UNIVERSITY OF TWENTE.

Business Information Technology

An Enterprise Architecture Framework for Digital Transformation

Master Thesis

Validation case: The European IT division initiative for Data and Analytics at Apollo Verdestein B.V.

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Abstract

The Digital Transformation era has unlocked unique opportunities for organizations to disrupt and innovate with new products and services by leveraging novel emerging technologies such as mobile computing, big data analytics, cloud computing, and the internet of things. The range of possibilities provided by Digital Transformations comes at the expense of constant change across multiple levels of the enterprise including organizational structures, operational processes, business strategies, and even corporate culture. In addition, highly competitive market conditions introduced by the new digital era have forced organizations to react quicker than ever before, pressuring organizations to employ faster learning cycles that translate into shorter time-to-market strategies. Lastly, Digital Transformations revolutionize the way in which IT and business units collaborate where extremely cohesive teams are expected to continuously innovate and deliver solutions that result in enhanced customer journeys and experiences driven by new corporate cultures.

Facing the challenges brought by the new digital era not only requires the adoption of emerging technologies, but committing to best practices that allow organizations to execute successful Digital Transformations. Conventionally, Enterprise Architecture has proven to be the discipline that best provides a basis for highly integrated environments, that are responsive to change and supportive in the delivery of the business strategy. However, organizations that have allocated resources and great efforts to become truly digital, criticize the Enterprise Architecture practice as it fails to grasp the fundamental concepts from the nature of Digital Transformations. Certainly, such discontent has drawn attention to perform this research. In response to these adversities, organizations must tackle these challenges systematically by embracing new or enhanced approaches that enable them to stay ahead of the competition while keeping up the pace of the new digital generation.

The main objective of this research is to design, validate, and evaluate an Enterprise Architecture framework that stimulates business agility, simplifies architecture development, and promotes collaboration across business and IT units in order to lead organizations to successful Digital Transformations. To structure the research a Desing Science Research Methodology (DSRM) is applied. Based on the results from performing a Systematic Literature Review in preparation for this thesis and the examination of a case study of a well-known multinational company, the Enterprise Architecture Framework for Digital Transformation is assembled and validated in the context of the Data and Analytics initiative at Apollo Vredestein B.V. Furthermore, three expert interviews carried out as part of the evaluation process corroborated that the effects produced by the artifact satisfy the main research objective of this thesis. At the same time, a series of improvements are suggested for the presented framework. Lastly, conclusions are drawn, limitations are outlined and future research directions are provided.

Acknowledgements

"What seems to us as bitter trials are often blessings in disguise." - Oscar Wilde

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Abbreviations

ADM	Architecture Development Method
AIDAF	Adaptive Integrated Digital Architecture Framework
API	Application Programming Interface
AVBV	Apollo Vredestein B.V.
BMM	Business Model Management
B&IT`	Business and Information Technologies
CC	Cluster Categories
CI/CD	Continuous Integration and Continuous Delivery
COTS	Commercial off-the-Shelf
CM	Capability Management
DEA	Digital Enterprise Architecture
DITP	Digital Innovation and Transformation Process
DSRM	Design Science Research Methodology
DT	Digital Transformation
EA	Enterprise Architecture
EA4DT	Enterprise Architecture Framework for Digital Transformation
EAM	Enterprise Architecture Management
EE	Enterprise Engineering
GDTC	The Global Digital Transformation Communication
GPS	Global Position System
IaaS	Infrastructure as a Service
IAF	Integrated Architecture Framework
ICT	Information and Communication Technologies
IoT	Internet of Things
IS	Information systems
ISO	International Organization for Standardization
LEAF	The Lightweight Enterprise Architecture Framework
MDM	Master Data Management
MVA	Minimum Viable Architecture
OAAF	The Open Group Agile Architecture Framework™
PaaS	Platform as a Service
RDBMS	Relational Database Management System
SaaS	Software as a Service
SCM	Social Collaboration Model
SBCE	Set-Based Concurrent Engineering
SDLC	System Development Life Cycle
SITAM	Stuttgart IT Architecture for Manufacturing
SLR	Systematic Literature Review

SME	Small and Medium
SOA	Service Oriented Architecture
SoS	Systems of Systems
STRMM	Strategic Risk Mitigation Model for Digital Transformation
T&O	Technology and Operations
TOGAF	The Open Group Architecture Framework

1. Introduction

1.1 Problem Statement

Apart from empowering people to collaborate and experiment with new emerging technologies, Digital Transformations require companies to change at multiple levels including organizational structures, operational processes, business strategies, and even corporate culture. Highly competitive market conditions introduced by the new digital era have forced organizations to react quicker than ever before. Today's ruthless business environments pressure organizations to employ faster learning cycles that translate into shorter time-to-market strategies. In the banking industry, for instance, new "born digital" start-ups have disrupted the market with the up-and-coming "Fintech" revolution. As a result, banks and financial institutions that have operated for decades are now expected to respond to dynamic market demands with outstanding business agility. Furthermore, Digital Transformations revolutionize the way in which IT and business units collaborate. Highly cohesive teams are expected to constantly innovate and deliver solutions that result in enhanced customer journeys and experiences driven by new corporate cultures.

Facing the challenges brought by the new digital era not only requires the adoption of emerging technologies i.e. mobile computing, big data analytics, cloud computing and the internet of things, but committing to best practices that allow organizations to execute successful Digital Transformations. Conventionally, Enterprise Architecture has proven to be the discipline that best provides a basis for highly integrated environments, that are responsive to change and supportive in the delivery of the business strategy. However, organizations that have allocated resources and great efforts to become truly digital, criticize the Enterprise Architecture practice as it fails to grasp the fundamental concepts from the nature of Digital Transformations. Certainly, such discontent has drawn attention to perform this research.

To begin with, architecting the digital enterprise goes hand in hand with architecting the agile transformation. Despite the fact that agile thinking has become a core element, part of the development cycle of well-known Enterprise Architecture approaches, these methods do not succeed to help organizations become more agile. Secondly, extrapolation of the earliest software development processes has influenced many of the best practices of today, and Enterprise Architecture is no exception. As experienced with the waterfall model, Enterprise Architecture approaches are perceived as "Big designs up-front", creating a sense of reluctance in organizations to commit to years-long architecture plans and efforts. Consequently, this situation calls out for a simplification of Enterprise Architecture development in preparation to confront Digital Transformations. Ultimately, no margin to experiment and discover alternative organizational structures between business and IT units indicates the absence of adopting fast-

learning cycles in Enterprise Architecture methods. The latter corroborates the need to constantly re-architect business and IT elements to cope effectively with agile and flexible ways to work.
In response to these adversities, organizations must tackle these challenges systematically by embracing new or enhanced approaches that enable them to stay ahead of the competition while keeping up the pace of the new digital generation. Hence, this situation has motivated this research to introduce an Enterprise Architecture framework to assist organizations in their journey to deploy successful Digital Transformation initiatives.

1.2 Research Context and Motivation

The new digital era has unlocked new opportunities for organizations to transform and innovate with new products and services. A survey performed by McKinsey & Company (2018) revealed that eight out of ten companies have committed resources and efforts to Digital Transformation initiatives in the past five years. However, success rates from these efforts are considerably low, resulting in less than 30 percent of successful cases. Particularly, organizations that experienced successful transformations highlighted the importance of adopting best practices involving leadership, capability management, upgrading tools, and communication. Results from the latter study, depicted by Figure 1, also indicated a tendency from organizations with successful transformations to deploy more technologies than others do. So-called emerging technologies or SMACIT (social, mobile, analytics, cloud, and internet of things) technologies serve as a vehicle towards successful Digital Transformations for those companies who are willing to embrace new organizational structures and processes that empower people to collaboratively experiment with technologies and deliver integrated products and services to customers (Sebastian *et al.* 2017). As a result, these substantial changes call out for management practices to govern these complex transformations (Matt, Hess & Benlian, 2015), in which practices such as Enterprise Architecture can be understood as the new prosecutors of the new IT function, moving away from the traditional role of a service provider to those of a consultant, enabler and innovator (Legner *et al.* 2017).

For many years the Enterprise Architecture discipline provided guidance in the form of a well-established governance instrument to consistently align business and IT with strategies and goals to ensure adaptability, consistency, compliance, and efficiency (Zimmermann *et al.* 2015). Multiple communities of practitioners, research institutes as well as consultancy firms and private corporations have reinforced its importance as a recognized practice employed across several business domains and industries. This corroborates the fact that the Enterprise Architecture discipline has played an important role in the last decades by providing a well-founded practice that enabled organizations to shift into highly integrated environments that effectively deliver key business strategies (Harrison, 2018). However, in today's fast-paced marketplace and highly dynamic business environments even large corporations such as Intel®, which have had an Enterprise Architecture mindset for years, struggled to keep their architecture

products and solutions simple and in line with the company's Digital Transformation strategies (Singh, 2019). The increasing complexity from the Enterprise Architecture practice prevents simple projects to adopt practical solutions and quick adaptions to change (Nandico, 2016).

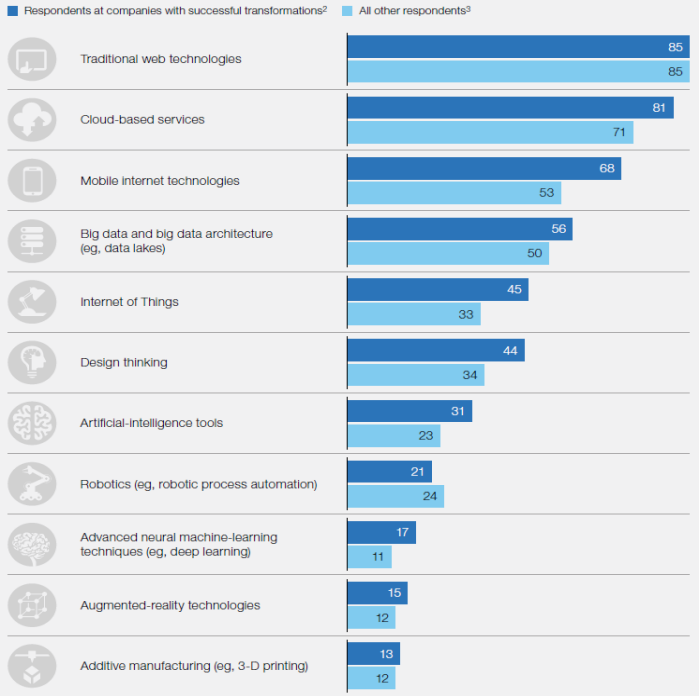


Figure 1. Organizations with successful DT deploy more technologies (McKinsey & Company, 2018)

At the same time, Digital Transformations encourage risk-taking, foster innovation, and develop collaborative work environments (Kane *et al.* 2015). This leads companies to embrace the philosophy of "learn fast, fail fast" allowing organizations to speed-up their learning cycles and become truly agile instead of falling into the trap of committing to years-long Enterprise Architecture plans with big designs up-front (The Open Group, 2019). For this reason, the Enterprise Architecture practices need to examine carefully the concept of business agility or enterprise agility for that matter, as successful development and integration of Digital Transformation through digital businesses require a high degree of agility in enterprises (Wißotzki & Sandkuhl, 2017).

Ultimately, the Digital Transformation has presented Enterprise Architecture and its community of practitioners new opportunities to evolve and deliver organizations solutions that transcend the traditional IT-business alignment, to a state where IT is pervasively embedded into every level of the organization and be an integral part of the business strategy (Sia, Soh & Weill, 2016). The Enterprise Architect prepared to guide companies towards successful Digital Transformations embraces new or enhanced practices supported by modern business models that enable organizations to stay ahead of the competition while keeping up the pace of the new digital

generation. In short, regardless of the difficulties and pitfalls perceived form practice, this thesis is motivated to investigate how Enterprise Architecture can assist organizations to embark on successful Digital Transformations and hence, contribute with useful insights to both the research and practitioner communities.

1.3 Research Objectives

As previously described in the introduction section, the high-level aim for this research is to provide an Enterprise Architecture framework that incorporates the fundamental concepts from the nature of Digital Transformation. In general, the concepts comprise business agility, team collaboration across business and IT units, and simplification of architecture development. Therefore, the main goal formulated as the main research question is:

How to lead organizations towards successful Digital Transformations by means of an Enterprise Architecture framework that stimulates business agility, simplifies architecture development, and promotes collaboration across business and IT units?

Furthermore, the main research question is further decomposed into the following objectives/sub-research questions:

Research Objective 1 (RO1): Contrast the structure of the Enterprise Architecture practice with the anatomy of Digital Transformations. To do so, definitions of these two main constructs are provided from the body of knowledge assembled by performing the SLR later discussed in section 2.2. Subsequently, the concepts are related to the sole purpose of understanding the extent to which Enterprise Architecture reacts to Digital Transformations according to literature. Thus, gaps to be addressed by the Enterprise Architecture discipline are identified and constituents to tackle Digital Transformations are established. As a result, the following knowledge questions are formulated:

a. What is Enterprise Architecture?
b. What is Digital Transformation?
c. What is the relation between the concepts of Enterprise Architecture and Digital Transformation?
d. What constituents from Digital Transformation initiatives are not contemplated by the Enterprise Architecture practice?

Research Objective 2 (RO2): Identify the state-of-the-art regarding Enterprise Architecture practice to support the realization of Digital Transformation initiatives. This objective aims at collecting existing Enterprise Architecture approaches that address the challenges of Digital Transformations. Frameworks, methods, and techniques analyzed and discussed as part of this

objective serve as key components of the artifact to be derived in the following stages of this thesis. Therefore, the following knowledge question is formulated:

a. What Enterprise Architecture frameworks, methodologies, and techniques are available that best provide a basis for Digital Transformation?

Research Objective 3 (RO3): Elaborate on how the Enterprise Architecture practice is delivered in organizations that have embarked on Digital Transformation initiatives. The development of EA in organizations to embark on successful Digital Transformations is an area of special interest in this thesis. Therefore, this objective aims at analyzing the approaches taken by organizations from different industries to embark on successful Digital Transformation initiatives. It does also extract the problem, solution, and impact on the business through the examination of a case study of a particular organization. This research objective, therefore, poses the following research questions:

a. How are organizations from multiple industries relying on Enterprise Architecture to deliver Digital Transformations into the organization?
b. What are the business problems, impact, and solutions from adopting an Enterprise Architecture approach for Digital Transformation in the case of a particular organization?

