purchases (eCommerce). For instance, in Australia, the government has established operational and functional national one-stop shop portals services. The central platform australia.gov.au has links to information and services provided by Australian federal government agencies, states, territories and local governments. Their success is the result of two interconnected ideas: channel strategies

and the service delivery ecosystem, and user-experience, i.e., a combination of service design, user-satisfaction and degree of digitization (Meyerhoff Nielsen and Jordanoski, 2020).

People are spending more and more time online. The advancement of technology in recent years allows the augmented diversity of applications, using new digital interactivity forms that are becoming available on mobile devices (Alberti, 2013) and permeates deeply into the core of many organizations' products, services, and operations (Yoo *et al.*, 2012). Digital transformation is the strategic transformation of the activities, processes, competencies and business and organizational models. (Arbaiza, 2018) points out three **main affected areas**: **customer experience**, **operational processes**, and transformation of **business models**. Reflecting on the effects of DT in those areas helps to understand the changes in directing and interacting with people.

Technology is an important asset that organizations utilize to obtain favourable organizational outcomes such as innovation and competitive advantage. According to Sedera and Lokuge (2019), most research works have investigated the role of digital technologies at the organization level but does not explain how organizations innovate with commonly available digital technologies. One possibility raised by the authors is that this issue may lie in how technology portfolio assets can provide a competitive advantage.

These authors studied a **portfolio** disaggregation through the **depth** and **breadth** technology dimension. The technology depth refers to the understanding extension of an organization possesses its digital technology portfolio. In contrast, technology breadth encapsulates the digital technology portfolio's scope and its diversity, extent, and value creation. These authors concluded that a high breadth of technology assets offers extensive and varied contexts for gaining value from unique configurations. Besides, tangible assets, such as digital technologies, provide a competitive advantage. The authors question the extent to which an organization possesses an accurate understanding of its capabilities, its **digital technology portfolio,** and the diversity and importance of the portfolio’s value creation over time. The portfolio disaggregation through the **depth** and **breadth** technology dimension is proposed to understand how assets such as digital technologies improve organization performance, assuming that they provide a competitive advantage.

The technological object is a set of information and IT assets. Although the term information technology was coined in the late fifties, it is not easy to identify what exactly an **IT asset** is due to its ubiquity. The definition has evolved ever since. The IT asset configuration can support an organization's competitive advantage and performance, which provides innovation mechanisms. **Information** is an integral part of **IT assets**, which is used in both **functional infrastructure areas of use** (like ERP, CRM systems) and **IT capability**. As **IT assets** are ubiquitous, there is a challenge in their identification process. There are no agreed identification metrics and shared understanding of IT assets' nature, structure and mechanisms (Adesemowo, 2019).

Digital technology affects innovation along the entire value chain from design to marketing via an augmentation of existing tools, products, processes and business models. In addition to allowing

organizations to achieve productivity improvements (e.g., by digitizing existing products or providing new ways of organizing the production system), digital technologies are significantly changing the nature of innovation. It relies on the fact that **component parts** of digital technology that are being combined into digital products are **nonmaterial** (protocols and languages) rather than **material** components; thus, there is no time-to-manufacture, no inventory issues, no delivery problems, and products can be shipped around the world instantaneously (Baller, Dutta and Lanvin, 2016).

3.5.3 Digital Platform and Ecosystem Characteristics

The systems that support digital businesses require transformation to maximize the economic value of network connections. It forces a shift to platforms and ecosystems that are collaborative by nature, by applying business models with multiple actors playing multiple roles (Derave *et al.*, 2020). The authors define **digital platform** as the offer of interactions based on information transfer (e.g., WhatsApp, Tinder), products (e.g., eBay), services (e.g., Airbnb), or investments (e.g., Kickstarter). A digital platform offers a service to its users, which is bound to an agreement. The primary service offered is interactions between users, and a software system enables these interactions. A **business platform** includes a **technology platform** as its main component.

A **business ecosystem** is a cooperative environment where symbiotic relationships are formed to create mutual value for its members. Digital ecosystems are characterized by a fusion-relation to digital technologies. The fusion of technology transforms the business **landscape** (Henningsson and Hedman, 2014) and enable organizations to take advantage of the ecosystem that allows innovations to be outsourced (Tai, Wang and Wang, 2019). In this scenario, individuals, organizations and firms no longer develop and implement their information systems in isolation. Instead, these **systems** are increasingly interconnected. The **digital platforms** and the **digital platform ecosystem** represent a broad view over a landscape of diverse and interconnected systems, platforms and ecosystems. Such digital, interconnected platforms attract heterogeneous complements and users to form ecosystems. These platforms and ecosystems operate within an institutional framework that enables or prevents various activities (Baskerville, Myers and Yoo, 2020).

Most of today's **platforms** and **ecosystems** are digital or online. They capture, transmit and monetize data, including personal data, over the internet and other networks. They may not be purely digital, but most successful digital platforms and ecosystems take advantage of the digital innovations and power of pervasive internet connectivity in the hands of billions of users. The main **platform players** are **Owners**, **Producers**, **Consumers** and **Providers**. A platform provides common standards, interfaces and tools to power core technologies to increase the productivity and profitability of an user, a company, or a set of companies (Yablonsky, 2020).

A **digital platform** usually creates a network of the relationships between the economic entities – producers, stakeholders, distributors, consumers, government agencies, and others – that facilitate the creation and distribution of a product or service through competition and cooperation.

Although some authors (Yablonsky, 2018) distinguish a technology platform from a business platform, the main component of this type of business is the technology platform. Multiple layers are needed to implement and integrate technological platforms effectively in practice. Any combination of internal resources or external partners (insourcing, outsourcing, as-a-service and cloud sourcing) can be a source for the technology platforms' stack. Every firm has tangible and intangible business assets (processes, human talent, technologies, infrastructure and information) that can be used or developed to bring the digital business platform to life (Burton and Basiliere, 2016) apud (Yablonsky, 2018).

A taxonomy was developed to summarizes the concepts presented (Bogea Gomes, Santoro and Mira da Silva, 2021). Some other taxonomies that discuss digital technology in other contexts were found (Canfora and Cerulo, 2004) (Kutzner, Schoormann and Knackstedt, 2018) (Suomela and Lehikoinen, 2005), but only one is closely related to our proposal (Berger, Denner and Röglinger, 2018). The multilayer taxonomy of the nature of digital technologies (Berger, Denner and Röglinger, 2018) represents the four layers (device, service, network, content) proposed by (Yoo, Henfridsson and Lyytinen, 2010), and splits each one into more detailed dimensions: human involvement, data treatment, input, output, multiplicity, direction, role of technology and scope. This proposal also encompasses the digital architecture layers (Berger, Denner and Röglinger, 2018), however, it is just one characteristic under the meta-characteristic of digital technology characterization in digital transformation. A broader view is proposed in this thesis, but it would be possible to extend this single characteristic with the dimensions proposed by them. Although the work of (Berger, Denner and Röglinger, 2018) addresses the same domain (digital technology), there exist differences between their proposal and ours. The goal of the multilayer taxonomy is to classify digital technologies on two levels of aggregation and make informed decisions about their adoption in each of the eight dimensions.

Moreover, literature also presents theories of digital object which is a central concept in the digital technology topic. Next section provides an overview of the theory adopted by this thesis.

3.5.4 Theories of Digital Object

Digital technology has been associated with trendy technologies, such as cloud, wearables, mobile devices, social media, business analytics, the Internet of things (IoT), and Artificial Intelligence (AI) (Arbaiza, 2018; Sedera and Lokuge, 2019; Berger *et al.*, 2020). The term digital technology was already used before the World Wide Web (better known as the Web) and the Internet. Everyday activities increasingly leverage digital technologies for personal and professional purposes, in organizational and non-organizational contexts. Digital technologies are fundamental components for organizations to digitally transform themselves. Literature has discussed the unique characteristics or properties of digital technologies: that offer opportunities to create new infrastructures, products, and business models, reshaping organizations (Drechsler *et al.*, 2020). Moreover, many efforts have been made to comprehensively understand digital technologies (Ekbia, 2009; Kallinikos, Aaltonen and Marton, 2010, 2013; Yoo, 2010; Yoo,

Henfridsson and Lyytinen, 2010; Faulkner and Runde, 2013, 2019; Baskerville, Myers and Yoo, 2020). The core concepts related to digital technology theories, ontologies, or conceptual frameworks identified in a literature review were consolidated in Figure 3.7 (Bogea Gomes, Santoro and Mira da Silva, 2022b).

Yoo (2010) describes **digital artifacts** as everyday artifacts with embedded computing capabilities. Digital artifact is one of the four dimensions of human experiences through digital technology, the other three being: time, space, and actors. Furthermore, the layered modular architecture extends the modular architecture of physical products by incorporating four loosely coupled layers: the devices, networks, services, and contents created by digital technology (Yoo, Henfridsson and Lyytinen, 2010). Digital artifacts vary in the processes, they mediate and how they are qualified as objects. Hence why, for Ekbia (2009), a digital artifact is a quasi-object, considering it can exist in more than one similar but distinct implementation.

Digital artifacts differ from physical objects and other cultural records (e.g., art objects, paper-based files) by their non-digital constitution, along several dimensions (Kallinikos, Aaltonen and Marton, 2010). These differences confer to the digital objects a distinctive functional profile. These authors subsume all digital technologies, devices, and digital cultural artifacts such as music, video, and image under the category of **digital objects**.

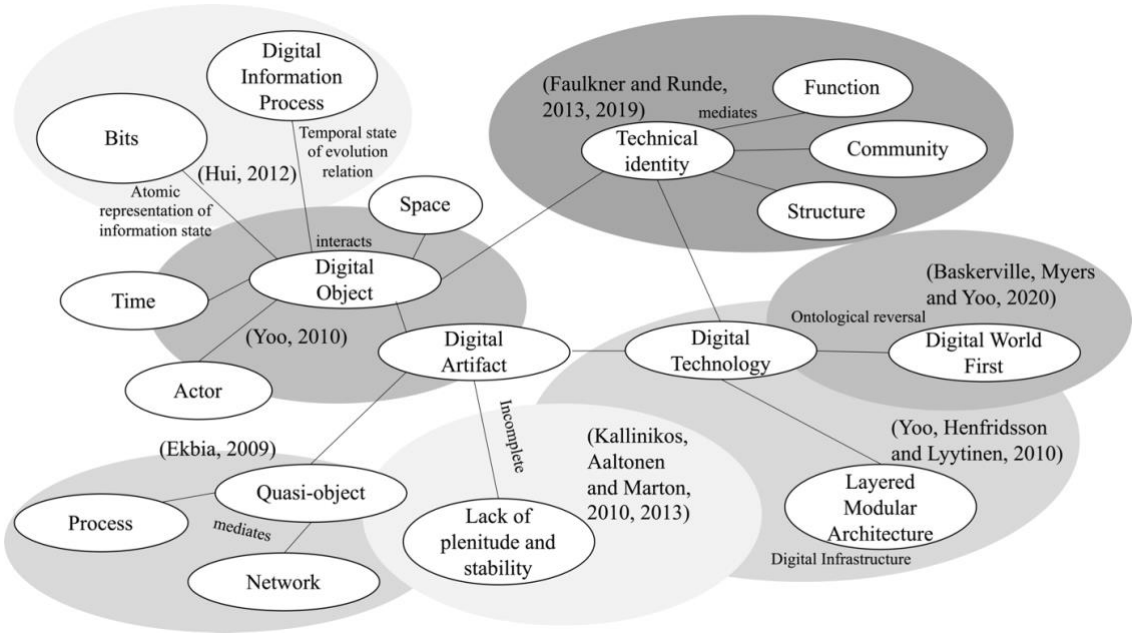

Figure 3.7. The selected theories' main concepts.

These theories provide a useful conceptual grid for studying social practices and identifying the peculiar generativity and instability that digital objects introduce - across various settings and situations. Digital artifacts such as files, images, and films or videos are considered fluid and editable, often embedded in complex, distributed, and shifting digital environments (Ekbia, 2009; Kallinikos, Aaltonen and Marton, 2010), although (Kallinikos, Aaltonen and Marton, 2013) argued that the term digital artifact is a mean of theorizing the mentioned incompleteness. They are objects, yet they lack the plenitude and stability afforded by traditional items and devices.

Digital objects are approached through the concept of "relations" with the material and the temporal relations, contrasting digital objects with natural objects (e.g., apples) and technical objects (e.g., hammers). They are abstract entities, such as information and data. As a technical object, a technical individual supports its inner structure functioning since it can adapt to an external milieu (i.e., a person's social environment) with its functioning. The main attributes that characterize the digital object are bits, digital information, and process. The related concepts are natural and technical objects (Hui, 2012).

Faulkner and Runde (2013) state that a **technological object** is a type of object that is a structured continuant. Structured means it is composed of distinct parts and organized in some way. Continuant means it is fully present at every point the time during which it exists. Since the **technological objects** are not agents, they do not have practices like human agents, although they occupy social positions. They also are not self-reflexive and cannot exercise conscious choices. The identity of technological objects is defined with a focus on the immaterial status of digital artifacts, their reproducibility (meager marginal cost), recombinability, and non-rival nature, likewise the ways these attributes are implicated in the innovation of products and services (Faulkner and Runde, 2009, 2011, 2013, 2019).

The **Theory of Digital Objects** (Faulkner and Runde, 2019) organizes an object's conception into two perspectives: the bearers of nonmaterial objects and the social positioning of digital objects. Digital objects are, therefore, distinct from other kinds of entities, such as events. The digital objects' identity and system functions flow from their social positioning in the communities where they arise (Faulkner and Runde, 2019). They focus on bearers of nonmaterial technological objects, where digital objects *qua* objects, i.e., all digital objects, are objects.

Digital artifacts are reprogrammable and self-referential entities whose distinct functional makeup is closely tied to data homogenization (or digitization), critical in enabling digital artifacts to develop innovative properties (Faulkner and Runde, 2009, 2011, 2013, 2019; Yoo, 2010; Yoo, Henfridsson and Lyytinen, 2010). As digital artifacts diffuse, these properties become involved in making modular and multi-layered digital infrastructures, that instantiate the independence of services from devices and content from the underlying networks (Yoo, Henfridsson and Lyytinen, 2010). Such condition opens the potential for innovation, enabling the mixing of inputs/outputs across the traditional and usually fixed industry borders associated with standard physical products, and vertical integration. Furthermore, the classical view of an information system that represents and reflects physical reality is increasingly obsolete: digital technologies are now creating and shaping physical reality (Baskerville, Myers and Yoo, 2020). They call this phenomenon **ontological reversal**, where the digital version is created first and the physical version second (if needed).

The Theory of Digital Objects from Faulkner and Runde (2019) were the selected one to use in this thesis, since they present a clearer and more complete solution in ontological terms. In the next section, the terms highlighted in *italic* correspond to the theory entities (Faulkner and Runde, 2009, 2011, 2013, 2019).

It is clear from the concepts associated with digital transformation that it demands a new way of thinking about technology. The Theory of Digital Objects from Faulkner and Runde (2019) is centered around an object's conception, positioning, and identifying technological objects in a community, and surfacing the hidden assumptions about how technology implicates human activities. A technological object is any object with one or more uses assigned to it by the members of some (human) community. Moreover, technology is composed of technological objects.

An object can be categorized as either material or nonmaterial. Material objects, such as scanners and smartphones, refer to an object's physical mode of being. Nonmaterial objects have a non-physical existence, examples include articles, operating systems, software, and conceptual schemes.

A material object can be a bearer of a nonmaterial object. Material bearers are vital for practical engagement with nonmaterial objects: a nonmaterial object must be born on a material object to be accessed. For example, for a digital book to be read by a human being, it must be displayed on a suitable material object, like a tablet. Similarly, if that digital book needs to be archived, it must be held on an appropriate material object. The nonmaterial object is distinct from all these material objects owning particular attributes. For instance, where an object serves as a material bearer to archive a nonmaterial object, properties such as durability and portability are likely to be essential attributes of the material object concerned. The hybrid refers to objects that comprise both material and nonmaterial objects as component parts (Faulkner and Runde, 2019).

A nonmaterial object (e.g., a computer program) is born from (or contained within) some syntactic object (e.g., computer language). In this case, it can call any syntactic object in which a nonmaterial object is born (or contained) a nonmaterial bearer of that nonmaterial object. Faulkner and Runde (2019) consider syntactic objects as the most important category of nonmaterial objects for their purposes; the syntactic objects consist of symbols arranged into well-formed expressions, i.e., these expressions adhere to the syntactical and semantic rules of the language in which they are couched. For example, manuals, and contracts are syntactic objects in natural language, while musical notation, Morse code, and mathematics are syntactic objects in artificial languages.

Any syntactic entity satisfies the two criteria for nonmaterial objecthood: it is an object and has a non-physical mode of being. In a syntactic object such as a novel, the component parts are letters and punctuation marks arranged to form words and sentences. Syntactic objects are ubiquitous in the digital world, and one type of them stands out as fundamental: the bitstring (Faulkner and Runde, 2019).

A bitstring is a type of syntactic object made up of bits, which are the 0s and 1s employed in a binary numbering system, where these bits are structured according to an appropriate file format to be readable by the computer hardware for which they are intended. Bitstrings, often called computer files, are one of the cornerstones of the digital revolution since the information stored and manipulated by computers, in general, is encoded in bitstrings. Bitstrings are divided into two

categories: program files (PF) (e.g., operating systems, applications, browsers, smartphone apps, and games) and data files (DF) (e.g., documents, videos, and audio recordings) (Faulkner and Runde, 2019).

Digital objects are ones that component parts include one or more bitstrings. Digital objects are components' structured ensembles, themselves objects. As a type of object, digital objects inherit the objects' characteristics (material and nonmaterial objects). Digital hybrids acquire the physical mode of their material components. In general, digital objects have community-dependent aspects (e.g., the same platform can be used for e-learning and business meetings) rather than intrinsic aspects.

A technological object is any object that has one or more uses assigned to it by members of some human community, besides having a "dual nature" in that it is constituted of both the <<physical form>> and the <<social function>> (Faulkner and Runde, 2013). Regarding the "dual nature", its physical form is crucial for the functions assigned to it. Those objects (e.g., a book) must generally possess the physical characteristics and capabilities required to perform the functions concerned. For their new forms (e.g., an e-book) or cases in which existing technological objects are used in a new way (e.g., phone as a smartphone), the group assigning the function may initially be very small, including no more than those responsible for the innovations concerned (Faulkner and Runde, 2009).

Furthermore, the context-dependent aspects, such as how the digital objects look (smartphones, banking apps) depend on their social positioning (Faulkner and Runde, 2019). A social position is a specific status within a system, which locates its occupant as a system's component. Any entity's social identity is the entity's kind of object according to its occupied social position. Social positions typically exist independently of, and usually before, any individual occupant. The technological object identity's definition can be used to pinpoint digital objects. For example, the social networking personal profile's identity, a technological object, is a digital object, as it is assigned to a community (e.g., LinkedIn).

3.6 Business Process Management (BPM)

Organizations perform better when they pay explicit attention to their business processes from start to end. It is essential to understand not only the parts of the business process, but also the people involved in these steps, the information being exchanged and handled, while going through the activities performed, and the technologies invoked when executing the various steps (Reijers, 2021). **Business Process Management (BPM)** is a boundary spanning discipline that aligns capabilities and technology to design and manage business processes. BPM is a systematic approach to overseeing work to ensure consistent outcomes and take advantage of improvement opportunities. Improvement opportunities include reducing costs, execution times, and error rates or gaining a competitive advantage through innovation. BPM manages chains of events, activities, and decisions that add value to the organization and its customers, referred to

as processes. It's worth noting that BPM doesn't focus on improving individual activities but centers on managing processes (Dumas *et al*., 2018). More than new combinations of digital technologies and other resources are required to implement digital transformation initiatives. Besides, new approaches to the business process must be aligned as a new combination of use or design.

BPM can be understood as an organization's core competency for managing all its business processes, from operational to managerial, spanning all organizational functional areas. Moreover, BPM networks organizations and environments, including consumers and other organizations, such as suppliers and customers (and beyond that, with their suppliers' suppliers and their customers' customers) (Beverungen *et al.*, 2021). BPM is the science and practice of overseeing how work is performed to ensure consistent outcomes and take advantage of improvement opportunities.

Contexts for BPM applications are highly diverse and determined by various contextual factors. For example, the nature of industries, organizational structures, and cultures can differ broadly across organizations. However, within one organization, the scope of BPM can have a greater diversity of processes, including innovation and strategic-planning processes. A BPM context framework was proposed considering four context dimensions (i.e., **goal**, **process**, **organization**, and **environment**) (Brocke, Zelt and Schmiedel, 2016).

In a previous study, using the BPM context framework (Brocke, Zelt and Schmiedel, 2016) as basis, (Denner, Püschel and Röglinger, 2018) identified a lack of context-aware BPM methods. For example, BPM methods that focus on the goal of exploration are rare. Furthermore, these authors suggest that BPM methods show room for improvement regarding context awareness, organization, and environmental dimensions.

Regarding the process dimension, particularly BPM methods geared toward the context factors, knowledge intensity, creativity, interdependence, and variability are seldom. Concerning the organizational dimension, size and industry have yet to be in focus. A supportive BPM culture is necessary to apply almost any BPM method. Concerning the environmental dimension, BPM methods for the context factors of competitiveness and uncertainty must be at the center of attention (Denner, Püschel and Röglinger, 2018).

BPM is applied to different purposes. While BPM has traditionally focused on increasing the efficiency and effectiveness of business processes through standardization or automation (exploitation), it also offers opportunities for innovation (exploration). Given this variety of contexts, there is an emergent body of knowledge studying whether process management also needs to examine factors inherent to BPM, such as the characteristics of processes or the goals of BPM initiatives (Brocke, Zelt and Schmiedel, 2016).

Furthermore, BPM can serve as an enabler for digital transformation. Hence, organizations must establish additional capabilities to cope with digitalization successfully (Imgrund *et al.*, 2018). Using the SME context, these authors show that process orientation and BPM constitute

facilitating conditions for digital transformation. However, according to the authors, enterprises must implement a **digital strategy**, increase **digital awareness**, adjust their **mindset**, and define **security** standards to cope with digital transformation requirements fully (Imgrund *et al.*, 2018).

3.7 BPM Capability

BPM is an enterprise capability that places it at the same level as other organizational management disciplines, such as risk management and human performance management. After introducing the typical reasons BPM programs fail, Dumas et al. (2018) introduce transversal aspects of BPM, such as governance and strategic alignment, and discuss how these are critical to avoiding failure. They organize these aspects in a BPM maturity model and show how to use it to assess an organization's BPM maturity. The use of capability as the representative of what an organization does and needs, without describing the how (the technical implementation), serves as a powerful communication tool among technology and organizational specialists (Imgrund *et al.*, 2018). It has a strong link to capability development, which builds on the resource-based view of the organization, striving for efficient and effective execution and the continuous management of business processes, as well as for the development of organizations' BPM capability. A mature BPM organization should carefully implement various BPM-specific methods and tools throughout the various phases of the BPM lifecycle, coordinating with methods and tools for project and program management. De Bruin and Rosemann (2007) identified six orthogonal factors that are critical to the success of a BPM program: (i) strategic alignment, (ii) governance, (iii) methods, (iv) IT, (v) people, and (vi) culture. They have organized these critical success factors in the BPM maturity model. Capability frameworks are the basis for maturity models that address how capabilities can be developed along an anticipated, desired, or logical path (Kerpedzhiev *et al.*, 2020).

3.7.1 Capability

Some aspects of the **capability** concept can be traced back to, among others, Aristotle, Adam Smith, and Karl Marx. However, its significant development is due to the pioneered approach of the economist-philosopher Amartya Sen and the philosopher Martha Nussbaum besides a growing number of other scholars across the humanities and the social sciences (Robeyns, 2009). Formulations of capability have two parts: valuable beings and doings (functioning) and freedom, in the sense of independence. Sen's significant contribution has been to unite the two concepts (Alkire, 2005).

In this work, **real freedom** means that one has all the required means necessary to achieve that doing or being if one wishes to. That is, it is not merely the formal freedom to do or be something, but the substantial opportunity to achieve it. According to Sen apud (Robeyns, 2009), **capabilities** are the notion of what activities one is able to undertake ('doings') and the kinds of persons one is able to be ('beings'). **Capabilities** are the **real freedoms** people must achieve their potential

doings and beings. In this way, the **capability approach changes the focus** from means (the **resources** people have and the public **goods** they can access) **to ends** (what they are able to do and be with those **resources** and **goods**).

This shift in focus is justified because **resources** and **goods** alone do not ensure that people are able to convert them into actual **doings** and **beings**. Two persons with similar sets of goods and resources may nevertheless be able to achieve very different ends depending on their circumstances. **Capabilities** are the **doings** and **beings** that people can achieve if they so choose — their opportunity to do or be such things.

As an example of those concepts, a person A may have a good analysis proficiency and benefit significantly from little input. Conversely, a person B may be not so good with analysis proficiency and thus requires more input of resources to develop an application. In summary, the notions of **capabilities** and **functioning** allow to recognize the diversity of human needs besides personal and contextual circumstances. By focusing on what people can do and be, rather than merely on the distribution of goods and resources, the **capability approach** recognizes the diversity of people's ability to convert those **resources** and **goods** into real **opportunities** and **achievements**. Figure 3.8 sums up Sen's theory.

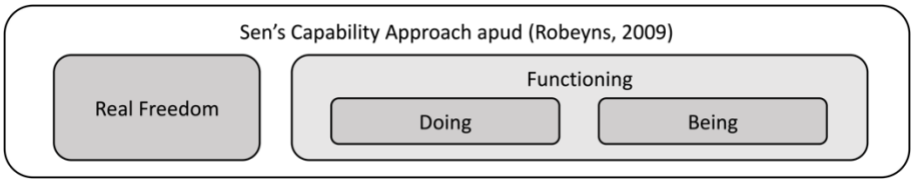

Figure 3.8. A representation for Sen's Capability approach apud (Robeyns, 2009).

Sen apud (Alkire, 2005) also considers that the **value** of a specific set of **capabilities** and **functioning** also crucially depends on what it does not allow one to do or be, or if it allows one to realize morally **"bad" functioning**, such as including malicious code in the Application to stollen user data. Moreover, it is necessary to include applications of the capability framework that are not concerned with what is valuable or not and, in some cases, are concerned with morally "bad" capabilities. In contrast to the **value-laden definition**, proponents of the **value-neutral definition** of capabilities and functioning state that doings and beings can be both positively and negatively valued and normatively neutral.

"Capabilities are intrinsic dispositional properties of agents that endow them with the power of exhibiting some behavior or bringing about certain effects in the world" (Azevedo *et al.*, 2015). Organizations are type of social agents. Robeyns (2009), on the theoretical frameworks of the Capability Approach, conceptualizes capability in the broadest sense and on the Business Capability (Loucopoulos *et al.*, 2016) to define digital capability, an essential concept for this thesis.

3.7.2 Business Capability

The **business capability** is the convergence of **capacity** and **ability** - capacity defines resource types and ability defines skill types - that an organization may possess or exchange to achieve a specific purpose or outcome, under specified standards and conditions, through a **combination of ways** and means to perform a set of tasks. Besides, a capability describes what the business does (outcomes and service levels) that creates customer value. A **business capability** is related to **business goals** and the **context within which it exists** (Loucopoulos *et al.*, 2016).

A business capability produces some business output received by some recipient, resulting in a financial transaction with an economic value associated with it. Moreover, a business capability abstracts and encapsulates the people, process/procedures, technology, and information into the essential building blocks needed to improve performance and redesign analysis. Furthermore, it is a **set of differentiated skills, complementary assets, and routines** that are assembled and provide the basis for competitiveness in a particular business.

A **business capability** may be **composed of other capabilities**. Besides, a **business capability relates and collaborates with one another** contributing to a business goal. A business capability is associated with a specific owner and produces some business output with economic **value** associated with it. This thesis adopts (Loucopoulos *et al.*, 2016)'s capability conceptualization, as summarized in Figure 3.9.

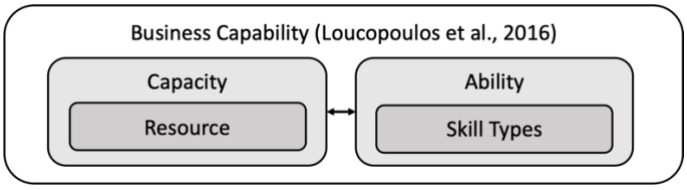

Figure 3.9. Business Capability based on (Loucopoulos *et al.*, 2016).

BPM has been structured by means of BPM capability frameworks, apart from lifecycle models (Kerpedzhiev *et al.*, 2020).

3.7.3 Business Process Capability

Organizations generally perform better when explicit attention is given to their business processes from start to end instead of neglecting them. Understanding the components of the business process, including the individuals involved, the exchanged and processed information, and the technologies utilized, is crucial for effective management. By optimizing and aligning these elements, organizations can enhance the development of their products or services (Reijers, 2021). Consequently, there is a greater emphasis on business capability (related to aspects of processes, information, and value) and business process management capability (related to aspects of process management) in the existing literature.

A business capability typically encompasses a (set of) business process(es) and is integral to establishing BPM capability. In other words, business processes are fundamental components

that contribute to the overall business capability and the formation of BPM capability. A bibliographic analysis was conducted to clarify the definition of business process capability and explore its central relationships. The analysis involved mapping this field's current state of the art and identifying gaps and trends associated with business process capability (Bogea Gomes, Santoro and Mira da Silva, 2022a).

With the conceptual model developing objective, out of the 68 papers examined, 51 provided insights into the business process capability concept. During the first period (2004-2009), only three papers focused on competitive advantage and knowledge resources. In the second period (2010-2014), the papers expanded their scope to explore topics such as strategy, capability types, organizational capabilities, outsourcing, alliances, and supply chain processes. The third period (2015-2019) saw more published papers, and new keywords such as Ambidextrous BPM, Risk, and Boundary Strategy emerged. However, the keywords ambidextrous BPM and risk were not identified in the subsequent period. The current period (2020-2024) has seen more papers overall, except for 2020, which had only one paper.

The analysis involved grouping the topics into research sub-areas and conducting a timeline analysis to identify gaps, research trends, and the interconnectedness of business process capabilities with various factors, including organization, boundaries, capability types, strategy, performance, knowledge resources, and competitive advantage. This approach helped map the connected concepts related to business process capabilities (see Figure 3.10) in clusters.

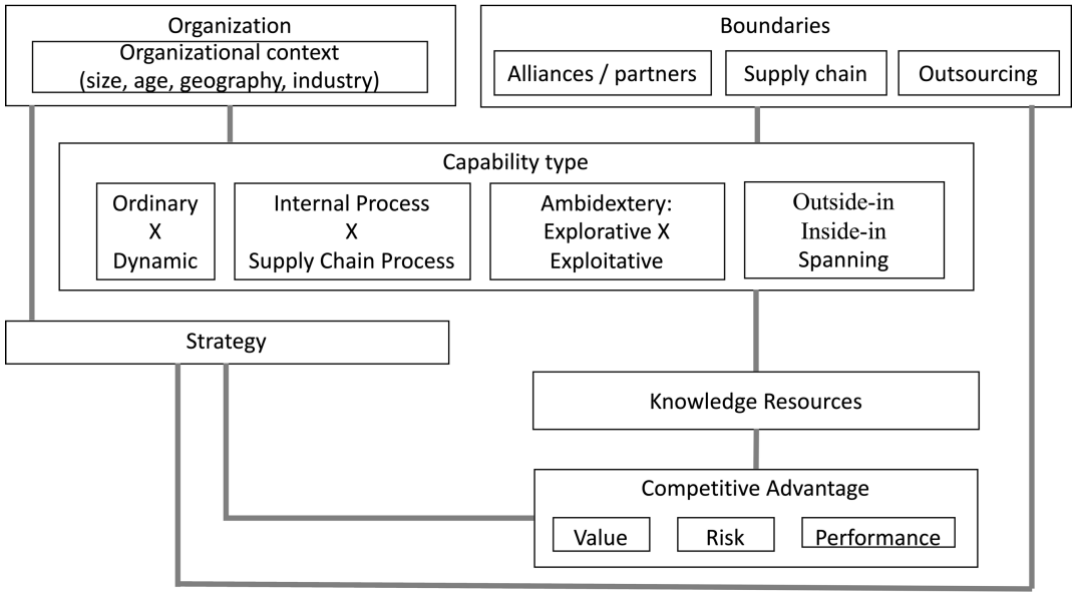

Figure 3.10 Business process capabilities connected concepts (Bogea Gomes, Santoro and Mira da Silva, 2022a)

(i) The **business process capability, organization, and boundaries** cluster. Organizations are increasingly prioritizing their business processes to excel (Looy, Backer and Poels, 2014). They are viewed as interconnected business processes that significantly influence organizational strategy and performance (Ferraris, Monge and Mueller, 2018). In addition to internal processes, organizations consider supply chain business processes to identify integration and coordination

opportunities within value chains and with external partners, including outsourcing (Caputo, Fiorentino and Garzella, 2019).

(ii) The **business process capability types of** clusters explore various types of business process capabilities and their applications:

> (a) *Ordinary x dynamic capabilities*. Ordinary capabilities allow organizations to efficiently operate their businesses, while dynamic capabilities enable them to adapt and improve existing capabilities or create new ones. Dynamic capabilities play a crucial role in organizational performance during periods of change in the business environment (Antonucci, Fortune and Kirchmer, 2020). Dynamic capabilities are rooted in the organization's resource-based view (RBV), which emphasizes the difficulty of replicating resources, leading to sustainable competitive advantages and differences in performance (Arief *et al.*, 2015).
>
> (b) *Internal x supply chain management business process*. Supply chain management encompasses the integrated management of the total flow within a distribution channel, from suppliers to end-users. It involves managing supplier relationships and ensuring supply chain quality from a business process perspective. Internal business process management focuses on managing functional areas to meet customer needs, including optimizing processes, flexibility, product quality, brand management, marketing, cost reduction, cross-departmental collaborations, and problem-solving abilities. It encompasses business processes unrelated to external supplies and customers (Peng *et al.*, 2016).
>
> (c) *Exploitative x explorative capabilities*. Recent research on management innovation suggests a combination of novel BPM competencies and organizational ambidexterity (Giacosa, Mazzoleni and Usai, 2018). Ambidexterity refers to an organization's ability to manage current demands (exploitation) while adapting to environmental changes (exploration). Achieving a balance between exploitation and exploration is crucial for organizational viability and success (Malik, Sinha and Blumenfeld, 2012). Organizational ambidexterity has been associated with technological innovation, organizational learning, competitive advantage, and survival (Koryak *et al.*, 2018). Additionally, business process capabilities can be classified in other forms, such as outside-in capability (anticipating market demands and building stable relationships with external stakeholders), inside-in capability (improving product or service innovation, financial management, and cost control), and spanning capability (developing business strategies and executing inter- and intra-organizational collaboration) (Wu and Chen, 2014).

(iii) The **business process capability and strategy** cluster emphasizes the importance of aligning internal and external business processes to enhance overall efficiency while safeguarding critical information from external supply chain actors through organizational relationships (Song *et al.*, 2021). The business strategy aims to create competitive advantages within the industry by effectively leveraging unique knowledge resources. Knowledge

management plays a direct role in creating customer value, generating profits, managing employees, and influencing the knowledge management process aligned with the business strategy. This process involves creating, sharing, and utilizing knowledge resources across functional boundaries, supported by various infrastructure capabilities such as a knowledge-based culture, structure, technology, and human resources (Chang and Chuang, 2011).

(iv) The **business process capability and knowledge resources** cluster acknowledge that knowledge is a strategic resource that must be managed to enhance an organization's competitive performance. Knowledge-based organizations rely on knowledge management as their primary source of competitiveness. The dynamic fabric of these organizations consists of knowledge management processes and capabilities, which are crucial for establishing and maintaining competitiveness (Mahdi and Nassar, 2021). Furthermore, it is essential to recognize that resources alone cannot be a source of competitive advantage. Resources become advantageous only when utilized through business processes (Ray, Barney and Muhanna, 2004).

(v) The **business process capability and competitive advantage** cluster recognizes that business process capability is a valuable resource that enables organizations to sustain competitive advantages. These advantages are safeguarded by isolated mechanisms such as social complexity, path dependency and unique historical conditions (Wu and Chen, 2014).

3.7.4 BPM Capability Framework

A survey on “a positive relationship between BPM and digital innovation” opened a discussion on whether the role of BPM needs to change and whether BPM-related capabilities should be re-interpreted for the digital age (Van Looy, 2017). In this scenario, BPM aims to create new opportunities for competitive business differentiation (Niehaves *et al.*, 2014) building on several new capabilities. Like other emerging approaches for boosting organizational readiness and maturity to cope with digital challenges, BPM transforms as well (Brkić, Tomičić Pupek and Bosilj Vukšić, 2020).

Kerpedzhiev *et al.* (2020) conducted a Delphi Study, exploring which BPM capability areas will become relevant in view of digitalization through a Delphi study with international experts from industry and academia. The study resulted in an updated BPM capability framework based on (de Bruin and Rosemann, 2007), and complemented by insights about the challenges and opportunities of BPM in the digital era. This BPM capability framework (Kerpedzhiev *et al.*, 2020) includes 30 capability areas structured according to six so-called core elements of BPM; which are Strategic Alignment, Governance, Methods / Information Technology, People, and Culture.

This thesis uses the BPM capability framework (Kerpedzhiev *et al.*, 2020) in view of digitalization, as a starting point to address our research question.

3.8 Unified Foundational Ontology (UFO) and OntoUML

A brief explanation of a selected subset of the ontological distinctions set out by UFO is offered in the remainder of this Chapter. It also shows how these distinctions are represented by the modeling primitives of OntoUML (as a UML profile). This section is largely based on to (Guizzardi, 2005; Guizzardi, Falbo and Guizzardi, 2008; Botti Benevides *et al.*, 2019; Derave *et al.*, 2019; Guizzardi *et al.*, 2022) (UFO-A), (Guizzardi, Falbo and Guizzardi, 2008; Botti Benevides *et al.*, 2019) (UFO-B), (Guizzardi, Falbo and Guizzardi, 2008; de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011) (UFO-C) and (Sales *et al.*, 2017; Sales, Baião, *et al.*, 2018) (COVER).