Research Objective 4 (RO4): Design an Enterprise Architecture framework for Digital Transformation. In line with the DSRM adopted by this thesis, the objectives to be attained by the artifact are derived. In addition, the results of the SLR and the examined case study serve the purpose of assembling the Enterprise Architecture Framework for Digital Transformation in response to the main research question. The constituent building blocks, associated methodology, and incorporated architecture techniques and patters are further explained and documented.

a. What are the objectives to be attained by the Enterprise Architecture framework for successful Digital Transformations?
b. What are the foundations or building blocks of the Enterprise Architecture framework for Digital Transformation?
c. How does the suggested framework stimulate business agility, simplifies architecture development, and promotes collaboration across business and IT units of the enterprise?

Research Objective 5 (RO5): Demonstrate and evaluate the Enterprise Architecture framework for Digital Transformation in an organizational context. The artifact is validated with a Technical Action Research methodology in the context of a real-world Digital Transformation initiative. Moreover, semi-structured interviews are conducted to evaluate the relevance of the artifact around the problem context. Expert feedback and improvement opportunities are documented for future research and DSRM cycle iterations.

a. Demonstrate through experimentation the applicability of the Enterprise Architecture framework in a Digital Transformation project for an organization.
b. Carry out expert opinion interviews to evaluate how the artifact supports a successful Digital Transformation initiative in the organization.

1.4 Research Methodology and Thesis Structure

This research adheres to the Design Science Research Methodology (DSRM) for research in the Information System (IS) field as defined by Peffers *et al.* (2007). Figure 2 depicts the general process prescribed by the method to present and evaluate a design science research in IS. In line with the intentions of this research, the process is composed of the following six steps:

1. **Problem identification and motivation:** The main problem is identified and the motivation to develop the research is justified. A SLR is performed at this stage, focused not just to aggregate all the existing content for the research question and objectives, but to support the development of evidence-based guidelines for practitioners (Kitchenham *et al.* 2009).

2. **Define the objectives for a solution:** The main research objectives are defined in order to provide an artifact that treats the problem identified in the first phase. This refers to the definition of requirements and expectations to be met by the artifact to be assembled.

3. **Design and development:** The activity includes the development of the Enterprise Architecture framework reference for successful Digital Transformations. Findings from the SLR as well as the analysis of a case study contribute to the formation of requirements to be considered in the artefact design.

4. **Demonstration and Evaluation:** A Digital Transformation initiative for Data and Analytics at Apollo Vredestein B.V. sets a practical environment on which the framework is applied. Under those circumstances a Technical Action Research methodology is employed. As part of the evaluation section, semi-structured interviews are carried out through an expert opinion process to evaluate the designed artifact.

5. **Communication**: This thesis report serves as a vehicle of communication of the conclusions from designing, demonstrating and evaluating the proposed framework in a real-world scenario.

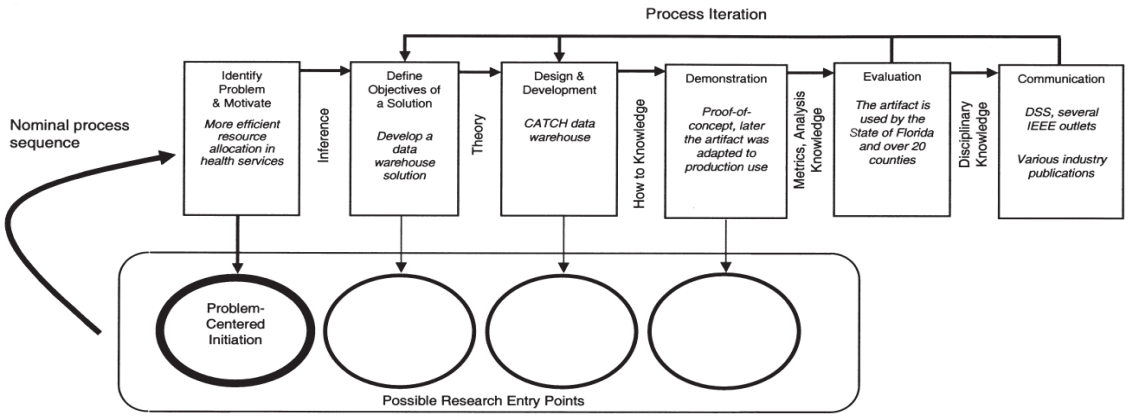


Figure 2. DSRM by Peffers *et al.* (2007)

After describing the main research methodology adopted for this thesis, the structure of the document is delineated in Table 1.

Table 1. Thesis document structure

Thesis section	DSRM Phase	Research Method	Research Questions
1. Introduction	Problem identification and motivation	-	-
2.1 Basic Definitions and Key Concepts	Problem identification and motivation	Systematic Literature Review	RO 1.a, 1.b, 1.c
2.2 Systematic Literature Review	Problem identification and motivation		RO 1.d, 2.a, 3.a
2.3 EA for DT at Intel®	Problem identification and motivation	Case study examination	RO 3.b
3. Design Analysis	Define the objectives for a solution	SLR and Case study results	RO 4.a
4. Artifact Design	Design and development		RO 4.b, 4.c
5. Framework Implementation and Validation	Demonstration and evaluation	Technical Action Research Expert opinion interviews	RO 5.a, 5.b
6. Conclusions	Communication	-	All research questions revisited

1.5 Systematic Literature Review Methodology

The Systematic Literature Review (SLR) performed is based on the methodology provided by Gaß *et al.* (2015) for literature reviews in the information systems (IS) field. The four-phase method was applied to distinguish between the body of knowledge relevant for the systematic review and the rest of the literature that is not aligned to the purpose of this research. Figure 3 depicts the process adopted for this literature review. The SLR method is composed of a database search, initial screening, clustering, and in-depth analysis.

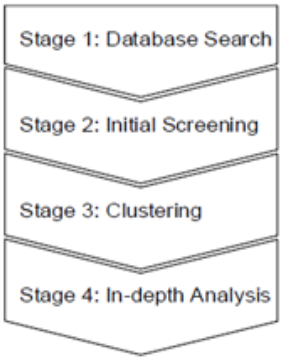


Figure 3. Gaß et al. (2015) 4-phase SLR for IS field

In the first phase, the scholarly literature search performed in this research aims to retrieve the most credible academic peer review content from well-known sources of scientific knowledge. Databases and search engines for scientific literature used in this research include *Scopus, SpringerLink, ScienceDirect,* and *IEEExplore*. As part of the literature, recognized publications from large communities of practitioners in the field of Enterprise Architecture were included in this literature study. Thus, this research considers *The Open Group* standards related to Enterprise Architecture as relevant sources of knowledge aligned to the interests and objectives of this project. *MIS Quarterly Executive*, as a further reliable source of practice-based research with the largest number of publications in the last years in the context of Digital Transformation, contributes to the body of knowledge of this systematic literature review.

The term “Enterprise Architecture” was naturally included in the search criteria, as it represents one of the core concepts of this research. The logical operator AND was used to relate EA with the concepts: “Digital Business Transformation”, “Digital Transformation”, “Digitalization” or “Digitization”. As there is not a unique definition and interpretation of the previously mentioned concepts across all literature and their relation to the EA practice, the logical operator OR was incorporated. The concepts of “Cloud Computing” and “Data Analytics” were also included in the search query as these technologies are subject to interest in this particular research. Further, the concepts of “organization”, “organisation”, “business” or “businesses” aim at retrieving the body of knowledge in the setting of public or private organizations. In some databases the term

"manufacturing" was used to: first, enrich the search criteria due to the lack of functionalities of specific search engines and secondly, to address the last research question regarding the specific industry where digital enterprise transformation initiatives are undertaken.

The process of screening set the conditions for inclusion and exclusion criteria from results retrieved on the selected research databases. Therefore, conditions required the documents to include the keywords listed above in the abstract section. The inclusion criteria for this literature review consisted of open-access documents or access granted through the use of the *University of Twente* credentials, documents written in the English language from the Computer Science, Business and Information Technologies subject areas published not before the year 2015. A reason to delimit the search to include studies published after the year 2015 is due to the fact that the term Digital Transformation has significantly skyrocketed from the beginning of 2015 according to *Google Trends*. The exclusion criteria considered for this study comprised the manual removal of duplicates found across all research databases, magazines, notes and documents that had no relation to the presented research questions.

The process continued by sorting the results by relevance, according to the proximity between the keywords and each abstract section and keyword parameters. Further, an abstract review of the remaining results was performed, where a selection of the most relevant literature was made considering the given research questions. Subsequently, Clusters are defined to categorize the literature into thematic areas or constructs. These were identified by looking back at each of the research questions and their main purpose when scanning the selected literature. The clustering process assisted in filtering out literature that had no association with the proposed research questions. Results from the undertaken systematic process are detailed in section 2.2.

1.6 Practical and Scientific Relevance

The research is relevant from two perspectives:

1.6.1 Practical relevance

Industry-leading research and surveys have shown that organizations that have adopted best practices to embark on Digital Transformation initiatives are more likely to succeed than those who did not (McKinsey & Company, 2018). The Enterprise Architecture framework and development method, as presented in this research, assists organizations to adopt the fundamental concepts of design and development of architecture in the context of a Digital Transformation. In other words, the presented study is relevant to the practical level as it compiles the constituents from Digital Transformations and translates it into a methodology for Enterprise Architecture development in organizations.

1.6.2 Scientific relevance

Throughout the last decade, several IS disciplines have evolved to provide faster, more effective, and comprehensive solutions to organizations. For instance, Agile and DevOps practices are introduced as vital methodologies to be implemented by IT for continuous software development and delivery. However, there has not been much progress in the field of Enterprise Architecture in the context of Digital Transformation. This research analyzes, compiles, and integrates methodologies from selected publications and proposes an Enterprise Architecture approach to Digital Transformation and validates its use on a concrete real-world case.

2 Problem Investigation

This section presents the relevant theoretical foundations of this research. Basic concept definitions and associations between core constructs are provided, as well as the state-of-the-art approaches, proposed by both the research and practitioner communities, for the development of Enterprise Architecture for Digital Transformation. This section focuses on addressing the first three objectives of this thesis.

2.1 Basic Definitions and Key Concepts

To provide a fundamental view around the concepts of Digital Transformation and Enterprise architecture, definitions are given and relationships between these concepts are established. Thus, the following subsections tackle research objectives 1.a, 1.b, and 1.c.

2.1.1 Enterprise Architecture and Digital Transformation

In the field of Business and Information Technologies, many concepts have been adopted to address and describe particular aspects of the Digital Transformation phenomenon including "Digitalization", "Digitization" and "Digital Business Transformation". Consequently, in the context of this research and with the sole purpose to avoid ambiguities the previous terms are defined and related to the Enterprise Architecture discipline. In order to provide a middle ground basis for key subject matters discussed in this research, the following section provides basic concept definitions regarding Enterprise Architecture and Digital Transformation. The concepts are delimited within the scope of the Business and Information Technology subject area.

Enterprise is defined as the collection of organizations that have common goals, covering all its missions and functions. On the other hand, architecture is defined as "*the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution*" (ISO, 2011). Both concepts are merged to form Enterprise Architecture, considered as the organizing logic of business, information systems, and technology in order to review, maintain and control the whole operation of an enterprise (Őri and Szabó, 2018). Consequently, in the context of Enterprise Architecture, the term enterprise *"can be used to denote both an entire enterprise, encompassing all its information systems, and a specific domain across multiple functional groups*" (Harrison, 2018). The main intention of an Enterprise Architecture is to determine how an organization can realize and achieve its current and future goals and objectives by aligning enterprise business functions with Information and Communication Technologies (ICT).

On the other hand, according to Gartner, Inc. (2020c), "*Digital transformation can refer to anything from IT modernization (for example, Cloud Computing), to digital optimization, to the invention of new digital business models.*" i.e. an operation or exercise to leverage new digital

technologies that enable major business improvements and influence all aspects of customers' life (Reis *et al.* 2018). Whereas a Digital Business Transformation defined by Gartner, Inc. (2020d) is known as "*the process of exploiting digital technologies and supporting capabilities to create a robust new digital business model*". Hence, stipulating a method of using technologies to structure changes and modifications of business processes, culture, and strategies of an organization to meet customer requirements and dynamic market demands. Further, Gartner, Inc. (2020e) defines Digitalization as "*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*". In practice, digitalization is how digital technologies allow computing to be implemented into daily activities that traditionally were considered to be performed by human beings (Zimmermann *et al.* 2018). Finally, digitization is the conversion of any analog resources to digital form (Legner *et al.* 2017) e.g. converting a specification from a specific business practice from paper to a digital document.

As depicted in Figure 4, the conceptual model illustrates the scope of the terminology previously defined in the context of an organization and its reach in relation to EA. From a bottom-up perspective, digitization can be implemented in the enterprise at the most basic level, where activities such as the digitization of information, provide the enterprise new ways to access and share data across all business units. EA provides a clear set of work to map these technological mechanisms in response to business needs. Digitalization initiatives are focused on delivering projects and employ technology to automate, optimize or modernize the business operations and processes of the enterprise.

Architecture and solution building blocks guarantee the logical integration of these complex relationships to deliver enhanced or new service capabilities. A vague distinction however between the Digital Business Transformation and Digital Transformation prevails since both terms relate to disruptive changes of new business models. Therefore, both concepts include the integration of digitalization projects to transform the business and its own strategy. Consequently, in the scope of EA, both concepts portray the extension and effective reach of the enterprise through digital capabilities. Essentially, since both Digital Business Transformation and Digital Transformation initiatives span over entire organizations and enterprises, these terms will be treated simply as Digital Transformation henceforth.

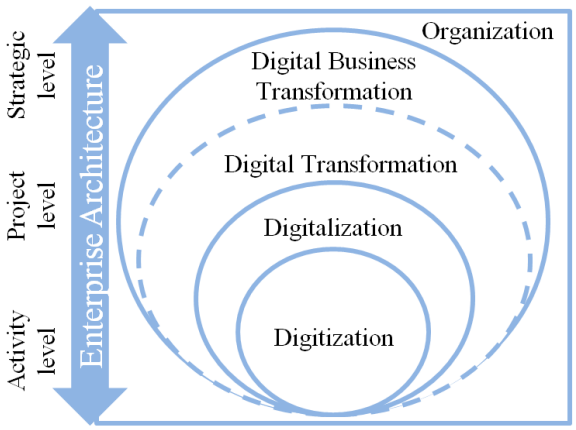


Figure 4. Digital transformation concepts in the context of EA

2.1.2 Enterprise Architecture in practice

Enterprise Architecture can be delivered in practice in multiple ways. Research and practitioner communities have introduced several frameworks, methodologies, reference models, among others, to help organizations achieve the right balance between business transformation and continuous operational efficiency. The main benefits of delivering EA in practice include better planning and improved decision-making processes based on well-structured and informed designs (The Open Group, 2018). The concept of frameworks built around Enterprise Architecture best practices set the foundational structures needed to develop architectures for organizations across multiple industries and domains.

Many organizations worldwide have committed to Enterprise Architecture best practices by adopting the most recognized frameworks such as TOGAF, FEAF, DoDAF, MODAF and Zachman. A framework describes a method for designing a target state of the enterprise in terms of a set of building blocks and for showing how these building blocks fit together (Harrison, 2018). In addition, it provides a common vocabulary, a set of tools and a list of recommended standards that can be used to deliver the building blocks. A framework allows an organization to simplify and speed-up architecture development, guarantee the materialization of a complete solution and effectively address the concerns of the main stakeholders of the enterprise (Lankhorst et *al.* 2009).

The increasing popularity over an entire decade and the great support from the EA practitioner community, holding a total of 266 architecture forum members (The Open Group, 2020), point out to The Open Group Architecture Framework (TOGAF) as an approved standard for developing EA in organizations, generic and not tied to a specific industry. In line with the intentions of this thesis, TOGAF is considered a critical practical element for the materialization of Enterprise Architecture and therefore a crucial tool for more effective and efficient Digital Transformation and IT operations (The Open Group, 2018). Moreover, the great majority of the frameworks for Digital Transformation retrieved from performing the SLR, described in the

following section are based on TOGAF, leaving no choice but to consider it a foundation of the intended artifact presented in this study.

2.1.3 The Open Group Enterprise Architecture Framework

The Open Group has developed throughout the years a well-established Enterprise Architecture framework known as The Open Group Architecture Framework. TOGAF has been developed through the collaborative efforts of the whole EA community (Harrison, 2018). As a best practice, the framework plays an important role in the organizations, reducing risks by standardizing the architecture development process. TOGAF serves the organizations as a generic architecture framework, employed as a best practice to portray the current needs and future needs of the business. The framework standard in its version 9.2 as depicted in Figure 5 reflects the architecture capability of an enterprise and is composed of the TOGAF Capability Framework, the TOGAF ADM and Content Framework, and the TOGAF Enterprise Continuum and Tools. Therefore, an organization that has the ability to effectively undertake the activities of an Enterprise Architecture practice consequently has an Enterprise Architecture Capability (Harrison, 2018). Moreover, the standard covers the development of four architecture domains composed of the Business Architecture, Data Architecture, Application Architecture, and Technology Architecture.

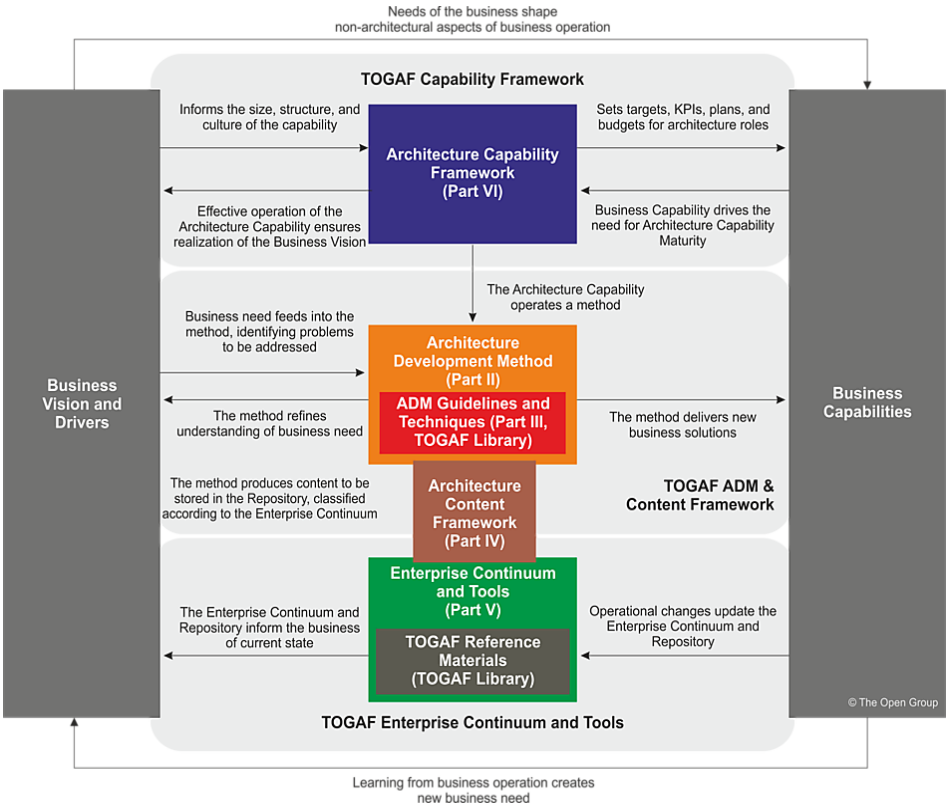


Figure 5. TOGAF 9.2 standard overview (The Open Group, 2018)

The suggested step-by-step cycle to develop EA, considered the core of TOGAF, is known as the Architecture Development Method (ADM). The ADM provides a tested, repeatable process for developing architectures that allow organizations to transform their enterprises in a controlled manner in response to business goals and needs (Harrison, 2018). Figure 6 illustrates the ADM cycle and its constituent phases. The cycle reflects the importance of competition that allows an architect to move from one stage to the next one. Moreover, a notion of interaction is expressed through the method, i.e. returning to a particular stage would require a competition of its subsequent phases.

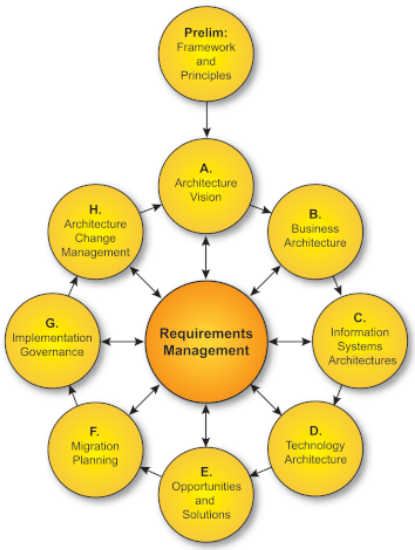


Figure 6. TOGAF Standard ADM cycle (The Open Group, 2018)

A brief description of all the phases of the ADM cycle is provided in Table 2. Each of the phases provides a set of activities with the intention to develop the appropriate architectural content. For example in the business architecture phase, the reference models and tools are selected, both baseline and target architectures are developed, a gap analysis is performed, candidate roadmaps are defined, impacts across the architectural landscape are resolved, a review with stakeholders is conducted and the creation of deliverables is undertaken. Similarly, as part of the Requirements Management function, every ADM stage is based on and validates business requirements.

The ADM cycle of TOGAF is designed as a generic method to meet most of the organizational requirements and copes with variable vertical sectors and industry types. Due to this wide range of applicability, The Open Group recommends to tailor or customize the method so that the organizations' specific needs can be satisfied. In addition to this, the cycle does not prescribe a specific order, it goes according to the priorities and principles of the organization to make use of the phases of the ADM cycle to achieve the desired business goals. Several publications including Harrison (2018), Lankhorst *et al.* (2009) and The Open Group (2018) further detail the TOGAF framework and its associated elements.

Table 2. ADM iteration cycles, stages and descriptions (Harrison, 2018)

Iteration Cycles	ADM Stage	Description
Architecture context	Preliminary Phase	Includes the preparation activities and initiation activities to create the Architecture capability. Architecture principles are defined in this stage.
	Architecture Vision	Sets the scope, constraints, and expectations for a TOGAF project. Stakeholders are identified and the business context is validated.
Architecture delivery	Business Architecture	Describes the fundamental organization embodied in the business process and people to support the agreed architecture vision.
	Information Systems Architecture	Documents the major types of information and application systems that enable the business architecture and consequently the architecture vision.
	Technology Architecture	It contains the embodied software and hardware that support previous architecture stages. Represents the fundamental organization of IT systems for the entire enterprise.
Transition planning	Opportunities and solutions	Describes the process of grouping projects into work packages for the delivery of target architectures defined across the previous phases.
	Migration Planning	A migration plan is detailed describing how to move from the baseline to target architectures.
Architecture governance	Implementation Governance	Provides oversight for the implementation of the architecture i.e. ensures that the implementation is compliant to the architecture.
	Architecture Change Management	Established the required procedures for managing change to the new architecture. Monitors that the architecture responds to the needs of the enterprise.

2.1.4 EA Modelling Support Tools and Notation

The intended Enterprise Architecture framework for Digital Transformation delivered as part of this thesis presents multiple architecture models across multiple views of the enterprise. Therefore, the ArchiMate® Enterprise Architecture standard (The Open Group, 2019b) is used as the modelling language that provides a unified specification of architectural domain elements depicted throughout the Implementation and Validation section of this document.

2.1.4.1 The ArchiMate Language

The ArchiMate Enterprise Architecture standard serves organizations with a visual language for describing, analyzing, and communicating concerns and solutions to the stakeholders involved in the Enterprise Architecture. Furthermore, it provides a complete set of entities and relationships for the proper representation of architecture models. An essential goal of ArchiMate is to deliver means for integration so that models can be created that depict high-level structures within domains and the relationship between domains (Lankhorst *et al.* 2009). In the context of Enterprise Architecture in practice, domains refer to the architecture domains of TOGAF later introduced in section 2: Problem Investigation section. In line with the principle of "Keep it simple", this research appropriates the meta-model simplification of ArchiMate 3.1 adopted at Intel to develop Enterprise Architecture models and views (BizzDesign, 2018). The simplified version is limited to use 30 out of the 74 elements of the original meta-model and 8 out of the 14 relationship types defined in ArchiMate 3.0. Figure 7 depicts the elements chosen elements.

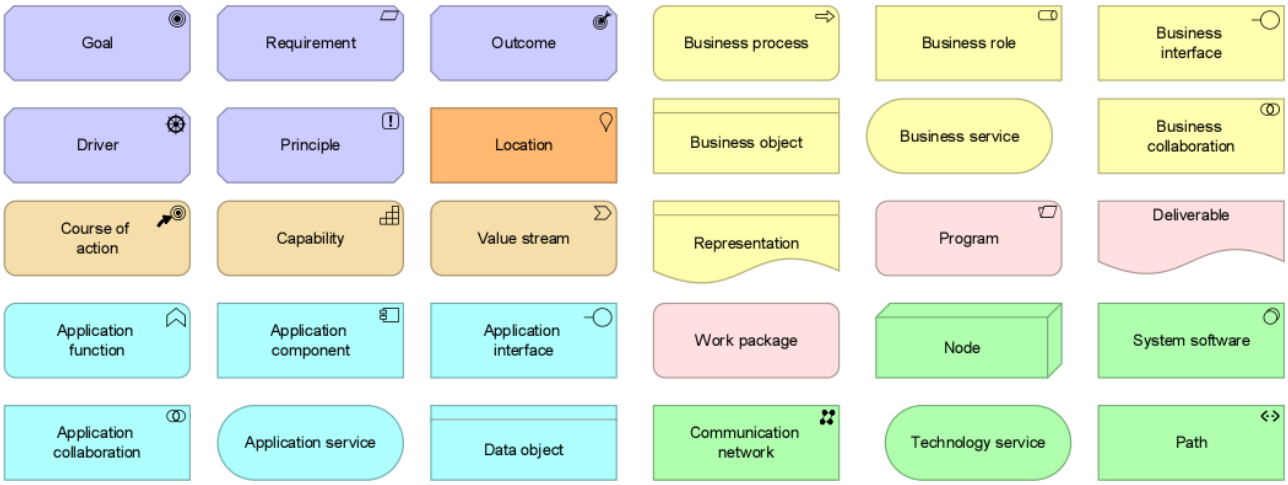
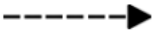


Figure 7. ArchiMate Meta-model selected elements (The Open Group, 2019b)

Table 3 summarizes the relationships defined by the ArchiMate 3.0 specification to be incorporated into the simplified-meta model.

Table 3. Selected ArchiMate relationship types with description and notation (The Open Group, 2019b)

Relationship Type	Description	Notation
Specialization	It represents that an element within the model is a particular kind of another.	
Realization	Represents than an element assist in the materialization of a more abstract entity.	
Aggregation	The element represents that an element combines one or more other elements.	
Serving	Represents that an specific element supplies its functionality to another element	
Association	Represents a generic relation between two elements that cannot be cover with other types	
Assignment	The relationship embodies the assigment of responsibility, performance of behaviour, storage or execution.	
Composition	Represents the existence of dependency between one or more elements i.e. one element consists of one or more other concepts.	
Flow	Used to model the simple flow between one element to another element e.g. information good or money.	