3.8.1 An Ontology of Endurants (UFO-A)

In what follows, it briefly presents the categories comprising UFO-A; the two subsequent sections focus on the categories of UFO-B and UFO-C, respectively. For an in-depth discussion, philosophical rationale, formal characterization, and empirical support for these categories, one should refer to (Guizzardi, 2005; Guizzardi, Falbo and Guizzardi, 2008; Botti Benevides *et al.*, 2019; Derave *et al.*, 2019; Guizzardi *et al.*, 2022).

This text highlighst in SMALL CAPS UFO terms the first time they appear and show in «guillemets» the corresponding OntoUML stereotypes. One should notice that OntoUML only represents types of entities and (Onto)UML stereotypes predicated over these types, not the entities instantiating these types. As such, when it mentions in the sequel the use of the stereotype, e.g., «relator» or «collective» for relators and collectives, what it means is that these stereotypes predicate over types whose instances are relators and collectives, respectively. Mutatis Mutandis, when it mentions the use of the relation of «mediation» between relators and their bearers, what it means that stereotyped relation is represented between a relator type and other type(s) such that mediation relations bind the instances of these types accordingly.

UFO makes a fundamental distinction between ENDURANTS and EVENTS. Endurants are entities that exist in time and can change qualitatively while maintaining their identity. Events, in contrast, are entities that unfold in time and accumulate temporal parts (e.g., a football game, a conversation, a speech). Endurants are further refined into SUBSTANTIAL and ASPECTS.

Substantials are existentially independent entities. They can be either Functional Complexes (e.g., Mick Jagger, my Car, the Moon) or COLLECTIVES («collective») (e.g., a deck of cards, a crowd). Collectives have uniform structures and contain other endurants as members («memberOf» relation).

Unlike substantials, aspects are parasitic entities and can exist only by inhering into other entities (their bearers), i.e., existentially dependent entities. Aspects can be INTRINSIC ASPECTS (which depend on one single bearer) or RELATIONAL ASPECTS (which depend on a multitude of bearers, thus connecting them). Intrinsic aspects can be Qualities (e.g., the colour of an apple, the weight of the rock, the inflation of a country) or a MODE (e.g., a belief, an intention, a headache, but also

dispositions such as electrical conductivity and magnetic attraction). Enrolment is an example of a relational aspect (also called a RELATOR in UFO). Qualities and modes are connected to their bearers via an existential dependence relationship of inherence1[17] (represented in OntoUML as a relation of <<characterization>> via the corresponding types); Relators are existentially dependent entities (e.g., the marriage between John and Mary can only exist if John and Mary exist) that bind together entities (their relata) via mediation (<<mediation>>) relations. Mediation is a type of non-functional existential dependence.

Let us first take a domain in reality that is populated by endurants. Entities in this domain will instantiate a number of KINDS, i.e., the genuine fundamental types of endurants exist in this domain. The term 'kind' is meant here in a strong technical sense, i.e., meaning that it is a type that captures essential properties of the things it classifies. In other words, the endurants instantiating a kind could not possibly exist without being of that specific kind. Kinds tessellate the possible space of endurants in that domain, i.e., all endurants necessarily belong to exactly one kind. OntoUML uses the stereotype <<kind>> simpliciter to represent types of substantial whose instances are functional complexes and the stereotype.collective. for those whose instances are collectives. Mode, quality and relator kinds are represented by the homonym's stereotypes (see figures 2-5). There can, however, be other static subdivisions (or subtypes) of a kind. These are naturally termed SUBKINDS (<<subkind>>).

Endurant kinds and subkinds represent essential properties of endurants, also termed rigid or static types (Guizzardi, 2005). There are also types that represent contingent or accidental properties of endurants; these are termed anti-rigid types (Guizzardi, 2005). These include PHASES (<<phase>>). Phases dynamically classify their instances, for example, in the way that 'being a puppy' captures a cluster of contingent intrinsic properties of a dog, or in the way that 'being a living person' captures a cluster of contingent intrinsic properties of a person. Living Person and Deceased Person form a partition (termed phase partition) representing every person instantiate exactly one of the two phases. Every instance of Living Person is only contingently an instance of Living Person (in the modal sense). For every P such that P is Living Person, there is a counterfactual situation in which P is not a Living Person, which implies that P is a Deceased Person in this counterfactual situation.

Another example of an anti-rigid type is a ROLE (<<role>>). Roles are anti-rigid and relationally dependent, for example, in the way that 'being a husband' captures a cluster of contingent relational properties of a man participating in a marriage. In other words, the contingent properties represented by phases and roles differ as follows: phases represent properties that are intrinsic to entities (e.g., 'being a puppy' is being a dog that is in a particular developmental phase; 'being a living person' is being a person who has the intrinsic property of being alive; 'being an available car' is being a car that is functional and, hence, can be rented). Roles, on the other hand,

[17] Inherence is a type of non-reflexive, asymmetric, anti-transitive and functional existential dependence relation (Guizzardi *et al.*, 2022).

represent properties that entities have in a relational context, i.e., contingent relational properties. For example, ‘being a husband’ is to bear a number of commitments and claims towards a spouse within the scope of a marital relationship; ‘being a student’ is to bear a number of properties within the scope of an enrolment relationship with an educational institution.

Kinds, Subkinds, Phases, and Roles are Categories of SORTALS. In the philosophical literature, a Sortal is a type that provides a uniform principle of identity, persistence, and individuation for its instances (Guizzardi, 2005).To put it simply, a sortal is either a kind (e.g.,‘Person’) or a specialisation of a kind (e.g., ‘Student’, ‘Teenager’, ‘Woman’), i.e., it is either a type representing the essence of what things are or a sub-classification applied to the entities that “have that same type of essence”.

Endurants are connected by relators while playing certain “roles”. For instance, people play the role of the spouse in a marital relationship; a person plays the role of president in a presidential mandate. ‘Spouse’ and ‘President’ (but also typically student, teacher, pet) are examples of what has technically termed a role in UFO. It is a relational contingent sortal since this type of role can be played only by entities of a single given kind. There are, however, relational and contingent role-like types that entities of multiple kinds can play. An example is the role of the ‘Customer’, which both people and organizations can play. It calls these role-like types that classify entities of multiple kinds of ROLE MIXINS («roleMixin»).

Role Mixins are examples of NON-SORTALS (also called dispersive types), i.e., types that classify endurants of multiple kinds. Role Mixins are contingent, relationally dependent non-sortals. There are, however, non-sortals that are rigid and relationally independent. These are termed CATEGORIES («category »), which represent essential properties that are shared by endurants of multiple kinds. For example, in a human body («kind»), the heart («kind») is a type of muscle («category»). Muscle is a category as one has muscles in other parts of its bodies.

EVENTS are represented in OntoUML by having their types stereotyped as «event» (Almeida et al., 2019). The language also includes several relations between events (e.g., parthood), between substantial and events (e.g., participation), and between modes (dispositions) and events (e.g., «manifestation»). Roles (and role mixins) whose relational dependence conditions are defined in terms of participation in events are termed HISTORICAL ROLES (and HISTORICAL ROLE MIXINS) («historicalRole» and «historical-RoleMixin»).

Finally, UFO also considers the existence of Types whose instances are other types (i.e., higher-order types), to form multi-level structures. These classes are represented in OntoUML by classes stereotyped as «Type» (Guizzardi *et al.*, 2015; Carvalho, Almeida and Guizzardi, 2016; Carvalho *et al.*, 2017). According to Guizzardi *et al.* (2015), it take types here to be special sorts of endurants.

3.8.2 An Ontology of Events (UFO-B)

UFO-B (Guizzardi, Falbo and Guizzardi, 2008; Botti Benevides *et al.*, 2019) explicitly differentiate between EVENTS and ENDURANTS regarding their relationships with time. ENDURANTS are fully present at whatever instant of time they are present, i.e., they are in time in the sense that, if in a circumstance c_1, a substantial S has the property P_1 and in a circumstance *c2,* the property P_2 (possibly incompatible with P_1), it remains the same substantial S in both situations. For example, John weighs 80 kg in c1 and 70 kg in *c2,* but he is the same John. EVENTS (sometimes also called PERDURANTS or OCCURRENCES) are individuals composed of temporal parts. They unfold in time, accumulating temporal parts. Examples of events are a conversation, a football match, and a symphony performance. Only some of its temporal parts will be present when an event is present. Consequently, events cannot change in the genuine sense since none of their temporal parts retains their identity over time.

For UFO-B (Botti Benevides *et al.*, 2019): (i) events are possible transformations from one Situation to another, i.e., they can change the state of affairs in reality from one (pre-)state to another (pos-)state; (ii) events are ontologically dependent entities as to exist, they existentially depend on their participants; (iii) events can be mereologically complex (following an extensional mereology); (iv) events are manifestations of dispositions; (iv) events relate to each other via temporal relations (*Allen Relations*) as well as via causation relations. Causation is derived from a mechanism of disposition activation by situations plus having events bringing about situations. In other words, if an event *e* brings about a situation *s*, which activates disposition *d*, which, in turn, is manifested by event *e'*, then it has that *e* has caused *e'*. Moreover, if *e* causes *e'*, which causes *e"*, then *e* indirectly causes *e"*. Indirect causation is, thus, a strict partial order relation.

Some authors, most notably (Galton, 2006), make a strong distinction between PROCESSES and EVENTS. For him: (a) processes are open-ended, whereas events are not, i.e., while events have a beginning and an end, processes go on from moment to moment and, in principle, can continue (although extraneous factors can prevent them from doing so). In other words, an event is a piece of history, while a process can be experienced in the present; (b) processes are homeomerous, i.e., if a process goes on over some time interval, then it goes on over each subinterval of that interval; (c) processes (but not events) can be the direct objects of experience. In this respect, processes are almost more like ENDURANTS than PERDURANTS: they are present from moment to moment, can be experienced directly, and undergo changes.

In UFO-B, in contrast, all events (atomic or complex, homeomerous or otherwise) are modally fragile entities (i.e., they cannot change) and only exist as past entities (Guizzardi, Guarino and Almeida, 2016). The term process is sometimes used to refer to complex events, but they are nonetheless entities of the same nature (Guizzardi *et al.*, 2022). The notion of ongoing complex events is detailed in (Guizzardi, Guarino and Almeida, 2016), and, in a nutshell, ongoing events are modelled as having successive numerically distinct events of the same kind that are proper parts of their successors. A definite description as a constant (e.g., this walk to the station, this fall of the rock) gives the illusion of numerical identity of these different succeeding events and is

individuated by a constant focus, namely a background endurant which is either the changing quality at hand (Guarino, Baratella and Guizzardi, 2022) (e.g., the vertical position of the falling rock) or the disposition of which the event is a manifestation (Guizzardi, Guarino and Almeida, 2016) (e.g., an intention to walk to the station).

3.8.3 An Ontology of Social and Intentional Entities (UFO-C)

One of the main distinctions made in UFO-C is between AGENTS and (non-agentive) OBJECTS. Agents (but not objects) are substantials that have intentionality. Intentionality in UFO should be understood in a broader sense than the notion of "intending something". It refers to the capacity of some properties of certain individuals to refer to possible situations of reality. Thus, "intending something" is a specific type of INTENTIONAL ASPECT termed INTENTION. Intentional Aspects can be SOCIAL ASPECTS or MENTAL ASPECTS. SOCIAL COMMITMENTS (i.e., commitments towards other agents) are examples of social aspects. SOCIAL RELATORS are relators composed of social aspects (e.g., commitments and claims).

Intentional Aspects include, besides Intentions, BELIEFS (that can be justified by situations in reality) and DESIRES (expresses a will of an agent towards a state of affairs in reality). Intentions are desired state of affairs for which the agent commits at pursuing (internal commitment, i.e., commitments the agent creates towards itself, self-commitments) towards a GOAL (the propositional content of that Intention), i.e., towards bringing about a certain state of affairs in the world. One particular type of Intention is a CLOSED INTENTION, which is a commitment to pursue a goal in a specific way, i.e., constrained by a particular type of action Type termed a PLAN. AGENTS can be physical (e.g., a single natural person) or social (e.g., an organization). There are various types of organizations (for instance, legal and nonlegal). This work focuses on legal types of organizations recognized by law as juridical persons, such as corporations, government agencies, non-profit organizations, or international and inter-governmental organizations (such as the United Nations).

ACTIONS are Intentional events, i.e., events that are performed by agents to satisfy their goals. Examples of actions are writing this thesis and a business process. Like events, actions can be atomic or complex. A complex action is composed of two or more participations of endurants. These participations, in turn, can be intentional (and therefore themselves actions) or unintentional events. Since only agents can perform actions, the object participating in an action is called a RESOURCE. A complex action composed of contributions from the actions of different agents is called an INTERACTION. A dialogue between two agents is an example of an interaction.

NORMATIVE DESCRIPTIONS are types of social objects that, being recognized by social agents, can bring other types of social objects into existence. Normative description can define one or more rules/norms recognized by at least one social agent. Examples of normative descriptions include the Italian Constitution, the University of Twente bylaws, but also a set of directives on performing some actions within an organization (a description of a plan). Figure 3.11 depicts a fragment of

UFO-C containing a summary of the categories discussed in this section. As previously discussed, this model is represented as a module in OntoUML[18].

[18] The OntoUML models in this thesis use a colour convention employed by that community: light red is used for types whose instances are substantials, yellow for those whose instances are events, green for those whose instances are relators, blue for those whose instances are qualities, orange for those whose instances are situations, purple for those whose instances are higher-order types, and grey for those types whose instances can belong to one or more of these ontological categories. A Strong variant of each of these colours is used to represent kinds within these categories (relator kinds, quality kinds, etc.), i.e., those types providing the principle of identity for their instances (Guizzardi, 2005).

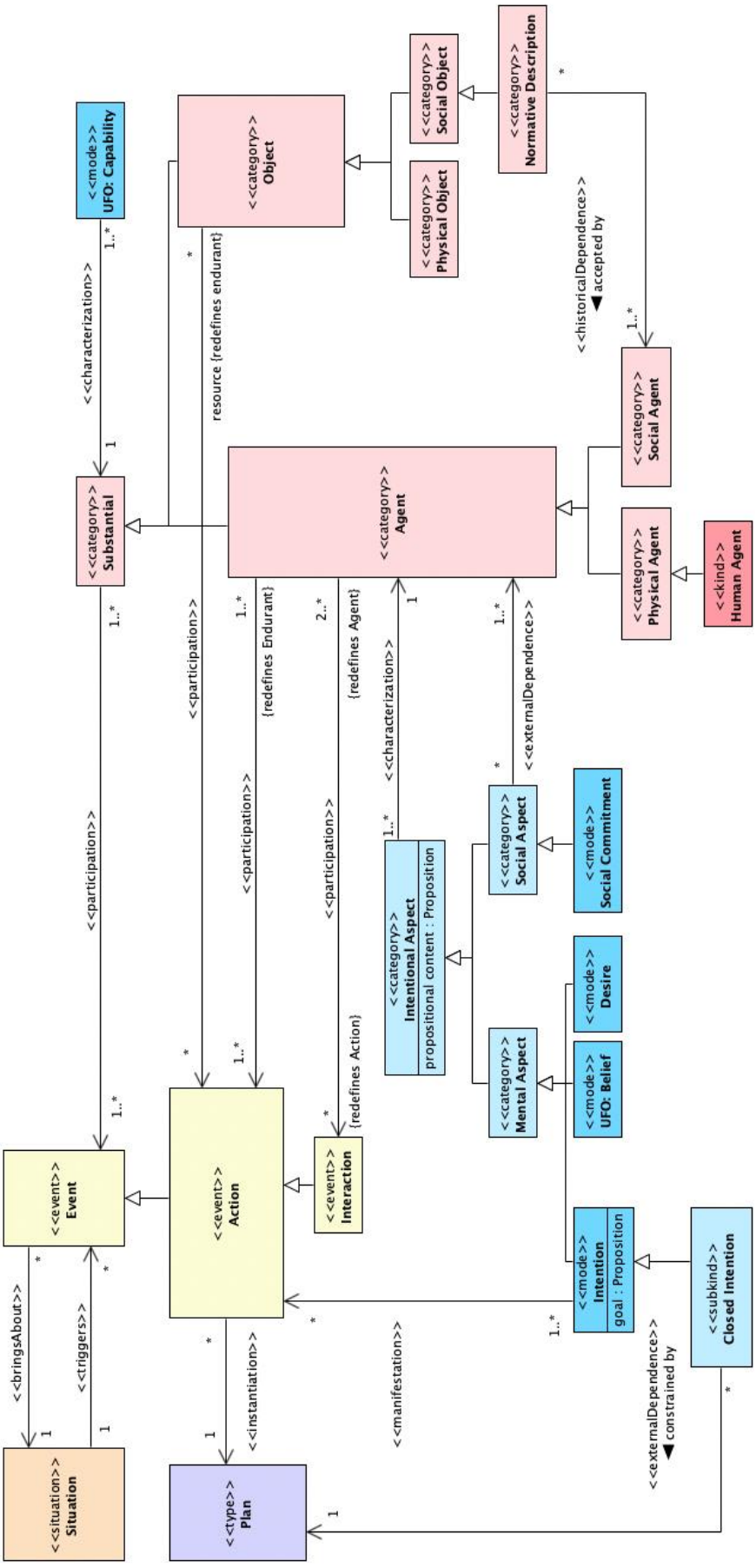

Figure 3.11. A UFO-C fragment.

3.9 Common Ontology of Value and Risk (COVER)

An organizational transformation aims at value creation for the business. Although its focus is value creation, at the same time, the transformation does come with costs and risks, sometimes unforeseen. Therefore, it is essential to understand the opportunities and potential challenges surrounding its value creation. Since, in an organizational transformation, the nature of the value ascription (for example, the customer relationship) is more important than the value exchange between subjects, as value ascription concept considers “what” value is and “why” something is valuable, while the concept of value exchange between subjects disregards this understanding, it looks to clarify the concepts involved. To that end, this thesis reuses the concepts related to value and risk from the Common Ontology of Value and Risk (COVER) (Sales *et al.*, 2017; Sales, Baião, *et al.*, 2018). Moreover, this thesis agrees with (Guarino *et al.*, 2016) on the importance of understanding “what” value is and “why” something is valuable.

Nothing is intrinsically valuable (Guarino *et al.*, 2016). Value only exists because people ascribe it to things; thus, value is subjective to a great extent. Customers familiar with technologies might ascribe a high value to a digital business, whilst their grandparents are unlikely to do so. Value depends on the mental aspects of the value-ascribing stakeholders (henceforth value beholders), such as desires, goals, needs, and preferences (Sales *et al.*, 2017). Moreover, for them, value is not a synonym for benefit. Value arises from weighing benefits and sacrifices. For instance, some people consider owning a smartphone of a specific brand (which is likely more expensive) to bring more benefits than the sacrifice of paying for it. Therefore, the value depends on the beholder and his or her mental aspects. However, this does not mean that an object’s intrinsic aspects (or parts) do not influence the value people ascribe to it.

According to Guarino *et al.* (2016), the analysis of value, value ascription mechanisms, and their motivating and influencing factors is helpful for decision-making processes. Several approaches have been developed in the value modelling literature, such as the Resource, Event, Agent (REA) Ontology (McCarthy, 1982), e3value (Gordijn and Akkermans, 2001), and the Value Delivery modelling Language (VDML) (OMG, 2018). (Guarino *et al.*, 2016) present and discuss the Value Ascription Ontology (VAO), aiming at elaborating on the nature of the value ascription relationship. Sales et al. (2017) built upon the Value Ascription Ontology (VAO) to propose a theory of value propositions grounded in UFO.

This theory elaborates on the nature of (economic) value, which “things” can have value, and how the process of ascribing value works. In particular, the authors adopt the interpretation of value as use value (or value-in-use), henceforth just ‘value’, as opposed to exchange (or market) value, given the former’s role in formulating value propositions. In this sense, the value of a thing emerges from how well its affordances match the goals/needs of a given agent in a given context.

Organizations need well-designed business strategies to gain a sustainable competitive advantage. One crucial aspect informing the design of business strategies are value propositions, which are types of value ascriptions. Value ascription is a judgement relationship between an

agent (the value beholder) and a value bearer, which the beholder judges as having value for someone (the value beneficiary). A value ascription is an aggregation of “smaller” judgments, i.e., the value ascription components. Each component focuses on the beneficiary’s experience from the perspective of one of its mental aspects (including beliefs).

Value propositions are the answer to why customers engage in a business relationship with one organization and not another – customers choose (Product and Service) offerings which they perceive to offer a superior value proposition. It may be beneficial for an organization to redesign itself and its offerings to maximize the value created for its customers. Offerings describe how a product, service or feature create value for a target market segment. A business is segmented into market segments to better design offers to its customers and bring value to the business (Sales *et al.*, 2017).

For Sales, Baião, *et al.* (2018), value and risk are intrinsically connected. COVER shows this duality between value and risk, considering them both to be the same type of phenomena but with opposite polarity. Value is a composition of benefits (which emerge from goal satisfaction) and sacrifices (which emerge from goal dissatisfaction). Risk is one type of sacrifice, as a value reducing factor. This suggests the process of ascribing value is strongly related to the process of assessing risk.

Given the strong connection between these two concepts, COVER generalizes the notions of value ascription and risk assessment into a type of relator that involves: (i) an agent who is responsible for the judgment, deemed the value and risk assessor, respectively; and (ii) the target of the judgment, which could be either an object or an event. According to COVER, the value/risk ascribed to an object is always derived from the value/risk ascribed to events (or experiences) “enabled” by their dispositions, regardless of whether these events are Intentional or not, and whether they affect one’s goals positively or negatively.

Representing value and risk as qualities means that they can also be measured according to a given scale, such as a simple discrete scale (e.g., <Low, Medium, High>) or a continuous scale (e.g., from 0 to 100) (Sales, Baião, *et al.*, 2018).

Chapter 4

Digital Transformation Ontology

Digital transformation is a type of organizational transformation that changes societies and industries through the convergence of multiple new digital technologies enhanced with ubiquitous connectivity (Beverungen et al., 2021). However, according to Reeves et al. (2018), the research underpinning the design and execution of corporate transformations is surprisingly poor and lacks an evidence-based approach. Thus, the main problem addressed in this thesis is that even though digital transformation has gained great research interest (Morakanyane, Grace and O'Reilly, 2017), there is a lack of common understanding of this concept.

This thesis proposes the Digital Transformation Ontology (DTO) to distinguish and represent organizational digital transformation concepts in an unambiguous way. Moreover, the ontology provides a domain-independent conceptual specification that can be able to guide digital transformation initiatives based on a solid conceptual foundation and a clear understanding of digital organizational transformation and related concepts.

This research started with a deep investigation of the problem (the DSR - problem identification and motivation steps). Transformation is an essential part of the strategic plans of many organizations because they must change constantly to stay in business and keep their competitive advantages. Such transformations can impact business models, operational processes, end-user experiences, and technological shifts (Henriette, Feki and Boughzala, 2016). The objectives of a solution are inferred from the problem definition and the knowledge of what is possible and feasible (DSR - define the objectives for a solution), which lead to the proposal of the Digital Transformation Ontology (DTO) to address the problem. The term *digital transformation* has been broadly used, even though it is hard to agree on a single definition (Gong and Ribiere, 2021). Digital transformation and innovation have directly impacted our society's relationships and consumption patterns. Technologies are constantly being integrated into daily life, introducing new shapes for all businesses. The economy and society have been rapidly digitalized (OECD, 2017). The digital world shapes experiences by seamlessly and inseparably intertwining the digital with the physical, thereby creating (or assisting in creating) the physical environments in which we live (Ismail, Khater and Zaki, 2017). Furthermore, digital technologies create and shape physical reality (Baskerville, Myers and Yoo, 2020).

After that, in the first cycle of the DSR – development step, the design of the first version of the ontology was proposed (see Appendix A): the artifact Digital Transformation and Innovation Business Process Management Ontology (DT&I-BPM-onto) (Bogea Gomes, Santoro and Mira da Silva, 2020), investigating the following research questions:

RQ1a. What are the conceptual elements involved in the context of DT&I and BPM?

RQ2a. Which relationships support the DT&I and BPM dynamics?

Subsequently, this artifact was evaluated (DSR - demonstration) according to the implicit or explicit functional specifications in the suggestion and communicated (DSR – communication). After finishing the first DSR cycle (presented in Appendix A), the following lessons were learned:

- Digital innovation is a broad topic, however, from this thesis inquire perspective it can be viewed as one of the vectors of digital transformation.
- An organization is a group of people who have banded together to form a community or other social, commercial, or political structure. Enterprise is a synonym for firm and company related to business organizations.
- A type of organizational change is organizational transformation. Organizational development is another type of organizational change. Change in organizations can be planned or unplanned; it can also be revolutionary (organizational transformation) or evolutionary (organizational development). Most planned organizational changes are evolutionary regarding an organization's day-to-day adaptations.
- Digital transformation is a type of organizational transformation.
- Digital transformation is an initiative in which organizations use digital platforms to improve performance, expand their reach, and ensure the best possible results for their business.

The second cycle (see Figure 4.1) was initiated with a new development activity, considering the artifact the Digital Transformation Ontology (DTO) and the following research questions, refined from the first cycle:

- RQ1. What is digital transformation?
- RQ2. What can be transformed in a digital transformation?
- RQ3: What are the characteristics of a digital transformation?
- RQ4. What are the outcomes of a digital transformation?

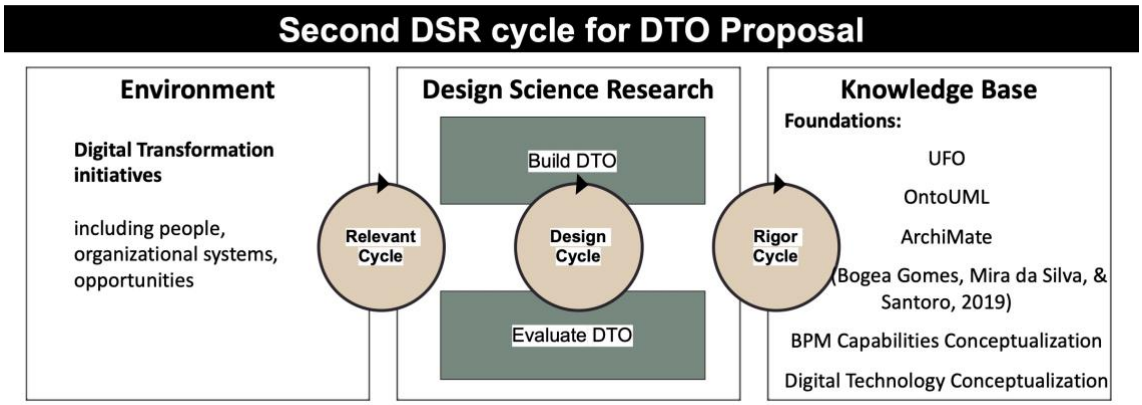

Figure 4.1. DSR framework for DTO Proposal – second cycle, based on (Recker, 2021)

This chapter explains each part that composes DTO as depicted in Figure 4.2: Section 5.1 presents the Core Ontology of Organizational Transformation (COOT). Section 4.2 introduces a Digital Transformation Ontology (DTO) proposal, to shed light on the dynamic relationship between digital BPM capabilities, digital technologies, and digital transformation.

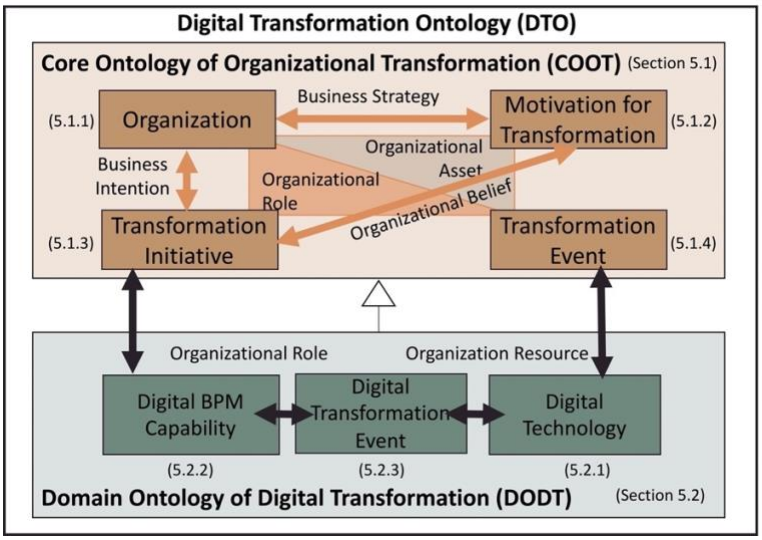

Figure 4.2. Thesis proposal structure.

4.1 Core Ontology of Organizational Transformation (COOT)

The Core Ontology of Organizational Transformation (COOT) aims to provide constructs central to creating a reference model of organizational transformation with its inherent social characteristics. COOT's purpose and intended uses are to share a common understanding of organizational transformation and to enable the knowledge to be reused by interested organizations and researchers, either for integrating or extending it with other ontologies.

The following Competency Questions (CQs) were established to determine COOT's precise scope:

CQ1. Which organization is to be transformed?

CQ2. How to characterize organizational transformation?

CQ3. What motivates an organizational transformation initiative?

CQ4. How does an organizational transformation initiative emerge?

CQ5. Who are the agents involved in an organizational transformation?

CQ6. What are the roles of the agents involved in an organizational transformation initiative?

CQ7. What organizational values are associated with organizational transformation?

CQ8. What factors enable organizational transformation?

CQ9. What transformable entities originate in and result from organizational transformation?

CQ10. What are the phases in an organizational transformation?

The literature review reported in Chapter 3 was used to identify the most important domain concepts and formulate the ontology's competency questions (SABiO's phase 2 (Falbo, 2014)). The concepts discussed here are the basis for the ontological choices when creating an ontology. In the models, it is indicated which concepts of UFO and COVER have been directly reused (by using the proper prefix UFO: Concept or COVER: Concept), and which have been extended (by using subtyping relations towards reused concepts). Some other concepts are based on other ontologies but are not directly reused. These are indicated in Table 4-1. In the following sections, several concepts related to organizational transformation are analyzed and represented in the ontology modules comprising COOT.

Table 4-1. Concepts based on other ontologies.

<<stereotype>>	Class	Reference
<<subkind>>	Formal Organization	W3C
<<collective>>	Group	UFO-A, W3C
<<subkind>>	Informal Organization	W3C

<<kind>>	Organization	UFO-C, (Bottazzi and Ferrario, 2009), W3C
<<relator>>	Organization Membership	W3C, (Bottazzi and Ferrario, 2009)
<<kind>>	Organizational Body of Norms	UFO-C, (Bottazzi and Ferrario, 2009), (Almeida and Cardoso, 2011)
<<mixin>>	Organizational Part	W3C
<<kind>>	Organizational Unit	W3C
<<subkind>>	Position	termed a Post in W3C; (Scheer, 2012)
<<roleMixin>>	Prospect Bearer	COVER
<<roleMixin>>	Prospect Beholder	COVER
<<roleMixin>>	Prospect Beneficiary	COVER
<<role>>	Subsidiary Organization	W3C

The two central concepts of COOT are the organization and its transformation. In the following text, the terms written in SMALL CAPS represent COOT classes. The ontology COOT is presented diagrammatically in a set of modules, namely The Organization Concepts on the Organizational Transformation (Section 4.1.1 and Figure 4.3), Motivation for Transformation (Section 4.1.2 and Figure 4.4), The Transformation Initiative (Section 4.1.3 and Figure 4.5), and The Transformation Event (Section 4.1.4 and Figure 4.6). As previously mentioned, COOT is grounded in UFO and its fragments: UFO-A (Guizzardi, 2005), UFO-B (Almeida, Falbo and Guizzardi, 2019; Botti Benevides *et al.*, 2019), and UFO-C (Guizzardi, Falbo and Guizzardi, 2008; de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011). The categories of UFO-A and UFO-B are directly reused by building the models in OntoUML; the categories of UFO-C are reused by extending the model depicted in Chapter 3, Figure 3.11 Moreover, in line with SABiO, COOT reuses COVER (Common Ontology of Value and Risk) (Sales *et al.*, 2017; Sales, Baião, *et al.*, 2018) and defines the concept of organization based on the W3C Organization Ontology (W3C, 2014), as well as some elements from the DOLCE Organization Ontology (Bottazzi and Ferrario, 2009; Almeida and Cardoso, 2011).

4.1.1 Organization Concepts on the Organizational Transformation

The first of these modules of COOT is depicted in Figure 4.3. This module directly extends some categories from UFO-C (see Chapter 3, sub-section 3.8.3), namely AGENT and SOCIAL AGENT, INTENTION and CLOSED INTENTION, NORMATIVE DESCRIPTION, SOCIAL RELATOR, PLAN, and ROLE. Two new kinds of agents are established: GROUP (having agents of all kinds as members) and ORGANIZATION. The notion of GROUP can be used to conceive collectives formed for organizational collaboration. These may be established between two or more ORGANIZATIONS, e.g., for the scope of a particular project. From this, an entity that meets the criteria for agency emerges. It has an identity and a defining purpose independent of the particular collective of collaborating Agents involved (e.g., a joint venture between Uber and Volvo to develop self-driving cars). The kinds of Social Being and Groups supply different principles of identity. It is considered that Group supplies an extensional principle of identity, i.e., two groups are the same if they have the same members,

while it can change the members of a social being (like an enterprise or football team) and still have the same social being. Moreover, the same Group can form different social beings with different purposes. This form of organization collective typically has a shorter lifetime than the ORGANIZATIONS from which it emerged, but not necessarily so.

An ORGANIZATION is a type of social agent which is specialized into two subkinds (FORMAL ORGANIZATION and INFORMAL ORGANIZATION), and which (being a social agent) accepts a particular type of normative description (termed an ORGANIZATION BODY OF NORMS). Both informal and formal norms were considered here as possible types of ORGANIZATIONAL BODY OF NORMS. COMPLEX ORGANIZATIONS are ORGANIZATIONS that are composed of at least two disjoint ORGANIZATIONAL PARTS. A COMPLEX ORGANIZATION is a role played by an ORGANIZATION, given that the type is contingent for ORGANIZATIONS (e.g., ORGANIZATIONS can become mereologically complex and cease to be so) and relationally dependent, i.e., ORGANIZATIONS become complex by establishing parthood relations with ORGANIZATIONAL PARTS[19]. The type ORGANIZATIONAL PART is a mixin given that some of its instances, namely ORGANIZATIONAL UNITS, are necessary ORGANIZATIONAL PARTS[20], while other instances, namely SUBSIDIARY ORGANIZATIONS, are only contingently so - in fact, an ORGANIZATION plays this role when being in a subsidiary relation with a larger ORGANIZATION. An example of a SUBSIDIARY ORGANIZATION is a FORMAL ORGANIZATION that belongs to another ORGANIZATION.

FORMAL ORGANIZATIONS are given full recognition within the ORGANIZATION's context as well as by broader scope organizations such as a state. When the ORGANIZATION is an INFORMAL ORGANIZATION, it is not a legal entity in its own right. An ORGANIZATION can be large, complex and contain other ORGANIZATIONAL UNITS and even SUBSIDIARY ORGANIZATIONS. Examples of ORGANIZATIONAL UNITS include branches, departments, and other business units.

A POSITION within an ORGANIZATION exists independently of the agents filling it. A POSITION (termed a Post in (W3C, 2014)) is considered here to be a minimal ORGANIZATIONAL UNIT, i.e., an ORGANIZATIONAL UNIT that can be occupied by at most one agent (Scheer, 2012).

The POSITION differentiates, for example, the current President of an ORGANIZATION (i.e., the agent currently playing that role) from the Presidency (or Presidential Office) (a minimal ORGANIZATIONAL UNIT). A POSITION can exist even if it is vacant. A POSITION is filled when an agent (termed the POSITION HOLDER) is assigned to that POSITION via a POSITION ASSIGNMENT. A POSITION ASSIGNMENT is bound to MEMBERSHIP by that agent in that ORGANIZATION. POSITION ASSIGNMENTS and MEMBERSHIPS are examples of social relators in UFO, i.e., they bundle commitments and claims that bind the parties (UFO-C).

[19] These are relations of functional parthood and, hence, material relations according to Guizzardi (2009).

[20] In fact, an ORGANIZATIONAL UNIT is necessarily an inseparable part of a specific instance of ORGANIZATION as represented here by an inseparable parthood relation (Guizzardi, 2007).

A POSITION is constrained to a set of ORGANIZATIONAL ROLES (the roles played by some agent when holding that position). If an agent, by virtue of his or their MEMBERSHIP[21], is bound to an ORGANIZATIONAL ROLE, it have that agent instantiating that role (in the sense of (Carvalho, Almeida and Guizzardi, 2016)). A POSITION ASSIGNMENT is just one type of MEMBERSHIP that can be established between an agent and an ORGANIZATION. Other examples include shareholders and members of the board. Moreover, these relationships can be established between ORGANIZATIONS and all types of agents (such as people, groups and other organizations). For this reason, both ORGANIZATION MEMBER and POSITION HOLDER are modelled as role mixins (contingent, relational dependent and dispersive type).

All agents are able to bear intentions. A BUSINESS INTENTION is a closed intention that inheres in a particular type of agent, namely an ORGANIZATION. The propositional content of a BUSINESS INTENTION is termed a BUSINESS GOAL. As a closed intention, a BUSINESS INTENTION is constrained by a particular type of plan, termed a BUSINESS STRATEGY. The ORGANIZATION BODY OF NORMS accepted by the ORGANIZATION also brings other types of ORGANIZATIONAL ASSETS into existence, including ORGANIZATIONAL ROLES and BUSINESS STRATEGIES (a specialization of the UFO notion of plan).

BUSINESS STRATEGIES and ORGANIZATIONAL ROLES are ORGANIZATIONAL ASSETS, i.e., resources controlled or owned by the ORGANIZATION. Being “owned or controlled” by an ORGANIZATION is understood as that ORGANIZATION having certain legal positions (e.g., bundles of rights, duties, legal powers, liabilities, etc.) (Griffo *et al.*, 2021) over that specific entity (Azevedo *et al.*, 2015). As it shall see in the remaining modules of COOT, ORGANIZATIONAL ASSETS are a cross-categorical type, i.e., a type whose instances can span across multiple fundamental ontological categories (e.g., types and relators). Cross-categorical types are depicted in grey in OntoUML models.

[21] The notion of organizational membership is akin to the notion of affiliation put forth by (Bottazzi and Ferrario, 2009). The authors define affiliation as “the conditions under which agents are a member of organizations". Agents are affiliated with organizations by playing certain roles and undertaking rights and obligations associated with those roles. The connection between organization members and (organizational) roles is established via membership relators, which are social/legal contracts, thus entailing properties such as duties, rights, powers, etc. (Griffo *et al.*, 2021). Although position assignments bind particular members to organizations, positions themselves can exist even if they are vacant - a notion not countenanced in (Bottazzi and Ferrario, 2009)’s original proposal. Both proposals allow non-human agents to be members of organizations. Finally, the notion of membership proposed here is more general than binding members to organizational positions. Hence, agents can be members of organizations without being their functional part, i.e., without occupying these “minimal units" of the organization. In any case, as for Bottazzi and Ferrario (2009), all memberships are bound to organizational roles and entail social/legal contractual properties.

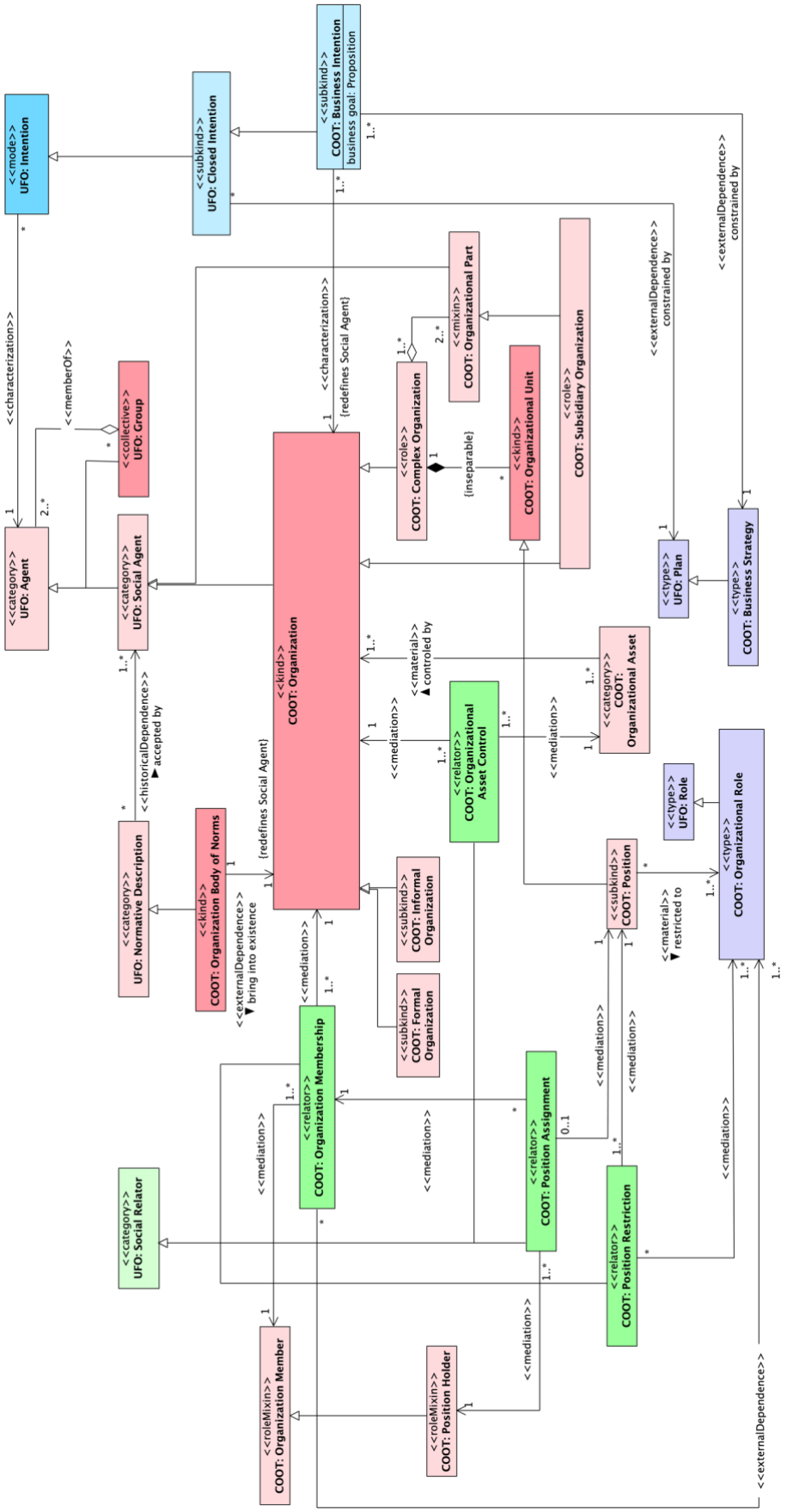

Figure 4.3 The Organization, its parts, members, intentions, and assets.

4.1.2 Motivation for Transformation

Figure 4.4 shows the COOT module that represents organizational transformation's motivational aspects. Central to this model is a generalization of the notions of Value Ascription and Risk Assessment from COVER (Sales, Baião, *et al.*, 2018) into the notion of PROSPECT[22] ASSESSMENT. Prospect means an apparent probability of advancement, success, and an outlook for the future. A PROSPECT ASSESSMENT is a relator binding a PROSPECT BEHOLDER (an agent, typically the ORGANIZATION itself, or one of its subparts or an agent member of the ORGANIZATION), a PROSPECT BEARER, VALUE ENTITY or a Value Experience (e.g., a service delivery)[23], and a PROSPECT BENEFICIARY. PROSPECT ASSESSMENTS can be value ascriptions (to given value bearers) or risk assessments (of a risk subject) (Sales, Baião, *et al.*, 2018).

One particular type of value ascription is a value proposition (Sales, Baião, *et al.*, 2018) connected with a market segment, which, in turn, is a collective of value beneficiaries (here also generalized into the notion of PROSPECT BENEFICIARY). The notion of VALUE ENTITY here is a generalization of the COVER notion of value object to include cross-categorical types such as ORGANIZATIONAL ASSET. A PROSPECT ASSESSMENT is created by a PROSPECT EVALUATION. This event also leads to the formation of ORGANIZATION BELIEFS (sort of UFO-C beliefs), which inhere in ORGANIZATIONS.

As it shall observe, these beliefs account for changes to be promoted in ORGANIZATIONAL ASSETS, including BUSINESS OFFERINGS. BUSINESS OFFERINGS are specializations of offering relationships (in the COVER sense) and bind an ORGANIZATION to an eligible market segment (a subset of a COVER market segment). (Sales et al., 2017) argue that value propositions and offerings are directly related, as at the business level value propositions provide an abstract idea of the value offered by the organization through all of its offerings for a specific market segment, measuring benefits and costs with coarse granularity. At the offering level, value propositions regarding benefits and costs are very precise.

For Sales, Baião, *et al.* (2018), an offering is a promise with conditional content made by an agent (the offeror) directed to a group of agents that form an eligible market segment. A value proposition (a type of value ascription) describes what an organization delivers to its customers. In other words, it is the ultimate answer to why customers choose to hire their services or buy their products. ORGANIZATIONS compete for various reasons (Sales, Baião, *et al.*, 2018), e.g., to offer better products at lower prices. Often, ORGANIZATIONS ultimately compete for customers (Watson, 2002). In competitive markets, after evaluating, assessing, and addressing potentially favorable and unfavorable prospects, ORGANIZATIONS carefully design Value Propositions that are aligned with BUSINESS STRATEGIES.

[22] We thank João Paulo Almeida for suggesting the use of this term here.

[23] As discussed in (Sales, Baião, *et al.*, 2018), a value experience is an event in the sense of (Guarino, 2017). These non-classical kinds of events are represented here with the stereotype <<variable event>>.

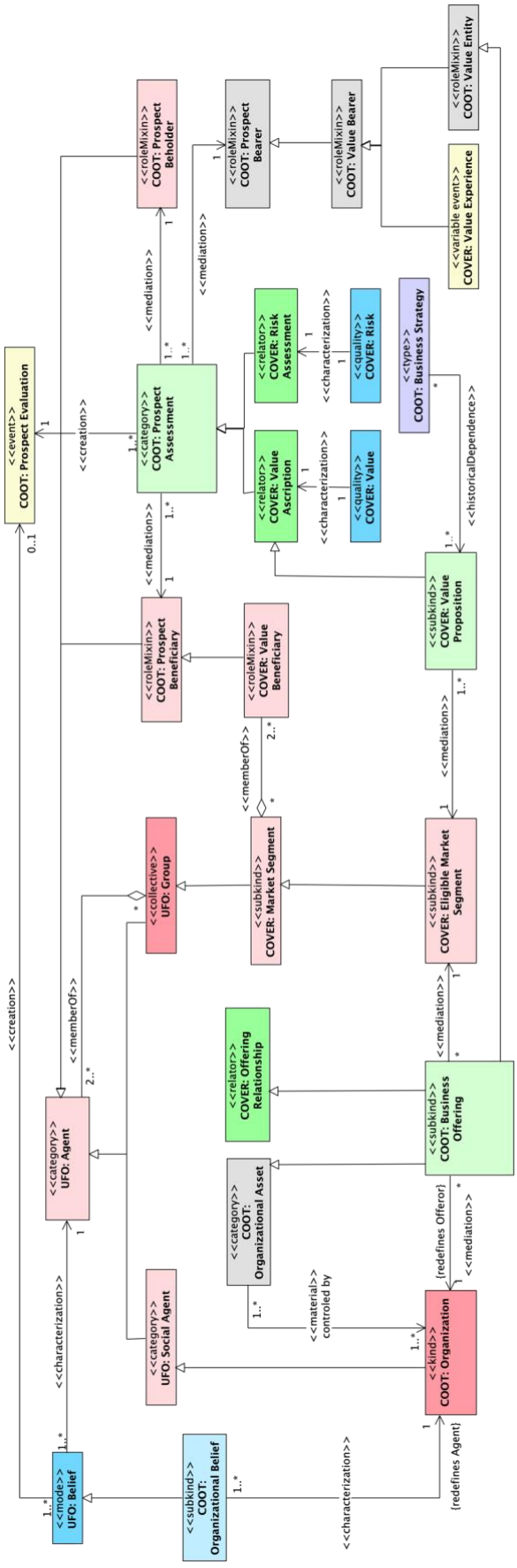

Figure 4.4 Motivation for Transformation.

4.1.3 The Transformation Initiative

The COOT module representing a transformation initiative is depicted in Figure 4.5. Here ORGANIZATION BELIEFS is the basis for forming particular BUSINESS INTENTIONS. A BUSINESS INTENTION (i.e., a closed commitment of the organization restricted to a plan) may or may not become (i.e., move on to a phase of) a TRANSFORMATION INITIATIVE.

A TRANSFORMATION INITIATIVE is a business intention for which agents (transformation initiative participants) have been allocated via social relators termed transformation initiative participant allocation. A transformation initiative participant allocation is thus a bundle of commitments and claims (vis-a-vis UFO-C) binding an agent to play certain organizational roles within the scope of a transformation initiative. The beliefs underpinning the formation of a transformation initiative are termed drivers, i.e., drivers of change. Drivers are organizational responses to prospect assessments.

The ORGANIZATION brings about an ORGANIZATIONAL TRANSFORMATION either to mitigate risks, e.g., by eliminating threats or vulnerabilities (Sales, Baião, *et al.*, 2018), or to seize opportunities envisaged in the assessment of Value Experiences (Sales *et al.*, 2017). An ORGANIZATIONAL TRANSFORMATION is a process analog to that discussed in (Guizzardi, Guarino and Almeida, 2016; Guizzardi *et al.*, 2022), i.e., it is a (typically mereologically complex) event manifesting a TRANSFORMATION INITIATIVE (a complex closed intention constrained by a TRANSFORMATION PLAN). That intention is what individuates the temporal parts of that event.

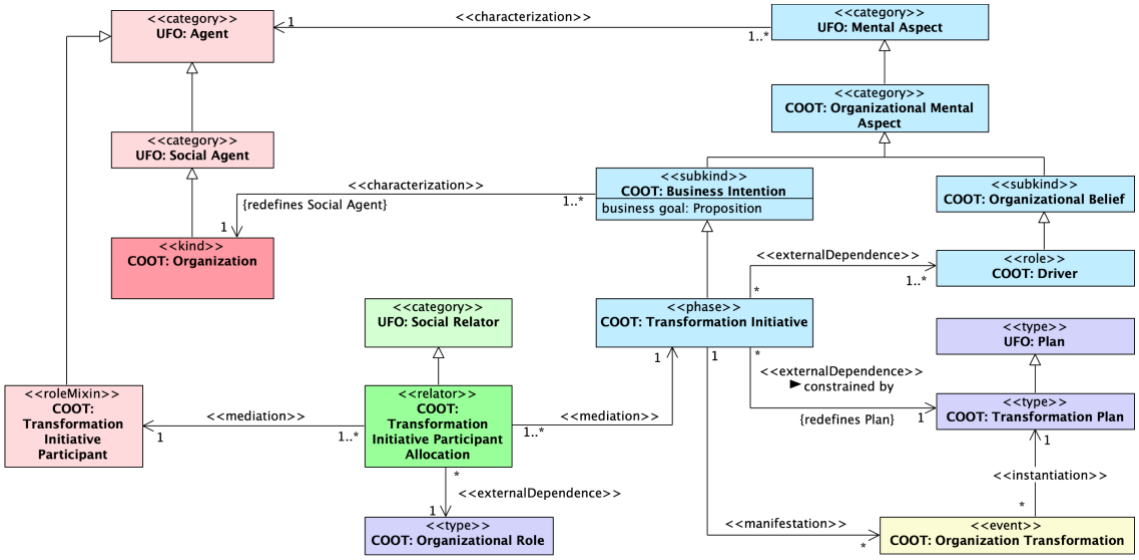

Figure 4.5 The Transformation Initiative.

4.1.4 The Transformation Event

The final module of COOT, as presented in Figure 4.6, focuses on ORGANIZATIONAL TRANSFORMATIONS as complex events. ORGANIZATIONAL TRANSFORMATIONS (<<event>>) are composed of participations (in the sense of UFO-B (Botti Benevides *et al.*, 2019)). These can be action contributions (in the sense of UFO-C (Guizzardi, Falbo and Guizzardi, 2008)) termed TRANSFORMATION AGENT PERFORMANCE, or resource participations (again, in the sense of UFO-C (Guizzardi, Falbo and Guizzardi, 2008)) termed TRANSFORMATION RESOURCE PARTICIPATION. The former is a manifestation of the commitments of a TRANSFORMATION INITIATIVE PARTICIPANT, i.e., the commitments comprising that agent's TRANSFORMATION INITIATIVE PARTICIPATION ALLOCATION (Guizzardi, Falbo and Guizzardi, 2008).

Transformation agent performance is an event with the participation of a transformation agent, a historical role that a transformation initiative participant plays in the scope of an organization transformation. Analogously, a transformation resource participation is an event with the participation of a transformation resource, a historical role that an organization resource plays in an organization transformation. An organization resource is a generalization of the notion of resource in (Azevedo *et al.*, 2015) to account for resources that are organizational assets.

Like all Events, ORGANIZATIONAL TRANSFORMATIONS map the world from (pre-)situations to (post-) situations (see UFO-B (Botti Benevides *et al.*, 2019)) as presented in Figure 4.6. In other words, they can promote the creation of (and other changes in) entities. Of particular interest here is that ORGANIZATIONAL TRANSFORMATIONS promote changes in TRANSFORMABLE ENTITIES. A TRANSFORMABLE ENTITY is anything that can be the subject of change in an ORGANIZATIONAL TRANSFORMATION. These include the ORGANIZATION itself, its ORGANIZATIONAL UNITS, as well as any other type of ORGANIZATIONAL ASSET. Business models, product and service offerings, and business processes (plans) are all considered organizational assets and, hence, types of transformable entities.

More specifically, an ORGANIZATIONAL TRANSFORMATION presupposes a (pre-)situation as a BASELINE (where TRANSFORMABLE ENTITIES might be present) and brings about a (post-)situation that is termed in this domain an OUTCOME (in which one or more TRANSFORMABLE ENTITIES are certainly present). TRANSFORMABLE ENTITIES that are the input to be transformed by this process are termed ORIGINAL ENTITIES. Those that are the transformed output are termed RESULTING ENTITIES. The RESULTING ENTITY and ORIGINAL ENTITY are historical roles (<<roleMixins>>) played by TRANSFORMABLE ENTITIES in ORGANIZATIONAL TRANSFORMATIONS.

ORGANIZATIONAL TRANSFORMATION generalizes the notion of change (W3C, 2014). Like any event, an ORGANIZATIONAL TRANSFORMATION is a manifestation of dispositions. In particular, it is a manifestation of commitments of one or more TRANSFORMATION INITIATIVE PARTICIPANTS allocated to that TRANSFORMATION INITIATIVE as well as of the capacities (in the UFO sense (Azevedo *et al.*, 2015)) of the involved agents and ORGANIZATION RESOURCES.

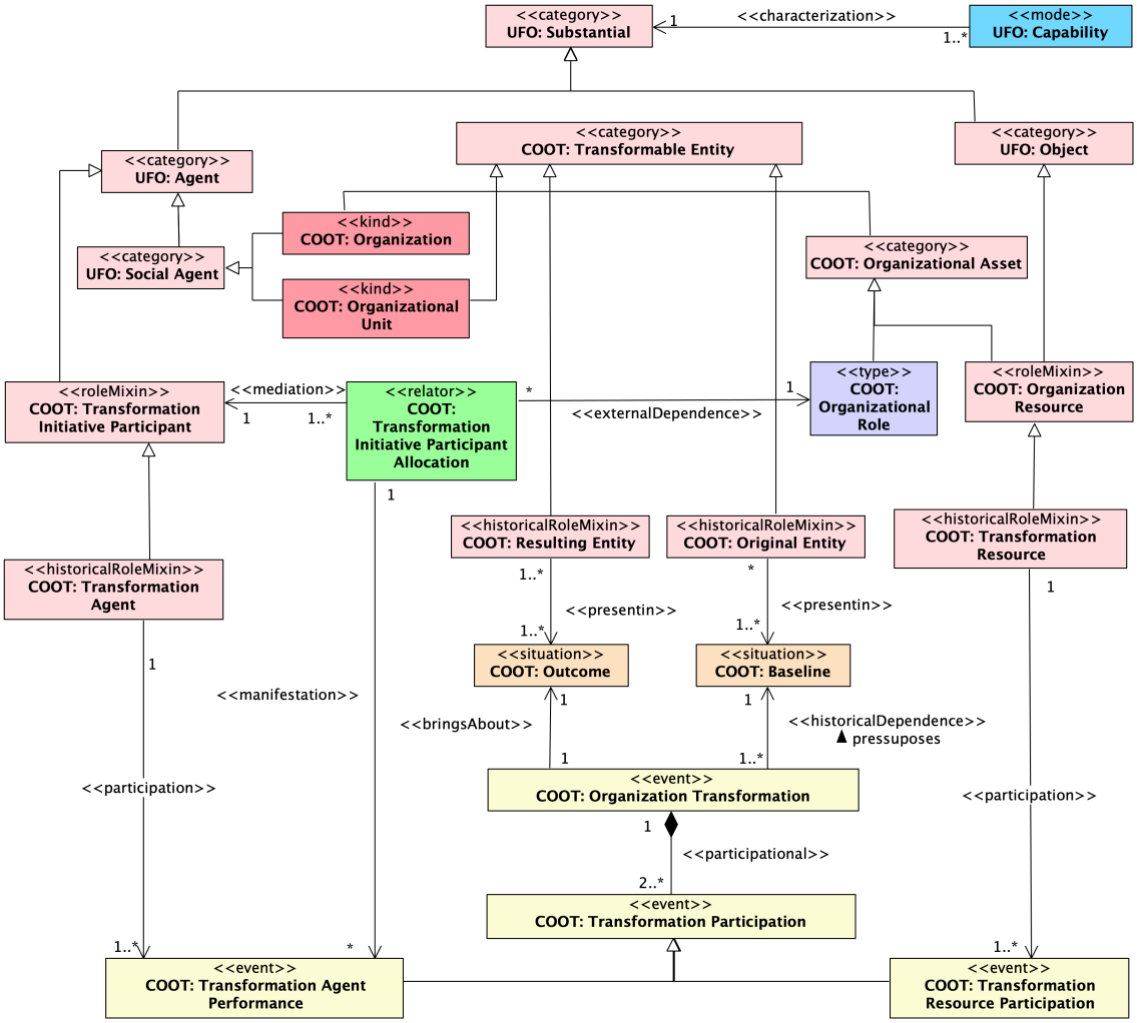

Figure 4.6 The Transformation Event.

4.2 Domain Ontology of Digital Transformation (DODT)

The Domain Ontology of Digital Transformation (DODT) aims to provide constructs to create a reference model of digital transformation with its inherent social characteristics. DODT's purpose and intended uses are to share a common understanding of digital transformation as a type of organizational transformation and to enable the knowledge to be reused by organizations and researchers, either for integrating or extending it with other ontologies.

Digital transformation arises from the Information Technology (IT) environment, blending and encapsulating digital technologies' transformational effects. IT is a collective term for various technologies involved in the processing and transmitting of information, including computing, telecommunications, and microelectronics. Moreover, IT has enabled human actors, Information Systems, and innovative products to interact via multiple digital channels (Bogea Gomes, Santoro and Mira da Silva, 2020).

Digital technologies are fundamental components for organizations to transform digitally. It is a type of technology involving one or more digital objects whose components include one or more

bitstrings. The Theory of Digital Objects (Faulkner and Runde, 2019) proposes to capture digital objects' ontological complexity and understand how their identity and usage are bound up with a "dual nature" constituting physical form and social function. It carried out an ontological analysis of this theory, grounded in the Unified Foundational Ontology (UFO), using OntoUML to identify the core components to answer what digital technology is. This analysis adds ontological clarity to the Theory of Digital Objects.

Digital transformation involves more than just the adoption of digital technologies. It requires businesses to re-conceptualize their business models and processes around these technologies (Baiyere et al., 2021). This process affects institutions' business models, strategic orientations, and values, and it has both technical and social dimensions (Bozkurt and Sharma, 2022). Business Process Management (BPM) is a field that consolidates knowledge on how to manage the design and re-design of individual business processes. BPM also aims to develop a foundational BPM capability in organizations catering to various purposes and contexts (Brocke, Zelt and Schmiedel, 2016). To implement process orientation effectively and efficiently in organizations, BPM requires capability areas related to strategic alignment, governance, methods, IT, people, and culture (de Bruin and Rosemann, 2007). The question in this thesis is whether digital BPM capability requires the same capability areas and plays a role in digital transformation.

In the following text, the terms written in SMALL CAPS represent DODT classes. The ontology DODT is presented diagrammatically in a set of modules, namely Digital Transformation event (Section 4.2.1 and Figure 4.7), Digital Technology (Section 4.2.2 and Figure 4.8), and Digital BPM Capability (Section 4.2.3 and Figure 4.9). The DT&I-BPM-onto (Bogea Gomes, Santoro and Mira da Silva, 2020), the conceptualization underlying the capability conceptualization proposal by (Loucopoulos *et al.*, 2016), a business process capability bibliometric analysis (Bogea Gomes, Santoro and Mira da Silva, 2022a), a Core Ontology to Organizational Transformation (COOT) (Bogea Gomes *et al.*, 2023), TDO (Theorizing Digital Objects) (Faulkner and Runde, 2019), and the Ontological Foundations of Competition (OFC) (Sales, Porello, *et al.*, 2018) were used to identify the most important domain notions and formulate this ontology's competence questions (SABiO´s phase 2 (Falbo, 2014)).

DODT's Competency Questions (CQs) were established to determine its precise scope:

- CQ1. What differentiates digital transformation from organizational transformation?
- CQ2. What are the assets needed to perform a digital transformation?
- CQ3. What transformable entities originate in and result from a digital transformation?
- CQ4. What is digital technology and its role in digital transformation?
- CQ5. What is digital BPM capability and its role in digital transformation?

4.2.1 Digital Transformation event

This subsection presents the digital transformation event (Figure 4.7), which covers the distinctions of digital transformation from organizational transformation (CQ1), the assets required

to perform a digital transformation (CQ2), and the transformable entities originate in and result from a digital transformation (CQ3).

First, the differences between digital transformation and organizational transformation are explained. A DIGITAL TRANSFORMATION event is a type of ORGANIZATIONAL TRANSFORMATION event, as presented in COOT. A DIGITAL TRANSFORMATION is enabled by a DIGITAL INNOVATION and characterized by DIGITAL TECHNOLOGY. A DIGITAL TRANSFORMATION also brings about a (post-)situation that is termed in this domain an OUTCOME (in which one or more TRANSFORMABLE ENTITIES are certainly present). Those entities that are in the transformed output are termed RESULTING ENTITIES, which are historical roles (role mixins) played by TRANSFORMABLE ENTITIES in ORGANIZATIONAL TRANSFORMATIONS, and their types of DIGITAL TRANSFORMATIONS.

Organization resources, organizational roles, digital business models, products, or processes can all be types of ORGANIZATIONAL ASSET. Any organizational asset can be a transformable entity. On the other hand, DIGITAL TRANSFORMATION is enabled by one or more digital innovations. Digital innovations are both the basis for, and the outcome of changes embodied in or enabled by DIGITAL TECHNOLOGIES and DIGITAL BPM CAPABILITIES, the assets needed (i.e., TRANSFORMABLE ENTITITES) to make a digital transformation (CQ2). The digital innovation's type can be DIGITAL BUSINESS PRODUCT (goods or services), DIGITAL BUSINESS PROCESS, or DIGITAL BUSINESS MODEL that are perceived as new, require some significant changes from the perspective of a particular community or market, and are either embodied in or enabled by the digital environment. Moreover, a digital business model in general is built on top of a digital innovation (Bogea Gomes, Santoro and Mira da Silva, 2021). A BUSINESS MODEL refers to the logic of the organization, the way it operates, its choices, and the consequences of these choices. Different designs have specific operation logic and create different values for an organization's stakeholders. Strategy refers to the business models selected through which the organization will compete in the market. A business model is a reflection of the organization's realized strategy (Casadesus-Masanell and Ricart, 2010). Business models are proven strategy-building blocks. They are abstract representations of a BUSINESS STRATEGY, rooted in its competitive environment, to deliver customer value. An organization's strategy is unique to it. A business model is an abstraction of strategy. In contrast, a business model simplifies an organization's strategy. Multiple organizations could use the same business model. Likewise, a set of one or more business models can represent an organization's strategy. Each business model captures an essential insight into creating economic value, which can be combined to create more complex models and strategies (Seddon and Lewis, 2003).

As for (CQ3) regarding the transformable entities originate in and result from of a digital transformation, one of these outcomes is DIGITAL PLATFORMS that capture, transmit and monetize data, including personal data, over the internet and other networks. They may not be composed by purely DIGITAL TECHNOLOGIES, although most successful digital platforms take advantage of the digital innovations and power of pervasive internet connectivity in the hands of billions of users (Yablonsky, 2018).

The systems that support digital businesses require transformation to maximize the economic value of network connections. It forces a shift to PLATFORMS and ECOSYSTEMS that are collaborative by nature, by applying business models with multiple actors playing multiple roles (Derave *et al.*, 2020). This thesis reuses the classes SERVICE OFFERING (UFO-S), DIGITAL PLATFORM, PLATFORM SOFTWARE and SOFTWARE from the Reference Ontology for Digital Platforms (identified in the diagrams as RODP). These authors define DIGITAL PLATFORM as the offer of interactions based on information transfer (e.g., WhatsApp, Tinder), products (e.g., eBay), services (e.g., Airbnb), or investments (e.g., Kickstarter). A digital platform offers a service to its users, which is bound to an agreement. The primary service offered is interactions between users, and a software system enables these interactions. A digital ecosystem is a cooperative environment where symbiotic relationships are formed to create mutual value for its members. Digital ecosystems are characterized by a fusion-relation to digital technologies.

A digital landscape is a broad view of diverse, interconnected application software, digital platforms, and digital ecosystems. The use of DIGITAL TECHNOLOGY as a business component transforms the business landscape. In this scenario, individuals and organizations no longer develop and implement their application software in isolation. Instead, these systems are increasingly interconnected (Bogea Gomes, Santoro and Mira da Silva, 2021). The fusion of technology transforms the digital landscape (Henningsson and Hedman, 2014) and enable organizations to take advantage of the ecosystem that allows innovations to be outsourced (Tai, Wang and Wang, 2019). The DIGITAL PLATFORMS and the digital ecosystem represent a broad view over a landscape of diverse and interconnected systems, platforms, and ecosystems. Such digital, interconnected platforms attract heterogeneous components and users to form ecosystems. These platforms and ecosystems operate within an institutional framework that enables or prevents various activities (Baskerville, Myers and Yoo, 2020).

Finally, VALUE SPACE is a consolidated network of specific value spaces, a digital technology layered architecture elements (content, service, network, and device) to create value in a digital transformation. It is a <<relator>> that can connect an evolving network of these specific value spaces interlinked through connections established (and dissolved) by a platform management, seeking to generate appropriate value (Henfridsson *et al.*, 2018).

The other outcome for CQ3 is DIGITAL BPM CAPABILITY PORTFOLIO, that participates together with DIGITAL PLATFORM of VALUE PROPOSITION to create the event PROSPECT EVALUATION through PROSPECT ASSESSMENT in COOT. The DIGITAL BPM CAPABILITY PORTFOLIO is composed by DIGITAL BPM CAPABILITIES. The use of CAPABILITY as the representative of what the organization does and needs, without describing the how (i.e., the technical implementation), serves as a powerful communication tool among technology and organizational specialists (Imgrund *et al.*, 2018). It has a strong link to capability development, which builds on the resource-based view of the organization, striving for efficient and effective execution and the continuous management of business processes, as well as for the development of organizations' BPM capability. Capability

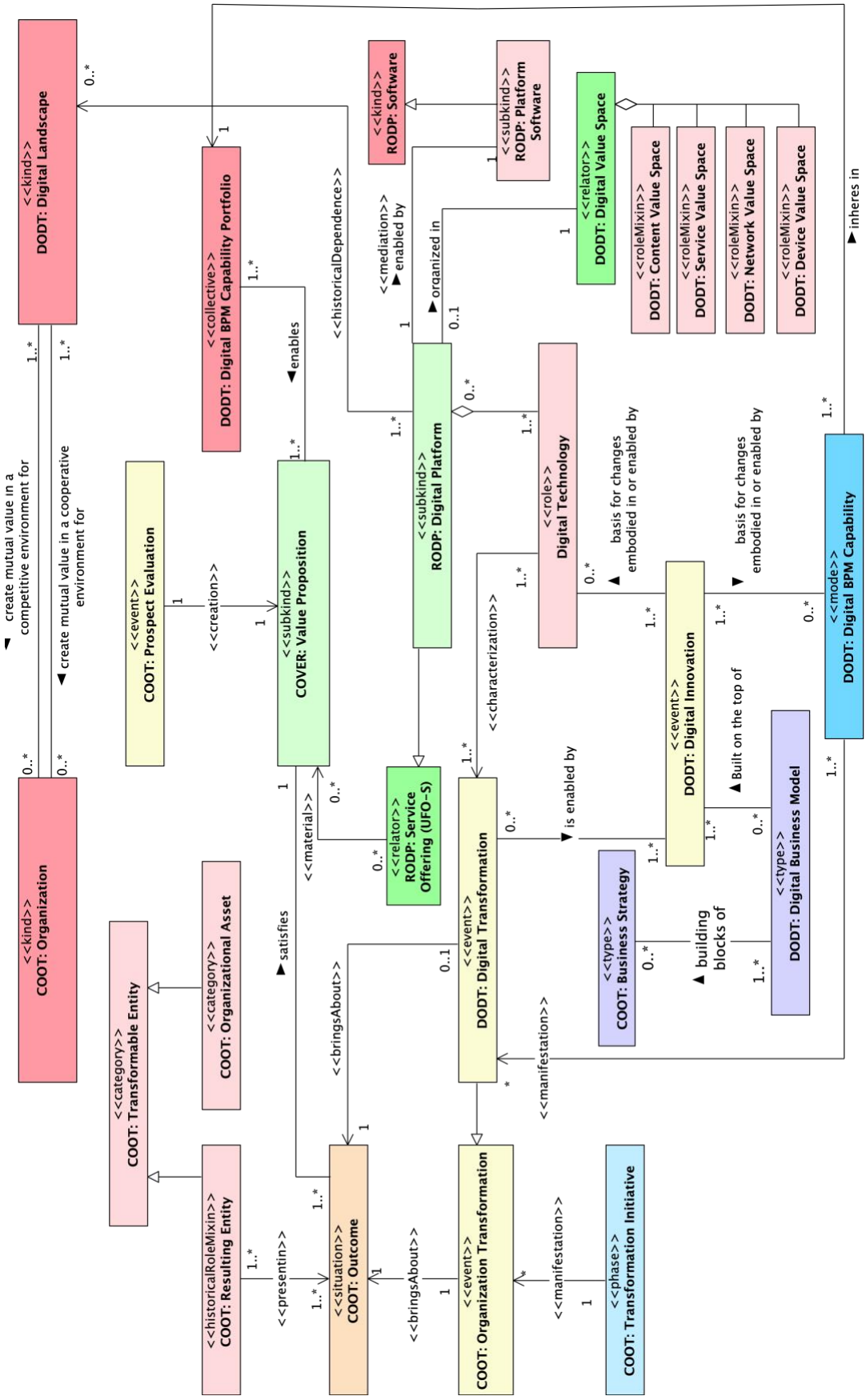

Figure 4.7. Digital Transformation Event.

frameworks are the basis for maturity models that address how capabilities can be developed along an anticipated, desired, or logical path (Kerpedzhiev *et al.*, 2020).

A survey on “a positive relationship between BPM and digital innovation” opened a discussion on whether the role of BPM needs to change and whether BPM-related capabilities should be re-interpreted for the digital age (Van Looy, 2017). In this scenario, BPM aims to create new opportunities for competitive business differentiation (Niehaves *et al.*, 2014) building on several new capabilities. Like other emerging approaches for boosting organizational readiness and maturity to cope with digital challenges, BPM transforms as well (Brkić, Tomičić Pupek and Bosilj Vukšić, 2020).

4.2.2 Digital Technology

Digital technologies are increasingly prominent in the lives of individuals, organizations, and society. An ongoing digital transformation (for example, music, books, and money) makes more and more industries fused with digital technologies, forming the digital industries. Digital industries possess typical characteristics that set them apart from most other industries. The dynamics of digital industries are characterized by a tension between competition and collaboration among actors. While some actors are direct competitors, they mutually depend on the industry's success. Digital industries are beneficially conceived as digital ecosystems, in which symbiotic relationships are formed to create mutual value in a simultaneously cooperative and competitive environment for its members (Henningsson and Hedman, 2014).

This thesis models, using OntoUML and UFO, an ontological analysis of the conceptualization underlying the Theory of Digital Objects to conceptualize DIGITAL TECHNOLOGY (see Figure 4.8). The generally accepted color-coding scheme from OntoUML was applied. Moreover, in the diagram, the entities from UFO (Guizzardi, 2005) were highlighted by appending the prefixes "UFO:" or “COOT:” to the name of the class.

Faulkner and Runde (2019) provide a framework that considers *material*, *nonmaterial*, and *hybrid objects* in a unified way, looking at digital phenomena and their potential. It informs the existing perspectives on theorizing *digital technology* per se and the relationship between people and *digital technology*. It considers the computation's role and how the *object's technical identity* and *object's functions* flow from their social positioning in the *communities* in which they arise. They (Faulkner and Runde, 2019) focus on the *digital objects'* conception and a *bearer* theory of how *material* and *nonmaterial objects* combine.

UFO (de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011) considers an OBJECT as a substantial, unable to perceive EVENTS or have INTENTIONAL MOMENTS. According to Markosian (2000), objects from different ontological categories, such as physical, non-physical, propositions, and universals, all exist in time; however, not all of them exist in space. The ones that exist in both time and space are the ones that count as *physical objects*. A *nonmaterial object* (TDO) can be a type of SOCIAL OBJECT (UFO).

The organizational consequences of technology cannot be fully understood without a reference to this framework. For example, understanding the organizational consequences of blockchain requires knowing about the properties of (nonmaterial) data structures, cryptographic keys, consensus mechanism protocols, and the material infrastructure elements required to maintain a geographically distributed ledger.

The technical identity of a TECHNOLOGICAL OBJECT within some COMMUNITY is constituted by its FUNCTION and STRUCTURE, which are beneficial to the community's interests. Structured means an object is composed of several distinct parts (COMPONENT PARTS), organized in some way. Since a community collectively assigns functions, those functions are never intrinsic to the objects concerned and are therefore always necessarily community relative. To sustain the function assigned to a technological object, it must generally possess the characteristics and capabilities required to perform it (Faulkner and Runde, 2011).

According to Faulkner and Runde (2013), technical identities might reside at different levels of abstraction, including nested technical identities. For example: networks monitoring iPhone applications are members of a broader class of iPhone applications, which are themselves members of an even broader class of application software. An application such as Google Translate derives its identity not only from the structures of the bitstrings comprising it, but also from the function assigned to those bitstrings, in this case, to translate text, documents, and websites from one language into another. TECHNOLOGICAL OBJECTS of a given TECHNICAL IDENTITY often vary in the details of their structures. However, despite their diversity, people can still identify different OBJECTS as tokens of the same type of technological device. Thus, while Google Translate, Microsoft Translator, and their various competitors vary somewhat in their structures, they share sufficient commonalities to be grouped as online translators.