2.2 Systematic Literature Review

The initial literature search yielded a total of 309 articles. After applying the exclusion and inclusion criteria a total of 215 results were retrieved. Further reading and detailed inspection of the papers as well as the removal of duplicates from papers found at more than one database led up to a total of 26 articles, where 4 additional references were added as a backward reference search process. The final number of literature and studies selected for this research resulted in a total of 30 papers respectively. Figure 8 summarizes the process of retrieved and selected papers at each stage of the systematic literature review, where *n* denotes the total amount of articles at each stage.

Results from classifying the body of knowledge are further documented in the *Research Topics*: *Examining Enterprise Architecture for Digital Transformation* report in preparation for this thesis. Therefore, the following section assembles the theoretical foundation needed to design the Enterprise Architecture Framework for successful Digital Transformation.

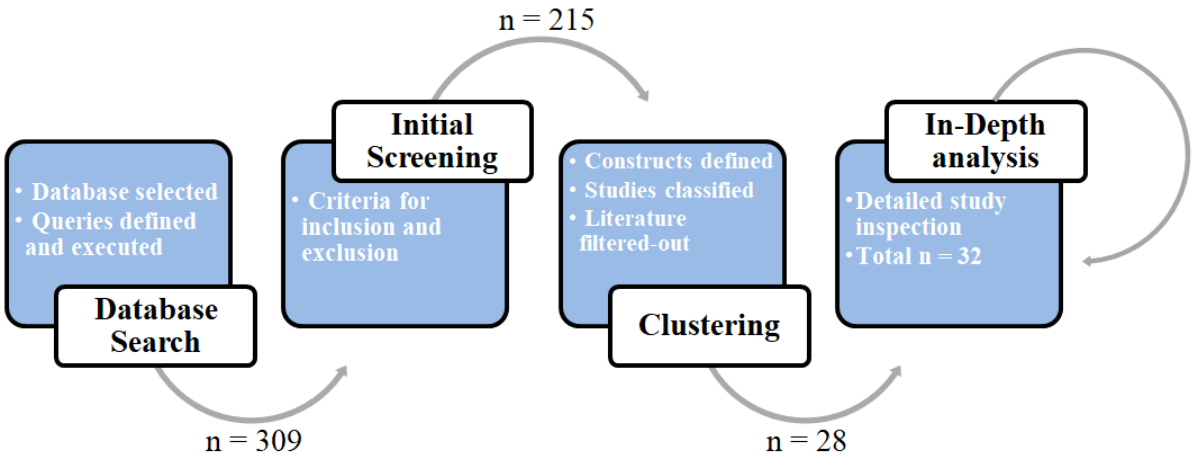


Figure 8. Study selection process and results

2.2.1 Enterprise Architecture Foundations for Digital Transformation

The foundations discussed in this section represent the pillars that must be contemplated in the EA practice to cope with the nature and constituents from Digital Transformation initiatives discussed in the introduction. As a result, this section tackles research objective 1.d.

Four major elements are found to be inherent to Digital Transformation projects in contrast to the EA discipline. Table 4 lists such elements as a way to differentiate both positions and reflect how EA can benefit from addressing new challenges posed by Digital Transformation. Based on these elements, further insights are provided according to findings extracted from the literature.

Table 4. Elements from EA related to DT initiatives based on Goerzig & Bauernhansl (2017)

Element/item	Enterprise Architecture	Digital Transformation
Development approach	Waterfall	Agile
Subject	Transactional stable systems	Customer-oriented/Fast changing service systems
Value stream	IS for stable value chains	Ecosystems and sensitive value creation
Driver	IT-focus	Business-focus

2.2.1.1 Customer journey, experience and value creation streams

The concept of customer journey i.e. a customer's continuous engagement with an organization's products and services constitutes a crucial facet in the nature of Digital Transformations. Therefore companies pursuing customer engagement strategies with digital transformation are intended to capture customer loyalty and trust by providing superior, innovative, personalized and integrated customer experiences (Sebastian *et al.* 2017). Additionally, the new era of digital technologies enables greater involvement and engagement between customers and organizations than ever before (Babar & Yu, 2019). Customer experience and *project-to-product* shifts are the major drivers for companies to embark on a digital transformation initiative. Architecture building blocks placed into adaptive operation models that comply with both digital and agile transformations will translate into successful customer journeys (The Open Group, 2019).

Traditional EA methodologies focus on Information Systems for stable value chains and customer needs, whereas digital transformation works with ecosystems and context-sensitive value creation (Őri & Szabó 2018). Organizations developing Digital Transformation initiatives should not only be prepared to embrace continuous changes in business processes, information systems, and technology domains but also be aware of the value creation streams embedded into those domains to successfully materialize improved customer journeys and experiences. These particular elements essential into DT projects now have to be tackled by new enterprise architecture practitioners. New technologies and digital transformations can assist in setting the basis of what customers need. Customer experience starts with companies who discover their customer needs instead of asking for them directly (The Open Group, 2019). Analysis of customer journey and *job-to-be-done* are approaches on which companies are relying on, therefore creating opportunities for improvement in the current EA practice where such perspectives are not entirely handled. A successful rollout of a Digital Transformation strategy essentially comes to the alignment of its four different dimensions: use of technologies, changes in value creation, structural changes and financial aspects (Matt, Hess & Benlian, 2015). Enterprise Architecture must lie in the middle of the DT phenomena, managing dynamic organizations with multiple needs moving at different speeds.

2.2.1.2 Architecture agility and evolution

Current EA mechanisms are built to map complex structures in organizations that are perceived to be moving at the same speed. Current architecture approaches must integrate designs built for today's digital enterprise, in such ways that established organizations are able to leverage their existing and legacy foundations including but not limited to IT architecture (Bossert, 2016). In contrast to software development, EA is based on waterfall mechanisms whereas digital transformation relies on an agile approach. Moreover, lifecycle phases adopted by EA include development-maintenance-documentation, where agile adopts development-usage-maintenance-documentation (Őri & Szabó 2018).

The high-level speed of organizations must be a result of how its internal agile teams work autonomously, not at the expense of effective alignment with the strategy and shared purpose of the enterprise (The Open Group, 2019). Rigidities raised by creating dependencies across teams negatively affect operational excellence. Proposals and modifications to current EA approaches consider architecting effective adaptive operating models. Consequently, extensions of such models must support guided and incremental change across multiple dimensions of evolutionary architectures (Ford, 2017). Emerging technologies implemented as part of Digital Transformation initiatives reduce significantly product development lifecycles and increase product release cadence, expecting that enterprises rely on adaptable and rapidly configurable business processes and companying IT systems in order to deliver appropriate products and services with significant agility (Babar & Yu, 2019).

Enterprise Architecture and their practitioners have been criticized for "Big Design Up-front", where conventional approaches impose rules and guidelines preventing simple projects to adopt practical solutions and quick adaptations to change (Nandico, 2016). Shorter time to market and higher quality of products and services are outcomes from promoting faster learning cycles in a digital and agile transformation of the enterprise. These are characteristics meant to be integrated under a new EA practice for DT. Agility can also be seen in the integration of technology and operations (T&O) analysts to form T&O teams, who rationalize with business counterparts to sort out technology platforms as part of digital standardization strategies, hence setting the foundations for EA development (Sia, Soh & Weill, 2016). Architecture change and evolution should be managed but also monitored. Proper evolution of the enterprise and its artifacts need to be supported by observe-and-response mechanisms placed at different levels of the architecture e.g. business and technology layers. These so-called sense-and-response loops provide the foundations for which the enterprise continuously adapts and improves (Babar & Yu, 2015; 2019). For instance, joint forces from human and machine collaboration are to be modeled and mapped throughout business and technology domains to determine causes and justify the need for change.

2.2.1.3 Architecture modularity

Easy ways to adopt architectures are also one of the main requirements from DT initiatives to Enterprise Architecture approaches. Current EA practices prescribe methods that impose cycles that should be followed from start to finish. To effectively cope with the agile and constantly evolving enterprise, EA practices should be modular instead of integrated. Extensive and complex integrated architectures create rigidities across domains. "*Modularity is about decomposing a system into parts that are loosely-coupled*" (The Open Group, 2019), where the system is any type of entity from a human or social to technical. Different segments of the architecture move at different speeds e.g. customer-oriented architecture and transactional architecture for the operational backbone (Bossert, 2016). Thus, IT architecture domains, for instance, provide independent mechanisms with collective units to seamlessly improve customer

experiences. Modular architectures that follow service-oriented concepts facilitate interoperability, sharing of data as well as its management (Helfert, Melo & Pourzolfaghar, 2018).

Enterprise Architecture approaches should comply with mechanisms of modularity brought by business units that work at different paces. In response to modularity, EA must integrate different governance and organizational structure of bimodal IT teams (Horlach, Drews & Schirmer, 2016). Digital Transformation projects require agile ways to innovate and respond to dynamic customer demands. Therefore EA techniques must deal with them at different levels including processes, applications, and infrastructure. In a way, EA development should align with some of the software architecture techniques that foster quicker, efficient and innovative ways of transforming organizations. Starting with agile (Fowler & Highsmith, 2001), followed by services-oriented concepts, interoperability, continuous delivery, and continuous integration, EA can significantly help organizations to respond quicker than traditional methods and approaches.

Out of the boundaries of software architecture and its contributions, in order to materialize DT projects, EA approaches must think modular, cross-functional and distributed business processes that allow integration into ecosystems (Goerzig & Bauernhansl, 2017). These particular ecosystems are self-contained and self-adjusting systems that when grouped they create value. Materializing Digital Transformations through modularized architectures will bring flexible, adaptable and agile enterprises resilient to change while retaining value delivered to customers.

2.2.1.4 Sociocultural alignment of the enterprise

In order to cope with agile and flexible ways to work, organizations undertaking Digital Transformations projects are required to consider changes in roles and responsibilities across multiple business units. These changes must be delivered consistently while considering systematic changes in processes, technology, and data. Understanding such associations is a challenge while factoring complexities of EA design, where aspects such as culture and social alignment should be also a priority (Babar & Yu, 2019). This requirement goes beyond traditional organization structure and mapping established in current EA practices by imposing new ways to collaborate among actors, minimizing inter-team dependencies and inter-silo coordination (The Open Group, 2019). Examples of results from successful alignments of social, technological, cultural and process perspectives are DevOps and Agile oriented teams.

"*Changing the organizational structure is not enough. It is key to change the culture, the ways of working, and the management system*" (The Open Group, 2019). Digital transformations transcend conventional architectural principles, striving organizations into new ways of operating and most importantly, collaborating. EA approaches should absorb new DT-driven culture across the entire enterprise and outline its relationships across actors, technology, data, and underlying business processes. Data-driven decision making, data-sharing, peer trust, team autonomy, and agile development are examples of how organizations foster DT cultures in

organizations and EA must be able to relate, structure and integrate these elements in the best possible way.

2.2.2 Enterprise Architecture practices for Digital Transformation

Enterprise Architecture practices are defined through a great variety of tools, techniques, methods and frameworks. This section examines the state-of-the-art regarding EA approaches in the context of Digital Transformations. Hence, these subsections address research objective 2.a.

2.2.2.1 Architecture frameworks

The Open Group Agile Architecture Framework™

Though recently launched, The Open Group has published the Open Group Agile Architecture Framework™ or OAAF (The Open Group, 2019), oriented to cover both the Digital and Agile transformation of the enterprise. OAAF provides the essential core concepts of agile architecture, playbooks as guidelines to solve agile architecture problems, patterns that describe types of solutions that can be applied to a variety of problems and finally methods, developed to solve problems using hands-on experiences. As this represents a first version of the framework, The Open Group refers to the specification as a "Snapshot" instead of an approved standard. Topics and key concepts covered by this snapshot version of the framework include: continuous architecture in an Agile world, designing business models, discovering and analyzing customer insights, architecting digital platforms, architecting an adaptive operating model, architecting the enterprise's Digital Transformation, defining a Minimum Viable Architecture (MVA) and finally, leveraging event-driven architecture to design modular systems and modernize legacy systems.

The framework highlights the importance of how the Digital Enterprise is complemented by the Agile Enterprise and vice versa. Companies walking the trail of Digital Transformation face great challenges of adopting digital models from using legacy systems while committing resources and efforts to become an effective and agile enterprise. The modular framework is meant to assist architects to shape Digital Transformations by including systems thinking view of architecture formulation (combining both emerging and intentional design), modularity and loosely-coupling to foster agility, dictionaries to bridge concepts of each discipline and an outside-in framework that starts from clients' pains and expected gains. As depicted in Figure 9, the dual transformation of the enterprise is motivated by two major components: customer experiences that influence Digital Transformation and project-to-product shift which embodies Agile Transformation.

The OAAF framework relies on bringing together each domain of the enterprise with its own body of knowledge to deliver high-quality products and services to customers. As an illustration, marketing brings new disciplines such as design thinking, IT provides flexible and adaptive

technologies by adopting Agile ways of working, and business operations are looking to leverage automation provided by software platforms in order to develop operational excellence. Therefore OAAF recognizes the value of each concept brought by each discipline including domain-driven and event-driven design, job-to-be-done, design thinking, etc. Additional modeling concepts such as capability modeling help to guide the modular decomposition of the enterprise and its systems.