It is also possible that similar or even identical OBJECTS may have contrasting functions assigned to them, to such an extent that the same object may have radically different technical identities in different communities. This is more likely to occur to intermediate products further upstream in the manufacturing process. For example, in the case of the gramophone turntable becoming a musical instrument in specific communities (Faulkner and Runde, 2009).

Modeling this theory in OntoUML demonstrated that DIGITAL TECHNOLOGIES have the <<participation>> of DIGITAL OBJECTS that are, in turn, OBJECTS characterized by some capabilities required to perform specific functions of this technological object. Finally, the first part of CQ4 is answered: *What is digital technology?* DIGITAL TECHNOLOGY is the TECHNICAL IDENTITY of a DIGITAL OBJECT, its type of use assigned by a COMMUNITY, and its SOCIAL FUNCTIONS. Digital objects are a type of technological object constituted by COMPONENT PARTS, including one or more bitstrings. BITSTRINGS, a nonmaterial object, can be beared by a MATERIAL OBJECT or remain as a NONMATERIAL BEARER. A nonmaterial bearer can be one of the various kinds of nonmaterial objects corresponding to the diverse kinds of information employed in computing. A DIGITAL OBJECT has a technical identity mediated by its structure and social function.

Concerning the second and last part of CQ4: "*What is digital technology's role in digital transformation?",* DIGITAL TECHNOLOGY is a type of resource, an ORGANIZATIONAL ASSET, that has its participation determined by a DIGITAL TRANSFORMATION event. Digital technology can be changed, embodied in, or enabled by a DIGITAL INNOVATION that is a TRANSFORMABLE ENTITY. As a type of resource, a digital technology, inserted in a VALUE SPACE, can participate in a DIGITAL PLATFORM, generating VALUE in a digital transformation according to platform management mediation. A digital platform is enabled by platform software, a type of technology, besides user roles, a type of organizational role, and an organizational asset like DIGITAL BUSINESS MODEL, DIGITAL BUSINESS PROCESS, and DIGITAL BUSINESS PRODUCT. In the DIGITAL LANDSCAPE, a digital technology is the primary element, interconnecting applications software and being interconnected by ECOSYSTEMS.

DIGITAL INNOVATION has forced organizations to change some well-established business processes. Consumers' digital expectations and demands are constantly changing. Digital transformation materializes how an innovation replaces or complements existing businesses, bringing new actors, structures, practices, values, and beliefs (Hinings, Gegenhuber and Greenwood, 2018). It requires mixing people, machines, and business processes, with all of the disorderliness that these could entail (Davenport and Westerman, 2018). Traditional organizations, like airlines and banks are some well-known examples where digital innovation mostly occurs through the redesigned process (Kirchmer and Franz, 2017).

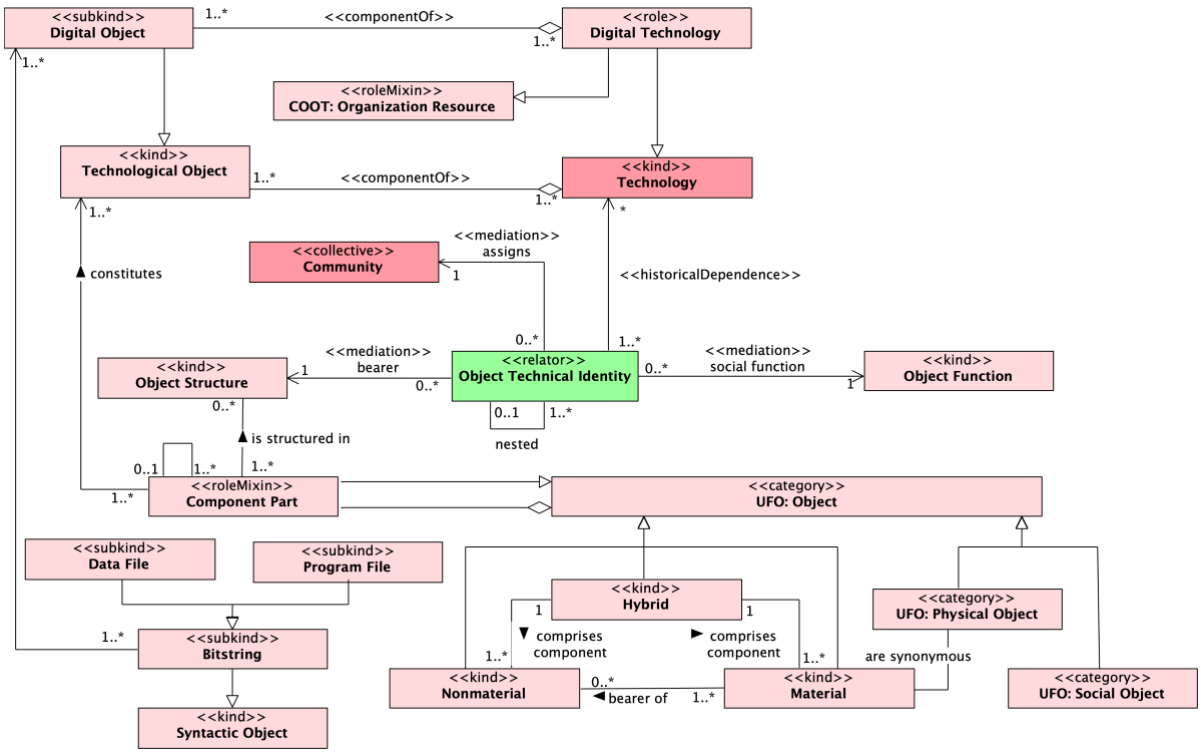

Figure 4.8. Digital Technology conceptualization.

4.2.3 Digital BPM Capability

Digital transformation encompasses the transformation of digital technology and digital processes. The Business Process Management (BPM) discipline needs to establish a background to understand and support such transformations. BPM is the science and practice of overseeing how work is performed to ensure consistent outcomes and take advantage of improvement opportunities.

BPM can be understood as an organization's core competency for managing all its business processes, from operational to managerial, spanning all organizational functional areas. Moreover, BPM networks organizations and environments, including consumers and other organizations, such as suppliers and customers (and beyond that, with their suppliers' suppliers and their customers' customers) (Beverungen *et al.*, 2021).

"Capabilities are intrinsic dispositional properties of agents that endow them with the power of exhibiting some behavior or bringing about certain effects in the world" (Azevedo et al., 2015). The interpretation of agents adopted here is not limited to physical agents, such as a person, a robot, or a dog, but also includes collective (e.g. a group of people) and social or group agents (e.g. an organization) (Sales, Porello, *et al.*, 2018).

BPM has been structured by means of BPM capability frameworks, apart from lifecycle models. The BPM capability enables effective and efficient business processes, which drive corporate success. BPM Capability frameworks are the basis for maturity models that address how capabilities can be developed along an anticipated, desired, or logical path. While descriptive maturity models extend capability frameworks through assessment criteria and methods, prescriptive models also include good practices for capability development and decision logic for determining suitable maturity levels. Maturity models support fit/gap analyses, the derivation of roadmaps, and the prioritization of BPM investments (Kerpedzhiev *et al.*, 2020).

While BPM can serve as an enabler for digital transformation, it cannot fully address all requirements. Digital transformation requires organizations to refocus their core competencies and rationalize non-performing activities capabilities (Imgrund *et al.*, 2018).

Loucopoulos *et al.* (2016) based their analysis of capability on a collection of capability definitions from various perspectives. For example, they cited (Jalali, 2017), who defines capability as the ABILITY and CAPACITY that allows an organization to achieve a business goal in a specific context. Furthermore, they cited the capability definition by (Leonard-Barton, 1992) from the strategic management perspective, as a set of differentiated skills, complementary assets, and routines that are assembled and provide the foundation for competitiveness in a specific business. Apart from that, they also cited the dynamic capability definition, considering it a source of sustainable advantage related to the ability to integrate, build, and reconfigure an organization's resource base to create valuable, rare, and difficult to replicate capabilities, (Teece, Pisano and Shuen, 1997).

As represented in COOT, an organization must compete in environments that change quickly and where it is hard to integrate meaning across different levels of abstraction and detail. An organization can be characterized by its BPM capabilities (Kerpedzhiev *et al.*, 2020), thus it can be argued that particularly at digital transformation events, DIGITAL BPM CAPABILITY is a <<role>> of capability, as conceptualized by (Azevedo *et al.*, 2015). The DIGITAL BPM CAPABILITY concept is represented in OntoUML as a <<relator>> (see model in Figure 4.9), since digital BPM capability mediates properties that are common to different roles, the DIGITAL BPM ABILITIES, and DIGITAL BPM CAPACITIES <<roleMixin>> to support the DIGITAL TRANSFORMATION, a type of ORGANIZATION TRANSFORMATION and an event as presented in COOT.

A DIGITAL BPM ABILITY is demanded by an ORGANIZATIONAL ROLE, so much as a DIGITAL BPM CAPACITY is required by an ORGANIZATION RESOURCE to perform a DIGITAL TRANSFORMATION as an organization transformation event. Organizational role and organization resource are types of ORGANIZATIONAL ASSET, which is in turn a type of TRANSFORMABLE ENTITY manifested in a digital transformation. Moreover, the economic value modelled in (Loucopoulos *et al.*, 2016) is considered a type of VALUE, and expand the relationships from economic value to value. Moreover, it can be considered that the DIGITAL BPM ABILITY has its own value for specific stakeholders, just like DIGITAL BPM CAPACITY and DIGITAL BPM CAPABILITY. The capability as a combination of abilities and capacities can have more value for specific stakeholders than the sum of the abilities and capacities' value. This answers the first part of CQ5: "*What is digital BPM capability?"*.

The business processes were modelled using a similar concept from software process ontology (de Oliveira Bringuente, de Almeida Falbo and Guizzardi, 2011). A TRANSFORMATION INITIATIVE manifests a DIGITAL TRANSFORMATION event. BUSINESS PROCESSES are types of TRANSFORMABLE ENTITY. A BUSINESS PROCESS can be divided into activities or other processes, known as SUB-PROCESSES. A BUSINESS ACTIVITY is a piece of work that requires DIGITAL BPM CAPABILITY to be completed. A BUSINESS ACTIVITY can be subdivided into SUB-ACTIVITIES based on completing other activities known as pre-activities.

Given the inherently competitive nature of business, dealing with competition is an essential aspect of organizational management and strategy, including protecting an organization's position within a MARKET. The organization to be transformed currently needs to make the VALUE PROPOSITION (resulting from the organizational transformation) towards a market. OFC presents an analysis of potential competition for MARKET segments between ORGANIZATIONS and represents the potential competition (Sales, Porello, *et al.*, 2018). In case of a digital transformation event as the sum of the reference DIGITAL BPM CAPABILITIES required to deliver value to a specific market segment and the potential competitor's capabilities that would allow them to make an equivalent value proposition to the same segment.

An organization can have its digital BPM capability organized as a DIGITAL BPM CAPABILITY PORTFOLIO to manage its digital transformation investments and can prioritize a digital transformation capability roadmap derived from a digital transformation maturity model.

As previously written, organizations perform better when they pay close attention to their business processes, the people involved, the information being exchanged and processed, and the technologies used to carry out the different activities. The BPM discipline has the background to understand and support this, ensuring consistent outcomes and taking advantage of improvement opportunities. Regarding the second and last part of CQ5: "*What is the digital BPM capability's role in digital transformation?"*, as digital transformation is about processes, the role of processes in digital transformation is related to the role of the digital BPM capability, i.e., the digital BPM capability represents the ability and the capacity needed to execute the digital transformation.

In conclusion, the central concepts of DODT are the transformation of an organization to digital: the DIGITAL PLATFORM and DIGITAL BPM CAPABILITY PORTFOLIO. A DIGITAL TRANSFORMATION, as a type of ORGANIZATIONAL TRANSFORMATION, is a (typically mereologically complex) event manifesting a TRANSFORMATION INITIATIVE as presented before in Section 5.1. A transformation initiative can be broken down into business processes, a type of *complex action* in UFO. A BUSINESS ACTIVITY is a piece of work that requires DIGITAL BPM CAPABILITY to be completed. The DIGITAL BPM CAPABILITY PORTFOLIO is composed by the DIGITAL BPM CAPABILITIES needed for the DIGITAL TRANSFORMATION.

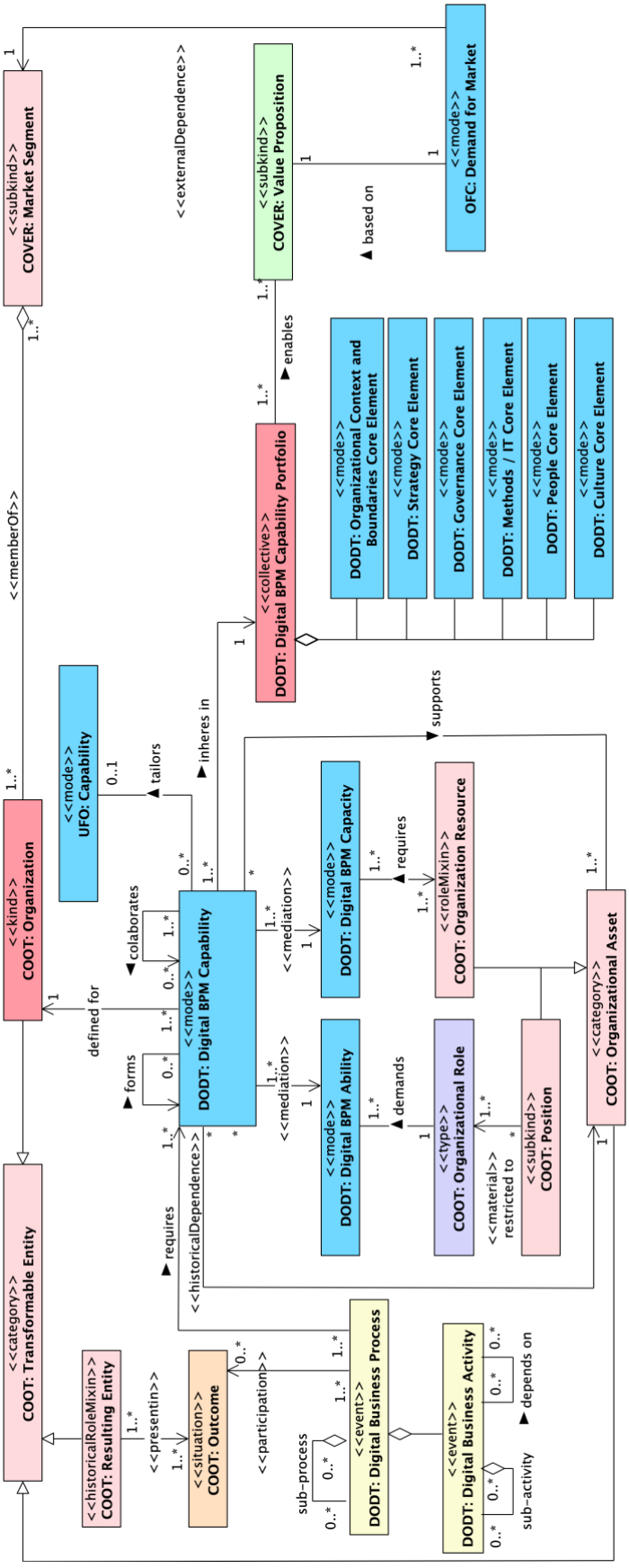

Figure 4.9. Digital BPM Capability conceptualization.

Chapter 5

Related Work

In the digital economy, transformation, innovation and integration across boundaries have become organizational development themes (Lee *et al.*, 2021). This chapter discusses the works related to this thesis, associated with organizational transformation and digital transformation ontology.

5.1 Literature Reviews on Digital Transformation and Innovation

In 2019, as a sub-product of the systematic mapping study (Bogea Gomes, Mira da Silva and Santoro, 2019) a total of 15 systematic reviews on Digital Transformation and Digital Innovation were identified. The twelve selected SLRs, summarized in Table 5-1, deal mainly with Conceptualization, Cases, Future and Challenges, as well as the identification of families of digital technologies that support the innovation process. None of these reviews could answer our research question, since they do not present the main Digital Innovation and Digital Transformation conceptual elements and their meanings.

Six SLRs address Conceptualization, each of them focusing on some of the concepts and the sum of them do not cover all. The goal of (Reis *et al.*, 2018) was to propose a definition for Digital Transformation. They delivered a general overview of the literature, along with some suggestions for future research.

Morakanyane, Grace and O'Reilly (2017) also studied the phenomenon of Digital Transformation, detailing what it is, how it behaves, what drives it, what impacts it creates, as well as where the impacts are felt. As the outcome, they developed a concept centric matrix and constructed a more inclusive and general definition. (Bockshecker, Hackstein and Baumöl, 2018b) searched for the conceptualization of the terms and the systematization of the phenomena connected to digitization, digitalization, and Digital Transformation.

Bohnsack *et al.* (2018) consolidated the state of the art on Digital Transformation by synthesizing existing research, revealing connections in the diversified literature, and identifying important gaps in our understanding of the area. Their result was organized into three distinguished and delineated building blocks of Digital Transformation: Determinants, Processes and Outcomes. (Tesch, Brillinger and Tesch, 2017) reviewed the literature, aiming at the applicability of digital Business Model Innovation (BMI) projects by elaborating on the categorization of tools and methodologies, considering two major logics of evaluation: Analytical/effectual and quantitative/qualitative. (Vesti *et al.*, 2017) defined disruption in the digital domain, also known as digital disruption.

From the two SLRs about Cases, (Vukšić, Ivančić and Suša Vugec, 2018) examined the collection of Digital Transformation case studies in the last decade from practice and explored how organizations perceive Digital Transformation, considering time, country of case, type of industry and Digital Transformation focus. (Cziesla, 2014) explored the diverse aspects of IT-enabled transformation in the financial service industry.

Among the four SLRs that address Challenges and Future, (Lund, 2014) investigated what are the challenges of actors' interactions in Digital Innovation and how they can be addressed.

(Henriette, Feki and Boughzala, 2015) proposed a research agenda for Digital Transformation from a managerial perspective. (Hausberg, P., Liere-Netheler, K., Packmohr, S., Pakura, S., Vogelsang, 2018) provided an overview of existing research on DT from a business perspective. Finally, (Mazza, 2017) identified which families of digital technologies are the basis for the innovation process, and which of them drive and are necessary for the implementation of the innovation activities in companies.

Table 5-1. The Summary of the identified and selected systematic reviews.

Title	DT	DI	Ref
A literature review on Digital Transformation in the financial service industry	1		(Cziesla, 2014)
A Preliminary Literature Review of Digital Transformation Case Studies	1		(Vukšić, Ivančić and Suša Vugec, 2018)
Activities to address challenges in Digital Innovation		1	(Lund, 2014)
Conceptualizing Digital Transformation in Business Organizations: A Systematic Review of Literature	1		(Morakanyane, Grace and O'Reilly, 2017)
Digital Transformation in Business Research: A Systematic Literature Review and Analysis	1		(Hausberg, P., Liere-Netheler, K., Packmohr, S., Pakura, S., Vogelsang, 2018)
Digital Transformation: A Literature Review and Guidelines for Future Research	1		(Reis *et al.*, 2018)
Same, same, but different!? A systematic review of the literature on Digital Transformation	1		(Bohnsack *et al.*, 2018)
Structured Literature Review of disruptive innovation theory within the digital domain		1	(Vesti *et al.*, 2017)
Systematization of the Term Digital Transformation and its Phenomena from a Socio-Technical Perspective--A Literature Review	1		(Bockshecker, Hackstein and Baumöl, 2018b)
The evaluation aspect of digital business model innovation: A literature review on tools and methodologies		1	(Tesch, Brillinger and Tesch, 2017)
The role of digital technology in the innovation process of companies: a systematic literature review in the innovation management field		1	(Mazza, 2017)
The shape of Digital Transformation: a systematic literature review	1		(Henriette, Feki and Boughzala, 2015)

The twelve identified Systematic Literature Reviews (SLRs) on Digital Innovation and Digital Transformation deal mainly with conceptualizations, cases, future perspectives, and challenges, as well as the identification of families of digital technologies that support the innovation processes related to digitization, digitalization, and digital transformation. However, to the best of the author's knowledge, none of these SLRs has proposed a conceptual model.

The Digital Transformation Ontology (DTO) proposal was structured in two principal sub-ontologies: the Core Ontology of Organizational Transformation (COOT) and the Domain Ontology of Digital Transformation (DODT).

The related work scope regarding COOT is the organizational change and transformation, while the related work scope concerning DODT is the digital transformation.

5.2 Organizational Change and Transformation Ontologies

In September of 2020, a systematic literature review was done to identify research related to organizational change and transformation. The context of the investigation was academic and industrial publications. The related research questions were looking for: (i) The difference between organizational change and organizational transformation concepts. (ii) Concepts, constructs, conceptualizations, and definitions of organizational change and transformation. (iii) Conceptual models, ontologies, and strategies that represent or explain organizational change and transformation. The databases were ACM Digital Library, IEEE Digital Library, Scholar Google, Science@Direct, Scopus, and Springer Link. The search was restricted to the title, abstract, and keywords; the publication year was not a factor. It included journal articles, conference papers, theses, and technical reports.

For that, the search string specified included “organization” and "change" or "transformation." Besides organization, including the terms "enterprise" and "business." Moreover, the terms "concept," "definition," "construct," and "strategy" (associated with a general notion or idea), "model," and "ontology" to identify the papers sought. The relevant literature reviews involving concepts/definitions and conceptual models/ontologies was scoured to understand what other researchers in this field have already developed. On the other hand, it was not interested in papers that lacked concepts with their meanings and definitions in their scope, regardless of whether they were written in a language other than English, had already been identified in another source (duplicated), or it could access the full text of the paper. The following criteria were used to select potentially relevant studies for review: Inclusion Criteria: Concentration on concepts, definitions, conceptual models, and ontologies. Exclusion Criteria: Duplicate document; not written in English.

The search string was created and run according to the rules of each database source. As a result, 1423 papers were found from various sources. It identified 148 duplicates in the subsequent step. The 1275 titles were read, separated by determined words related to this SLR goal, pre-selecting 154 papers for abstract reading. Other ontologies that represent the concept of organizational transformation was searched. and, to the best of our knowledge, only one work was considered comparable to DTO.

The work reports a preliminary integrated domain ontology – the Domain Ontology for Organizational Change (DOOC) - for articulating the scope of organizational change, with the intention to provide a foundation for developing interactive communication methods and tools to enable effective stakeholder engagement (Harris, 2018). Comparing DOOC and COOT competency questions (see details in Table 5-2), it can be concluded that while DOOC is related to change in general, which can be a transformational or developmental change, the scope of

DTO / COOT is focused on transformational change. Moreover, DOOC focuses on what changes and why, whereas DTO / COOT covers concepts from the motivation for transformation to the conception of the transformation initiative, i.e., “How to transform?”. The general scenarios addressed by DOOC are related to engaging stakeholders in a collaborative definition of the scope of a change (why change?) and communicating the scope of organizational change to all affected stakeholders (what changes?).

One interesting difference between DTO / COOT and DOOC is that DTO / COOT considers all agents involved in an organizational transformation, whereas DOOC considers only the stakeholders who would benefit from the changes. The DTO competency questions COOT CQ1, CQ2, CQ4, CQ6 and CQ10 and DODT CQ1, CQ4 and CQ5 are beyond the scope of DOOC. Regarding COOT CQ1 (What is the organization to be transformed?), COOT CQ2 (What conceptualizations characterize organizational transformation?), and DODT CQ1 (What differentiates digital transformation from organizational transformation?), DOOC does not address the concepts of Organization and Organizational Change. It assumes that an organizational unit is “a defined group of responsibilities for accomplishing a specific purpose” and represents this entity as such. Conceptualizing organization is essential to COOT, because its parts, namely organizational units, can also be objects of a transformation (transformable entities).

Regarding COOT CQ4 (i.e., “How does an organizational transformation initiative emerge?"), DOOC concepts respond to the “what changes” question by “identifying any of the organization’s operational structures and outputs where changes are needed to achieve the desired outcomes”, but it does not explain whether this change arises spontaneously or not. In DTO, in addition to operational structures and outputs, other organizational components, such as the strategy or the business model, are also subject to transformation, which is a type of change. The organization itself is subject to change, for example, in a merger or acquisition. This characterization is important because it is used as a basis for definitions and modelling in DTO.

Regarding COOT competency question CQ6 (i.e., "What are the roles of the agents involved in an organizational transformation?"), in DOOC, the motivation for change comes from stakeholder perceptions, without highlighting the stakeholder’s role, and the organization has certain goals in response to these perceptions. DTO, on the other hand, takes a broader perspective, i.e., change considers all agents that may be involved (for example, in the car rental company project, these involve customers, brokers and front office clerks).

Finally, concerning COOT CQ10 (i.e., “What are the steps in an organizational transformation?"), change steps are not part of the scope of DOOC.

Table 5-2. Comparing DTO / COOT and DOOC and competency questions.

DTO Competency Question	**DOOC Competency Question**
COOT CQ1. Which organization is to be transformed?	Out-of-scope. Organization was probably considered a known, established concept and was neither defined in the ontology nor mapped in the diagram presented.

DTO Competency Question	DOOC Competency Question
COOT CQ2. What conceptualizations characterize organizational transformation?	Out-of-scope. Change was probably considered a known, established concept and was neither defined in the ontology nor mapped in the diagram presented.
COOT CQ3. What motivates an organizational transformation initiative?	1. What are the external opportunities (Bell and Rochford, 2016) to create or grow market share or to deliver more value to external or internal stakeholders (Frow and Payne, 2011)?
	2. What are the external threats or internal weaknesses that may increase costs, reduce market share (Bell and Rochford, 2016) or reduce stakeholder value (Frow and Payne, 2011)?
	3. What are the desired outcomes for the organization and for the beneficiary stakeholders (Daly, 1995)?
	4. What are the goals and indicators that reflect and measure the achievements of these outcomes (ACMP, 2014)?
	1b. What is the benefit to these stakeholders?
COOT CQ4. How does an organizational transformation initiative emerge?	Out-of-scope. DOOC explores what changes, but not how an initiative towards change emerges.
COOT CQ5. Who are the agents involved in an organizational transformation?	1a. Who are the stakeholders who would benefit from change?
COOT CQ6. What are the roles of the agents involved in an organizational transformation initiative?	Out-of-scope. The focus of change is on stakeholders in general, without highlighting their roles.
COOT CQ7. What organizational values are associated with organizational transformation?	1c. What is the perceived value of this benefit to the stakeholders?
COOT CQ8. What factors enable organizational transformation?	1. What is the resulting output of the change initiative in terms of offerings and/or organization capabilities?
COOT CQ9. What transformable entities originate in and result from organizational transformation?	2. What offerings are being transformed or newly established?
	3. What business activities are changing or being established?
	4. What resources (people, process, technology, information, policies, etc.) used by these business activities are affected?
	5. What relationships and relationship channels (external and internal) are changing?
	6. What structures (financial, governance and management) are changing?
	7. What incentive or reward mechanisms are changing?
COOT CQ10. What are the phases in an organizational transformation?	Out-of-scope. The focus is on "what changes" (within the organization) and "why change".

5.3 Digital Transformation Ontologies

In September of 2019, a search was performed using Google Scholar with the string {ontology AND "business process management" AND {"digital transformation" OR "digital innovation"}} anywhere in the text. This search returned approximately 430 results. In the next step, the same search was done with BPM in the string {ontology AND BPM AND {"digital transformation" OR "digital innovation"}} anywhere in the text. This search had approximately 256 results. From these results, it was selected the titles contained the terms ontology, "Business Process Management"

or BPM, and Digital Transformation or Digital Innovation. Around 100 titles were identified. Of these, those that have the word Ontology in the title were selected, resulting in two titles:

- Using ontology and modelling concepts to develop smart applications: Example Dutch Railway (Bach, von Rosing and von Scheel, 2017);
- Onto-Digital: An ontology-based model for digital transformation's knowledge (Zaoui and Souissi, 2018).

The first study presents a case “on the Dutch Railway process of cutting edge smart application development within advanced customer process handling through the role oriented processes and services” (Bach, von Rosing and von Scheel, 2017). The subject is out of our scope. The second study reviewed some examples of Information and Communications Technology (ICT) integration in the following business sectors: education, health, and industry 4.0. These authors used a construction method to generate their Knowledge Model guided by two questions: (i) “What are the key dimensions of digital transformation?”, and (ii) “Can we build a generic digital transformation model?” According to the authors, the answer to the first question allows the data preparation for the second question, whose answer is used to design the knowledge model.

A comparison of the DTO terms with the Onto-Digital was made, with the terms in Table 5-3. From the comparison, it can be concluded that although (Zaoui and Souissi, 2018) find digital transformation to be the cornerstone of any business development strategy, the Onto-Digital that they propose presents digital transformation from the perspective of integrating ICT into the value chain, while DTO proposes an ontology from the perspective of business transformation.

Thus, the current thesis addresses the lack of a formal model that relates BPM and digital transformation, which is still an open issue. It provides an overview of the literature based on proposed definitions, the study of the phenomenon, challenges, and suggestions for future research in digital transformation. As a result, they developed conceptualizations of digital transformation terms and the systematization of the phenomena. Besides, they consolidate the state of the art in digital transformation, synthesizing existing research, revealing diverse connections in the literature, and identifying gaps on the topic, as well as case studies.

Table 5-3. Comparing DTO / DODT and Onto-Digital competency questions.

DTO Competency Question	**Onto-Digital Competency Question**
DODT CQ1. What differentiates digital transformation from organizational transformation?	Out-of-scope. It was probably considered a known, established concept and was not defined in the text.
DODT CQ2. What are the assets needed to perform a digital transformation?	The question “What are the key dimensions of digital transformation?” can indirectly answer the DODT CQ2.
DODT CQ3. What transformable entities originate in and result from a digital transformation?	The question “Can we build a generic digital transformation model?” can indirectly answer the DODT CQ3.
DODT CQ4. What is digital technology and its role in digital transformation?	Out-of-scope. It was probably considered a known, established concept and was not defined in the text.
DODT CQ5. What is digital BPM capability and its role in digital transformation?	Out-of-scope, although the dimensions include Structural, Informational, Environmental, Security,

DTO Competency Question	Onto-Digital Competency Question
	Quality, Financial, Cultural, Innovation and Participative, some of which are part of the area of interest of the BPM framework.

5.4 Summary

The research background analysis (see Chapter 3) and related work analysis provide evidence that digital transformation is a merging of business processes and digital technologies with a focus on innovative business models to create significant value for organizations through combinations of information, processes, computing, communication, and connectivity technologies across organizational boundaries.

Researchers and practitioners have been developing and studying digital transformation solutions applied to varied business processes and diverse digital technologies. However, at the time of this thesis' writing, no known existing work proposed a Digital Transformation Ontology considering the use of digital BPM capabilities and digital technologies to improve digital transformation initiatives.

Although it is acknowledged that all initiatives related to digital transformation are essential as they allow a better understanding of this relatively new research area, overall, most of the existing solutions lack validation grounded in a foundational ontology and are not well-integrated with other ontologies. At the time of this thesis' writing, no complete conceptual model has been identified that covers all relevant aspects, such as the potential transformable organization, its parts, members, intentions, and assets; the transformation motivation, transformation event, and transformation initiative that design and implement the desired transformation; and the digital transformation components, such as BPM capabilities and digital technologies. As these ontologies did not answer my questions, it was not possible to reuse them.

Chapter 6

Demonstration and Evaluation

In DSR, the demonstration step focuses on applying the artifact in order to assess whether it is able to solve one or more instances of the problem, while the evaluation step compares the objectives of a solution to actual observed results from the use of the artifact (Peffers *et al.*, 2007). The artifact in this thesis is DTO, a reference ontology. According to SABiO (Falbo, 2014), the testing process for reference ontologies includes two main perspectives: (i) ontology verification to ensure that the ontology is being built correctly and (ii) ontology validation to ensure that the correct ontology is being built.

Chapter 6 shows that DTO comprises two sub-ontologies, COOT and DODT. This thesis uses the case study approach to evaluate DTO, i.e., COOT and DODT, following the guidelines proposed by SABiO. The two steps of the testing process are verification and validation.

In Section 6.1, the ontology competency questions were answered with the DTO in the demonstration step, and in Section 6.2 the evaluation step observes the DTO results, modelling a case study for each DTO sub-ontology, i.e., COOT and DODT. Section 6.3 discusses the test results, correlating research questions with competency questions and case study model instantiation.

The DSR demonstration step involves the SABiO ontology verification and the DSR evaluation step, the SABiO ontology validation, as presented in Figure 6.1.

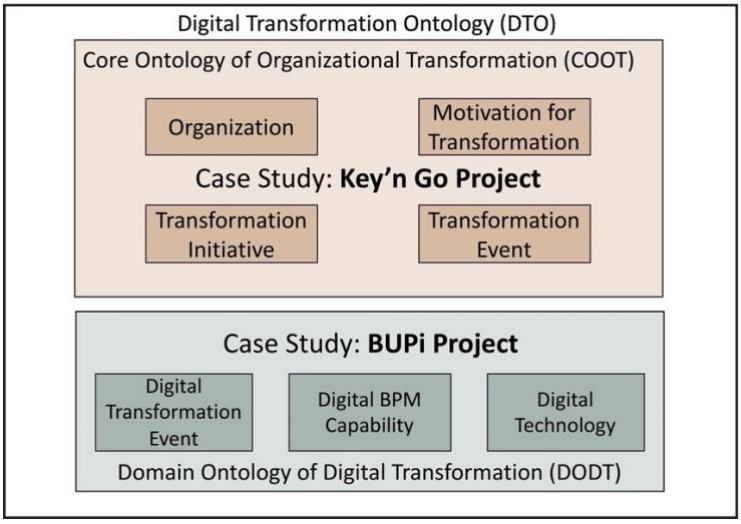

Figure 6.1. Case studies to demonstrate DTO.

6.1 DTO Demonstration

The Verification step is an assessment-by-human approach to ontology evaluation and was performed manually, confirming that the concepts and relations defined in DTO (COOT and DODT) were able to answer the competency questions.

6.1.1 COOT Demonstration

The Verification step confirms that the concepts and relations defined in COOT were able to answer the competency questions, as shown in Table 6-1.

Table 6-1. COOT Verification by Competency Questions.

Competency Question	**Description, Concepts and Relations**
CQ1. Which organization is to be transformed?	An ORGANIZATION is a type of social agent organized as a group of agents into a community or other social, commercial, or political structure. It is specialized into two subkinds (FORMAL ORGANIZATION and INFORMAL ORGANIZATION), and which (being a social agent) accepts a particular type of normative description (termed an ORGANIZATION BODY OF NORMS). COMPLEX ORGANIZATIONS are organizations that are composed of at least two disjoint ORGANIZATIONAL PARTS. The type of ORGANIZATIONAL PART is a mixin given that some of its instances, namely ORGANIZATIONAL UNITS, are necessary ORGANIZATIONAL PARTS, while other instances, namely SUBSIDIARY ORGANIZATIONS, are only contingently so - in fact, an organization plays this role when being in a subsidiary relation with a larger organization. FORMAL ORGANIZATIONS are given full recognition within the organization's context as well as by broader scope organizations such as a state. When the organization is an INFORMAL ORGANIZATION, it is not a legal entity in its own right. A POSITION within an organization exists independently of the agents filling it. A POSITION is considered here to be a minimal organizational unit, i.e., an organizational unit that can be occupied by at most one agent. A position can exist even if it is vacant. A position is filled when an agent (termed the POSITION HOLDER) is assigned to that position via a POSITION ASSIGNMENT. A position assignment is bound to MEMBERSHIP by that agent in that organization. A position is constrained to a set of ORGANIZATIONAL ROLES. A position assignment is just one type of membership that can be established between an agent and an organization.
CQ2. What conceptualizations characterize organizational transformation?	An ORGANIZATIONAL TRANSFORMATION is an instance of a TRANSFORMATION PLAN – a higher-order type whose instances are Action types. TRANSFORMATION PARTICIPATION constituting an organizational transformation may include participation by Objects playing the role of Resources (TRANSFORMATION RESOURCE PARTICIPATION), or intentional participation of Agents playing the ORGANIZATIONAL ROLE of transformation agents (TRANSFORMATION AGENT PERFORMANCE), a manifestation of the commitments of a TRANSFORMATION INITIATIVE PARTICIPANT, i.e., the commitments comprising that agent's TRANSFORMATION INITIATIVE PARTICIPATION ALLOCATION. Organizational transformations are manifestations of dispositions, including the CAPABILITIES of different Agents and Resources.