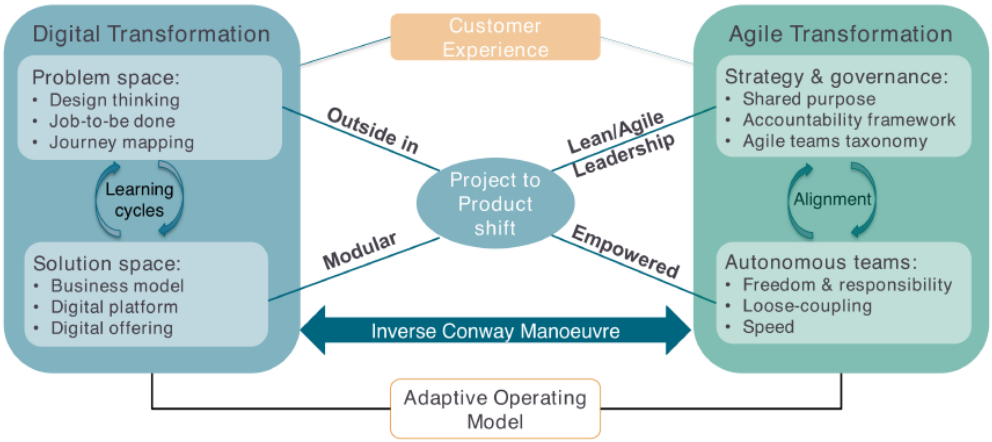


Figure 9. O-AAF Big Picture (The Open Group, 2019)

In contrast to other EA frameworks who require big design upfront, the OAAF is designed as a "*plug and play*" framework where organizations identify the elements required to be changed using OAAF the agile architecture foundations and proceed to the framework's playbook to enable the change. Further, the framework does not prescribe a process or a strict order; architects can refer to playbooks as the tools and start steering the organization to real digital transformations. Despite the recognition granted to the development of TOGAF by the community of practitioners, the OAAF is proof that existing frameworks and methodologies are not enough for organizations to walk the difficult trail towards successful Digital Transformations. A brief discussion of the main fundamental concepts and guidelines provided by OAAF are presented below. The fundamentals concepts outline the building blocks of the framework, whereas the guidelines offer solutions to solve different agile architecture problems.

OAAF Fundamental and Building Blocks

Continuous Architectural Refactoring

An important aspect of developing architecture is considering its "evolvability" i.e. the ability for the architecture to be changed or evolve over time. The architectural refactoring needs to be guided and incremental (Ford, 2017). In the TOGAF standard, for instance, the concept of architecture evolution is related to Change Management. However, the concept goes beyond the adoption of a monitoring process for managing architectural changes based on individual requirements. The increasingly fast pace of the technological industry, the adoption of Agile

approaches at scale, the failure of expensive high-profile long-running projects have made organizations built-in "ease-of-change". Evolutionary architectures are the ones that have no end-state (Ford, 2017). The framework presents three enablers or considerations for planning for successful continuous architectural refactoring as described in Table 5:

Table 5. OAAF considerations for continuous architectural refactoring

Enabler/Consideration	Objective
Understanding and Guiding the Architecture	Aims at understanding the conditions under which the organization operates and influences the architecture evolution, and placing the necessary structures that will allow the architecture to evolve within those constraints. Three key components of the enabler are: 1. *Constraints:* Forces that influence architecture evolution e.g. financial, cultural, technical, regulatory, political, time-based. 2. *Fitness functions (Ford, 2017):* Allow architects to ensure that systems' characteristics remain constant over time. Represent a physical tangible manifestation of constraints and architecture goals. 3. *Guardrails:* Are conceived as lightweight governance structures preventing people to get off track based on what the organization is expected to do.
Creating the Right Technical Environment	Reinforces the concept of empowering teams to iteratively make architectural changes by embracing the practices of continuous integration and continuous delivery (CI/CD), and componentization. The latter leads to the development of loosely-coupled architectures to support the organizational evolution on an ongoing basis. CI/CD, on the other hand, prevents the formation of "long-running" branches by integrating developers' work into unified build processes and allows developers to make architectural changes with the confidence of not breaking any functionality that directly impact business users.

Enabler/Consideration	Objective
Creating the Right Non-Technical Environment	Poses the importance of developing an architecture roadmap, as architecture refactoring needs to be guided and incremental. A roadmap should meet the following key criteria to achieve continuous architecture refactoring: - *Vision:* A target end state is established as a way to assess individual changes. - *Step-wise:* intermediary steps need to be included between "as-is" and "to-be" states. - *Flexible:* Target and intermediary states may evolve as the understanding of the architecture and its constraints evolve. - *Open:* The architectural roadmap is available to the whole team and everyone must feel empowered to comment on it.

Architecting the Digital Enterprise

As illustrated in Figure 10, the core of the enterprise, the new digital age requires organizations to shift from outputs to outcomes-driven architectures. An interesting point of view, from a car manufacturing company, is the way they look at the product based on how the customer uses it rather than how it is created/delivered. In addition, modularization design stimulates the composition of systems in parts that are loosely-coupled. This brings many benefits: first, it enables parallel working in order to shorten capability or product development lead times, second, reduced impact introduced by changes in segments of the system, therefore, making it resilient to change, and third, failures in part of the system are less likely to propagate to the entire system. These constituents for architecting the Digital Enterprise are supported by the Set-based Concurrent Engineering (SBCE) method coined by Ward & Sobek (2014) in contrast to the Big Design up front styles.

Enclosing the model in Figure 10, key areas of development are identified. The business model is critical to elaborate on the innovative value proposition to be delivered by digital services/products. Moreover, strategic marketing enables the enterprise to discover what the customer wants and how the competition (if any) provides it. Customer insights provide key inputs to help define an innovative value proposition, whereas customer journeys help teams and management "walk in the shoes" of their customers. The digital platform acts as an enabler that scales and grows rapidly and efficiently, providing business models high levels of automation and self-service capabilities. Ultimately, the adaptive operating model takes advantage of modularity and composability to gracefully adapt to changing customer experience requirements. Tools such as service blueprinting help to bridge customer journeys with required and to-be-developed capabilities.

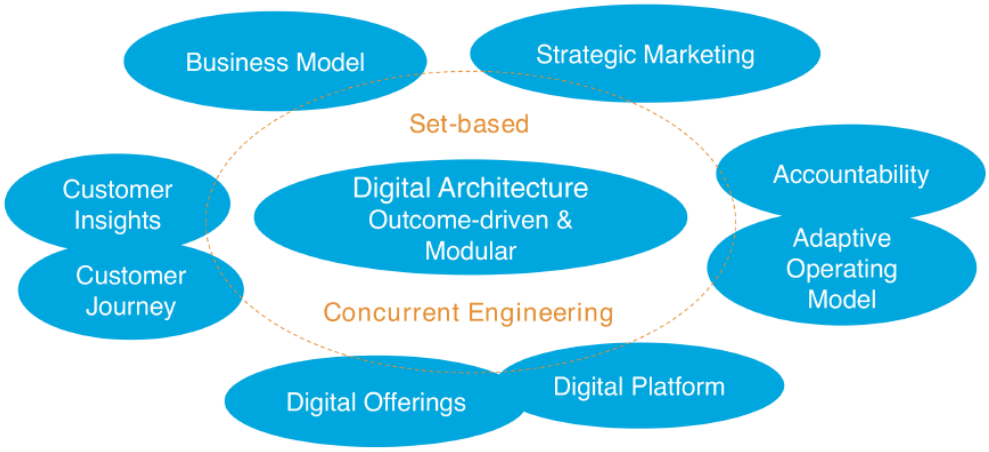


Figure 10. Architecting the digital Enterprise (The Open Group, 2019)

Architecting the Agile Transformation

The OAAF constantly reminds us that architecting the digital enterprise goes hand-in-hand with architecting the agile transformation. This building block refers to the importance for the organization to cover three major areas: first, adopting a new way of working, second, deploying new management systems and third, changing the organizational structure. This new way of working encourages rapid iteration and experimentation which promotes continuous learning, fact-based decision making, cohesive cross-functional teams coached by leaders and lastly, performance orientation by peer pressure. In essence, the organizational structure is flattened where the management system cascades goals at all levels of the organization and promotes constructive dialog. The framework highlights the importance of the inclusion of the enterprise culture as an additional dimension towards the agile transformation. Figure 11 depicts the model of how the agile transformation can be assessed, where changes to a dimension will require the deployment of new elements on another.

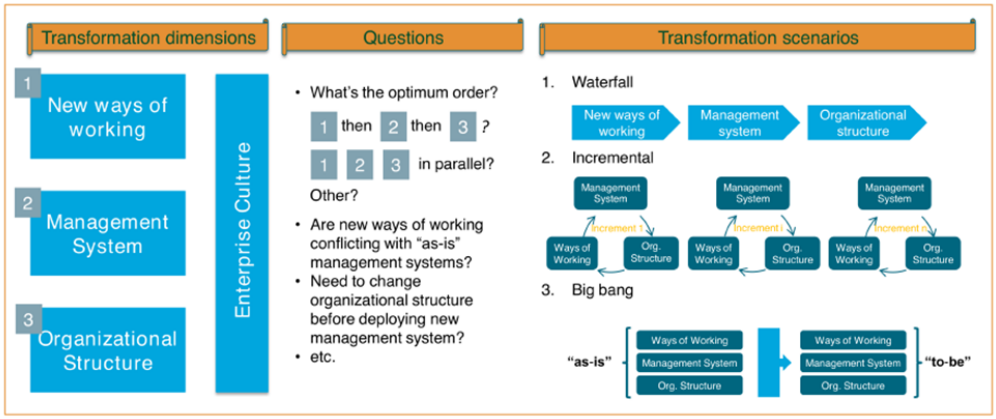


Figure 11. Agile transformation proposition (The Open Group, 2019)

OAAF Playbooks and Guidelines

Minimum Viable Architecture

The concept is mainly based on the term Minimum Viable Product (MVP) coined by Ries (2011) defines as: "*that version of the product that enables a full turn of the Build-Measure-Learn loop with a minimum amount of effort and the least amount of development time*". The purpose of MVP is to assess whether or not a product meets customer expectations, minimizing the time and investment required to experimentally verify the product. Its adoption has become increasingly popular where agilists have coined the term Minimum Viable Architecture (MVA).

Rather than embracing the concept as a good enough architecture by opposition to big-up-front designs, or the minimum architecture work required to create an MVP, the OAAF associates MVA to the minimum definition of the intended architectural vision entirely based on the heuristics for structuring architecture decisions. The heuristics include: focusing on focusing on decisions that require architectural thinking, delay architecture decision supported by Set-Based Concurrent Engineering (SBCE) to optimize when architecture decisions are made, the inclusion of evolvability as a key non-functional requirement, and adoption of "sacrificial architectures" (Fowler, 2014) as part of experimenting with MVP.

Adaptive Operating Model

The rise of the complexity of the digital enterprise requires going beyond process architectures toward rethinking operating models. Designing operating models starts from a clear formulation of the enterprise value proposition according to specific variables e.g. value delivery chains, organization structure, location, information exchange, suppliers and management system. OAAF characterizes the adaptive operating model by a flatter and modular organization, with a loosely-coupled information system and autonomous accountable teams driven by an agile culture.

The modular nature allows the operating model for a "plug-and-play" reconfiguration in response to evolving customer feedback. Later on, analysis of customer journeys can be performed at every stage of particular processes, identifying channels that support the interactions with the user as well as the required or missing set of capabilities. Figure 12 illustrates an example of service blueprinting as a tool to analyze customer journeys.

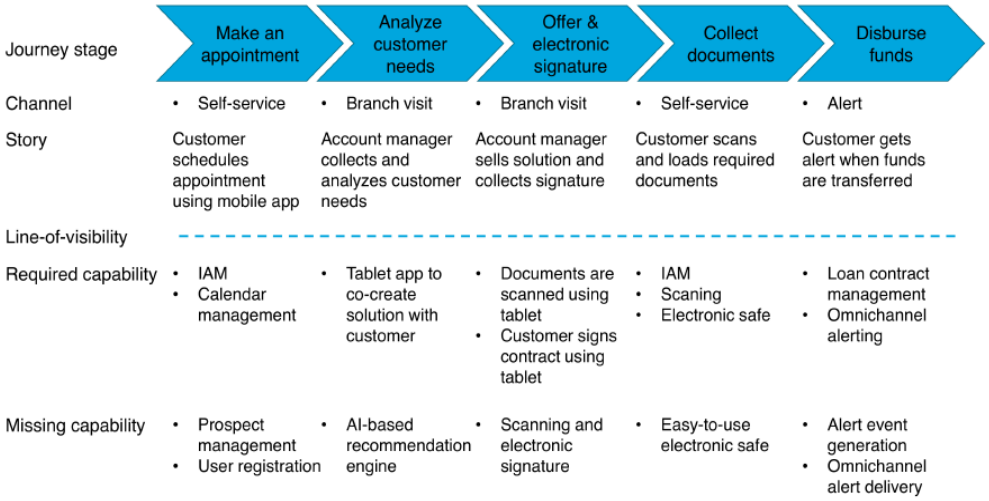


Figure 12. Customer Journey service blueprinting (The Open Group, 2019)

Agile Governance

The TOGAF Standard defines governance as: "*the ability to engage the involvement and support of all parties with an interest in or responsibility to the endeavor with the objective of ensuring that the corporate interests are served, and the objectives achieved*". Governance is conventionally required to reconcile what can be described as conflicts of interest, agreements, responsibilities and keep updated involved stakeholders on the contracts that have been made. In Agile, governance is a balancing act between accountability to a contract and the autonomy of teams to ensure that goals/objectives are achieved. An Agile governance structure must adhere to known bodies of regulation i.e. Corporate and IT governance while developing the Enterprise Architecture aligned with the goals and objectives of the organization. Policy-making groups still exist, but architecture models are not imposed or defined by them. It should be an outcome as a result of the collaboration from IT and business units. Co-creation is an important feature of agile governance delivered through cooperation teams such as centers of enablement or innovation hackathons.

Legacy Integration and Modernization

Legacy systems are still growing in size and complexity for many of the organizations embarking on Digital Transformation initiatives. The need to connect new digital capabilities and modernize legacy applications is achievable by a progressive journey from monolithic to modular architectures. In other words, the objective of this guideline is to provide a roadmap to help progressively architect the overall system into a loosely-coupled one. Figure 13 illustrates this journey. The steps toward modularization are briefly described as follows:

1. Build RESTFul API domain extensions to the legacy systems. The use of mediation technologies is required to translate the legacy data types into API data types.

2. Segregation of both the Front-end and Back-end development by jointly defining APIs that cater the need from both sides.

3. Begin modularizing the monolith by formalizing boundaries between sub-domains.

4. Increase modularization by creating microservices aligned with the context of the boundaries, with the help of Domain-Driven Design (Evans, 2003). Shift toward event-orientation by implementing Event Sourcing patterns.