Competency Question	Description, Concepts and Relations
CQ3. What motivates an organizational transformation initiative?	A PROSPECT EVALUATION process can lead to the formation of ORGANIZATIONAL BELIEFS, including account for changes to be promoted in ORGANIZATIONAL ASSETS as BUSINESS OFFERING. The Beliefs that underpin the formation of the (internal) commitment termed a transformation initiative are termed DRIVERS. Here, the term DRIVERS always mean drivers of change. Drivers are organizational responses to prospect evaluations.
CQ4. How does an organizational transformation initiative emerge?	ORGANIZATIONS compete for various reasons, e.g., to offer better products at lower prices. Ultimately, organizations compete for customers. Two organizations compete if they offer products or services that meet the same customer needs, by making a value proposition towards a customer group. In competitive markets, therefore, after evaluating, assessing, and addressing potentially favorable and unfavorable prospects, organizations need well-designed BUSINESS STRATEGIES, such as an ORGANIZATIONAL TRANSFORMATION.
CQ5. Who are the agents involved in an organizational transformation?	TRANSFORMATION AGENTS are a category that can be instantiated by instances of the human agent, artificial agent, social agent or group (collective of agents) kinds. An Agent is an entity capable of bearing Mental Aspects, such as Beliefs, Desires and Intentions (UFO-C).
CQ6. What are the roles of the agents involved in an organizational transformation initiative?	Like all events, ORGANIZATIONAL TRANSFORMATIONS are manifestations of dispositions (UFO-B), including the capabilities of different endurants, such as agents and resources. Agents play the role of transformation agent; in which case they are termed TRANSFORMATION AGENT PERFORMANCE. An organizational transformation is a manifestation of a TRANSFORMATION INITIATIVE, a closed intention bound to a particular (TRANSFORMATION) PLAN. An agent is allocated (TRANSFORMATION INITIATIVE PARTICIPANT ALLOCATION) as an initiative participant to play a certain role in the scope of a TRANSFORMATION INITIATIVE.
CQ7. What organizational values are associated with organizational transformation?	The ORGANIZATION brings about an ORGANIZATIONAL TRANSFORMATION either to mitigate risks or to seize opportunities envisaged in the assessment of value experiences. A VALUE PROPOSITION is a particular type of Value Ascription connected to a Market Segment, which, in turn, is a collective (i.e., a group) of Value Beneficiaries.
CQ8. What factors enable Organizational Transformation?	The PROSPECT ASSESSMENT is a relationship between a PROSPECT BEHOLDER (an Agent, typically the organization itself, one of its sub-organizations or an Agent member of the organization), a PROSPECT BEARER (which can be an Object, e.g., an ORGANIZATIONAL ASSET, or an experience, e.g., a service offering, a process execution), and a PROSPECT BENEFICIARY. It relates to

Competency Question	Description, Concepts and Relations
	the creation of ORGANIZATIONAL BELIEFS, which can enable ORGANIZATIONAL TRANSFORMATIONS.
CQ9. What transformable entities originate in and result from organizational transformation?	Like all events, organizational transformations map the world from (pre-)situations to (post-)situations (in the sense of UFO-B). In such transformations, there are always entities to be transformed, termed TRANSFORMABLE ENTITIES. Transformable entities include ORGANIZATIONS and ORGANIZATIONAL ASSETS. When participating in an organizational transformation event, transformable entities can play the role of an ORIGINAL ENTITY (present in the BASELINE situation) or a RESULTING ENTITY (present in the OUTCOME situation).
CQ10. What are the phases in an organizational transformation?	An assessment creates a PROSPECT EVALUATION and ORGANIZATIONAL BELIEFS. Some of the organizational beliefs will give grounds for the formation of business intentions. A BUSINESS INTENTION with commitments (closed intention) is a formal BUSINESS STRATEGY (a type of Plan). A business intention may become (i.e., move on to a phase of) a transformation initiative. A transformation initiative is a business intention for Agents (initiative participants) via social relators termed INITIATIVE PARTICIPANT ALLOCATION.

6.1.2 DODT Demonstration

The Verification step confirms that the concepts and relations defined in DODT were able to answer the competency questions, as shown in Table 6-2.

Table 6-2. DODT Verification by Competency Questions.

Competency Question	Description, Concepts and Relations
CQ1. What differentiates digital transformation from organizational transformation?	A DIGITAL TRANSFORMATION event is a type of organizational transformation event, as presented in COOT. A digital transformation is enabled by a DIGITAL INNOVATION and characterized by DIGITAL TECHNOLOGY. A digital transformation also brings about a (post-)situation that is termed in this domain an outcome (in which one or more transformable entities are certainly present). Those that are the transformed output are termed resulting entities, historical roles (role mixins) played by transformable entities in organizational transformations, and their types of digital transformations.
CQ2. What are the assets needed to perform a digital transformation?	Digital innovations are both the basis for, and the outcome of DIGITAL TRANSFORMATION. They are the results of changes embodied in or enabled by DIGITAL TECHNOLOGIES and DIGITAL BPM CAPABILITIES; the types of assets needed to perform a digital transformation.

Competency Question	Description, Concepts and Relations
CQ3. What are the transformable entities originate in and result from a digital transformation?	One of the outcomes is DIGITAL PLATFORMS that capture, transmit and monetize data, including personal data, over the internet and other networks. They may not be composed by purely DIGITAL TECHNOLOGIES, although most successful digital platforms take advantage of the digital innovations and power of pervasive internet connectivity in the hands of billions of users (Yablonsky, 2018). A DIGITAL PLATFORM should be organized in DIGITAL VALUE SPACES. Another outcome is the DIGITAL BPM CAPABILITY PORTFOLIO, is composed by DIGITAL BPM CAPABILITIES, needed to the digital transformation. A BUSINESS ACTIVITY is a piece of work that requires DIGITAL BPM CAPABILITY to be complete. It participates together with the digital platform of the value proposition to create the event PROSPECT EVALUATION through prospect assessments in COOT.
CQ4. What is digital technology and its role in digital transformation?	DIGITAL TECHNOLOGY is the TECHNICAL IDENTITY of a DIGITAL OBJECT, its type of use assigned by a COMMUNITY, and its SOCIAL FUNCTIONS. Digital objects are a type of TECHNOLOGICAL OBJECT constituted by COMPONENT PARTS, structured in an OBJECT STRUCTURE, including one or more bitstrings. BITSTRINGS, a NONMATERIAL OBJECT, can be beared by a MATERIAL OBJECT or remain as a NONMATERIAL BEARER. DIGITAL TECHNOLOGY has its participation determined by a DIGITAL TRANSFORMATION event as a type of resource, an ORGANIZATIONAL ASSET. Digital technology can be changed embodied in or enabled by a DIGITAL INNOVATION that is a TRANSFORMABLE ENTITY. As a type of resource, a digital technology, inserted in a VALUE SPACE, can participates in a DIGITAL PLATFORM, generating VALUE in a digital transformation.
CQ5. What is digital BPM capability and its role of digital BPM capability in digital transformation?	The DIGITAL BPM CAPABILITY is a combination of digital BPM abilities and digital BPM capacities. As digital transformation is about processes, the role of processes in digital transformation is related to the role of the digital BPM capability, i.e., the digital BPM capability represents the ability and the capacity needed to execute the digital transformation.

6.2 DTO Evaluation

A similar approach to the works of (Brank, Grobelnik and Mladenic, 2005) and (Suarez-Figueroa, Kamel and Poveda-Villalon, 2013) was taken as the basis to evaluate the coverage and precision criteria of COOT and DODT, that is, the ontology was used in an application and the results were evaluated.

A case study approach was used for the validation of DTO by investigating a phenomenon in its natural setting over a period of time. The single-case study strategy was applied for each ontology. The cases studied are Keyn'Go® for COOT and BUPi for DODT, which are presented in detail in sub-sections 6.2.1 and 6.2.2.

The COOT and DODT Competency Questions are used to evaluate the ontologies, as the CQs are the questions that the ontology should be able to answer (Falbo, 2014).

6.2.1 COOT Case Study: Key'n Go®

The Scenario

Europcar® is one of the main current players in the car rental industry, in 2018 it had a revenue of 2.929 billion Euros and is established in over 140 countries (Europcar, 2019). InterRent® belongs to the Europcar®'s group since 1988. From the '80s until now, its goal has been to provide an exceptional experience to its customers. According to Hans Åke Sand, InterRent's CEO for 20 years in Sweden, "*Over ten years ago, when this industry was starting to grow here, we realized that we should not just provide our customers with a car if they ask for one. (…) We developed a service concept, according to which we provide immediately accessible transportation solutions to temporarily occurring transportation problems*" (Gronroos and Sand, 1993).

The car rental business is a relevant sector, considering the growth of mobility systems in the past years and the projection for their future (Oliveira, Carravilla and Oliveira, 2018). There are challenges (e.g., issues of cabotage regulations, security and insurance) and opportunities (e.g., building a profitable rental operation) in this industry. InterRent®'s current strategy gives it an advantage over its competitors, allowing them to achieve higher profitability and a greater number of satisfied customers (Lazov, 2017). However, on the other side, the forefront requires rethinking the business to improve the perceived value, both by customers and shareholders.

The AS-IS Process

Most consumers choose a service based on what is grasped as the better "value for money" option, which is, in fact, the most logical approach. Brokers are responsible for the suggestions, making them the most important "bridges" between a company and the consumer. Brokers make their offers by comparing the companies' NPS (Net Promoter Score). If a company has a higher NPS, it goes up in the suggestion list; if it has a lower NPS, it goes down, or it is not even offered as an option.

The strategy of InterRent® company was to improve service quality based on processes to impact positively the NPS score. To achieve this goal, InterRent® has interacted with customers, using a Customer Focus Group initiative and reviewed the entire customer journey process. Clearly, they engage process stakeholders (including customers), collecting data, identified the existing problems, and choose components for analyses the findings (the pain points presented below). Thus, Inter-Rent® works on how to innovate the process. These stages are aligned with the collectively form an iterative cycle of capturing, synthesizing, and reconciling stakeholder perceptions proposed by Robson (2002) to support business process innovation.

Starting from the need to rent a vehicle, the Customer usually searches the Car Rental Brokers websites, on Car Rental companies' websites or simply contacts the Car Rental companies, informing, among other things, the location, date, time, type of vehicle. Then, the vehicle rental starts. The journey currently involves the following critical processes from the Customer's perspective: "Receive Offer", "Book Vehicle", "Pick Up Vehicle", "Check Vehicle Conditions", "Receive Vehicle", "Use Vehicle", "Drop-off Vehicle". Although customers are increasingly performing the first two processes ("Receive Offer" and "Book Vehicle") through Web applications, the "Pick-Up Vehicle" process was still done face-to-face manually.

InterRent® noted that the Customer usually had to wait in a queue to be helped at the car rental desk, and often is asked to review optional accessories and insurance policies, in addition to previously selected items. This procedure implied the need to increase the number customer service employees, in the store, even though it does not guarantee reduced waiting time for customers; during peak season, queues are still a pain points for customers. The "Drop-Off Vehicle" process is also quite time sensitive as customers are usually heading to the next step of their journey; for example: the user might have to coordinate rental car's drop-off time with flight times (at the airport) and being asked to go through a careful damage inventory, together with Rent-a-car personnel, might affect their schedule. The main sources of pain on the Customer Journey, which negatively impacts on the NPS score, were identified as:

1. Waiting time in queues, to be served at the car rental desk
2. Stressing about the insurance and terms & conditions – in addition to customer service personnel's pitches for upselling opportunities
3. On picking up: Damage inventory; the need to check for inventory damage before being able to pick the car.
4. During Dropping-off: in addition to damage inventory, the customer also needs to wait to deliver the Vehicle despite time constraints

The InterRent® Customer Journey AS-IS process model is presented in Figure 6.2, highlighting those issues and the need for changes.

The TO-BE Process

As a mid-tier company, InterRent® had the ideal size to implement in, swiftly fashion, innovative solutions and still leverage the advantages of being a company of a Europcar's group company. It made InterRent® the best pilot for testing innovative solutions that, if proven to be successful, could be implemented in Europcar. Hence, InterRent® launched its "Hassle free Project", from people to people - the Keyn'Go® - and offered a complete Digital Customer Journey, for a reasonable price. The target market segment aimed is the customer who value their time and is technology friendly. Keyn´Go® project helped to address previously identified pain points as detailed in Table 6-3.

The benefit proposed by the InterRent® solution could be classified as an innovation in the car rental process, since it has been designed to optimize the time in the process of the renting a vehicle and the number of people involved in the process. They propose a service with fixed pre-defined conditions and insurance, aiming for the best cost benefit for their customer. See Figure 6.3 where the To-Be process is presented.

During the Key'n Go® process the customer is impacted by the Wow-factor, which in marketing means that the customer "relates to exceptional customer service in which an employee gives the customer more than they expected or something they did not expect at all", the customer feels happy and becomes "an ambassador" of the brand, sharing the service by word-of-mouth, increasing the NPS. Europcar´s NPS is 50% (Merino, 2019). Key'n Go®, albeit being a Mid-Tier brand reaches an average 54% with peaks over 60% during high season, comparing who uses Key'n Go® and who waits in queue: Key'n Go® customers feel valued and return with 90-100% in NPS score.

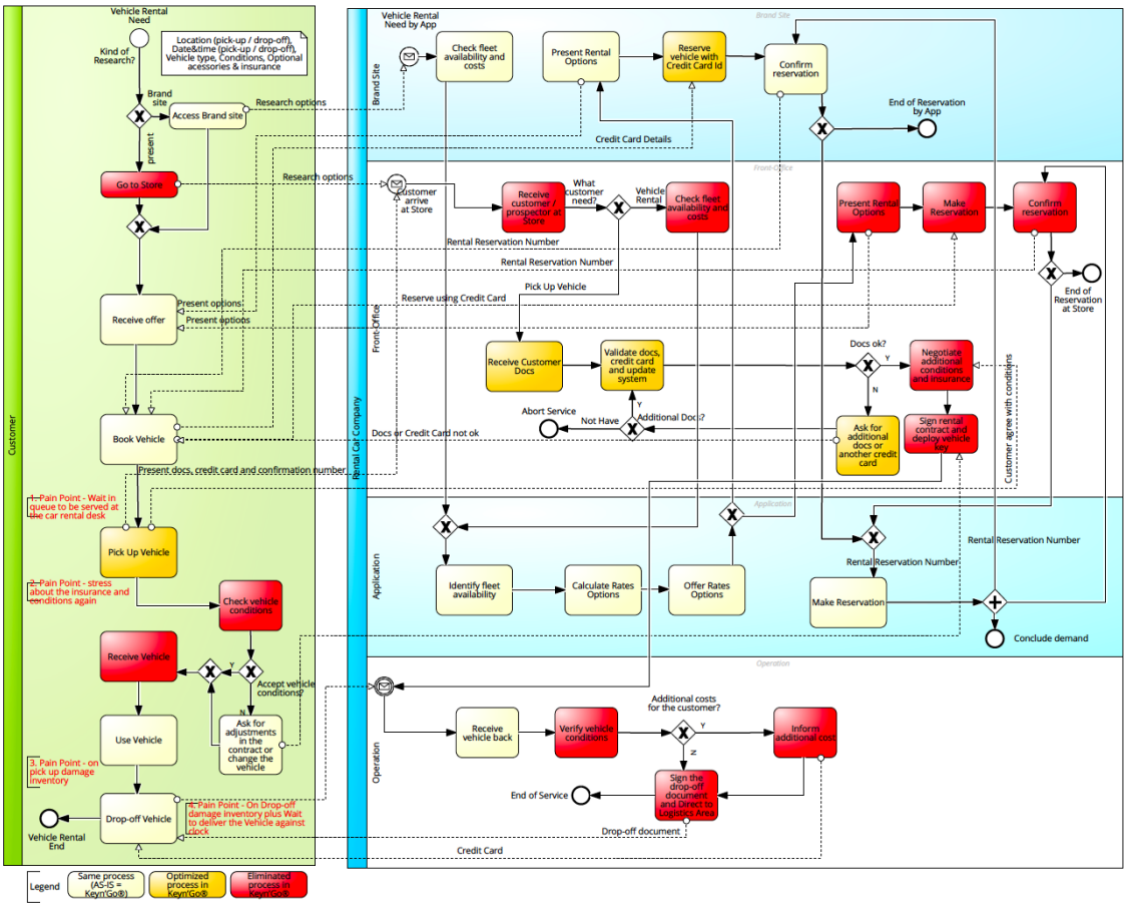

Figure 6.2 InterRent® As-Is process.

Table 6-3**.** Pain points addressed by Key'n Go®.

Pain point identified	Key'n Go®
Waiting in a queue to be served at the car rental desk	Uses automated kiosks, making it possible to deliver the car in a shifty minute while also giving the customer the power to choose a car he wishes from the fleet accessible.
Need to review insurance and conditions again	Assists customer by a ground-hostess (does not sell anything) in the doubts about using the kiosk.
On Picking Up damage inventory	The Key'n Go® bundle includes the premium insurance pack, that covers this kind of situation. Now the customers going to the agreed place, to pick-up the keys at the beginning drop-off the keys at the end.
On Drop-off damage inventory, in addition to waiting time to deliver the vehicle	

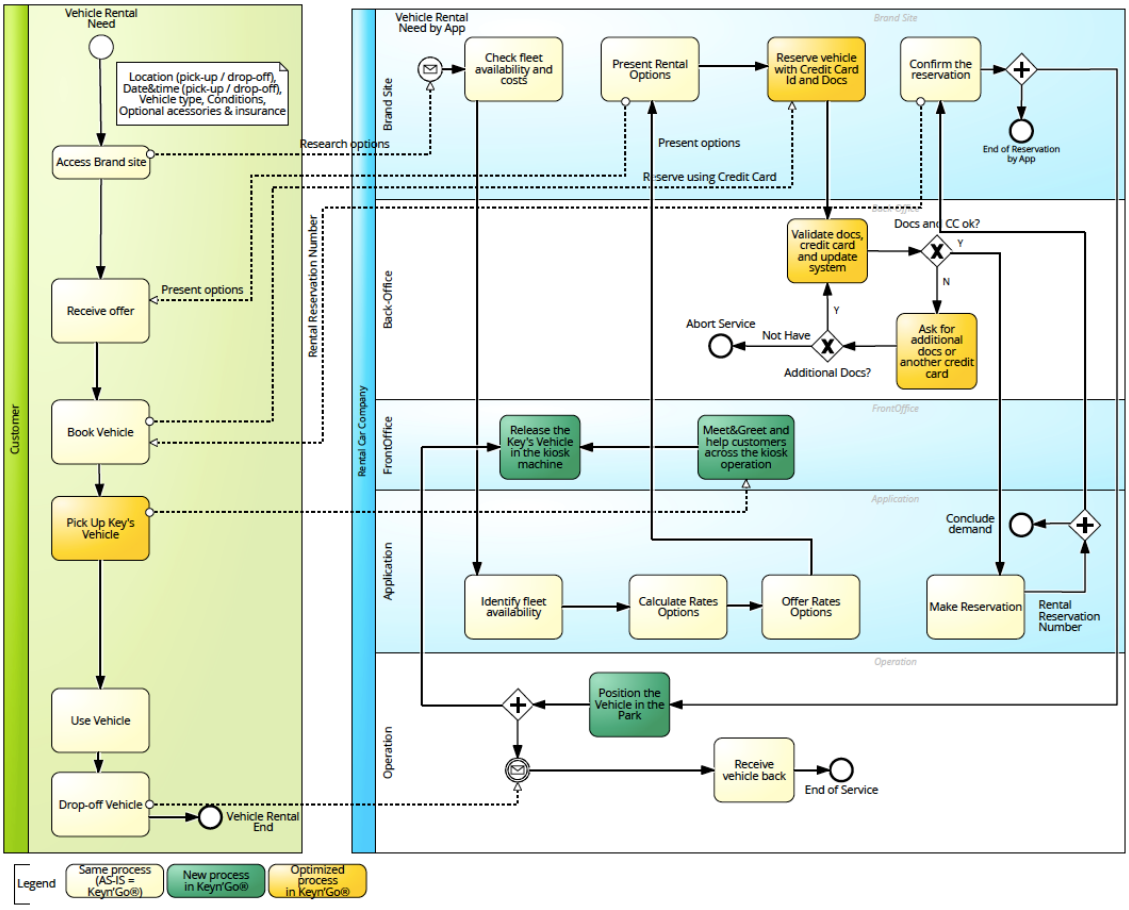

Figure 6.3 Keyn'Go® To-Be process.

Case Study Design and Planning

This case covers the situation before and after the launch of Key'n Go®, aiming to understand the transformation and its results. The effects of transformation were analyzed through the interpretation of this context. It is a holistic case study with a single unit of analysis which is the car rental process. The data collected was qualitative, providing better understanding of the

studied phenomenon in the data analysis. The procedures and protocols for data collection are defined in Table 6-4. Triangulation was made using interviews and document analyses.

Table 6-4.The case study protocol.

Goals and scope	Data Collection	Analysis	Interpretation
Exploratory	▪ Process models ▪ Interviews	Analysis of the case using COOT	Interpretation of the results to answer the CQs

The case study design contains the following elements (see Table 6-5):

Table 6-5. The case study design elements.

Design Elements of Case Study	Key'n Go®
Objective to achieve	Testing COOT considering verification and validation perspectives
The case to be studied	Key'n Go®
Theory: frame of reference	COOT
COOT Competency questions:	CQ1. Which organization is to be transformed? CQ2. How to characterize organizational transformation? CQ3. What motivates an organizational transformation initiative? CQ4. How does an organizational transformation initiative emerge? CQ5. Who are the agents involved in an organizational transformation? CQ6. What are the roles of the agents involved in an organizational transformation initiative? CQ7. What organizational values are associated with organizational transformation? CQ8. What factors enable organizational transformation? CQ9. What transformable entities originate in and result from organizational transformation? CQ10. What are the phases followed in an organizational transformation?
Data Collection methods	Interviews and document analyses.
Strategy selected	A single-case study for COOT.

Data Gathering

The project involved a team of three fully dedicated senior participants. Each member had the responsibility to interface with the other areas affected by the project. Those areas maintained their As-Is operations, participated under demand in the project, and in the end implemented the new operation. In 2018 the Key'n Go® project was launched and completed in a relatively short period of six months. The case study data was collected between February 2019 and February 2020. The pilot began in March 2019 and was followed by Go Live waves and operations. Various data sources were used, including interviews, media documents and observations.

First, the company documents (e.g., internal videos presenting the project and financial reports (Europcar, 2019)) and analyzed public documents such as web magazine news (Merino, 2019), (*Europcar Mobility Group Presents SHIFT 2023, Its 2023 Roadmap to Further Capture Profitable Growth*, 2019) (*Serviços de mobilidade Com uma experiência do cliente totalmente digitalizada*, 2019) were reviewed, which provided good starting points for the interviews and a clear insight into the company's situation. Moreover, both the Key'n Go® App and the traditional InterRent® App were used to simulate a customer experience. It is worth mentioning that one of the co-authors is a member of the group responsible for strategy formulation and project development.

Secondly, the team members were interviewed (see details in Table 6-6).

The Director and iRPM were project members since the beginning, and the iROM joined after. Although three interviews might be considered too few for a single case study, observing the situation, it was considered enough in this case because the interviewees were the main representatives of the project members, and they were able to provide all the needed information about the main topics covered in the interview.

Table 6-6. Members of the Key'n Go® team interviewed.

Id	**Role**	**Responsibilities**
Director	InterRent® Mid-Tier segment Director	Commercial and Operations Leader at InterRent in the mid-tier segment, holding responsibility in the Repositioning of the Brand, both in B2C and B2B2C segments, accountable for the budget definition and execution. Besides being the Key'n Go® Project Director, manages all the resources needed to deliver the repositioning of the brand in time.
iRPM	InterRent® Key'n Go® Product Manager	Responsible for the product features definition, managing IT team's development squads and end-to-end testing of implemented solutions.
iROM	InterRent® Key'n Go® Operations Manager	In charge of the Key'n Go® front-end and NPS follow-ups. Reports to the iRPM on customers' feedback on functionality drivers.

The interview was planned to raise general concerns based on our research questions, i.e., the topics of interest in the case study. The questions were open, using Key'n Go®'s as-is operations and existing business process models as a basis, generating a broad range of answers and comments from the interviewees. The interview session began with open questions and moved towards more specific ones. As scheduled, first the authors presented the case study goals, and explained how the data would be used. Then the interview session started with the main questions, which comprised the most significant part of it. Just before the end of the interview, the key findings were summarized by the researchers in order to obtain feedback and avoid misunderstandings.

During the interview, the as-Is operations and process models of Key'n Go® served as a basis to answer the questions. The interviewers took notes of the obtained results and consolidated them

in Table 6-7. Each respondent answered on the subject of the first 11 questions individually, but Question 12 was answered and discussed in a group.

Table 6-7. Research and Interview questions and their respective summarized answers.

Interview Question	**Director**	**iRPM**	**iROM**
(1) Does the current InterRent® customer journey process differ from that of competitors? If so, where? Why do customers choose InterRent® today?			
	Price and convenient location of the network	Low rate	Price
(2) What are the concerns regarding the current customer journey process, which led to the decision to evaluate the current business model with Key'n Go®?			
	Low NPS is driven by long queues and aggressive sales pitches	Quality	NPS and aggressive ancillary sales
(3) What works well with the current customer journey process?			
	Fleet	Fleet	Fleet
(4) Why was this project carried out?			
	Identified the need to boost sales having NPS as a barrier	Because of broker pressure to increase NPS	To address a differentiation scenario compared to competition
(5) Can you describe it chronologically?			
	In 2018 Europcar changed its management organization into Business Units. InterRent® started to be managed by the Low-Cost Business Unit. At this moment a need was identified, and the DT Project was launched.	2018 Project Launched 2019 Q1 Pilot 2019 Q2 to Q4 Go Live	2019 Q1 Alicante Pilot 2019 Q2 Go Live waves
(6) What are the stages of the project and the main results and lessons learned in each stage?			
	Pain points identification Focus group Solution development Solution deployment Next steps evaluation (new opportunities)	Pain points identification Focus group Solution development Solution deployment Next steps evaluation (new opportunities)	Pain Points identification Focus group Solution development Solution deployment Next steps evaluation (new opportunities)
(7) What has changed with the launch of the Key'n Go® product?			
	Growing the NPS metric and RPD (Revenue Per Day)	Quality and Sales	Quality and Prices
(8) What do customers praise most about the Key'n Go® product?			
	Transparency and simplicity	Simple and fast	No queue
(9) Are there additional inputs to improve the customer experience in the Key'n Go® process?			
	Upsell in the Kiosk	Upsell in the Kiosk	Upsell in the Kiosk
(10) What can be automated in the Key'n Go® process that might bring significant results?			
	Wi-Fi availability	Additional driver	Wi-Fi connection
(11) What characteristics of Key'n Go® differentiate it from competitors in the industry, what characteristics of InterRent®'s current business model and InterRent®'s current process, contributed most to the success of Key'n Go®?			
	No queue, self-digitalization of the documents	One minute to Pick-up	No queue

Interview Question	Director	iRPM	iROM
(12) Could you classify this case, considering how the business ecosystem transformed (before / during project / after key'n Go® launch)? See Table 6-8.			

Table 6-8. Business Ecosystem Transformed.

DT&I-BPM-Onto Class	Contextual factors (Brocke, Zelt and Schmiedel, 2016)	Data collected in the interviews from question (12)
Business Process	Process degree of value contribution?	Core process
	Repetitiveness process?	Repetitive
	Knowledge-intensive process?	Low / High / Low
	Creativity-intensive process?	Low / High / Low
	Interdependence of process participants?	High
	Process variability?	Low
	Business organizational process scope?	Inter-organizational process
Business Organization	Business industry?	Service industry
	Business size?	Large organization
	Culture supportive of BPM?	Highly supportive
	Availability degree of the organizational resources?	Medium / Low / Low
Business Environment	Degree of environment competitiveness?	Highly / Low / Low
	Degree of environment uncertainty?	Medium / High / Medium

As for the Validation and Test Case Design, since a reference ontology should be able to represent real world situations, in order to validate COOT, its concepts and relationships were instantiated using data extracted from the Key'n Go® project. The Key'n Go® project was launched as a new digital business model at InterRent®, a car rental company of the Europcar® Group. Established in more than 140 countries, Europcar® is currently one of the main players in the car rental industry. The car rental business is a relevant sector, considering the growth of mobility systems in recent years and projections for its future (Lazov, 2017).

By instantiating concepts, test cases can be designed for the competency questions to ascertain whether the ontology can answer them when instantiated in real case scenarios. In the following paragraphs, each competency question is highlighted in bold at the beginning of the corresponding paragraph, and the terms marked in SMALL CAPS in the description relate to the concepts presented in COOT. Moreover, Figure 6.4 and Figure 6.5 depict the result of instantiating COOT for the InterRent® case study. For the sake of traceability with the original COOT modules, in these figures were applied the same color convention used in the modules. The CQs are in non-sequential order to facilitate the narrative of the case.

CQ1. Which organization is to be transformed?

The Organization to be transformed is InterRent®, a car rental company recognized as a FORMAL ORGANIZATION by the Europcar® Collective of organizations, having its own Constitution (ORGANIZATION BODY OF NORMS). InterRent® belongs to the highly competitive Low-Cost Market Segment.

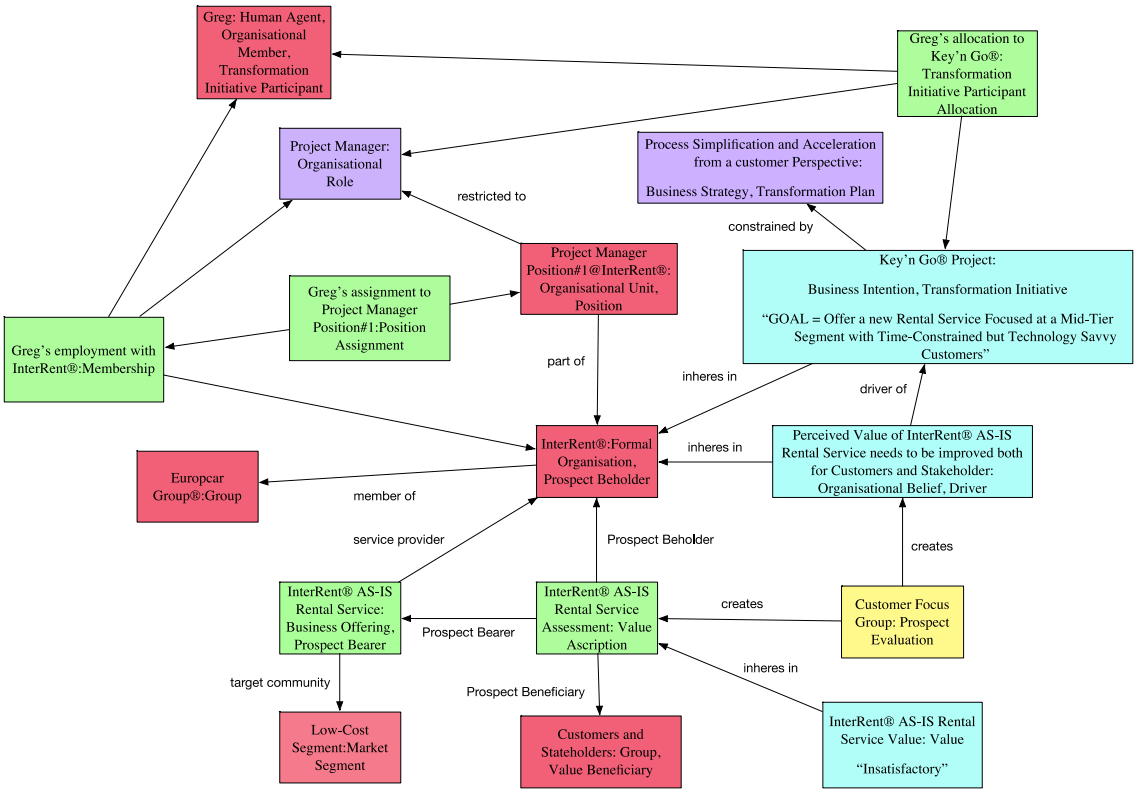

Figure 6.4. Mental aspect of the organizational transformation.

CQ7. What organizational values are associated with Organizational Transformation?

As with other car rental companies, in building a profitable rental operation (Value Ascription), InterRent® encountered challenges such as establishing service with "satisfactory" Value for customers. Given the market challenges, the InterRent® board decided to hear from its customers and interacted with them using a Customer Focus Group as a PROSPECT EVALUATION to review the entire customer journey process. The InterRent® AS-IS Rental Service Assessment engaged process stakeholders, collected data, identified the existing problems and selected components to analyse the PROSPECT EVALUATION findings. The InterRent®. AS-IS Rental Service Value was determined to be "Unsatisfactory".

CQ8. What factors enable organizational transformation?

InterRent® interacted with customers through a Customer Focus Group initiative to review the entire customer process and experience, collect data and identify problems. InterRent® then set up a group to examine the findings of the Customer Focus Group. This same PROSPECT

EVALUATION event (the Customer Focus Group) produced, as a result, another PROSPECT ASSESSMENT (a Value Ascription), specifically a Value Proposition, namely quality services for a fair price and a profitable rental operation, connected with a (Mid-Tier) Market Segment - which, in turn, is a collective (i.e., a GROUP) of Value Beneficiaries (i.e., customers who value their time and are technology friendly).

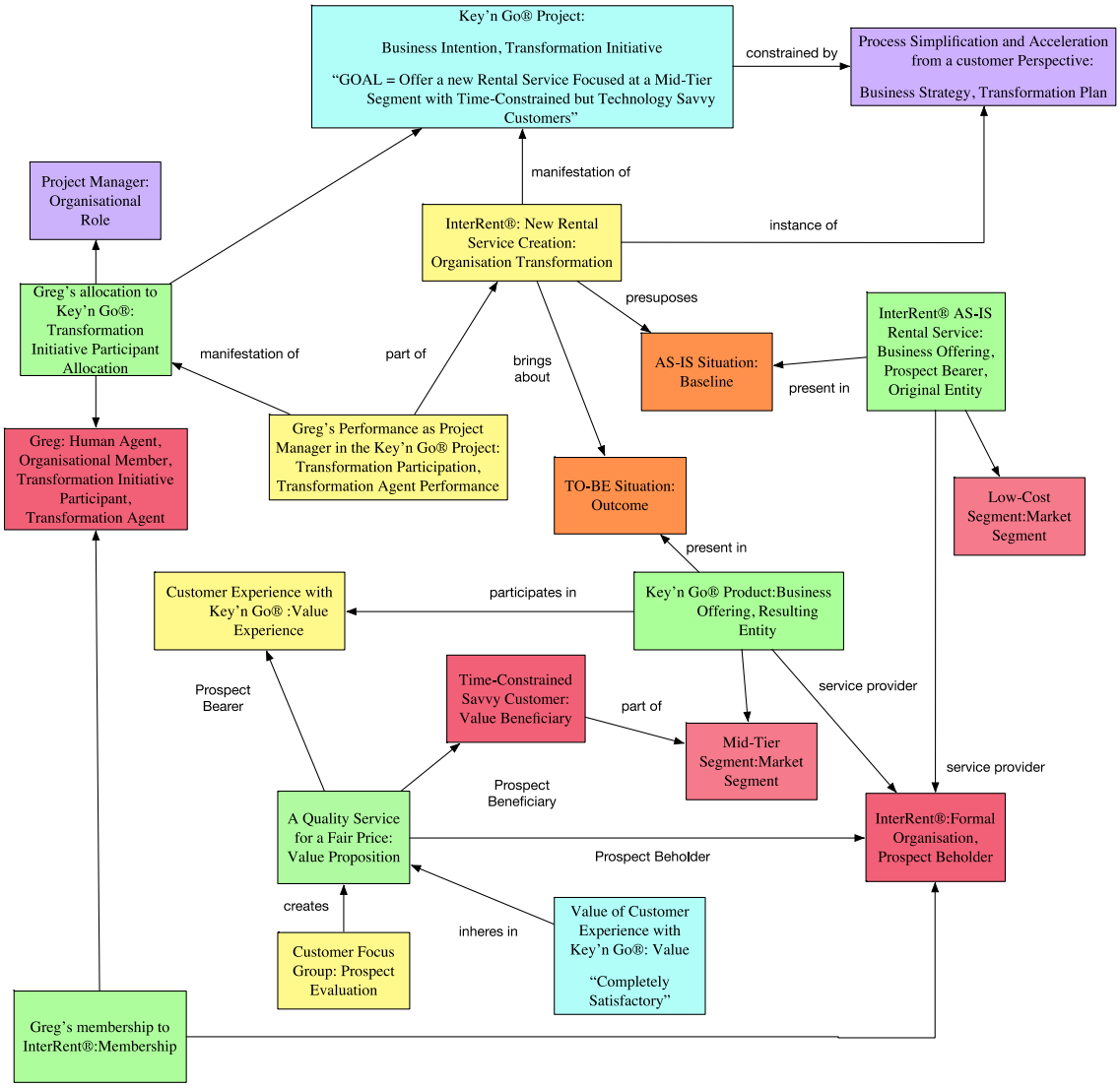

Figure 6.5. The Key'n Go® transformation event and initiative.

CQ2. What conceptualizations characterize organizational transformation?

After that, InterRent® perceived (ORGANIZATIONAL BELIEF) that the front-end process required rethinking to improve the Value of InterRent® AS-IS Rental Service both for customers and shareholders. The main DRIVERS motivating this was the fact that the perceived Value of InterRent® AS-IS Rental Service needs to be improved both for customers and stakeholders. Some of the ORGANIZATIONAL BELIEFS warranted the formation of BUSINESS INTENTIONS, which are types of self-commitments towards a BUSINESS GOAL (the propositional content of the intention) -

in this case, offering a new rental service focused on a Mid-Tier segment with time-constrained but technology-friendly customers. A manifestation of the BUSINESS INTENTION is the ORGANIZATIONAL TRANSFORMATION, which, in this case, is the InterRent® New Rental Service Creation. A BUSINESS INTENTION may become (i.e., move on to a phase of) a TRANSFORMATION INITIATIVE.

CQ4. How does an organizational transformation initiative emerge?

One type of intention is closed intention, which is a commitment to pursue a Goal in a specific way. A CLOSED INTENTION is constrained by a particular type of Universal Action (termed a Plan in UFO-C, and a BUSINESS STRATEGY in COOT). The BUSINESS STRATEGY was, from a customer's perspective, to improve quality and further simplify and accelerate processes. InterRent®'s BUSINESS STRATEGY was designed to enhance its advantage over competitors to secure higher profitability and a greater number of satisfied customers (Merino, 2019).

CQ10. What are the phases in an organizational transformation?

A PROSPECT EVALUATION comprises intentions either to mitigate Risks – e.g., eliminate threats or vulnerabilities (Sales, Baião, *et al.*, 2018) identified in a Risk Assessment – or to seize opportunities envisaged in the assessment of Value Experiences (Sales et al., 2017), such as those resulting from a Value Ascription that characterizes a specific Value. The PROSPECT EVALUATION leads to the formation of ORGANIZATION BELIEFS which substantiate the formation of BUSINESS INTENTIONS. A BUSINESS INTENTION with commitments (closed intention) is a formal business strategy (a type of plan) that may move on to the phase of a TRANSFORMATION INITIATIVE.

Figure 6.4 depicts the model of the mental aspect of the ORGANIZATIONAL TRANSFORMATION, comprising a set of beliefs and intentions. An ORGANIZATIONAL TRANSFORMATION (InterRent® New Rental Service Creation) is a manifestation of a TRANSFORMATION INITIATIVE (the Key'n Go® Project), which as a Closed Intention, is bound to a particular (transformation) Plan. As with all events, an ORGANIZATIONAL TRANSFORMATION maps the world from what, in UFO-B, are termed (Pre-)Situations to (Post-)Situations. In COOT, these are termed BASELINE and OUTCOME, respectively.

CQ5. Who are the agents involved in an organizational transformation?

The Agents of the Key'n Go® project (TRANSFORMATION INITIATIVE) were a team of three fulltime senior participants. Each member was responsible for interacting with certain areas affected by the project. Those areas maintained their as-is operations, participated on-demand in the project and implemented the new operation only when it was concluded.

A POSITION within an ORGANIZATION exists independently of the Agents filling it. Following (Scheer, 2012), COOT considers a POSITION to be a minimal ORGANIZATIONAL UNIT, i.e., an ORGANIZATIONAL UNIT that can be occupied by at most one Agent. A POSITION can exist even if it is vacant. POSITIONS can be filled when Agents, termed POSITION HOLDERS (in this case, Greg), are assigned to that POSITION via a POSITION ASSIGNMENT (InterRent® Project Manager – Greg). A POSITION ASSIGNMENT is bound to that Agent's MEMBERSHIP in that ORGANIZATION.

CQ6. What are the roles of the agents involved in an organizational transformation initiative?

The Key'n Go® project was a BUSINESS INTENTION binding Agents (e.g., Greg) as the TRANSFORMATION INITIATIVE PARTICIPANT via Social Relators termed TRANSFORMATION INITIATIVE PARTICIPANT ALLOCATION (Greg's allocation to the Key'n Go® project), where each Agent plays a Role (e.g., Key'n Go® project manager) within the scope of a TRANSFORMATION INITIATIVE.

CQ3. What motivates an organizational transformation initiative?

The Beliefs that gave grounds for forming the (internal) commitment termed a TRANSFORMATION INITIATIVE were termed DRIVERS. Here DRIVERS are always drivers of change. In this case, DRIVERS (e.g., customers, differentiation, competition) are organizational responses to a PROSPECT EVALUATION (i.e., pain points from the customer's perspective).

CQ9. What transformable entities originate in and result from organizational transformation?

In such transformations, there are always entities to be transformed. These are termed TRANSFORMABLE ENTITIES. These entities are endurants, i.e., persons capable of qualitative change while preserving their identity (UFO-A). Both ORGANIZATIONS and ORGANIZATIONAL ASSETS are types of TRANSFORMABLE ENTITIES. TRANSFORMABLE ENTITIES can play the Role of both the ORIGINAL ENTITY (present in the BASELINE situation) and RESULTING ENTITY (present in the OUTCOME situation), while participating in an organizational transformation event. In this case, the BASELINE is the InterRent® AS-IS situation and the OUTCOME is its TO-BE situation (Key'n Go®). The AS-IS and TO-BE Business Process Models were presented in (Bogea Gomes *et al.*, 2020).

The customer journey process was one of the main examples of a TRANSFORMABLE ENTITY. To achieve its BUSINESS STRATEGY, the front-end process requires rethinking the business to improve the Value perceived by both customers and shareholders. Thus, InterRent® worked on how to innovate the process to support its business. These stages were aligned collectively in the form of an iterative cycle of capturing, synthesizing and reconciling stakeholder perceptions, as proposed by (Robson, 2002) to support business process innovation. Figure 6.3 shows the Key'n Go® transformation event and initiative.

The Key'n Go® project reviewed the entire customer journey process and defined a new path by eliminating each pain point one after another without jeopardising the promise of quality service for a fair price (Value Proposition). InterRent® changed certain ORGANIZATIONAL ASSETS (such as the customer journey process) in order to launch its BUSINESS OFFERING, the "Hassle free Project, from people to people – the Key'n Go®".

6.2.2 DODT Case Study: BUPi

The Scenario

BUPi (Balcão Único do Prédio in Portuguese, "Unique Property Registration" in a direct translation to English) is a current Portuguese government digital transformation project. It is a platform for identifying, mapping, and comprehending the Portuguese territory, where knowledge is turned into value for all. They ran the pilot phase with ten municipalities from 2017 to 2020.

The term property means what is usually called land. A property can be rural or urban. There is also the possibility of a mixed property when it contains urban and rural parts, with neither being designated as the main one. BUPi was launched as a pilot project in 2017, intending to get to know Portuguese territory (community, public and private areas) in a simplified and innovative way. BUPi has four goals: territorial planning, resource valuation, identification of owners, and prevention of wildfires. It was launched in 10 municipalities within a period of one year.

BUPi aims to simplify the land registry based on the principles of a single point of contact and crucial citizen involvement using a digital environment, transforming knowledge into value for all involved. It is the result of a digital transformation from previously independent services based in different Portuguese government institutes (multiple points of contact managed for each landowner) to identify, map, and understand the Portuguese territory (different processes for each institute, without interoperability nor integrated data between them).

This digital transformation initiative will implement a new Portuguese land registry system in the future by creating a unique Property Identification Number (NIP), granting access to and sharing information with the public administration using a single platform for identifying the territory. It will employ a combination of an integrated and interoperable process and data from all the Portuguese government institutes involved in Portugal’s land registry, including layers such as orthophoto maps toponymy, asset database, land registry database, forests natural parks common land, road and hydrographic network, public domain goods, satellite images, and local information.

Moreover, BUPi LAB was created in January 2018 to design an automated method capable of facilitating the acquisition and organization of knowledge about the territory. In May 2019, the network of BUPI’s service counters were expanded to respond to population adherence. By the end of 2019, the Portuguese government approved BUPi’s expansion to the whole country. Furthermore, in May 2020, a Mission Unit (eBUPi) was created to operationalize this expansion, and finally, in February 2021, new municipalities joined BUPi.

Before the introduction of BUPi, there were multiple points of contact to conclude the property registrations. The agencies of Register Area, Cadastral Area, and Taxes Area had their own data files without the need for validation between agencies. Every part of the property registration had a different process, besides different emoluments and tax regimes. They had different Property Identification Numbers, which makes property identification among the agencies difficult. The landholder was responsible for performing and adhering to the process of each part. As a result,

the property was not always registered with all agencies. In the future, there will be a single point of contact for the property registration with BUPi. Moreover, they will all have the same Property Identification Number, making it easier for the agencies to identify the buildings.

“There are properties in Portugal whose titleholders, locations, and exact boundaries are unknown. This lack of knowledge makes it harder to plan and manage land and fight fires in rural areas” (Interviewer 1 – Interview 2). In the pilot phase, eBUPi elaborated and negotiated strong interinstitutional engagement through Interinstitutional protocols. They visited counters and properties, simulated rural property purchases, interviewed landholders, employees, and local associations, tested communication approaches, and monitored the customer service at BUPi counters. They proposed an innovative platform that gather different sources of information, which allows citizens to identify their lands remotely, in a declarative way, using georeferenced descriptions validated by qualified technicians. Furthermore, they did several training cycles and involved all stakeholders to share experiences, problems, and best practices.

In May 2021, during the period of interviews, the pilot project phase identified 157.444 property records. At the end of the pilot phase, 50% of land was identified.

Case Study Design and Planning

This case covers the situation before and after BUPi (until its current phase – the project is not finished yet), aiming to understand the digital transformation initiative and its results. The data collected was qualitative, providing a better understanding of the studied phenomenon in the data analysis. The procedures and protocols for data collection are summarized in Table 6-9. Triangulation was made using interviews and document analysis.

Table 6-9. The case study protocol.

Goals and scope	Data Collection	Analysis	Interpretation
Exploratory	Interviews Document analysis	Analysis of the case using the DODT	Interpretation of the results to answer the competency questions in the light of the background theory.

The case study design contains the following elements (see Table 6-10):

Table 6-10. The case study design elements.

Design Elements of Case Study	BUPi
Objective to achieve	Testing DODT considering verification and validation perspectives
The case to be studied	BUPi
Theory: frame of reference	DODT

Design Elements of Case Study	BUPi
DODT Competency questions:	CQ1. What differentiates digital transformation from organizational transformation? CQ2. What are the assets needed to perform a digital transformation? CQ3. What are the transformable entities originate in and result from of a digital transformation? CQ4. What is digital technology and its role in digital transformation? CQ5. What is digital BPM capability and its role in digital transformation?
Data Collection methods	Interviews and document analysis.
Strategy selected	A single-case study for DODT.

Data Gathering

The triangulation was made using interviews with the eBUPi General Coordination, eBUPi Digital Advisory and documents analysis.

Multiple data sources were used, including interviews, media documents, and observations. First, BUPi documents were reviewed, such as the presentation "Expanding the Simplified Land Digital Registry - Portugal", exposed in Permanent Committee on Cadastre in the European Union (PCC)[24], Blog BUPi[25], news about BUPi as the winner of the Portugal Digital Awards 2019 digital transformation project category[26], Institutional Video[27], and OECD Report (OECD, 2020). After that, the BUPi site was analysed to obtain a clear insight into the project's situation to gather starting points for the interviews.

Second, the two main members of the eBUPi team were interviewed: the eBUPi General Coordination and the eBUPi Digital Advisory. Although three interviews with two project participants could be considered too few for a single case study, it was sufficient in this case

[24]In Permanent Committee on Cadastre in the European Union (PCC). Retrieved from https://webcache.googleusercontent.com/search?q=cache:ssMzFTsj5cAJ:https://eurogeographics.org/wp-content/uploads/2021/04/PCC_UE_26052021Tavares.pdf+&cd=1&hl=pt-PT&ct=clnk&gl=pt

[25]https://blog.bupi.gov.pt/

[26]https://irn.justica.gov.pt/en-gb/Noticias-do-IRN/BUPi-vence-premio-Best-Digital-Transformation-Project-2019

[27]YouTube. Retrieved from https: //www.youtube.com/watch?v=xB9yFWhshc0

because the interviewees were representative of the essential stakeholders, and they were able to provide all the information about the main topics covered in the interview.

The interview was planned to raise general concerns based on our competency questions, i.e., the topics of interest in the case study. The interview session began with open questions and moved towards more specific ones. As scheduled, first, the authors presented the case study goals and explained how the data would be used. Then the main questions were asked, which occupied the most significant part of the interview. Before the end of the interview, the researcher summarized the key findings to obtain feedback and avoid misunderstandings. The interviewer took notes during the interview and consolidated them after the interview, which were later confirmed with the interviewees.

As for the Validation and Test Case Design, since a reference ontology should be able to represent real-world situations, in order to validate DODT, its concepts and relationships were instantiated using data extracted from the BUPi project. The CQs are in non-sequential order to facilitate the narrative of the case.

By instantiating concepts, test cases for competency questions can be designed to determine whether the ontology can answer them when instantiated in a real-world scenario. In the following paragraphs, each competency question is highlighted in bold at the beginning of its corresponding paragraph. The terms in the description marked with SMALL CAPS are related to the concepts presented in DODT, whereas those marked in italic correspond to the BUPi instantiation. Furthermore, Figure 6.6 consolidates the outcome of instantiating DODT for the BUPi case study. For the sake of consistency with the original DODT modules, the same color scheme was used in this figure.

The *Single Portuguese Building Registry* (BUPi) is a DIGITAL TRANSFORMATION event, a type of organizational transformation, manifesting as the *BUPi Project*, a TRANSFORMATION INITIATIVE, enabled by the *Building Digital Registry,* a DIGITAL INNOVATION of the Portuguese government. On top of this digital innovation, a *Single Portuguese Digital Building Registry* was built*,* an innovative DIGITAL BUSINESS MODEL launched as a part of the Portuguese government's *Portugal Digital* action plan (DIGITAL LANDSCAPE), which aims to be the driving force behind the country's transformation through the digital empowerment of people, the digital transformation of organizations, and the digitalization of the State, creating mutual value in a cooperative / competitive environment for organizations.

BUPI Information System (APPLICATION SOFTWARE), *Simplified Digital Building Registry Ecosystem* (DIGITAL ECOSYSTEM) and *BUPi Platform* (DIGITAL PLATFORM) are participants in a digital landscape.

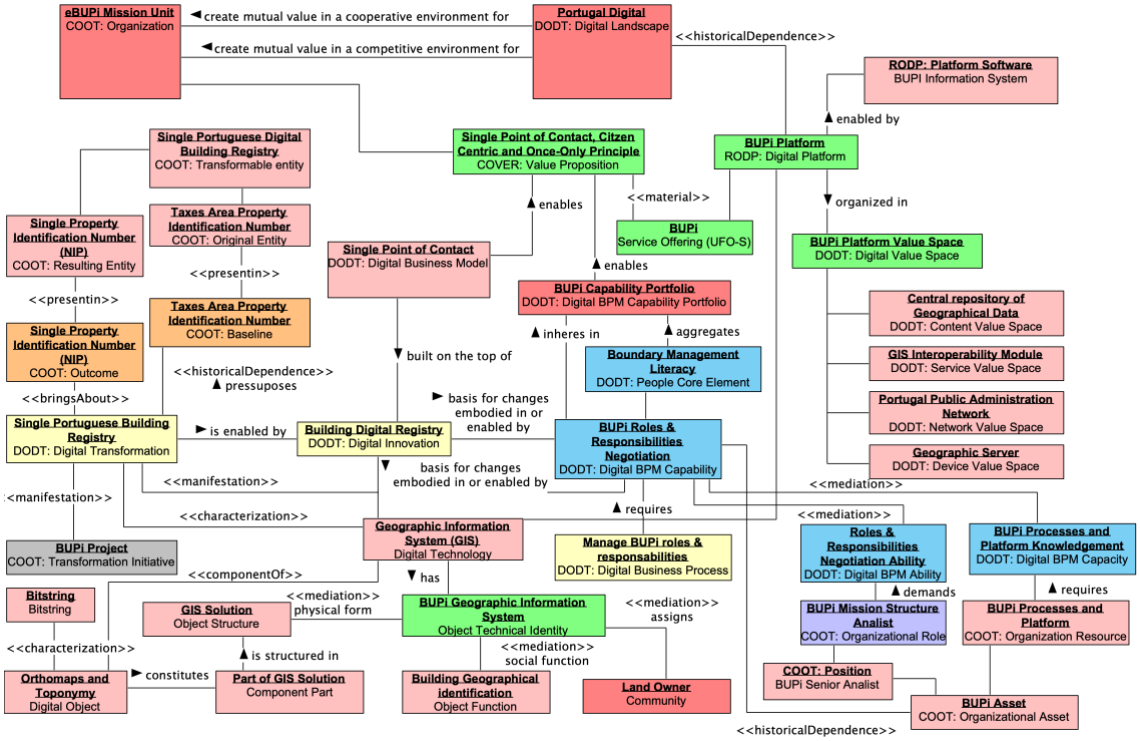

Figure 6.6. The BUPi digital transformation.

CQ1. What differentiates digital transformation from organizational transformation?

A digital transformation event is a type of organizational transformation event, as presented in COOT. A digital transformation is enabled by a digital innovation and characterized by digital technology. Furthermore, digital innovation is the basis for changes in or enabled by digital technology, that has digital object as a component, which in turn is characterized by at least one bitstring component.

In the BUPi case (see Figure 6.7), the *Single Portuguese Building Registry* (DIGITAL TRANSFORMATION) is enabled by *building digital registry* (DIGITAL INNOVATION) and characterized by for example *geographic information system (GIS)* (DIGITAL TECHNOLOGY). Furthermore, *building digital registry* (DIGITAL INNOVATION) is the basis for changes in, or enabled by, *geographic information system (GIS)* (DIGITAL TECHNOLOGY), that has *orthomaps and toponymy* (DIGITAL OBJECT) as its components, which in turn are characterized by at least one *bitstring* (BITSTRING) component.

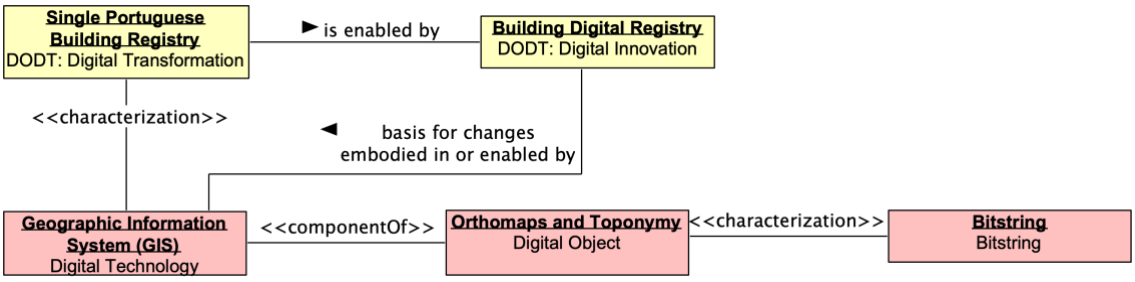

Figure 6.7.The role of digital BPM capability in digital transformation (BUPi example).

CQ2. What are the assets needed to perform a digital transformation?

Digital innovations are both the basis for, and the outcome of DIGITAL TRANSFORMATION. They are the results of changes embodied in or enabled by DIGITAL TECHNOLOGIES and DIGITAL BPM capabilities; the assets needed to perform do a digital transformation.

In the BUPi case (see Figure 6.8), the *Single Portuguese Building Registry* (DIGITAL TRANSFORMATION) is enabled by *building digital registry* (DIGITAL INNOVATION) and characterized by for example *geographic information system (GIS)* (DIGITAL TECHNOLOGY), BASIS FOR CHANGES EMBODIED IN OR ENABLED BY *BUPi roles & responsibilities negotiation* (DIGITAL BPM CAPABILITY) and *geographic information system (GIS)* (DIGITAL TECHNOLOGY). Furthermore, *BUPi roles & responsibilities negotiation* (DIGITAL BPM CAPABILITY) inheres in *BUPi capability portfolio* (DIGITAL BPM CAPABILITY PORTFOLIO) and *geographic information system (GIS)* (DIGITAL TECHNOLOGY) participates in the *BUPi platform* (DIGITAL PLATFORM). Both, the *BUPi capability portfolio* (DIGITAL BPM CAPABILITY PORTFOLIO) and the *BUPi platform* (DIGITAL PLATFORM) together enables a *single point of contact, citizen centric and once-only principle* (COVER: VALUE PROPOSITION).

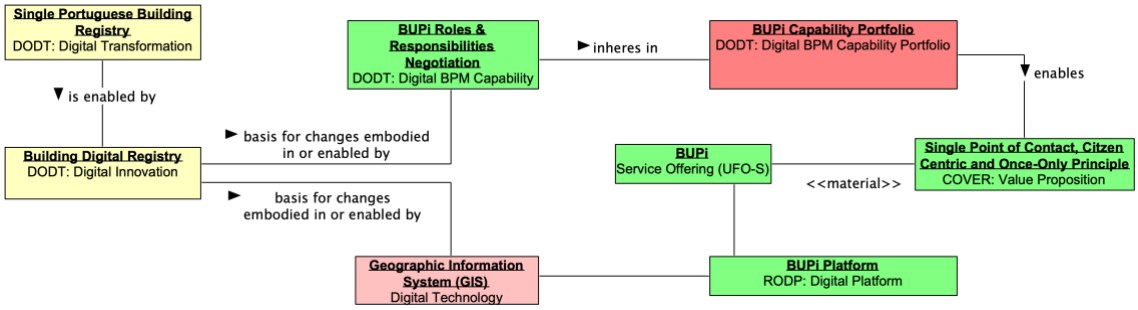

Figure 6.8.Assets needed for Digital Transformation (BUPi example).

CQ3. What are the transformable entities originate in and result from of a digital transformation?

The outcome of a digital innovation can be a DIGITAL BUSINESS PRODUCT (goods or services), DIGITAL BUSINESS PROCESS, or DIGITAL BUSINESS MODEL that are perceived as new, require some significant changes from the perspective of a particular community or market, that are either embodied in or enabled by the digital environment.

One of these outcomes is DIGITAL PLATFORMS that capture, transmit and monetize data, including personal data, over the internet and other networks. They may not be composed by purely DIGITAL TECHNOLOGIES, although most successful digital platforms take advantage of the digital innovations and power of pervasive internet connectivity in the hands of billions of users (Yablonsky, 2018). Another outcome is the DIGITAL BPM CAPABILITY PORTFOLIO that participates together with DIGITAL PLATFORM in VALUE PROPOSITION, to create the event PROSPECT EVALUATION through PROSPECT ASSESSMENT in COOT.

As presented in COOT, organizational transformation promotes changes in transformable entities. A transformable entity is anything that can be the subject of change in an organizational transformation. Since digital transformation is a type of organizational transformation, it inheres

the properties of organizational transformation. A transformable entity within the scope of a digital innovation.

As an ORGANIZATIONAL TRANSFORMATION, a DIGITAL TRANSFORMATION presupposes a (pre-)situation as a BASELINE (which TRANSFORMABLE ENTITIES might be present, whether it can have digital technology involved) and brings about a (post-)situation that is termed in this domain an OUTCOME (in which one or more TRANSFORMABLE ENTITIES are certainly present). In the case of digital transformation, at least one outcome involves digital technology. TRANSFORMABLE ENTITIES that are the input to be transformed by this process are termed ORIGINAL ENTITIES. Those that are the transformed output are termed RESULTING ENTITIES.

In the case of BUPi (see Figure 6.9 and Figure 6.10), an outcome is a new *single point of contact* (DIGITAL BUSINESS MODEL), a type of *single Portuguese digital building registry* (TRANSFORMABLE ENTITY) built on top of the *building digital registry* (DIGITAL INNOVATION). The *single property identification number (NIP)* (RESULTING ENTITY) is also a type of *single Portuguese digital building registry* (TRANSFORMABLE ENTITY), presenting in *single property identification number (NIP)* (OUTCOME) brings about *single Portuguese building registry* (DIGITAL TRANSFORMATION) enabled by *building digital registry* (DIGITAL INNOVATION).

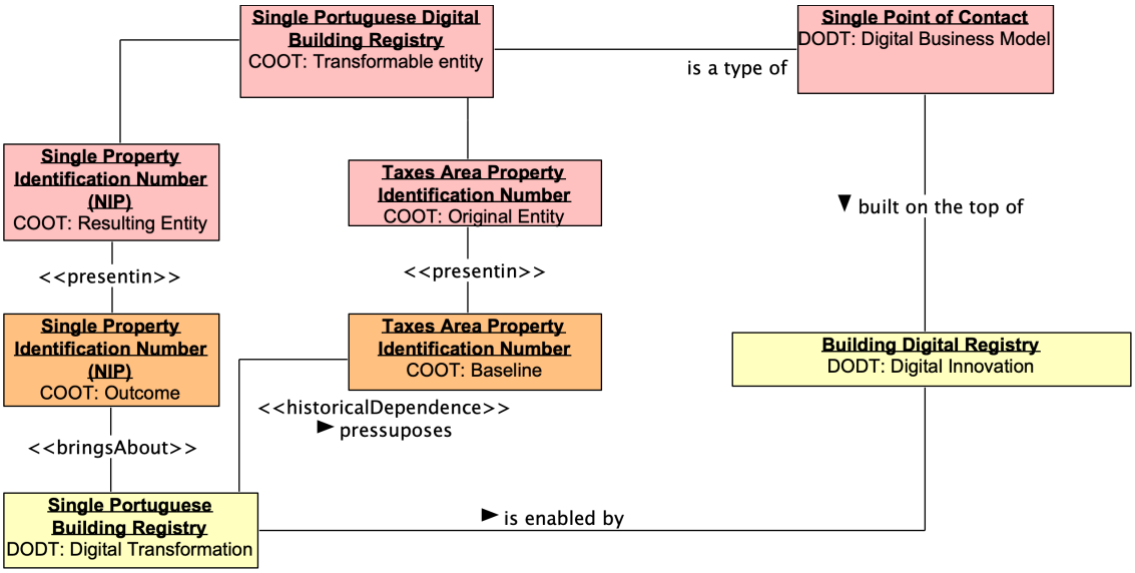

Figure 6.9. Digital transformation outcome (BUPi example).

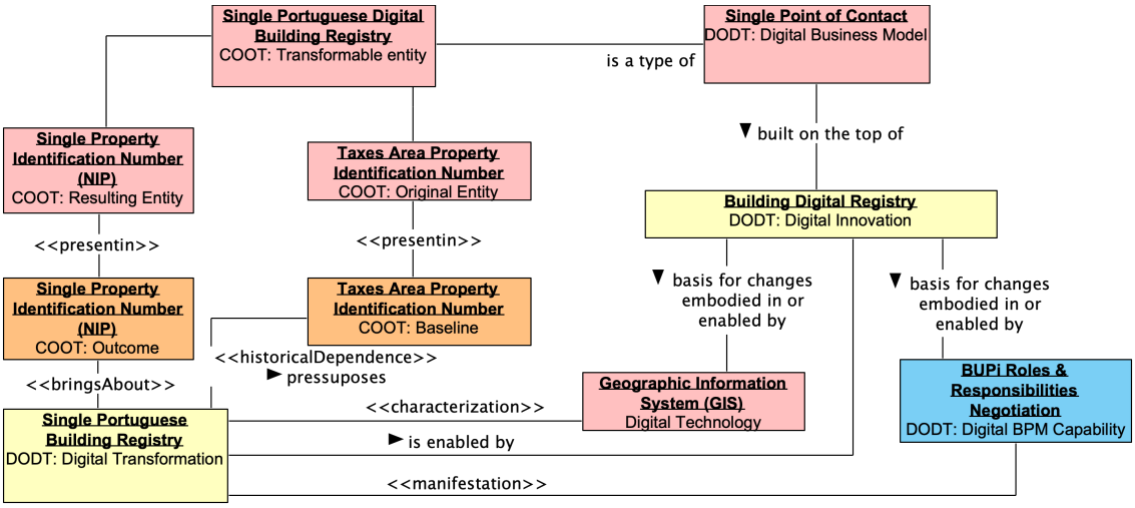

Figure 6.10. What can be transformed in a digital transformation (BUPi example).

CQ4. What is digital technology and its role in digital transformation?

Digital innovation is the for changes embodied in or enabled by digital technology. Digital technology has a technical identity of a digital object, with its type of use assigned by a community, mediated by its social functions and physical form.

In BUPi (see Figure 6.11), one example of the *building digital registry* (DIGITAL INNOVATION), basis for changes embodied in, or enabled by, the *Geographical Information System (GIS)* (DIGITAL TECHNOLOGY). GIS has a *BUPi GIS* (TECHNICAL IDENTITY OF A DIGITAL OBJECT) with its type of use assigned by the *BUPi community* (COMMUNITY), mediated by its *building geographic identification* (SOCIAL FUNCTION) and GIS solution (PHYSICAL FORM).

Digital objects are a type of TECHNOLOGICAL OBJECT that constitutes COMPONENT PARTS, including BITSTRING and is structured in an OBJECT STRUCTURE. Bitstrings, a nonmaterial object, can be beared by a material object or remain as a nonmaterial bearer.

In BUPi, *orthomaps and toponymy* (DIGITAL OBJECT) constitutes *Parts of GIS Solution* (COMPONENT PART) that is characterized by *bitstring* (BITSTRING) and which in turn is structured in a *GIS solution* (OBJECT STRUCTURE).

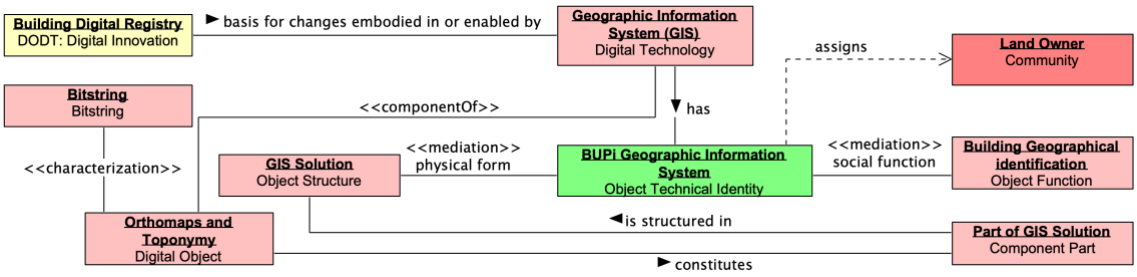

Figure 6.11. What is a digital technology (BUPi example).

Moreover, DIGITAL TECHNOLOGY participates in a DIGITAL PLATFORM, usually created for a network of the relationships between the economic entities – producers, stakeholders, distributors, consumers, government agencies, and others roles – that facilitate the creation and distribution of a product or service through competition and cooperation (Yablonsky, 2018). The concepts of DIGITAL PLATFORM (Derave *et al.*, 2020) and VALUE SPACE (Henfridsson *et al.*, 2018) was reused and integrated into the DODT proposal.

The VALUE SPACE, according to Henfridsson *et al.* (2018), has the ability to connect, is an evolving network of digital resources interlinked through connections established (and dissolved) by a platform management, seeking to generate appropriate value. In a digital transformation, a consolidated value space is created by combining and connecting specific value spaces' digital technology layered architecture elements (content, service, network, and device) within an evolving network. This integrated structure generates value by leveraging the capabilities of these interconnected components.

Using the BUPi case as an example (see Figure 6.12): The outcome of digital transformation is implemented in a *BUPi Platform* (DIGITAL PLATFORM) representing a *BUPi Platform Value Space* (VALUE SPACE) which is composed of *geographic information system (GIS)* (TECHNOLOGIES AND DIGITAL TECHNOLOGIES), besides other digital and non-digital technologies. A value space comprises the layers of CONTENT (for instance, *central repository of geographical data*), SERVICE (for instance, *GIS interoperability module*), DEVICE (for instance, *geographic server*), and NETWORK (for instance, *Portugal public administration network*). A digital platform is a type of DIGITAL LANDSCAPE (*Portugal Digital*) that generates mutual value for an ORGANIZATION in cooperative and competitive environments. In the digital landscape a digital technology is a primary element, interconnecting APPLICATIONS SOFTWARE (such as the *BUPi Information System*) and being interconnected by ECOSYSTEMS (such as the *Simplified Building Digital Registry Ecosystem*).

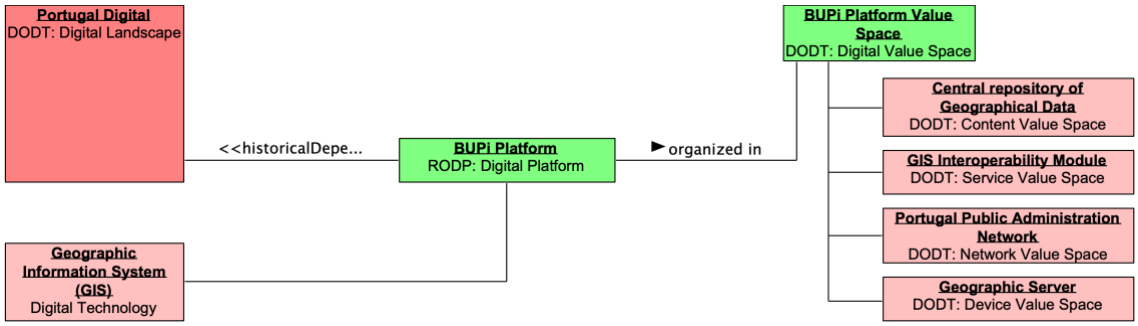

Figure 6.12. A digital platform of a digital transformation (BUPi example).

CQ5. What is the role of digital BPM capability in digital transformation?

BPM has been structured by means of BPM capability frameworks, apart from lifecycle models (Kerpedzhiev et al., 2020). The BPM discipline has the background to understand and support the role of business processes, ensuring consistent outcomes and taking advantage of improvement opportunities, considering besides business processes, the people involved, the

information being exchanged and processed, and the digital technologies used to carry out the different activities. The *Building digital registry* (DIGITAL INNOVATION) is the basis for changes embodied in or enabled by DIGITAL TECHNOLOGY like GIS in BUPi and DIGITAL BPM CAPABILITY like *BUPI roles & responsibilities negotiation*.

Capability is the convergence of capacity and ability – for example, BUPi *roles and responsibilities negotiation* (DIGITAL BPM CAPABILITY) mediates *BUPI processes and platform knowledge* (DIGITAL BPM CAPACITY) which in turn is required by the *BUPi Processes and Platform* (ORGANIZATION RESOURCE), a type of *BUPi asset* (ORGANIZATIONAL ASSET). Besides it mediates *roles and responsibilities negotiation ability* (DIGITAL BPM ABILITY) which in turn is demanded by *BUPi Mission structure analyst* (ORGANIZATIONAL ROLE), also a type of *BUPi asset* (ORGANIZATIONAL ASSET).

BUPi roles and responsibilities negotiation (DIGITAL BPM CAPABILITY) inheres in the BPM capability portfolio (DIGITAL BPM CAPABILITY PORTFOLIO), that enables the single point of contact, citizen centric and once-only principle (VALUE PROPOSITION) (see Figure 6.13).

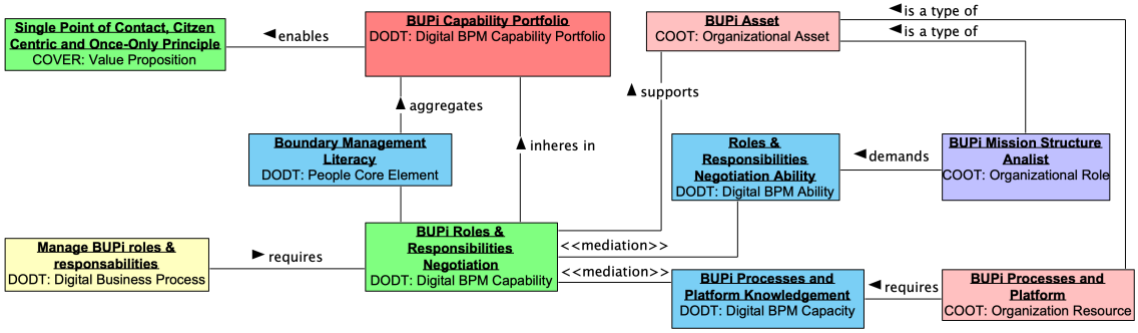

Figure 6.13. The role of digital BPM capability in digital transformation (BUPi example).

6.3 Discussion

COOT's goal is to represent what an ORGANIZATIONAL TRANSFORMATION is, the characteristics of the planned transformation event and its outcomes to provide the proper ground for understanding a particular type of transformation – the digital transformation. DODT's purpose is to share a common understanding of DIGITAL TRANSFORMATION as a type of organizational transformation. COOT and DODT comprise DTO.

Four research questions were set concerning DTO to achieve this goal, as presented in Table 6-11. DTO RQs encompass DODT CQs, which focus is digital transformation, and COOT CQs, which focus is organizational transformation. In the discussion section, each RQ will relate to the corresponding CQs, showing how the CQs are functionally responding to the RQs. A sub-section was structured for each RQ, highlighting the COOT CQs and the DODT CQs related to them.

Table 6-11. DTO Research questions.

DTO Research Questions
RQ1. What is digital transformation?
RQ2. What can be transformed in a digital transformation?
RQ3. What are the characteristics of a digital transformation?
RQ4. What are the outcomes of a digital transformation?

The competency questions of COOT and DODT are presented in Table 6-12.

Table 6-12. Competency questions.

Competency Questions	
COOT	**DODT**
CQ1. Which organization is to be transformed?	CQ1. What differentiates digital transformation from organizational transformation?
CQ2. How to characterize organizational transformation?	CQ2. What are the assets needed to perform a digital transformation?
CQ3. What motivates an organizational transformation initiative?	CQ3. What are the transformable entities originate in and result from a digital transformation?
CQ4. How does an organizational transformation initiative emerge?	CQ4. What is digital technology and its role in digital transformation?
CQ5. Who are the agents involved in an organizational transformation?	CQ5. What is digital BPM capability and its role in digital transformation?
CQ6. What are the roles of the agents involved in an organizational transformation initiative?	
CQ8. What factors enable organizational transformation?	
CQ9. What transformable entities originate in and result from organizational transformation?	
CQ10. What are the phases in an organizational transformation?	

RQ1. What is digital transformation?

COOT competency questions related with RQ1
CQ1. Which organization is to be transformed?
CQ3. What motivates an organizational transformation initiative?
CQ5. Who are the agents involved in an organizational transformation?
CQ6. What are the roles of the agents involved in an organizational transformation initiative?
CQ7. What organizational values are associated with organizational transformation?
CQ8. What factors enable organizational transformation?

Concerning COOT Research Question 1 (i.e., "What is an organizational transformation?"), in our instantiated case, InterRent® is an organization operated by a group of people (staff and managers) that are organized into a commercial structure. This group has a common goal to obtain profit by offering a car rental service, thus sharing the same business objectives and purposes. InterRent® has branches in more than 30 countries. This complex organization, constituted by other organizations, including organizational units, was represented by means of COOT classes and relationships. InterRent® has internal roles (in COOT, these are POSITIONS in InterRent® and TRANSFORMATION INITIATIVE PARTICIPANT ALLOCATION in the Key'n Go® project) instantiated by its staff (ORGANIZATION MEMBERS in COOT) at runtime. The composition of connected roles and their players encapsulated as role composites (POSITION ASSIGNMENTS in COOT) executes a goal-oriented function. This explicit allocation of participants in the TRANSFORMATION INITIATIVE can be essential for creating a team's sense of responsibility for the project's success, considering its common business objectives and purposes.

Given an organization's dependence on continual interaction with the environment in which it resides, any organization is an open system (Burke, 2017) that promotes and enforces a set of restrictive guidelines, rules, incentives, and sanctions (Frank, 2011b). InterRent® depends on and continually interacts with the car rental market environment. One example is InterRent®.'s motivation towards the Key'n Go® project strategy. The ORGANIZATIONAL BELIEF ("perceived value needs to be improved") drives the business intention ("offering a new rental service focused on the mid-tier segment as an eligible market segment"), and makes the organization allocate participants (TRANSFORMATION INITIATIVE PARTICIPANT ALLOCATION), committing to a (new) BUSINESS STRATEGY ("process simplification and acceleration from a customer perspective"), culminating with the elaboration of a transformation plan.