5. Shift from ACID to BASE (Basically Available, Soft State, Eventual consistency).

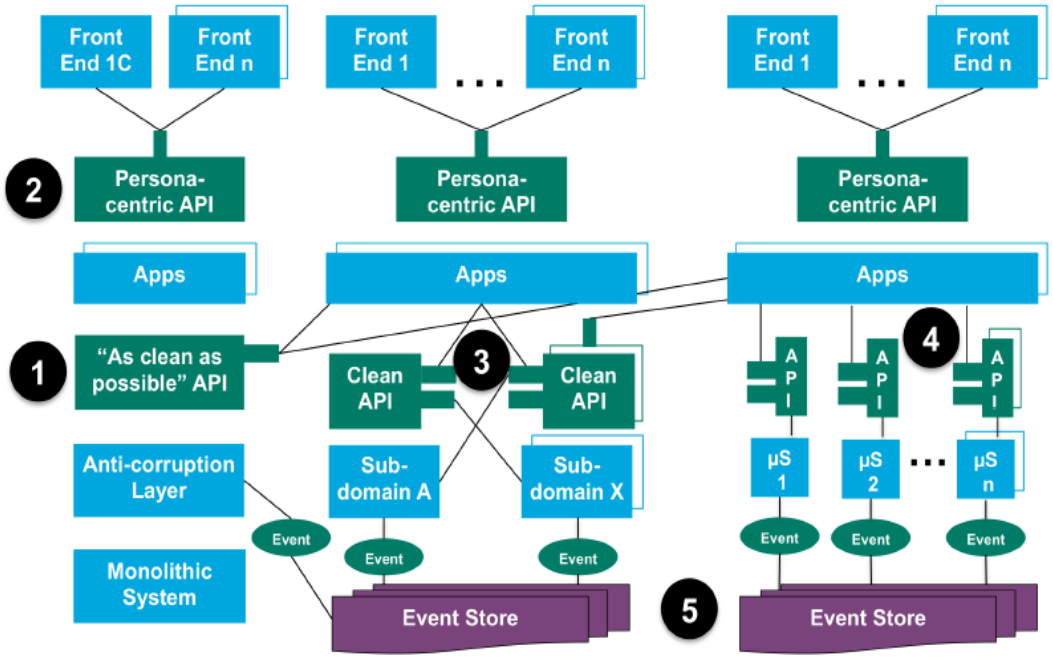


Figure 13. Monolithic to modular journey (The Open Group, 2019)

Adaptive Integrated Digital Architecture Framework

As proposed by Masuda & Viswanathan (2019); Masuda *et al.* (2017), the Adaptive Integrated Digital Architecture Framework (AIDAF) supports and promotes IT strategies toward Digital IT. Technologies leveraged by this framework are Cloud Computing, mobile IT and Big data. Additional concepts include an architecture assessment model, a global communication/knowledge management model and a risk management model integrated into AIDAF. Additionally, it complies with agility elements brought by new Digital IT application systems while coping with each phase defined in System Development Life Cycle (SDLC). An overview of the strategic architecture framework is shown in Figure 14, where the main components of AIDAF and related models are placed across two separate dimensions; the elements of agility published by Gill (2014) composed by speed, responsiveness, feasibility, leanness, and learning in the vertical axis and the phases of SDLC in the horizontal axis.

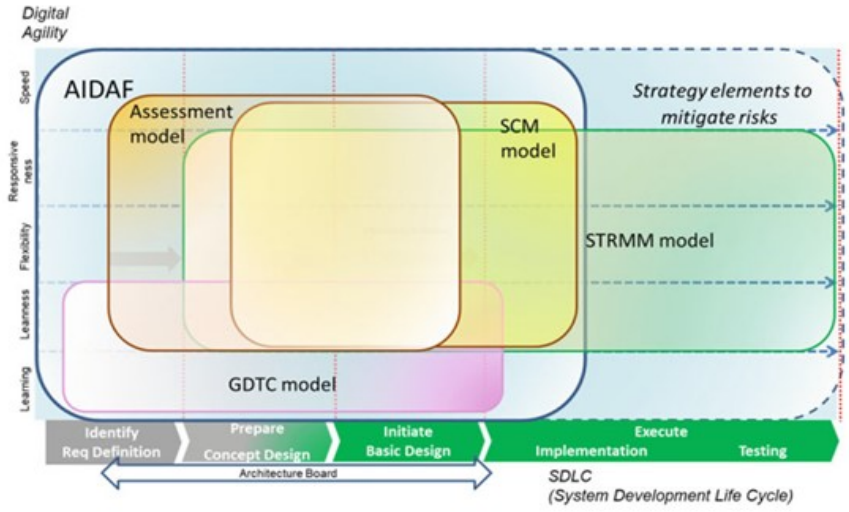


Figure 14. Strategic architecture overview AIDAF and related models (Masuda & Viswanathan, 2019)

The elements and related models of the AIDAF framework are composed into:

1. *Adaptive Integrated Digital Architecture Framework—AIDAF:* Represents the overall architecture structure of an adaptive framework to promote digital transformation through the adoption of technologies such as Cloud Computing and mobile IT. The model integrates both EA frameworks such as TOGAF and the Adaptive EA cycle model as illustrated in Figure 15.

2. *Assessment meta-model in Architecture Board:* Embodies the board for architecture review regarding solution architectures of the new digital IT projects on the basis of defined evaluation criteria. The assessment model assists in reviewing requirements in shorter times to respond to concerns and business requirements with a lean structure of architecture deliverables such as roadmaps, as-is (i.e. current) and target architectures.

3. *GDTC model for global communication on enterprise portal:* The Global Digital Transformation Communication (GDTC) model consists of the effective knowledge management process on digital architectures reviewed by the architecture board as part of AIDAF. It provides the mechanisms for which architecture artifacts are shared involving architecture guidelines on a learning basis.

4. *Social Collaboration Model for Architecture Review in Architecture Board (SCM):* Enacts as the collaboration and communication mechanisms offered to the architecture board performed on the enterprise portal and social networking services of the organization. SCM aims at achieving great collaboration between the Architecture Board, top management and PMO members.

5. *Strategic Risk Mitigation Model for Digital Transformation (STRMM):* Represents the risk mitigation model toward digital transformation. Risks are mapped based on the actions performed by the Architecture board review, where proper mitigation strategies are suggested.

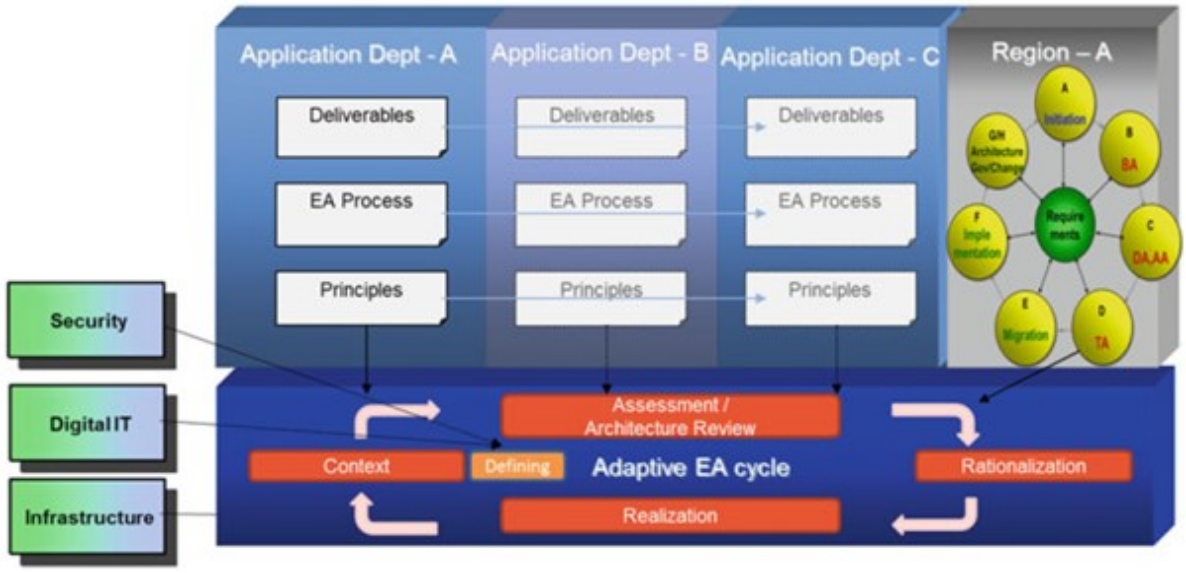


Figure 15. AIDAF proposed model with TOGAF (Masuda & Viswanathan, 2019)

Essentially, the EA framework depicts in Figure 15 the integration of an EA Adaptive cycle (lower section) with TOGAF or any other simple EA framework (upper section) for different business unit divisions. The Adaptive cycle provides initiation documents, including conceptual architecture designs, for new cloud/mobile IT-related projects that are constantly elaborated on a short-time basis. TOGAF and other simple EA framework based on business or operational units are able to respond to different policies and strategies from a mid to long term perspective. Therefore the upper-level of the framework allows the selection of an EA framework in line with the characteristics of each business division operational process and future architecture.

The Lightweight Enterprise Architecture Framework

Nandico (2016) proposes a lightweight Enterprise Architecture framework for organizations confronted with Digital Transformation scenarios with an agile development approach. As illustrated in Figure 16, the framework itself is based on TOGAF, adopts definitions of its content meta-model and follows the Architecture Development Method (ADM). Service-oriented architecture building blocks set the foundations of this approach, focusing on self-contained pieces of work with specific business purposes as atomic elements for any architecture. Further, the framework is intended to be used as minimalistic as possible, where core viewpoints and vital pieces of information are collected, structured and maintained by the architecture team.

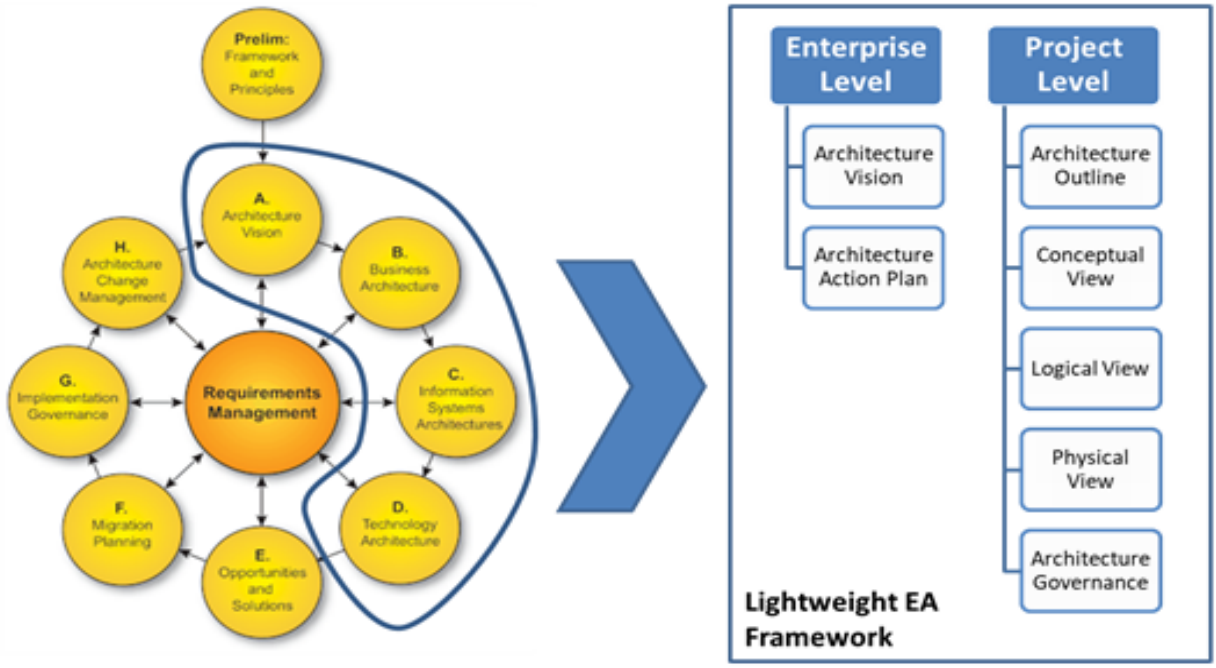


Figure 16. TOGAF ADM for LEAF

LEAF is characterized for structuring its deliverables from two different, yet aligned perspectives: the enterprise level and the project level. The enterprise-level aims at providing high-level representation of business domains and logical components to be placed in pursuit of the target architecture and how this latter gets implemented addressing properly the stakeholders concerns. On the other side, the project level results in a more detailed blueprint of individual defined projects that enable a digital transformation program. Table 6 provides a brief description of the viewpoints in the LEAF approach for Digital Transformation initiatives.

Table 6. Viewpoints from Lightweight Enterprise Architecture Framework (Nandico, 2016)

Viewpoint	Description
Architecture Vision	Compiles Business Domains models (abstract areas of knowledge, rules, policies, views, etc.) from top-level value chains. Further statements per domain are described and a view of high-level logical components is produced based on business requirements, objectives, and goals.
Architecture Action Plan	Describes the measures (e.g. business and technological capabilities), required to get the target architecture implemented. Outlines the set of work required to develop and deploy the architecture required to deliver a DT program.

Viewpoint	Description
Architecture Outline	Ensures that individual projects of the DT program contribute to the action plan and to the realization of the architecture vision. Projects are placed into the domain models and requirements aligned with stakeholders.
Conceptual View	New business services are determined at the right granularity from required business capabilities in the architecture context. Business services are mapped and related to defined business domains.
Logical View	Application services derived from business services are structured into logical application components i.e. ideal to-be applications, differentiated by business domain. Associated technology to be applied goes according to architectural knowledge.
Physical View	The usage of Commercial-off-the-shelf software or Cloud solutions is evaluated to cover logical components and their respective services. Gap analysis is performed to check the coverage of provided information systems and fulfilled requirements.
Architecture Governance	Deviations are drawn from checking the actual project architecture against the architecture outline. Mitigation actions should be undertaken to alleviate deviations from the architecture vision and architecture action plan.