The Key'n Go® project has a structure replicating the main InterRent®. organizational units and their relations. In COOT, an organizational structure includes roles associated with positions. The positions are described in terms of tasks, responsibilities and required skills. Our case also confirmed the relationships among those concepts because, during the Key'n Go® project, InterRent®. was involved simultaneously in a multi-organizational structure. During the project, InterRent®. continued operating as usual. While part of the staff was working on the Key'n Go®

project, other parts of the same organization were operating on the current *modus operandi* of a low-cost segment with their partners and suppliers. In this case, a new rental service is launched, while the other services remain unchanged.

DODT competency questions related with RQ1
CQ1. What differentiates digital transformation from organizational transformation?

Concerning DODT Research Question 1 (i.e., " What is digital transformation?"), in our instantiated case, BUPi *Single Portuguese Building Registry* (DIGITAL TRANSFORMATION) is enabled by BUPi *building digital registry* (DIGITAL INNOVATION) and characterized by DIGITAL TECHNOLOGY, in our instantiation *geographic information system (GIS)* (DIGITAL TECHNOLOGY), that has as component *orthomaps and toponymy* (DIGITAL OBJECT), which in turn is characterized by at least one *bitstring* (BITSTRING) component.

6.3.1 RQ2. What can be transformed in a digital transformation?

COOT competency question related with RQ2
CQ9. What transformable entities originate in and result from organizational transformation?

Concerning Research Question 2 (i.e., "What can be transformed in a digital transformation?", or yet, "What are the potential subjects (of change) in ORGANIZATIONAL TRANSFORMATION?"), as has seen before, ORGANIZATIONAL TRANSFORMATION promotes changes in TRANSFORMABLE ENTITIES. A TRANSFORMABLE ENTITY is anything that can be the subject of change in an ORGANIZATIONAL TRANSFORMATION. The customer journey process was one of the main examples of a subject of change for InterRent®. It includes entities such as the business model, the business process, and (the manner of) the service offering.

The constructs discussed here allow us to state that, as with all events, ORGANIZATIONAL TRANSFORMATIONS map the world from (Pre)Situations to (Post)Situations (UFO-B). A BUSINESS INTENTION manifestation that becomes a TRANSFORMATION INITIATIVE results in an ORGANIZATIONAL TRANSFORMATION. There are entities to be transformed in such transformations, called TRANSFORMABLE ENTITIES. TRANSFORMABLE ENTITIES are capable of qualitative change while preserving their identity. The ORGANIZATIONAL TRANSFORMATION event changes the TRANSFORMABLE ENTITIES, i.e., the entities that are impacted by the transformation and being transformed from the original entity (present in the BASELINE situation) to the resulting entity (present in the OUTCOME situation).

For instance, in the case of the Business Model baseline (AS-IS Situation), the customer added extra things (such as insurance) in the rental, i.e., the ORIGINAL ENTITIES included the car rental and accessories. However, in the case of the Business Model outcome (TO-BE Situation), the RESULTING ENTITY, a package is predetermined. Another example: in the business process baseline (AS-IS Situation), the process considering that the car is delivered manually at the store

by ORIGINAL ENTITIES. However, in the business process outcome (TO-BE Situation), RESULTING ENTITY, the car key is delivered automatically through a machine, bypassing the lines in the store.

The COOT CQ9 answer alone the DODT research question 2 related to the transformable entities ("What transformable entities originate in and result from a digital transformation?").

6.3.2 RQ3. What are the characteristics of a digital transformation?

COOT competency questions related with RQ3
CQ2. How to characterize organizational transformation?
CQ4. How does an organizational transformation initiative emerge?
CQ10. What are the phases in an organizational transformation?

Concerning Research Question 3 (i.e., "What are the characteristics of a planned ORGANIZATIONAL TRANSFORMATION?"), a DRIVER or motivation is a recurrent concept explored by many authors as an internal or external cause of organizational change (Zivkovic, Puvsara and Zivkovic, 2011). Drivers may include economic, social and environmental factors, as well as mergers and acquisitions (Joseph and George, 2007), constraint satisfaction, high technological needs and market uncertainty (Bock, Warglien and George, 2020), economy and value deficiencies (Rouse and Baba, 2006), discovery-driven decision-making (Purchase *et al.*, 2011), global market trends (Savič, Ograjenšek and Rejc Buhovac, 2016), critical competitive factors, internal economy (Bahner and Stroh, 2004), competitors, constraints, critical success factors, opportunities, threats and risks (Harris, 2018).

An ORGANIZATIONAL BELIEF involves assumptions (Harris, 2018) and behavioral systems (von Rosing and von Scheel, 2016), for example, competition by innovation (Linz, Müller-Stewens and Zimmermann, 2017). It also involves internal and external factors that motivate organizational transformation, which was explored by (Zivkovic, Puvsara and Zivkovic, 2011), as well as requiring a readiness for organizational change regarding the proposed implementation processes, as described by (Reza, Jalali and Moazeni, 2018). After undergoing an assessment, InterRent® established the belief that the front-end process required a rethinking to improve the Value perceived by both customers and shareholders. As a result, they carried out a Transformation Initiative, namely the Key'n Go® project. The planned ORGANIZATIONAL TRANSFORMATION process by InterRent® was characterized by its drivers and the need to differentiate between customers and competition.

Its DRIVERS (kind of organizational beliefs) inhere in internal (stakeholders) and external (customers) organizational change motivations. They include economic factors (higher profitability), global market trends (digital business), and critical competitive factors (a significant number of satisfied customers). The stakeholders were motivated to commit to a business intention (offer a new rental service) with a business goal of higher profitability. A significant number of unsatisfied customers demanded a paradigm change, leading to a Transformation

Initiative: The Key'n Go® project. Modelling helped to understand the drivers, as mentioned in the literature, and the process that leads to the transformation from the motivation factors (drivers) to the transformation results (OUTCOME).

ORGANIZATIONAL TRANSFORMATION is a type of organizational change, either disruptive, strategic or radical. An Organizational transformation is an event that creates a new vision for the organization, promoting a paradigmatic change to support the organization to fit its environment better or create desirable future environments (Porras and Silvers, 1991).

DODT competency questions related with RQ3
CQ2. What are the assets needed to perform a digital transformation?
CQ4. What is digital technology and its role in digital transformation?
CQ5. What is digital BPM capability and its role in digital transformation?

Concerning DODT Competency Question 2 (i.e., "What are the assets needed to perform a digital transformation?"), in BUPi case, as can be observed the main assets needed to do the *Single Portuguese Building Registry* (DIGITAL TRANSFORMATION) are digital BPM capabilities like *BUPi roles & responsabilities negotiation* (DIGITAL BPM CAPABILITY), that compose the *BUPi capability portfolio* (DIGITAL BPM CAPABILITY PORTFOLIO) and digital technologies, like *geographic information system (GIS)* (DIGITAL TECHNOLOGY) that compose the *BUPi platform* (DIGITAL PLATFORM).

Relating to DODT Competency Question 4 (i.e., "What is digital technology and its role in digital transformation?"), many DIGITAL TECHNOLOGIES participate in BUPi's digital platform (DIGITAL PLATFORM), which was developed considering the data and relationships network to facilitate achieve the Single Portuguese Building Registry (DIGITAL TRANSFORMATION) service through the collaboration of BUPi's stakeholders. DIGITAL TECHNOLOGIES as *GIS* enables BUPi *building digital registry* (DIGITAL INNOVATION). *BUPI GIS* - its TECHNICAL IDENTITY OF A DIGITAL OBJECT - is identified by its type of use assigned by the *BUPI community* (COMMUNITY), mediated by its *building geographic identification* (SOCIAL FUNCTION) and *GIS solution* (PHYSICAL FORM). In BUPi, *orthomaps and toponymy* (DIGITAL OBJECT) constitutes *Parts of GIS Solution* (COMPONENT PART) that is characterized by *bitstring* (BITSTRING) and which in turn is structured in a *GIS solution structure* (OBJECT STRUCTURE).

Regarding DODT Competency Question 5 (i.e., "What is digital BPM capability and its role in digital transformation?"), capability is the convergence of capacity and ability – for example, BUPi *roles and responsibilities negotiation* (DIGITAL BPM CAPABILITY) mediates *BUPI processes and platform knowledge* (DIGITAL BPM CAPACITY) which in turn is required by *BUPi Processes and Platform* (ORGANIZATION RESOURCE), a type of *BUPi asset* (ORGANIZATIONAL ASSET). Besides it mediates *roles and responsibilities negotiation ability* (DIGITAL BPM ABILITY) which in turn is demanded by *BUPi Mission structure analyst* (ORGANIZATIONAL ROLE), also a type of *BUPi asset* (ORGANIZATIONAL ASSET).

6.3.3 RQ4. What are the outcomes of a digital transformation?

COOT competency question related with RQ4
CQ9. What transformable entities originate in and result from organizational transformation?

The purpose of this transformation event could be either to mitigate risks or to seize opportunities for the business. Concerning Research Question 4 (i.e., "What are the OUTCOMES of an organizational transformation?"), a TRANSFORMABLE ENTITY represents the object of transformation. In an initial situation, some organizational elements of a transformable entity may or may not exist. When they exist, they could be presented in a different form, be related to other organizational elements, or have another purpose.

A planned organizational transformation event starts with drivers of change (a type of organizational belief) formation as an organizational response to PROSPECT ASSESSMENT. After this understanding, the organization establishes a commitment named Business Intention. Next, the organization moves on to a phase of structuring a transformation initiative as a manifestation of the ORGANIZATIONAL TRANSFORMATION, resulting in the transformation OUTCOME.

An appointment is a type of commitment whose goal is clearly tied to a certain amount of time. For example, a medical appointment (a type of appointment and also transformable entity) is a transformable entity (<<category>>) in a hospital ORGANIZATIONAL TRANSFORMATION implementation. Before the transformation, the medical appointment could only be done in-person. Now, it has two possible types: online and in-person. A resource participates in a type of TRANSFORMATION PARTICIPATION, an event that composes an ORGANIZATIONAL TRANSFORMATION event. For the in-person medical appointment type, the computer is used as an IT-enabled technology resource to register the patient, store his/her data, or to generate medical documents). For the online medical appointment type, the computer is used as a digital technology resource, the virtual environment that enables the occurrence of the medical appointment.

In the InterRent® case, the TRANSFORMABLE ENTITY is the car rental service, i.e., the customer journey process. The OUTCOME (the new customer journey process) is composed of new organizational elements (the software application for the process of returning cars) integrated with organizational elements that already exist in the organization, such as the cars for rental. After the transformation, the old process for returning cars could be discontinued (if not currently used by other InterRent® services), or InterRent® could later evaluate the incorporation of the new organizational element (i.e., the software application) into its current process by reusing it for the other services (possibly with adaptations), resulting in a more automated process for returning cars. The software application was developed for the Key'n Go® process for returning cars as part of the organizational transformation outcome presented in detail in (Bogea Gomes *et al.*, 2020). This entity, now transformed, was designed on the basis of a PROSPECT ASSESSMENT, which also served as a strategy formulation and benchmarking approach (Joseph and George, 2007), by collecting interpretations about the firm's key elements as suggested by (Bock, Warglien and

George, 2020). To summarize, an outcome is the business intention's expected result from an ORGANIZATIONAL TRANSFORMATION event.

A Transformation Initiative is "how to conduct a change" (Joseph and George, 2007). Organizational transformation is also referred to as business transformation (Lee and Ivan, 2006; Maguire, Mendibil and Bititci, 2008; Flower *et al.*, 2011; Trad and Kalpić, 2017), a roadmap (Joseph and George, 2007), and even a paradigmatic change (Sheldon, 1980). COOT captured those concepts from the literature and precisely describes what an organizational transformation is, how a planned organizational transformation event is characterized and what the outcomes from an organizational transformation are. COOT was able to cover the situations before and after the Key'n Go® project and its effects, to provide a clearer picture of the project by making the transformable entities explicit, along with the related desires, goals and needs of the value-ascribing stakeholders.

DODT competency question related with RQ4
CQ3. What are the transformable entities originate in and result from of a digital transformation?

Regarding the digital transformation outcomes (CQ3), in BUPi the outcome of digital transformation is implemented in a new *BUPi Business Model* (DIGITAL BUSINESS MODEL) representing the *BUPi Platform Value Space* (VALUE SPACE) and the *BUPi digital BPM capability portfolio* (DIGITAL BPM CAPABILITY PORTFOLIO) that participate together to create *the single point of contact, citizen centric and once-only principle* (VALUE PROPOSITION).

6.4 Limitations

The evaluation was based on only one case for each DTO's sub-ontology which could have led to a lack of relevant issues or to a bias. COOT was instantiated in the real-case scenario Key'n Go, and DODT in the real-case scenario BUPi. Both cases were in progress by the time of the application in the thesis, thus part of motivation was analyzed in a historical mode. Moreover, COOT and DODT were applied to model the scenario characteristics based on primary (collected in the interviews) and secondary (collected in the documentation) information.

The low number of participants in each case study could also be a problem because not all necessary and different perceptions could be gathered. However, it is argued that digital transformation initiatives can vary significantly in terms of participant involvement. While some organizations may have few participants, others may have a broader range of stakeholders engaged in the process. The level of participation often depends on factors such as the organization's size, structure, industry, and the scope of the digital transformation effort. In both these two cases, it was observed that the transformation initiatives were considered strategic, led by a lean core team with appropriate competencies, including stakeholder engagement.

Eventually, the initiatives that involved more participants were in specific activities. So, it cannot be considered a limitation.

An important aspect regarding the evaluation is the ontology concepts coverage. Regarding this, there some observations:

(i) in BUPi, there was no prospect assessment before stating the transformation initiative, probably because the mission structure was designed with that objective from the beginning. On the other hand, in InterRent, a Customer Focus Group was held, indicating that gathering customer input and feedback was necessary before starting the transformation initiative.
(ii) In the BUPi instance, it was not identified the Business Strategy class instance. However, according to COOT, as value propositions are aligned with business strategies, the value propositions identified in the case ("single point of contact, citizen-centric, and once only principle") are aligned with the organization's business strategies. Additionally, the business model ("single Portuguese digital building registry") reflected the organization's realized strategy.
(iii) Neither case identified an instance of the Organization Body of Norm's class, but the interviewees mentioned evidence suggesting that the organizations have their constitution or norms.
(iv) In the case of the digital transformation initiative, the People Core Element was identified, explicitly focusing on Boundary management literacy. However, exploring other core elements of the digital BPM capability was still needed. It can suggest that further investigation or analysis is required to better understand the digital BPM capability in this context.
(v) Finally, the evaluated cases did not bring counterexamples of DTO concepts and relationships.

Other cases from different organizations would validate the theoretical approach investigated in this thesis. Future works will include refining the ontology through the application of more real-world cases to better guide the development of digital transformation initiatives based on experience while reducing their risk of failure. Nevertheless, it was possible to validate whether the artifact (DTO) answered the research questions adequately.

6.5 Theoretical and Practical Implications

The purpose of this thesis was to develop and evaluate the Digital Transformation Ontology to solve the identified research problem of designing and implementing digital transformation concepts within organizations.

Considering the research questions, the emphasis is on organizational characteristics, motivation for transformation events, as well as digital BPM capabilities and digital technologies for digital transformation events, which support the digital transformation journey in organizations. This thesis investigates the relationships between organizational beliefs, business intention, business

strategy, organizational assets, and organizational roles. DTO aims to enable organizations to leverage and evaluate digital transformation possibilities for identifying critical resources that, when reused and recombined, result in a successful digital transformation within the realm of organizational transformation, digital BPM capabilities, and digital technologies concepts (not necessarily the current ones).

DTO provides an actionable and descriptive orientation for practitioners to outline the digital transformation event for organizations. It can primarily assist them in identifying a successful digital transformation goal, modeling the organizational characteristics and motivational aspects required to achieve the digital transformation goal, and being aware of the required technological resources and organizational capabilities to serve business strategy.

During the planning and execution of a digital transformation initiative, the DTO can serve as a template to reach a shared understanding with key stakeholders such as owners, process owners, technology specialists, government agencies, and others in their roles to set goals and strategy by drawing on multiple stakeholders with diverse backgrounds from various agencies. To support the development of a digital transformation strategy, practitioners must first identify the fundamental organizational beliefs and business intentions.

Chapter 7

Conclusion

This chapter concludes the thesis by highlighting its main contributions, limitations, and future perspectives of this research.

Physical reality is being created and shaped by digital technologies. Frequently, the digital version comes first, and then the physical version (if necessary). The economy and society have been rapidly digitalized, introducing new habits, novel ways of living together, new cultures, new shapes for traditional businesses, and new types of businesses regularly. The traditional understanding of an information system as representing and reflecting physical reality is becoming obsolete. Even though digital transformation has gained great research interest, the need for a common understanding of this concept is evident.

This thesis developed and evaluated the Digital Transformation Ontology (DTO) following a two-cycled DSR methodological approach. They have been applied in real-world case studies: COOT on a car rental company and DODT on a Portuguese government digital transformation project. The case studies´ results showed that the proposed ontology was able to represent most of the important concepts of a digital transformation initiative, making it a viable alternative for supporting initiatives of this type.

7.1 Contributions

This thesis' main contribution is to investigate the subject of organizational transformation and digital transformation providing an unambiguous and explicit conceptual foundation for these domains, with the objective to clarify the notion of organizational transformation, as well as a special type of organizational transformation, a digital organizational transformation, and their related concepts. It is based on an extensive literature review and research papers that captured the domain of interest through a collection of classes organized into a conceptual model to achieve the successful digital transformation initiative, and, furthermore, to show how the DTO could be taken as a basis to the analysis of a digital organizational transformation case. The formalism of UFO and OntoUML language provide greater precision when defining domain-independent concepts and provides a solid theoretical basis to underpin the construction of specific vocabularies for each domain.

The organizational transformation concepts were detailed, and a model was elaborated, establishing the understanding of business, organization, agents, roles, business value proposition, organization offering, transformable object and transformation initiative, as well as the dynamics of organizational transformation. The main concepts related to the type of an organizational transformation - the digital transformation - are digital technology, and digital BPM capabilities, ontologically analyzed, besides the digital technology and digital BPM capability's role in digital transformations.

DTO provides a domain-independent conceptual specification to guide digital transformation initiatives based on a solid theoretical foundation and a clear understanding of digital organizational transformation and its related concepts. This thesis' three-tiered research methodology uses the inquiry strategy of design science methods as the first level to answer these thesis research questions. The SABiO methodology was adopted in the second level to

develop the artifact. The third level describes the research methods necessary to fulfill the methodological strategy components' requirements. Two sub-ontologies— the Core Ontology of Organizational Transformation (COOT) to represent organizational transformation and the Domain Ontology of Digital Transformation (DODT) to represent a specific type of digital organizational transformation— comprise DTO to create a reference model representing the digital transformation paradigm.

During DTO design and development, qualitative analysis of literature and interview data according to the case study approach were applied in real-world case studies: COOT on a car rental company and DODT on a Portuguese government digital transformation project. The results obtained clarify what is a digital transformation, what can be transformed in it, what are their characteristics and what are their outcomes, contribute with helpful insights to the digital transformation and organizational transformation fields, aiming at better characterizing and analyzing these fields.

7.2 Limitations

However, this thesis is not free of limitations, which in turn allow various future research opportunities, mainly related to more reflection and discussion.

- First, the digital transformation research topic has a broader domain than the one analyzed in this research since it is transversal and specialized in other research topics. The DTO is general and should cover only some aspects needed for all digital transformation.
- This research did not consider other factors that influence a digital transformation initiative (just two samples, among others: culture and supply chain digital boundaries strategy).
- Regarding this proposed artifact, DTO, it can be pointed out the following limitations (some of these limitations are exclusively related to the artifact developed, while the others could have broader implications):
    - Even though several "build-evaluate" DSR cycles were during the iterative design process to develop the proposed artifacts, only two development cycles were made effective.
    - Some conclusions are theoretical and need testing in more real-world scenarios. In that way, in this research, it is assumed that an organization minimally has already been aware of digital strategy.
    - The lack of knowledge regarding the Ontologies and OntoUML language is an apparent limitation of the presented proposal. Ontologies and OntoUML language could make communication with those unfamiliar with them more difficult.
    - The competency questions proposed are based on the author's interpretation, so they may not be consensual.

7.3 Future Work

Future work includes:

(i) refining DTO using other real cases' application scenarios; conducting further evaluations in different application scenarios to increase the maturity and quality of DTO and to ensure that it has the potential to support organizations consistently.

(ii) developing a method of using DTO to support an organization that intending to start a digital transformation journey.

(iii) exploring in detail the concepts and relationships generating a Digital BPM Capability ontology. The capability defines the resources necessary to execute a digital strategy and, consequently, enables the implementation of a digital transformation value proposition proposed.

In addition, the conceptual reference ontology proposed here will be further codified with the support of gUFO - a lightweight implementation of UFO in OWL 2 DL (Almeida *et al.*, 2019). The resulting artifact could then be used to support automated reasoning in semantic web organizational transformation initiatives.

Finally, in the spirit of works such as (Nardi *et al.*, 2013) for the domain of services, (Azevedo *et al.*, 2015) for capabilities, (Amaral *et al.*, 2020) for trust management, (Sales *et al.*, 2019) for value modelling, (Prince Sales *et al.*, 2018) for risk modelling, and (Oliveira *et al.*, 2022) for Enterprise Risk Modeling, is intended to employ the ontology proposed here to provide an ontology-based evaluation and redesign of the Enterprise Architecture Standard ArchiMate regarding its support for Organization Transformation, i.e., the so-called ArchiMate Migration and Implementation Layer (Josey *et al.*, 2016).

Appendix A

Results from the first DSR Phase for DTO Proposal

The first design cycle was developed considering the practical environment (digital transformation and digital innovation) and the available knowledge base from an existing literature review on digital transformation and digital innovation, the first artifact of this thesis was developed - the Digital Transformation and Innovation Business Process Management ontology (DT&I-BPM-onto) (Bogea Gomes, Santoro, & Mira da Silva, 2020) as presented in the Figure A.1. The DT&I-BPM-onto investigated the following research questions:

• (RQ1a) What are the conceptual elements involved in the context of the DT&I and BPM?

• (RQ2a) Which relationships support the DT&I and BPM dynamics?

The main goal of the DT&I-BPM-onto is to establish the conceptual foundation of digital transformation and innovation in BPM, which could be applied in different scenarios allowing for a common understanding and sharing of information. Our research pointed that we have one or more types of digital innovation, managed by BPM and using one or more layers of technology (Fichman, Dos Santos and Zheng, 2014; Henfridsson *et al.*, 2018) can support the design of Digital Innovation. DT&I-BPM-onto model organize the concepts in three perspectives in the model: Digital Transformation and Innovation (DT&I), Business Process Management Contextual Factors, and Digital Technology, which are independent layers but orthogonally related (Bogea Gomes, Santoro and Mira da Silva, 2020). The ontology DT&I-BPM-onto comprises the main concepts and relationships included in the Digital Innovation and Transformation domain. The whole DT&I-BPM-onto was represented as a cube and these perspectives as faces of a cube, as depicted in Figure A.1.

The transformation of an organization, digital or not, is the first line of our investigation. Digital innovation is seen as a broad topic that is one of the vectors of digital transformation DT&I-BPM-onto explored digital transformation and innovation, considering that Digital transformation is an event in which companies use digital platforms to improve performance, increase their reach, and ensure best results for their business. It is about IT's transforming the business with digital innovations (vom Brocke *et al.*, 2017), combining effect of one or several digital innovations, bringing new actors (and actor constellations), structures, practices, values, and beliefs that change, threaten, replace, or complement existing rules of the game within organizations and fields ((Hinings, Gegenhuber and Greenwood, 2018) and potentially impacting all key processes in the organization (Prem, 2017). It is a structural change in organizations in which innovation is one of the vectors of a transformation.

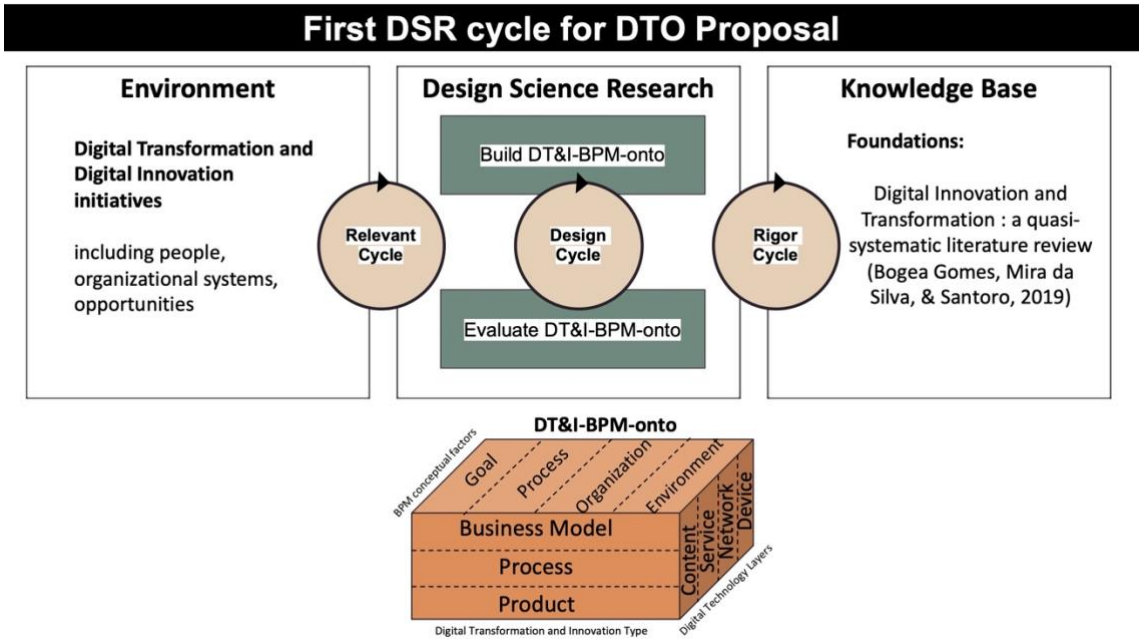

Figure A.1**.** DSR framework for DTO Proposal – first cycle, based on (Recker, 2021).

In the first design cycle the Key'n Go case study (Bogea Gomes et al., 2019) was produced, as basis for the evaluation of DT&I-BPM onto (Bogea Gomes, Santoro and Mira da Silva, 2020). Their abstracts are presented following.

DIGITAL TRANSFORMATION FROM A BUSINESS PROCESS MANAGEMENT INNOVATION: A CAR RENTAL CASE STUDY (Bogea Gomes et al., 2019)

Digital innovation has forced companies to change some well-established business processes. Thus, incorporate information technology into business processes is not enough. We argue that both BPM role and related capabilities might need to be re-interpreted for the digital future. In this sense, the BPM discipline must identify relevant instruments for building on new ways to analyze, understand and support such transformations. This paper examines the results from a car rental company case in the light of DT&I-BPM-Onto, an ontology that encompasses relevant theory on the digital transformation domain. The company carried out a successful initiative by digitizing its primary end-to-end process that contributed to improvement of the company´s Net Promoter Score (NPS). The focus of the case study was the process' redesign; thus, we investigated: (i) the factors that led the decision to digitalize the process; (ii) how the digital transformation was conducted; (iii) the characteristics of the industry, the business itself, the transformed process, and the type of innovation implemented. The main contribution of this paper is to demonstrate that DT&I-BPM-Onto supports taking a broader picture of a process transformation case. Moreover, we provide insights and practical lessons for future projects and further research.

AN ONTOLOGY FOR BPM IN DIGITAL TRANSFORMATION AND INNOVATION (Bogea Gomes, Santoro and Mira da Silva, 2020)

Digital transformation is an event in which companies use digital platforms to improve performance, increase their reach, and ensure best results for their business. It is about IT's transforming the business with digital innovations (vom Brocke *et al.*, 2017), combining effect of one or several digital innovations, bringing new actors (and actor constellations), structures, practices, values, and beliefs that change, threaten, replace, or complement existing rules of the game within organizations and fields (Hinings, Gegenhuber and Greenwood, 2018) and potentially impacting all key processes in the organization (Prem, 2017). It is a structural change in organizations in which innovation is one of the vectors of a transformation. This article treats these two terms as a single compound term: Digital Transformation and Innovation (DT&I).

A.1 DT&I-BPM Onto Design and Development

In this section, a UML Class Model is developing to map the results get from the ontology development. To determine the domain and scope of ontology, 13 competency questions were defined (step 1). Then reusing existing ontologies was considering (step 2) and the important terms in the ontology was enumerated (step 3). The classes and the class hierarchy were defined

in a Taxonomy (step 4). The properties of classes (slots) and their facets (steps 5 and 6) were detailed. The outcome is an UML Class Model distributed in three groups of concepts, preserving the Taxonomy configuration:

- BPM with main concepts as Business, Business Goal, Digital Transformation Strategy, Business Environment, Business Organization, Business Process;
- DT&I involving Perspectives, DT&I Process, DT&I Object, DT&I Outcome, DT&I Agent and Value; and
- Digital Technology, including Digital Resource, Path Channeling, Use / Design Recombination, and Value Space.

Some concepts of one Group of concept model have interrelations with one another. When it happens is represented as a grey box.

Step 1 – Determine the domain and scope of the ontology.

The growing understanding of the domain can lead to a better understanding of the purpose of the ontology and the identification of new intended uses (Noy and McGuinness, 2001). This is the motivation of their first phase.

The application of business process innovation, together with digital technologies, is the base to build more and more successful companies. Examples include Amazon.com with the process of selling books at web; eBay with the web processes that increased the auctions popularity; LinkedIn and Facebook processes to manage relationships and personal networks; and traditional companies that offer services based on Internet connections, such as online airlines ticketing and Internet banking (Kirchmer and Franz, 2017). The BPM consolidates various tools, approaches, techniques, methods, and entire methodologies to support all stages of the business process lifecycle from diverse disciplines. Nowadays, a sustainable BPM program also involves ingredients like process architecture, process discovery, process innovation, process analytics, BPM strategic alignment, and governance. Besides, BPM is gaining a competitive advantage through innovation (Dumas *et al.*, 2018). BPM and digital innovation are joint directions for organizations to change and improve (Van Looy, 2017). From these and other examples, the authors observed that a successful DT&I initiative needs new technologies or the recombination of existing technology by use or design (Henfridsson *et al.*, 2018), but it also demands novel business processes or the existing business processes recombination by use or design. The considerations above motivated the consolidation of the concepts into three groups: DT&I and related concepts, BPM Contextual Factors, and Digital Technology.

The research questions discussed in the Introduction captured the general purpose of this study. The “Define Objectives of a Solution” DSRM phase identified the ontology as the artifact proposed to support companies in the organization of their digital business processes, using the BPM and

DT&I conceptualizations. Now, the competency questions support the determination of the ontology precise scope through a list of questions:

CQ1. Which conceptualizations characterize DT&I?

CQ2. Which events motivate a DT&I initiative? Does it emerge spontaneously?

CQ3. What is the role of technologies in DT&I?

CQ4. What is the association between DT&I and BPM?

CQ5. Which contextual elements characterize DT&I in specific domains?

CQ6. What is the impact of DT&I on people's lives (professional, personal life)?

CQ7. Which are the perspectives addressed by DT&I?

CQ8. Who are the agents involved in DT&I and what are their roles?

CQ9. Which types of value are associated with DT&I?

CQ10. What are the overall benefits expected with DT&I?

CQ11. What factors enable DT&I?

CQ12. What are the types of objects resulting from DT&I?

CQ13. Which stages compose the DT&I lifecycles?

Step 2. Consider reusing existing ontologies.

Existing ontologies, ontological conceptual patterns, and foundational ontologies are important resources to reuse (Falbo, 2014). Moreover, reusing existing ontologies may be a requirement if an ontology needs to interact with particular ontologies or controlled vocabularies (Noy and McGuinness, 2001).

The research in this article reused an existing ontology about value propositions (Sales *et al.*, 2017) to integrate the concept value into the proposal with the definitions as "nothing is intrinsically valuable. Value only exists because people ascribe it to things, and thus, value is, to a great extent, subjective". The value "depends on mental aspects of the value-ascribing stakeholders (henceforth value beholders), such as desires, goals, needs, preferences and so on", and "is not a synonym of benefit. Value arises from weighing benefits and sacrifices"… "The intrinsic aspects of an object (or its parts) influence the value people ascribe to it". This ontology supports answering the competency question CQ9 in terms of the concepts about types of value. The authors did not identify any other ontologies for reuse related to the competency questions that were enumerated.

Step 3. Enumerate important terms in the ontology.

It is important to elicit a list of the terms involved in order to create an ontology. At this stage, it is necessary to reflect on the following questions: What terms should the ontology talk about? What

properties do these terms have? What should the ontology say about these terms? This is also useful for guaranteeing that researchers will answer the competence questions identified in Step 1.

For analyzing which terms should be essential in this ontology, initially, the authors used outcomes from a SMS (Bogea Gomes, Mira da Silva and Santoro, 2019) about digital transformation and the concept of digital innovation as the basis the previous outcomes, presented in the Chapter 3. The authors used the knowledge provided from this SMS as base to model this DT&I-BPM-Onto proposal. As a result, the authors enumerated the important terms in the ontology using this expanded set of articles. The terms identified were organized into main groups: DT&I, BPM, and digital technology. Whether the business is undergoing a DT&I or not, business processes are managed so that the company can achieve its organizational goals. The third group has terms related to the digital platform and the set of technologies that support the business.

To enumerate the important terms of DT&I, in addition to answering the competency questions raised, the authors needed a broad view of the literature, hence the various authors cited. The authors pointed out what they adopted, sourced from the literature, the proposed adaptations, and extensions. The detailed explanation about important terms of DT&I is in the Step 6.

Step 4. Define the classes and the class hierarchy.

Using the theoretical background described in the Step 3, the authors designed the class hierarchy. This article uses the combined top-down and bottom-up approaches, as suggested by (Noy and McGuinness, 2001),. These approaches help to define the more salient concepts first and then generalize and specialize them properly. The authors summarized the terms and their descriptions, generating a dictionary of terms, as suggested by Falbo (2014). The dictionary is available in the Google drive folder cited below[28].

Step 5. Define the properties of classes—slots.

According to Noy and McGuinness (2001), the classes will not only provide enough information to answer the competency questions from Step 1, but they should also provide the internal structure of concepts and their properties. These properties become slots attached to classes. A slot should be attached at the most general class that can have that property. Slots are the properties of each concept describing the various features and attributes of the concept (also roles or properties) and its restrictions (also called role restrictions).

[28] https://drive.google.com/open?id=1l8PAgrb49CS-fxFs3thbIliVzjdwSCt9

An ontology plus a set of individual instances of classes, constitutes a knowledge base. An ontology development includes defining classes in the ontology, arranging the classes in a taxonomic (subclass–superclass) hierarchy, defining slots, describing the allowed values for these slots, and filling in the values for slots for instances.

In the DT&I-BPM-Onto, for instance, the DT&I Object has motivation drivers, type, degree of newness, and components. Moreover, the motivation drivers can assume the following allowed values: financial, operational, employees, differentiation (in general, classified as internal context); and technologies, operating environment, customers, competition, and start-ups (in general, classified as external context). The instances of the class DT&I Object have slots describing these properties, which are important to characterize the classes of the ontology.

Step 6. Define the facets of the slots.

According to Noy & McGuinness (2001), slots can have different facets describing the value type, allowed values (domain), and the number of the values (cardinality), among other features. After the initial knowledge acquisition made up this phase, the authors developed class diagrams for graphically showing domain and cardinality. Using the same organization of class hierarchy, the authors present the DT&I-BPM-Onto below, organized in the three groups of concepts.

DT&I and related concepts

The following competency questions are associated to this group: CQ1, CQ2, CQ6, CQ7, CQ8, CQ9, CQ10, CQ11, CQ12, CQ13. The main conceptualizations that characterize DT&I (**CQ1**) are related to digital, transformation and innovation. The authors use the term **digital** in this article, embracing the terms digitization and digitalization. **Digitization** is defined as the process of changing from analog to digital form (Oswald and Kleinemeier, 2017). In other words, digitization is simply converting and creating a digital version of analog/physical things (such as paper documents, movie, health records, business cards) that can be used by a computing system. **Digitalization** is defined as the process of moving to a digital business, to use of digital technologies, to change or create a business model, and to provide new revenue and value-producing opportunities.

Many authors highlight that digitalization means turning interactions, communications, business functions, and business models into (more) digital formats. **Digital transformation** is the process through which companies converge multiple new digital technologies enhanced with ubiquitous connectivity with the intention of reaching superior performance and sustained competitive advantage by transforming multiple business dimensions. Digital transformation arises from a mix of personal and corporate IT environments, and it is the integration of digital technologies and business processes in a digital economy (**CQ10, CQ11**). For some authors, (Oswald and Kleinemeier, 2017) for instance, **Digitalization** and **Digital transformation** are considering synonymous. **Digital transformation** refers to the combined effects of several **digital innovations**, bringing new actors, structures, practices, values, and beliefs that change, threaten,

replace or complement existing rules of the game within organizations and fields (Hinings, Gegenhuber and Greenwood, 2018).

The unique properties of digital technology enable new **innovation** process types that are distinctively different from the analog innovation processes of the Industrial Era (Nylén and Holmström, 2015). Digital innovation may refer to incremental, radical, or revolutionary changes in thinking, products, processes, or organizations (Yoo, Henfridsson and Lyytinen, 2010), (Schumpeter, 1934). In fact, innovations vary along a continuum from **incremental** to **radical** (Hage, 1980), (Jon-Arild Johannessen, Bjørn Olsen and G.T. Lumpkin, 2001). The revolutionary innovations describe situations in which discontinuities redefine the meaning of industry by creating new technological regimes or paradigms. The term radical (or revolutionary) innovation, was used by Damanpour and Evan (1984), Dosi (1982) and Dewar and Dutton (1986), to characterize innovations that produce fundamental changes in the activities of an organization. By contrast, authors use the term incremental innovations to represent the innovations that depart from existing practices.