2.2.2.2 Architecture methods

In contrast to Enterprise Architecture frameworks for Digital Transformation, methods found in the literature address a specific set of concerns across several domains of the enterprise. A set of simplified reference architectures, models, processes, analysis techniques, top management questionnaires, etc., integrate the body of knowledge as additional mechanisms to enhance current architecture approaches.

It has been clear that data-driven approaches are essential to enhance existing business processes, achieve operational excellence and improve customer intimacy (Gartner, Inc. 2017). Thus, the overall performance of the organization increases when decisions are made supported by existing data and information. As seen in Dremel *et al.* (2017), an organization can benefit from creating separate business units to handle innovation projects for Digital Transformation. Thus, a clear

need to restructure organizational business units was performed by creating a so-called "Innovation Hub" to leverage Big Data Analytics. Consequently, interdisciplinary collaboration was exploited between the IT, the Innovation Hub, and the sales and marketing departments. Capability Management (CM) should be integrated as part of the core process to create cross-functional teams to develop successful data-driven strategies within organizations.

An aggregation of approaches called "Digital Innovation and Transformation Process (DITP)" is proposed by Wißotzki & Sandkuhl (2017). As depicted in Figure 17, the method begins at "Specifying a Concept" with a clear business purpose. The "Find Digital Potentials" phase follows with a digital analysis of relevant digital approaches that could be relevant for the business concept e.g. research of digital trends in different sources such as the Gartner Hype Cycle (Gartner, Inc. 2019). Then, the "Design New Business Model" stage presents the elaboration of a well-structured business model based on each architect's personal preference tool selection offered in the area of Business Model Management (BMM). Later on at the phase "Record your Capabilities", the organization must identify the required capabilities by the current and future enterprise to deliver its intended business model. To do so, guidelines for Capability Management (CM) in order to collect, model and carry out gap analysis are required. For the last two phases "Engineer the Architecture" and "Transform Your Company", the process relies on Enterprise Architecture Management (EAM) to draft a model that includes the required architecture objects and their dependencies to deliver the intended business model. In addition, the transformation part rolls out from a pilot project to the actual implementation of the project as an operationalized business model based on EA.

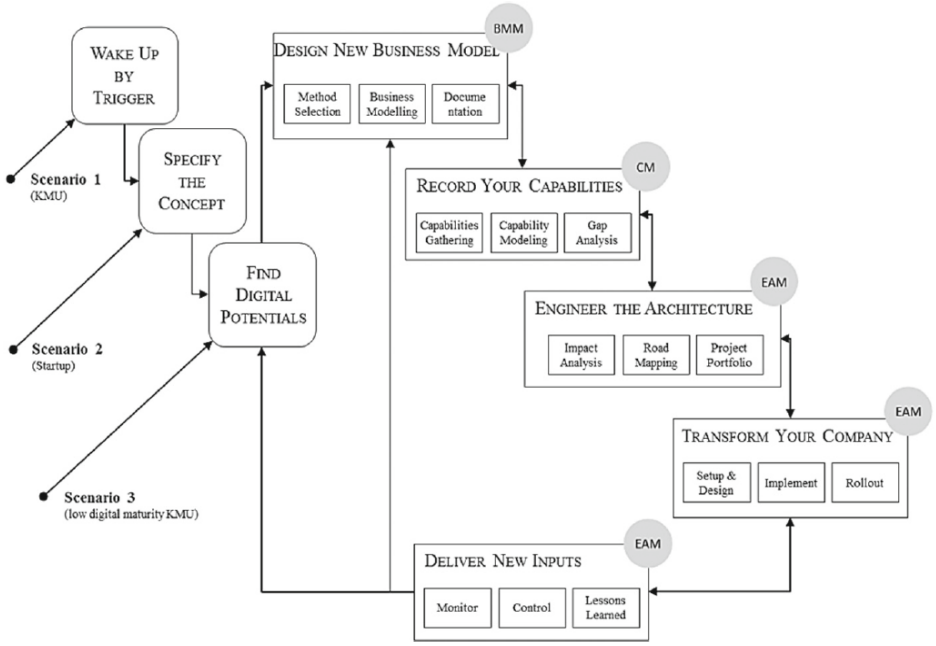


Figure 17. DITP method proposed by Wißotzki & Sandkuhl (2017)

Similar to the BMM segment view introduced above, an integrated architectural value perspective combined with a service-oriented view is presented by Zimmermann *et al.* (2018). Figure 18 provides a general structure of digital strategy as the value-oriented framing for digital transformation. Value-oriented modeling supported by both business model canvas (Osterwalder & Pigneur, 2010) and value proposition canvas (Osterwalder *et al.* 2014) is mapped to the digital business operating model (Ross, Weill & Robertson, 2006). Thus, the business process standardization and integrations are identified in order to materialize new digital services and products to be delivered to customers. Value elements and results from the business model canvas are mapped into the architecture value models of EA. Semantically associated products and digital services are structured within services and product composition models following composite patterns (Gamma *et al.* 1993). Additionally, well-formulated Digital Transformation strategies set stronger foundations for better Enterprise Architecture development. Guidelines for top management as the one presented by Hess *et al*. (2016) contribute to the success of new digital business models. Strategic questions from this method are grouped into the dimensions proposed by (Matt, Hess & Benlian, 2015) to evaluate all relevant aspects from a Digital Transformation.

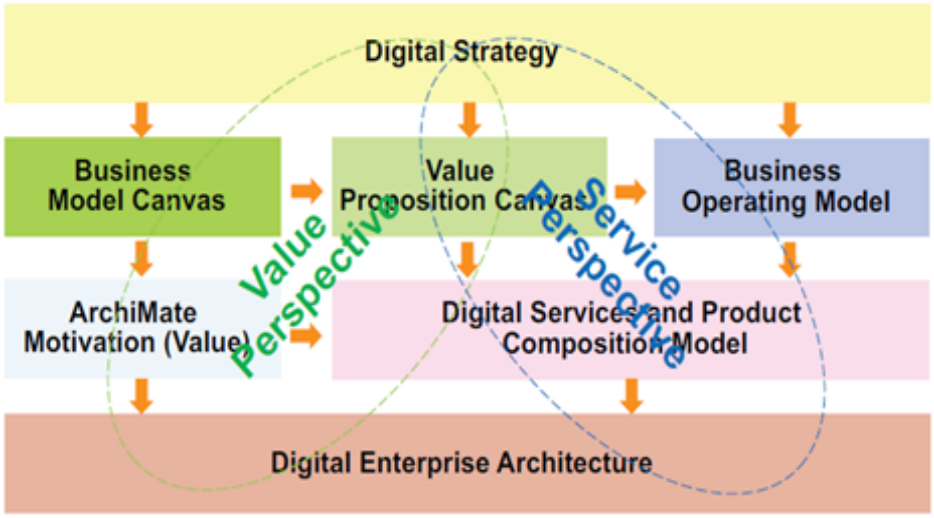


Figure 18. Value Perspective of Service-Dominant Logic (Zimmermann, *et al.* 2018)

Studies reviewed in this research highlighted the importance of agility and multi-level speeds across the architecture to successfully deliver Digital Transformation initiatives (Bossert, 2016; Horlach, Drews & Schirmer, 2016). Companies that are born digital do not face any challenges of adopting technology compared to longtime established organizations, who have struggled with legacy systems for many years. Furthermore, moving an entire company at the pace of a digital-born company is unlikely to happen. Bossert (2016) has proposed a "Two-speed Architecture" lined-up with the bimodal concept defined by Gartner, Inc. (2020f) as "*the practice of managing two separate but coherent styles of work: one focused on predictability; the other on*

exploration". The approach essentially establishes the separation of an organization's elements into those that require quick changes in response to dynamic customer experiences (fasts speed architecture) and those who represent the integrity of transactions e.g. operational support and legacy systems (transactional architecture). Though it focuses on the IT domain, the approach deals with the rigidities of the stable transaction architecture as well as the fast release cycle essential to cope with customer-facing environments.

Figure 19 depicts the reference architecture and building blocks of the two-speed architecture, where technologies and software deployed on the upper level of the diagram are focused on customer experience and interaction channels whereas the lower part contains slower cycle release technologies e.g. stable high-quality master data management platforms. At the fast speed architecture front, the method relies on microservices architecture to foster innovation and agility of deployed digital services.

Horlach, Drews & Schirmer (2016) relate to the previous approach with an alignment model between traditional IT, digital IT and business as shown in Figure 20. Agile and customer-facing systems access on a frequent basis customer data managed by systems supported by traditional IT. Decentralization of Digital IT can lead to conform to non-IT business units and achieve a greater level of alignment. So-called "bimodal IT" leverages emerging tools and platforms for agile customer front-end systems while supporting traditional mission-critical backend systems.

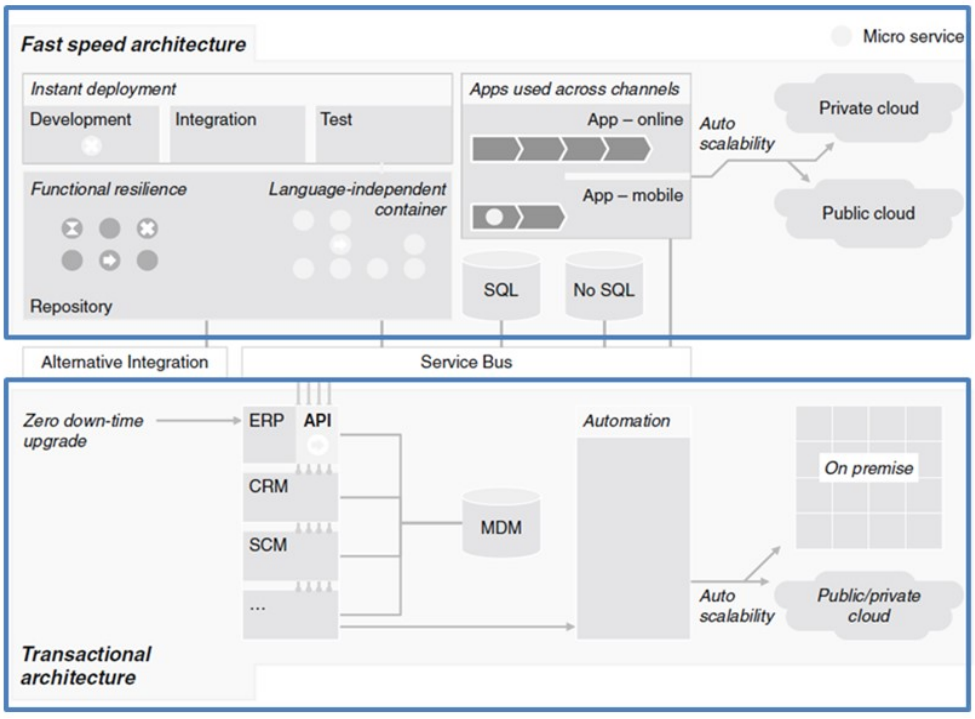


Figure 19. Building blocks of the Two – speed architecture Bossert (2016)

Examples of such emerging technologies include modular infrastructure and cloud service solutions. Besides, concepts of this approach can be applied to the field of business intelligence, where traditional IT is concerned around profound business objectives and security, where Digital IT focuses on further BI activities such as predictive and prescriptive analytics.

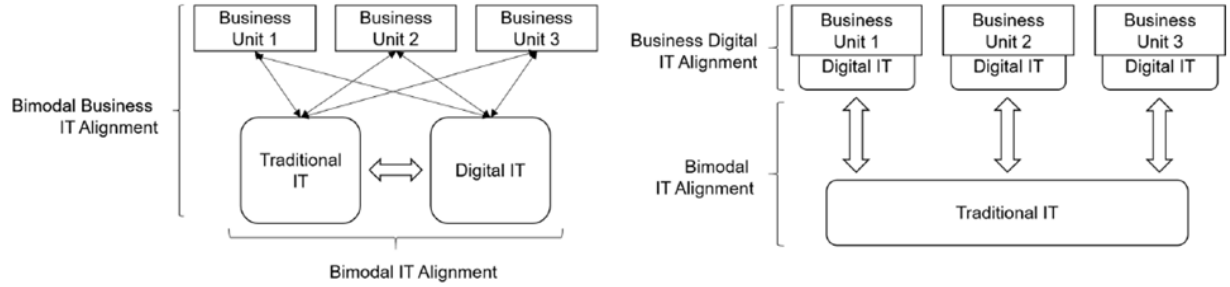


Figure 20. Traditional IT, digital IT and business bimodal alignment (Horlach, Drews & Schirmer, 2016)

Due to its popularity, TOGAF and ADM both set the foundations of various methods and techniques briefly discussed in this section. However, modifications are made to these methodologies to fit the nature of Digital Transformation projects by structuring relevant building blocks in response to the elements discussed at the introduction of this section (Enterprise Architecture building blocks for Digital Transformation).

Molnár & Őri (2018) introduce the concept of hypergraph based formalism for EA representation. The approach based on TOGAF's meta-models elaborates on the use of hypergraphs to use formal mathematical analytical methods for discovering misalignments among IT strategies, information systems, and information architecture. Hence, it provides a method to check and control inconsistencies across several structures of the architecture, setting the right course for the organization to embark on Digital Transformation journeys. Additional studies have also focused on performing assessments on the current state of alignment between the business and IT by revisiting governance strategies as an effective tool for coordinating and achieving digital transformation (Őri & Szabó, 2018). Thus, in the latter study an Enterprise Architecture Management model, based on TOGAF and ADM, is introduced to discover and analyze misalignment symptoms connected to DT initiatives based on the concepts of both EA and Enterprise Engineering (EE). Similarly, TOGAF with ADM is once more adopted by other methods such as the one introduced by Hafasi & Assar (2016) to customize the framework into four focus areas: unified data views, stakeholder management, EA vision, and EA repository. In short, each of these core subjects provides problem-solving tools to steer into Digital Transformation projects.