Van Looy (2015) states that business innovations that are enabled by IT are also referred to as digital innovations. The concept of business innovation or innovation incorporated or strengthened by IT first appeared after the popularization of the Internet. From there, mainly due to the fast pace of new technologies emergence, digital innovation has been exerting an increasing influence on organizations and their business processes (Van Looy, 2017). Fichman, Dos Santos and Zheng (2014) define digital innovation as a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT. However, for Fielt and Gregor (2016), it is often unclear what is meant by digital innovation and how it differs from traditional (IS/IT) innovation.

Yoo, Henfridsson and Lyytinen (2010) define digital innovation as the process of carrying out new combinations of digital and physical components to produce novel products. Henderson and Clark (1990) argue for the importance of the reconfiguration of existing products. Next Drazin R and Schoonhoven C B (1996) note that the emergence of a dominant design leads to additional innovation with new approaches and technologies. For Henfridsson *et al.* (2018) the idea that novel products and services derived from the process of carrying new combinations of components endures across disciplines. New combinations of components can create novel products, services, processes and business models (Nylén and Holmström, 2015). Furthermore, Jon-Arild Johannessen, Bjørn Olsen and G.T. Lumpkin (2001) adopt the innovation object type from (Schumpeter, 1934), while (Schumpeter, 1942) and (Kirzner, 1976) assess the innovativeness of the firms in six areas: products, services, methods of production, opening new markets, sources of supply, and ways of organizing. The authors relate the work of (Johannsen and Leist, 2012), (Kirchmer and Franz, 2017), (Recker, 2015), (Yoo, Henfridsson and Lyytinen, 2010), (Union, 2013), (Henfridsson *et al.*, 2018) and (Fichman, Dos Santos and Zheng, 2014) to these six areas in Table A-1.

Table A-1. Comparison among the different definitions of innovation according to the six areas of innovative activity

Focus	Main Concepts					
	Product	**Service**	**Process**	**Business Model**	**Technology**	**Organization**
six areas of innovative activity (Johannsen and Leist, 2012)	New product	New service	New method of production	Opening new markets	New sources of supply	New ways of organizing
two major forms of innovation (Kirchmer and Franz, 2017)				Business model	Technology	
innovation as applying to the development of (Recker, 2015)	New product	New service offerings	New process	New business model	New technologies	New management practices
changes in (Yoo, Henfridsson and Lyytinen, 2010)	Product		Process			Thinking or organizations
creation of new or improved (Union, 2013)	Product		Process	Marketing		Organization
the idea that novel (Henfridsson *et al.*, 2018)	Product	Service				
innovation class (Fichman, Dos Santos and Zheng, 2014)	Product	Product - goods and services	Process	Business Model		

In summary, researchers can consider innovation can as a core element of transformation. **DT&I** is an integrated event, where digital innovation(s) is/are involved by digital transformation. Finally, the **DT&I Object Types** are **products** (goods and services). Examples include the Apple iPhone introduction (good) and the online banking introduction (service); the **process** as the Zara Store (fashion brand) manufacturing process innovation allows them to be quick in responding and sending clothes to their shops, and they also do some re-designing in that time; and **business models** (market, organization, new management practices) such as Uber. Technology belongs to another nature. The authors discuss specifically technology in “The role of digital technology in DT&I” section below.

Many events motivate a DT&I initiative, and it does not emerge spontaneously (**CQ2**). Related to the **context of digital transformation**, many drivers (internal and externals) contextualize why companies digitally transform. There is no concrete distinction between these two interconnected concepts, although sometimes they are categorized as internal and external. The drivers identified are **financial**, **operational**, **employees**, **differentiation** (in general, classified as internal context); and **technologies**, **operating environment**, **customers**, **competition**, and **start-ups** (in general, classified as external context).

Researchers associate types of value with DT&I (**CQ9**). According (Porter, 1991) apud (Ismail, Khater and Zaki, 2017), two areas within the **firm's value chain**[29] are being identified and transformed or impacted: an operational and a human element. Transforming the **operational element** targets key business operations and processes. When transforming operations, companies further disseminate new digital technologies. Therefore, the **human element** is impacted by the new culture. Moreover, (Porter, 1991) apud (Ismail, Khater and Zaki, 2017) identify two areas within the **firm's value system**[30] that are being transformed or impacted: a **customer element** and a **network element**. The transformation of the customer experience might, for instance, reshape customer value propositions through digitally enhancing the products and services. Besides, exploiting digital technologies beyond their borders might impact their supply chains. Although deploying these technologies enables a wider network, this can also lead firms to cut away unnecessary layers in the value system.

Akram and Åkesson (2011) explain how digital innovation has transformed value networks in manufacturing industries. The relationships are the mediums or mechanisms to exchange values. A network generates value through exchanges among entities, called value currencies. Value currencies include goods, services, revenue, knowledge, and intangible benefits. Their framework has the purpose of understanding: (i) how digital innovation transforms the value network's roles, relationships, value creation, value perception, etc.; and (ii) vice-versa (i.e., how value network contributes to digital innovation). Using these definitions, the authors explore the relationship between value network and DT&I through the concepts of value network (roles/actors, deliverables/interactions, exchanges, transactions, relationships, characteristics/nature digital) and DT&I (characteristics of digital innovation, dimensions of digital innovation, materiality properties of digital innovation).

Based in the analysis above and the concept of value and value ascription from (Sales *et al.*, 2017), which states that "nothing is intrinsically valuable. Value only exists because people ascribe it to things, and thus, value is, to a great extent, subjective", this work considers that a DT&I creates **value** for stakeholders and reuse the Value Propositions ontology (Sales *et al.*, 2017). For this ontology, the value "depends on mental aspects of the value-ascribing stakeholders (henceforth value beholders), such as desires, goals, needs, preferences and so on", and "is not a synonym of benefit. Value arises from weighing benefits and sacrifices." Besides, they also affirm that "the intrinsic aspects of an object (or its parts) influence the value people ascribe to it."

[29] A firm's value chain includes the various activities within the firm's own boundaries, from inbound logistics to services and also consists of supporting activities to facilitate the end-to-end production process. Porter's (1991) apud (Ismail, Khater and Zaki, 2017).

[30] A firm's value system, on the other hand, extends to suppliers upstream and also to channels and end-customers downstream. Porter's (1991) apud (Ismail, Khater and Zaki, 2017)

The authors follow the perspectives addressed by DT&I (**CQ7**) from Ismail et al. (2017), which distinguishes **digital transformation perspectives** that sometimes overlap. The authors start with the **Digital Era** perspective, in which they remember it also called the Fourth Industrial Revolution. The Digital Era perspective has brought a fundamental change in the world due to the pervasive nature and proliferation of the use of digital technologies. Communication takes place on worldwide computer networks (i.e., the Internet). Nevertheless, the Digital Era is more than a technical implementation. It is also an environment defined by the social interactions, where both development and the diffusion of innovations are much faster than before. For example, Digital is an environment in which individuals can interact, exchange ideas, share information, provide social support, conduct business, direct actions, create artistic media, play games, participate in political discussions, and share rules and ethics, using this global network as a social experience.

The **social/economic** perspective represents the new global economy, characterized by dynamism, customization and intense competition involving **embedding knowledge, technology, and innovation into products and services**. The social/economic perspective also brings the novel concept of a circular or sharing economy, where flows of materials, energy, labor, and new information interact and promote a restorative, regenerative, and more productive economic system.

Next, the **industry/ecosystem** perspective highlights how the disruptive nature of digital technologies has revolutionized the way that industries operate and how the traditional boundaries between them have dissolved. New technologies have also accentuated the changing network dynamics, where consumers and communities co-create value in a **digital ecosystem**. Additionally, the **network** perspective explores the value network competition, where both consumers and communities co-create value in a digital ecosystem. The **company/institutional** perspective enforces the sentiment that the need for transformation is also a business reality, which occurs in all industries and impacts companies of all sizes and shapes.

Finally, the **Individual** perspective relates to how the technological changes substantially affect the way in which individuals present themselves and communicate (**CQ6**), including: de-materialization of possessions in the form of photos and videos; re-embodiment of physical bodies into pictures and videos; sharing more with the help of digital devices; co-constructing the sense of self through digital enablers, such as social media and blogs; and a distributed memory, where human memories are outsourced to engines and hard drives.

In short, the DT&I turns ideas into value, through an event that occurs as a process in four stages; it happens in one or more knowledge areas, in one or more perspectives, it results in one or more digital innovation objects, and it is performed by one or more DT&I agents.

Agents (synonym for actors, in this case) perform DT&I (**CQ8**). For Henfridsson *et al.* (2018), actors perform value-generating and appropriating activities within and across value spaces. Actors can be firms, individuals, and software agents, such as robots, scripts, and algorithms. The concept agent, i.e., a person or thing that produces a particular effect or change, includes

the individual, organization, society, and software as type of agent. Each agent plays different **DT&I Roles**.

DT&I occurs over a **DT&I Object Type** (**CQ12**), which in turn may be a business model, a process, or a product that is the bearer of transformation & innovation. The result expected of the DT&I initiative is the DT&I Outcome. The DT&I Object concept is associated with its purpose (**types of DT&I Object**) and effect (**degree of newness**). A DT&I Object has one or more components. At least one of these **DT&I Object Component** concepts has to be digital (digitization or digitalization) to configure a DT&I. Moreover, its components have the **level of originality** as a novel component concept or an existing component concept. In the case of an existing component, it can be a new combination of use and/or design.

The **DT&I Process** (**CQ13**) concept aggregates four stages: discovery, development, diffusion, and impact, as proposed by (Fichman, Dos Santos and Zheng, 2014). In the **discovery** phase, researchers discover new ideas to address identified problems or needs. This stage involves creating something new or finding and evaluating innovative technology in the external environment to potentially develop or adopt. Besides, from the identified alternatives, researchers should analyze whether solution alternatives would be a process, product, or business model innovation.

In the next phase, **development**, researchers develop an idea for a core technology with complementary products and services that together form a solution to a usable innovation. After designing the whole idea, the following phase is **diffusion**. The central activity in this stage is deployment. The organization of the resources needs to persuade and enable a population of firms or individuals to adopt and use the innovation. This stage involves questions like, "Who is adopting, how, and why? What kinds of firms are more prone to adopt innovation? What kinds of deployment barriers are most salient, and how can they be overcome?" When deployment goes well, the result is the innovation is absorbed into daily life.

The last phase is **impact**. The questions in this phase may include, "What transformations resulting from the digital innovation are being observed at the level of individuals, firms, markets, and society? How can adopters' appropriate maximum value from the innovation?" Figure A.2 consolidates the model of the DT&I group of concepts.

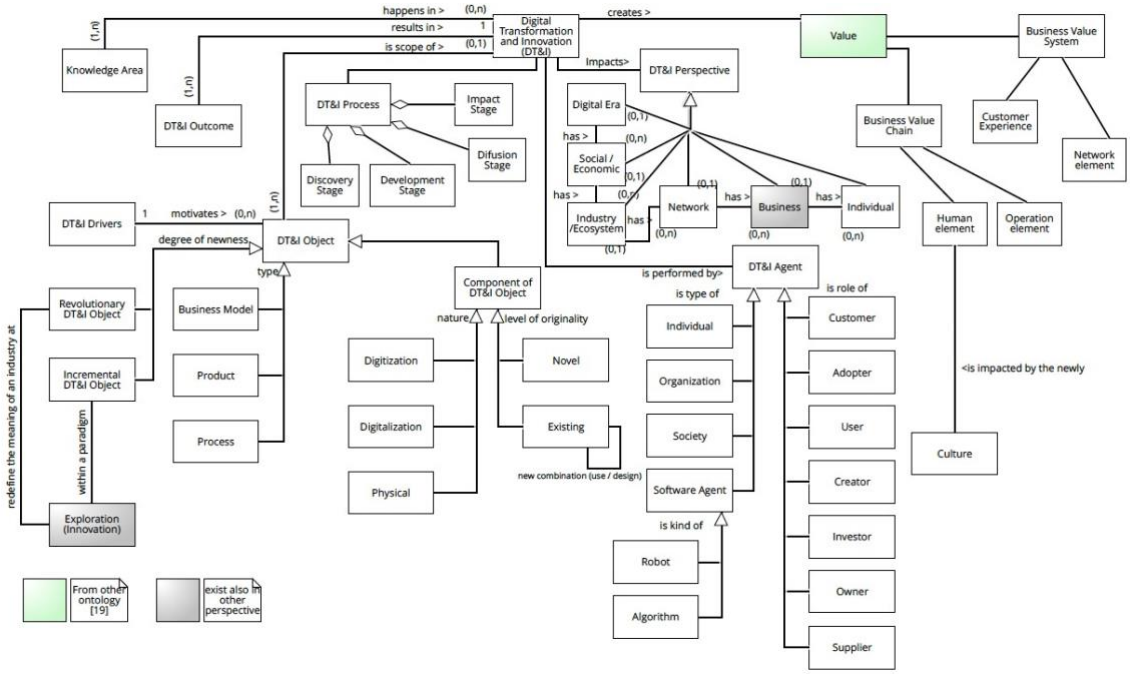

Figure A.2. DT&I group of concepts.

BPM considering DT&I

The competency questions associated with this group are: CQ4, CQ5. The association between DT&I and BPM (**CQ4**) is natural. In a DT&I initiative, the process needs to be managed to support the digital innovation transforms the business. **BPM** is the discipline “that combines knowledge from information technology and knowledge from management sciences and applies this to operational business processes” (van der Aalst, 2013). Van Looy (2017) explores whether the BPM role needs to change and whether the BPM-related capabilities need to be re-interpreted in the Digital Era.

Depending on the characteristics of the organization, the DT&I differs from one company to another. For instance, a DT&I is the mission of the start-up company. But could not be the main mission of a traditional company. The contextual elements characterize DT&I in specific domains (**CQ5**), as observed by (Brocke et al., 2016). The **business contexts** in which BPM is applied **are highly variable**, so BPM should not follow a one-size-fits-all approach. Aiming to understand of contextual factors role in BPM, Brocke et al. (2016) study the context-based phenomenon on external and internal contextual factors. They reviewed the literature on context-aware process design and derive the following dimensions of context: (1) goals of BPM, (2) characteristics of the process, (3) specifics about the organization in which BPM is applied, and (4) the broader business environment in which BPM is embedded. They state that not all business processes have the same characteristics, and this diversity is important for the success of BPM. Furthermore, they argue that BPM could successfully meet a variety of contemporary challenges, being more sensitive towards the relevant context of its application. Moreover, the methods must be adapted to avoid the failure of BPM projects in specific contexts.

Therefore, Brocke et al. (2016) developed the BPM Conceptual Framework, which is a framework that helps to identify and discuss relevant **contextual factors** (CQ7). This framework also helps to develop skills and methods that are context sensitive. They also state that within context in BPM are situational factors related to dimensions of **goals**, **process**, **organization**, and **environment**. For Denner, Röglinger, Schmiedel, Stelzl, and Wehking (2018), the goal dimension has been addressed separately, as it is orthogonal to the other dimensions. Additionally, the goal dimension could be different for each situation, contrary to the dimensions of process, organization, and environment, which represent given business context factors. The authors adopt this terminology , and for the case of the DT&I-BPM-Onto, they also propose an extension of the goal dimension's contextual factors from (Brocke et al., (2016). They do so to make the **offering strategy** an explicit part of the **business goal strategy** that in turn is part of their business goal concept, which represents whether the offering is digital, not digital, or mixed. Figure A.3 consolidates the model of the BPM group of concepts.

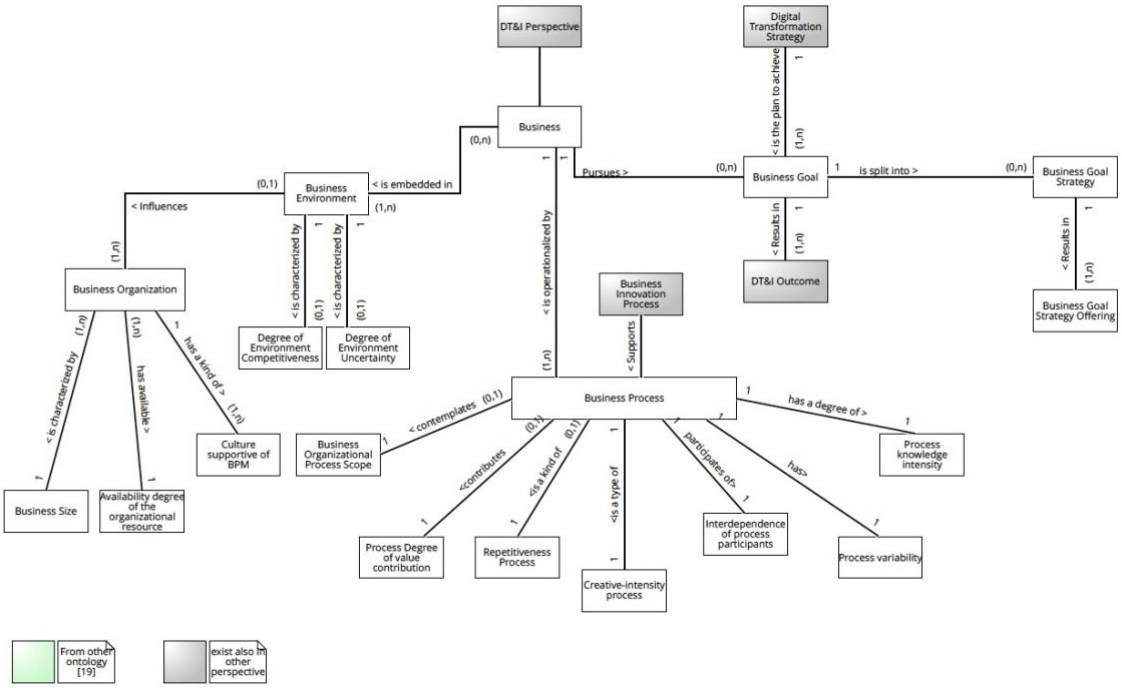

Figure A.3. The BPM group of concepts.

The role of digital technology in DT&I

The competency question associated with this group is: CQ3. The role of technologies in DT&I (**CQ3**) is associated with business value creation much more than technology by technology. According to Misséri (2013), a mechanism for value creation to sustain the growth and competitiveness is digital innovation. It relies on the evolution and uses of information and communication technology (ICT) as well as digital platforms, based on business ecosystems, collaborative platforms, open innovation, communities of practice, and social networks.

The pervasive digitization extends the modular architecture of physical products through the incorporation of four loosely coupled layers created by digital technology. The digital technology

architecture layers are **device**, **network**, **service**, and **content** (Yoo, Henfridsson and Lyytinen, 2010). Based on these digital technology architecture layers, (Henfridsson *et al.*, 2018) trust that digital innovation introduces a new landscape to anyone seeking to generate or **capture new value**. They propose the **value spaces** framework as a tool for better understanding value creation and capture in digital innovation. For them, it is important to make a distinction between **recombination in design** and **recombination in use** and to explore how they play out together. In addition, they redirect the attention from products and services toward digital resources, showing how these resources interact. They also affirm that each **value space** has **digital resources** that may belong to a specific value space or not, holding the potential to simultaneously be part of multiple value paths.

Besides, this digital technology architecture is typically product agnostic. The association between two digital resources, from the same space or not, is made by a **value connection**. The **path channeling** is presented as the set of activities designed to guide value paths through a particular resource or a combination of appropriate digital resources and values, which are called path channeling. The meaning and importance of a digital resource must be considered in terms of use/design recombination because it is through these terms that value is created and captured. Finally, (Henfridsson *et al.*, 2018) state, "recombination is at the heart of innovation." The authors followed the statements above and argue that recombination of use and design involving the digital technology layers goes beyond technology value spaces. Rather, it should be extended for spaces that are not purely technological as showed in “Component of DT&I Object” Class at Figure A.2. Figure A.4. consolidates the model of the digital technology group of concepts.

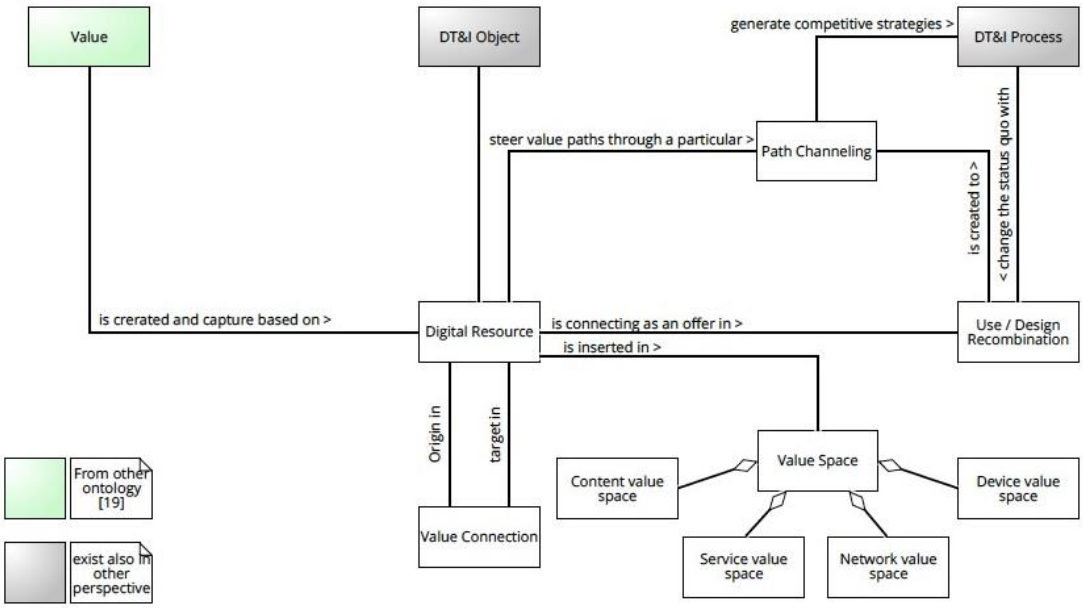

Figure A.4. The digital technology group of concepts.

A.2 Case Study Findings supported by DT&I-BPM-Onto

We took the DT&I-BPM-Onto as a basis to structure and analyze our findings, to further understand the success of this case and what lessons could be learned from it. In this sense, based on the interviewees' responses, media documents and observations, as cited in the previous section, we identify the main entities of this case. The terms highlighted in bold in the following paragraphs correspond to the classes (concepts) and relationships postulated by the ontology.

InterRent®'s **business goal** can be broken down into the quality increase and further process' simplification and acceleration, from a customer's perspective, in addition to the internal productivity gain. Therefore, the InterRent®'s **business goal strategy** was offering a new digital solution, the Key'n Go®, without discontinuing the current operation, which meant the coexistence in the same brand, of two very different products. The InterRent® plans to achieve its business goal offering the Key'n Go® product.

The Key'n Go® reconfigures the customer journey process, considering the pain points identified, that requires some significant changes on the part of InterRent, and it is enabled by IT. It combines effects of **digital innovation** (the Customer Journey process, the App, the Kiosk), practices (the revisited back-office functions), **values** (business activities occur faster and increases its source of value creation), and beliefs (the customer at the center of the process) that change, threaten, replace or complement existing business rules within InterRent® and Car Rental Industry. The **agents** in this case they are diverse: a new **type of** actors mixing with existing actors, with a new combination's responsibilities of the existing and new **roles**: for instance, a hostess to Meet&Greet (new actor and role) and the back-office (existing actor and role) activities.

The elements of InterRent®'s **value chain** is being impacted: the key business operations and processes are transformed, and, as a consequence, the human element is impacted by the new culture. Moreover, the elements of InterRent®'s **value system** also are being impacted: The transformation of the customer experience reshaped the customer value propositions through the Key'n Go® initiative. Besides, InterRent® impact its network, or supply chains (i.e., the Brokers). The Key'n Go® transforms the **value network's** roles, relationships, value creation, value perception, etc.

Thus, Key'n Go® impacts the **industry/ecosystem** since it contributes to changing the car rental business network dynamics. Besides, the Key'n Go® impacts the **business and individual perspectives** relates to car rental experience. The **knowledge areas** involved are mainly car rental business domain, logistics, and technology.

InterRent® DT&I Process

We observed that the previous InterRent® customer journey was not that different from the competitors, and therefore not generating a high degree of competitiveness. The competition is focused on price. The concerns with the current customer journey process were that, in the customer's perception, InterRent® could offer increased quality, simplification, and speed of the

process. From the company's perspective, productivity could be better. Analyzing this, they observed that the back office was not the focus. The main issue was the long queues to get the car, according to the pain points identified internally. The stages followed by InterRent® in order to redesign the business process were: Pain Points identification, Focus Group validation, Solution development, Solution deployment, Next steps Evaluation (new opportunities).

DT&I-BPM-Onto describes the main stages of the own digital transformation and innovation process (Fichman, Dos Santos and Zheng, 2014): discovery, development, diffusion and impact.

At the discovery stage, InterRent® used the focus group to validate the pain points previously identified from the consolidation of the NPS reports and social media complaints of their customers. Afterwards, they could come up with ideas to address those problems or needs, as for example, suggestion of extras' acquisition directly on the kiosk as a last chance. Next, they started the development stage by designing a project for a usable innovative solution. In the following stage, the diffusion, they deployed the solution, persuaded and enabled the customers to adopt the innovation. The last stage is impact. Many questions could be raised, such as: "What transformations resulting from the digital innovation are being observed at the level of individuals, firms, markets, and society? How can adopters' appropriate maximum value from the innovation?" The last stages are currently being conducted in different physical places.

InterRent® Ecosystem Characteristics

According to the DT&I-BPM-Onto, the characteristics of the industry, the business itself, the transformed process, and the type of innovation implemented impact the DT&I Initiative and need to be considered. During the interviews, the participants discussed those topics, summarized in Table 6-8 cited before in Chapter 6. According to the interviewees, the **Customer Journey process** has core value contribution, since it is essential to the business' results; it is a repetitiveness process kind; with low interdependence between others business process, and low variability. During the transformation event, the process knowledge-intensity and creativity change temporarily from low to high, in the discovery and development phases of the DT&I.

About the **Business Organization**, for the interviewees, InterRent®'s organization belongs to a large business size company group in the service industry. Currently, the business has a medium availability of resources, that change temporarily to low in the transformation event (team project), and a culture that is highly supportive of BPM (related to this kind of operation). For InterRent®, the Car Rental industry **environment**, prior to Key'n Go®'s launch, has a high degree of competitiveness. During the transformation event, it was changed to low (newness factor, no other company has something similar). The degree of uncertainty in the industry environment for InterRent®, prior to the release of Key'n Go®, before the Key'n Go® launch, was medium, but temporarily changed to high during the transformation event (associated with the project's risk) and come back to medium after the successful end of the project.

The InterRent® DT&I Object and Outcome

The **type of object** of InterRent®'s initiative was the business model, because it changed its

market and organization, provided new revenue and value, produced opportunities and brought new management practices. Moreover, the **degree of newness is** incremental, with **focus** on customer journey process **exploration**. It has one or more **components**. In an DT&I initiative, not all components are digital, as the Key'n Go® App. Related to **the level of originality**, the Key'n Go® App component, is a **novel** component, and other components, as the Credit Card App, is an **existing** component. The InterRent®'s initiative carries out **new combinations of digital** (App) **and physical** (Kiosk) **components**, with new approaches of the **process** and **technologies**, to produce the Key'n Go®. In the case of an existing component, it can be a new combination of use and/or design. Namely, this case is a **new combination of use**.

The **nature** of the Key'n Go® object could be classified as a digitalization example, since the process of moving to a digital business, using digital technologies, and creating a business model that provides new revenue and value-producing opportunities. The **outcome** of the InterRent®'s initiative is the Key'n Go® itself. The **drivers** that motivate the Key'n Go® are mainly the differentiation (low-cost to mid-tier), customers (pain points) and competition (NPS). The launch of the Key'n Go® process brought InterRent® a change in level (from low-cost to mid-tier) and praise from customers, reflected in the registered NPS. Customers are delighted, according to one of the testimonials, "Good price and fast check-in and checkout." There is always room for improvement, and the team is working on projects to improve the customer experience in the Key'n Go® process, including other potential automations. Currently, the characteristics of Key'n Go® set it apart in the industry, but competition is strong, and competitors have also been working towards a similar business model.

A.3 Discussion

The results of the case study outline what are the necessary steps taken to achieve a successful digital transformation initiative and, furthermore, how the DT&I-BPM-Onto could be taken as a basis to support the analysis of other DT&I cases in the industry. The applicability and value of an ontology in this case was to support the categorization of the entities and understand the relationships among them. Thus, the case could be framed to conceptualizations established in the literature. The research questions are more easily answered and further reflection could be done.

Concerning the (RQ1), the factors that led to the decision, to transform an existing Car Rental business through a digital process, were the business goal and business goal strategy stablished. The strategy of listening to the customer's voice and placing them at the center of the process, aiming to improve the InterRent®'s NPS, enhancing service and improving the top line. The ontology supports to organize this information through the DT&I Process stages and it facilitated the identification of what led to the decision of the Key'n Go initiative. As lessons learned, a company might consider research for opportunities, involving external people. Listening to the customer's voice was the strategy defined to achieve the business goal of increase the quality and further process' simplification and acceleration, from a customer's perspective, in addition to

the internal productivity gain. Other organizations, with other Goal can define another Strategy.

Regarding (RQ2), the process' transformation was conducted in a Project Management lean structure which allowed a very close and interactive process within the team and business executives. The speed, in identifying opportunities during the project and implementing new features (lessons learned), was essential for its success. The ontology describes the concepts of value including value chain (operation, process and human resources) and value system (customer and supply chains). They were useful to learn the process end-to-end considering the whole network, moreover the DT&I Process stages. One issue to better explored here is the configuration of the project team and interfaces. It will not necessarily be the more adequate to all organizations (since there are other contexts and cultures).

Related to (RQ3), how the characteristics of the industry, the business itself, the transformed process, and the type of innovation contribute to the success of the case. The ontology helped to organize the knowledge about the goals and current results that originated the DT&I demand, what is important to customers and what the competitors are doing. It was fundamental to help explaining the success of the project. It is important consider the Industry and Organization contexts. Other industries and organizations can result in a different outcome.

All along, to support the business strategy, the DT&I InterRent® initiative focused on the business goal, developing business resources and technology resources that enabled it to be more competitive and change its level in industry, which is also supported by the concepts of the DT&I-BPM-Onto model. The business resources included a business process innovative redesign and they developed a kiosk technology to automatize part of its operation. InterRent® initiative took into account the Customer learning curve as well: a hostess to Meet & Greet is there to support them.

The DT&I-BPM-Onto describes the process characteristics considering the BPM contextual factors. Mapping this business and its industry characteristics, facilitated an analysis of scenarios for the DT&I initiative. For instance, it is interesting to observe that some process' characteristics changed throughout the DT&I initiative, like the Knowledge-intensity, Creativity-intensity and Degree of Environment Uncertainty. Besides these characteristics transform with the DT&I outcome, as Availability Degree of the Organizational Resources and Degree of Environment Competitiveness. Make the process explicit and analyze it in advance could be interesting to the strategy.

In the operation launching, the company had to convince about the advantages of the project, not only the Executives and Partners (including Brokers and B2B2C parties), but also to other product team members. Understanding all the DT&I Agents (types and roles) involvement, as the Key'n Go® initiative did, was vital to avoid problems. The DT&I Process stages of diffusion and impact are still in progress, so there is opportunity to bring even higher NPS levels, learning and refining the initiative. The ontology could also support these analyses, decision making and evolution in each of these stages. Furthermore, exploring the business value system brought more insights about success and failures in such initiatives.

The ontology enlightens that a DT&I initiative turns ideas into value, through an event that happens in one or more knowledge areas, in one or more perspectives, resulting in one or more digital innovation objects, performed by one or more agents. Agents (synonym for actors, in this case) perform activities within the DT&I initiative. Agents can be individuals, organizations, the society or software agents (as robots and algorithms). Besides, each agent plays different roles in the DT&I initiative, such as customer, user, creator, owner, partners and supplier.

Interviewee 1 explained that the brokers directly influenced the Key'n Go® initiative. However, at the launching of Key'n Go®, interviewee 1 realized that the brokers' website wasn't selling the Key'n Go® initiative because their algorithm was not prepared to equalize this new type of service with the traditional form of car rental. Then, there was a negotiation between the Key'n Go® initiative and the brokers to adjust the algorithms. This issue was very important for the success of Key'n Go® and the ontology supported us to realize that in fact it was the software agent (the algorithm) who played the role of a car rental partner. The Key'n Go® initiative had to align with the other offers on the broker's website. Thus, it is important to assess the whole network chain including all the new agents to ensure the success of the project.

In this case study, the focus was not on the value of the digital technology platform that supports digital transformation. So, DT&I-BPM-Onto presents concepts related to this that were not explored in this paper. Moreover, the object components were not explored in detail, as our case is still in progress. But this can be useful for other cases that are in the beginning of transformation process. The ontology supported to organize knowledge about the demand for an DT&I initiative, aiming to facilitate the interpretation of case studies of digital transformation in the industry. This can help discovering new opportunities for improvement and future work on this topic.

A.4 Conclusion

The InterRent's® DT&I initiative provided an opportunity to closely investigate its shift to allow a new digital customer journey. i.e. to manage the transformation of their main business process. This case covers the situations before and after the Key'n Go®, and its effects were analyzed through the participants' interpretation about their context.

The main goal was to investigate deeply the steps taken to achieve the successful digital transformation initiative and, furthermore, to show how the DT&I-BPM-Onto could be taken as a basis to the analysis of this case. Therefore, the case study aimed to understand why the company decided to perform a transformation of its primary process into digital, which factors influenced this decision making, how this process transformation was conducted, and which capabilities influenced its success. To answer the research questions, the case was analyzed based on the interview results and compiled documents, grounded in the DT&I-BPM-Onto. The DT&I-BPM-Onto was used as a source of knowledge in discussions and a learning process about the domain.

The main contribution of this paper is taking the perspectives of DT&I-BPM-onto, towards the InterRent® case study and thus providing a broader picture in analyzing this successful case.

Although the proliferation of the use of digital technologies has brought a fundamental change in the world due to their pervasive nature, the digital business is more than a technical implementation. And the digital business value is not a synonym of benefit. It depends on aspects such as desires, goals, needs of the value-ascribing stakeholders.

The theoretical implication of this research is the indication that the ontology can serve as a theoretical basis to support the evaluation of cases involving the digital transformation of business process. The main practical implications are the lessons learned from the case study per se that could be used bey companies conducting their own with digital transformation process.

The main limitation of this research refers to the use of only one case from a single car rental company. Other cases of different companies would confirm the theoretical approach examined in this paper. Future works include the refinement of the ontology as the foundation for digital transformation and innovation that will be integrated into a digital transformation and innovation business process management to guide the development of digital transformation initiatives while reducing their risk of failure.

Appendix B

Supporting Artifact for DTO Proposal: Visualization

Some authors have investigated the diverse approaches that relate Enterprise Architecture (EA) and Digital Transformation as new opportunities for enterprises in various contexts, for example, Digital Transformation versus the new challenges for Enterprise Architecture Management (EAM) (Kaidalova, Sandkuhl and Seigerroth, 2018), the evolution of EA considering newly-defined value-oriented mappings between digital strategies, digital business models and an improved digital EA (Zimmermann *et al.*, 2018), and the EA approaches to address integration and coherence in the face of complexities pertaining to digital ecosystems (Korhonen and Halen, 2017).

Our research observed that there is still a lack of (i) conceptual models to provide an accurate representation of the digital transformation elements within EA approaches; and (ii) standard visualizations of such elements to specific stakeholders. We investigated the relation between EA and Digital Transformation resulting these two articles present following.

A Reference Model for Digital Transformation and Innovation (Bogea Gomes *et al.*, 2019)

Abstract: Digital Transformation (DT) has a direct impact on relations and forms of consumption. New technologies are being incorporated continuously into our day-to-day life, introducing new shapes for traditional and original kinds of businesses. Nevertheless, it is interesting to notice that most novelty is based mainly on processes, rather than on technology. A DT initiative should start with conceptual modeling to organize and structure knowledge of its scope. However, there is not a specific proper language to model DT initiatives. Based on an extensive literature review, we propose an Ontology – the DI-BPM-Onto - with this purpose. The ontology proposed conceptualizes three aspects: Digital Transformation and Innovation (DT&I), Business Process Management Contextual Factors, and Digital Technology, which are independent layers, but orthogonally related. On the other side, modeling tools like the well-known standard ArchiMate are widely used by companies to provide an unambiguous understanding of their businesses, and already support the description, analysis, and visualization of most enterprise architecture (EA) elements. Therefore, in this paper, to better model DT initiatives, we propose a Reference Model that extending the ArchiMate with the main concepts of DT identified in the DI-BPM-Onto to better model DT&I initiatives and to discuss to what extent ArchiMate would support the implementation of DT&I initiatives. A practical modelling scenario concerning UBER is used to carry out a preliminary evaluation of the proposal.

Basis for DTO core.

Visualization of Digital Transformation Initiatives Elements through ArchiMate Viewpoints (Bogea Gomes *et al.*, no date)

Abstract: Digital transformation stems from a mix of personal and corporate IT environments and involves integrating digital technologies and business processes in a digital economy. As such, organizations expect that digital transformation improves performance, increases their reach, and ensures better business results. However, there is still a lack of (i) conceptual models to provide an accurate representation of the digital transformation elements; and (ii) standard visualizations of such elements to specific stakeholders. In a previous work, a reference model to support digital transformation initiatives using ArchiMate was proposed. In this paper, we address the second part of this problem regarding the need for specific visualizations. We followed the Design Science Research approach to learn how to identify the needs of the stakeholders, extending and improving the reference model through the design of a set of architectural viewpoints. We used the well-known ArchiSurance case to demonstrate the application of the viewpoints and semi-structured interviews to evaluate the proposal, providing insights to the discussion of the results obtained.

Basis for DTO core

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