A different approach towards Digital Transformation is introduced by Bondar *et al.* (2017), where the Zachman EA framework (Zachman, 1987) is accommodated for architecting Systems of Systems (SoS) for emergent behaviors. The collective behavior of simpler parts of a system is

conceptualized as emergent behavior, which arises from the cumulative actions and interactions of the constituents of an SoS (Bondar *et al.* 2017). The classification schema provided by Zachman is integrated with the layered SoS architecture of Hsu *et al.* (2009) to describe and organize primitive architecture information of complex entities. Essentially, the architecture of SoS can leverage the mechanisms to effectively manage, recognize and exploit emergence behaviors in organizations. Thus, the approach handles evolving structures through the architecture of SoS creating a strong input for Digital Transformation endeavors.

2.2.2.3 EA and industries undergoing Digital Transformations

The reviewed literature for this research pointed to several industries including the public sector, manufacturing, financial sector, logistics, and healthcare who rely on EA mechanisms to support Digital Transformation in organizations. Though not all the cases integrate standardized EA mechanisms, methodologies or approaches, they still provide relevant architecture deliverables critical for industries to embark on Digital Transformation as part of their digital business strategy. In this subsection, research objective 3.a is discussed.

Temel & Ayaz (2019) used architecture design for improving product and energy efficiency in a tire manufacturing plant. Kassner *et al.* (2016) presented the SITAM reference architecture that enables the realization of the data-driven factory alongside the exploitation of big-industrial data across the entire product life cycle. Moreover, Dremel *et al.* (2017) restructured the organization and underlying business processes to establish a mature Data Analytics strategy for digital transformation in the automotive industry. Extension of EA meta-models is introduced by Schirmer *et al.* (2016) that contribute to IoT based projects performed at the Port of Hamburg. Thus, interrelationships among projects were understood, improving decision making processes for the future development and roll-out of IoT at the port authority.

In the banking industry, Sia, Soh & Weill (2016) highlighted the importance of mapping the digital capabilities across several structures including processes, people and technology. Enterprise Architecture is vital for setting up the foundations of the operational back-end of the financial institution, yet equally important for standardizing technologies in preparation of new digital transformation across the entire organization. Furthermore, Enterprise Architecture requires agile mechanisms to cope with the new digital era in the Healthcare industry as per Masuda & Viswanathan (2019). AIDAF acts as a complement to current methodologies such as TOGAF's ADM and even going further integrating DT risk mitigation management, social collaboration models and global communication structures implemented in a pharmaceutical company. Finally, Helfert, Melo & Pourzolfaghar (2018) present an EA reference model for designing and transforming smart services that address concerns regarding different aspects of the smart city e.g. noise monitoring service. Hence, EA can assist in simplifying the complexities brought by Smart Cities innovation projects promoted by municipalities in the public sector industry.

2.2.3 Comparative Analysis of EA Frameworks for DT

As a result of investigating the state-of-the-art regarding EA frameworks for Digital Transformations, Table 7 compares the main three approaches discussed in section 2.2. First, the three EA approaches are applicable enterprise wide, i.e. the frameworks are intended to cover all domains of the enterprise. Moreover, one of these approaches is designed specifically to develop a Digital Transformation under certain emerging technologies, i.e. Cloud and Mobile IT in the case of AIDAF. Secondly, two out of the three methodologies are based on TOGAF, specifically by adopting the ADM as the core of the EA development. Consequently, the execution method of these approaches is cycled-based, while the OOAF is introduced as a "plug and play" method, meaning it does not prescribe a beginning nor the end of an iterative process. Key concepts of the Agile architecture fundamentals in OOAF provide the basis to address the enterprise-specific needs.

On the other hand, there is no evidence of real-world implementations of the LEAF case according to the literature. However, the AIDAF framework was successfully transferred as part of the EA program at a pharmaceutical company. In the case of the OAAF, some of the architecture foundations and guidelines are suggested as successful practices retrieved from organizations' experiences. Regarding architecture agility, both AIDAF and LEAF incorporate as part of their customized frameworks, a simplified version of ADM. In AIDAF, the Adaptive EA cycle makes the provision of the initiation documents, including architectural designs, for new cloud /mobile-IT related projects that are continuously drawn up on a short-term basis (Masuda & Viswanathan, 2019). The LEAF framework uses TOGAF and its content metamodel, limiting it only to the phases relevant to undertake the Digital Transformation program. As per OAAF, architecture agility is handled by managing the three transformation dimensions presented in section 2.2.

Ultimately, architecture change is perceived differently in all three frameworks. LEAF imposes the architectural governance as the mechanisms to manage and compile deviations of the architecture outline. On the contrary, AIDAF manages change through the System Development Life Cycle (SDLC) of the framework. The principles and concepts to address architecture change in OAAF are under the continuous architectural refactoring concept. From a maturity perspective, AIDAF is built upon results from previous studies performed by the authors of the framework in addition to the transference of the framework in a real-world case scenario. On the other hand, LEAF is introduced as a result of experience, delivered as a tool for enterprise architects from a practitioner in a highly-recognized IT consultancy firm (Capgemini). The Open Group has recently published the draft version of the OAAF framework (July 2019), with no real-world implementation cases at the moment this thesis was written. Additional classification concepts are borrowed from the EAF2 method (Franke *et al.* 2009), for categorizing EA frameworks.

Table 7. EA frameworks comparative analysis

Dimension/criteria		OAAF	AIDAF	LEAF
Enterprise reach		All domains	All domains	All domains
Technology-based		No	Cloud/Mobile IT	No
TOGAF based		No	Yes	Yes (version 9.1)
Execution method		Ready-to-use set of guidelines	Adaptive cycle attached to TOGAF ADM or other	Cycle based on TOGAF ADM
Real-world implementation		Limited	Yes	No
Architecture agility		Agile transformation dimensions	Adaptive EA short-term cycle	Simplified lightweight ADM cycle
Architecture change		Continuous architecture refactoring	Managed through AIDAF SDLC	Architecture governance
Level of maturity		Low	Medium	Medium
Architecture Governance	Maintenance Process	Not included	Included	Included
	Guidelines/Principles	Included	Included	Included
	Building Blocks	Limited	Limited	Included
	Patterns	Included	Not included	Included
	Roles/skills	Limited	Included	Included
	Maturity Model	Included	Not included	Not included

2.3 Case Study: EA for Digital Transformation at Intel®

In the whitepaper presented by Singh (2019), Intel provides an overview of their Enterprise Architecture efforts to provide a framework for Digital Transformation, helping them essentially to "bring order to chaos". In essence, this subsection addresses research objective 3.b.

Enterprise Architecture is defined at Intel as applying technology advancements across the entire architecture ecosystem to radically change the way the company operates, competes and grows across businesses and geographies. On the other hand, a DT for Intel refers to the use of technology that generates, stores and processes data to achieve a fundamental change to an organization's day-to-day business.

2.3.1 Business Problem

The company recognizes the need to adapt to necessary transformations and technology disruptions not only to survive but to thrive. In today's highly competitive and fast-paced marketplace, the continuous success of Intel hinges on quickly adapting to market disruptions and opportunities through innovation and Digital Transformation. Despite the fact that the company had included EA as part of its enterprise capabilities, business challenges and associated negative effects came to light, forcing the company to embrace a new EA approach. Obstacles faced by the organization and their negative effects included:

- Inconsistent approach to EA from several IT organizations. This created an imbalance of EA resources and skill sets across Intel IT.
- Business and IT strategies were not aligned due to weak integration between IT and business units (BUs). IT was perceived as an order taker and PC supply organization rather than a business partner.
- Business and IT units worked in silos, with little or no partnership.
- Intensive labor required to analyze the impact of any change, or identify areas of improvement much needed for DT.
- Slow-moving pace to keep up with change required at Intel business and technology landscapes.
- The architecture was created and managed in silos along with lacked consistency and cohesiveness of end-to-end integration between architecture domains i.e. business, data, applications, and technology (BDAT).
- Difficult track of the technology debt or technical gaps due to lack of visibility into EA building blocks. Cases to which Intel refers to the concept of technical debt are:
    - Redundant applications that enable similar business processes and functions.
    - Duplicate IT services for infrastructure, platforms, database solutions and more.
    - Solutions that are not consuming reusable assets.

- Reducing/avoiding/de-commissioning custom-coded solutions and integrations that implement non-differentiating capabilities.

2.3.2 Enterprise Architecture Solution

On their journey towards a successful Digital Transformation, Intel decided to reformulate the approach to EA. Essential parts of the solution include the participation of people, establishment of new processes and technology, alongside the incorporation of a new EA operating model. In addition to this, Intel took advantage of TOGAF as a means to materialize their EA goals. This section briefly describes two of the main parts of the solution exploited by Intel for enabling business transformations.

2.3.2.1 EA Operating Model for DT

After researching commonly used EA operating models, Intel decided to pursue a Federated model given the size of the company. This model deployed a centralized architecture group under the CTO and architects in other value streams and solution groups. The new EA organizational structure is depicted in Figure 21. For the organization, value stream groups are generally verticals such as finance, marketing, supply chain, and human resources, whereas solution groups are horizontal units specialized by domains e.g. information security, platforms, infrastructure, and Enterprise Architecture. New entities were created as part of the new operating model to support EA efforts.

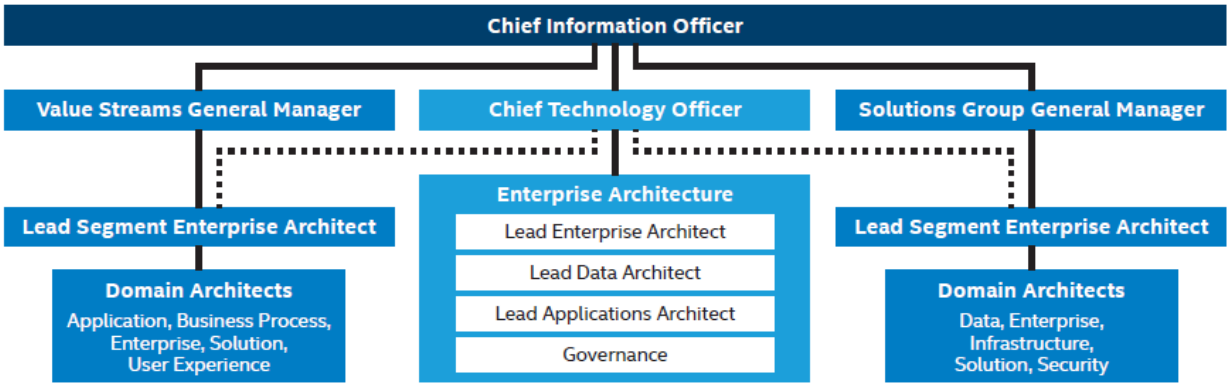


Figure 21. EA operational model at Intel Singh (2019)

EA Center of Excellence (CoE): Supports directly Intel's overall Digital Transformation and defines practices and principles for delivering uniform, cohesive and consistent architecture blueprints for all BDAT domains. Furthermore, the CoE promotes innovation, simplifies and modernizes architecture deliverables, reduces technical debt and enforces the reusability of IT assets.

Technical Workgroups (TWG): Work cohesively to develop and deliver EA standards. TWGs act as mediators to deliver the strategic vision for EA across the BDAT domains. These groups are

in charge of maintaining the IT asset inventory and repository. These include services/APIs, applications, infrastructure components, business processes, data models, policies, run/build analyses, and capabilities.

EA community of Practice (EA CoP): Responsible for delivering a uniform, cohesive and consistent reference EA that is aligned with EA principles, guidelines and policies. This group discusses and shares best-known methods, practices, and learnings. The EA CoP through learning continuously and sharing wins by socialization, functions as a fast track to deliver architecture blueprints and remove any existing barriers.

EA Compliance and Governance: Acts as an EA governance process to ensure that solutions comply with EA policies, principles, guidelines and standards, driven by committees. These work in tandem with other entities e.g. for understanding the EA principles and keeping solutions compliant, while the CoE is responsible for an overall EA compliance health check.

2.3.2.2 EA in Practice for Digital Transformation

A second major component of the EA solution deployed at Intel includes the use of the TOGAF Architecture Development Method as the basis of a high-level, eight-step process that enables the organization to achieve EA objectives. Figure 22 illustrates the cycle by following the industry-standard EA framework. The activities that comprise the method are:

1. Moved by a business outcome statement (BOS), reference architectures are associated with each of the digital business transformation outcomes of the organization and as a result, strategy development is enabled. The digital business transformation outcomes included: productive workforce, engaged customers, reimagined and optimized decision making and operations and new products and services.

2. A course of action maps the strategies to capabilities and capabilities to business processes. The process addresses the identification of gaps in value streams that execute the strategy and accommodate business architecture elements to alleviate the gaps if necessary.

3. The portfolio management approach provides insights into the organizations' current solution offerings. Capabilities are then mapped to solutions offerings, enabling the company to run a gap analysis to address the new business requirements. Plans and efforts are built based on the results of such analysis so that goals can be met.

4. Management and source of the required internal or external resources are performed so that plans can be executed. This step is essential for executing the plans defined in the previous phase.

5. Support continuous delivery as the foundation of architectural refactoring. The EA tool supplies complete insight into the artifacts of the digital ecosystem of Intel (reuse, build or buy). Faster decisions can be made based on an instant impact analysis of the architecture.

6. Services are built and managed to provide support to solutions, leveraged by close communication between Agile teams.

7. Systems of record are defined for business process rules, data bindings, and data transformations with full visibility into the BDAT architecture domains of the EA. Integrated business and data architectures are delivered through application architecture. Intel uses the definitions of Gartner listed in Table 8, to differentiate enterprise systems on their Enterprise Architecture approach for Digital Transformation.

Table 8. Systems classification for Digital Transformation

System Type	Description
System of record	Defined as an established legacy application or homegrown system in support of core transaction processing that manages the organization critical master and transactional data. The change rate of these systems is low.
System of differentiation	Represent application components that commission unique company processes or industry-specific capabilities. The change rate of these systems is moderate.
System of innovation	Portray new systems that address new business requirements and opportunities. Rate of change is high.

8. Governance is implemented for all the BDAT domains. The facilitated risk or compliance issues can be identified from storing integrated IT data artifacts into a common architecture repository. For instance, applications containing sensitive data are not allowed to be hosted in a demilitarized network zone or cannot store information without unencrypted server environments.

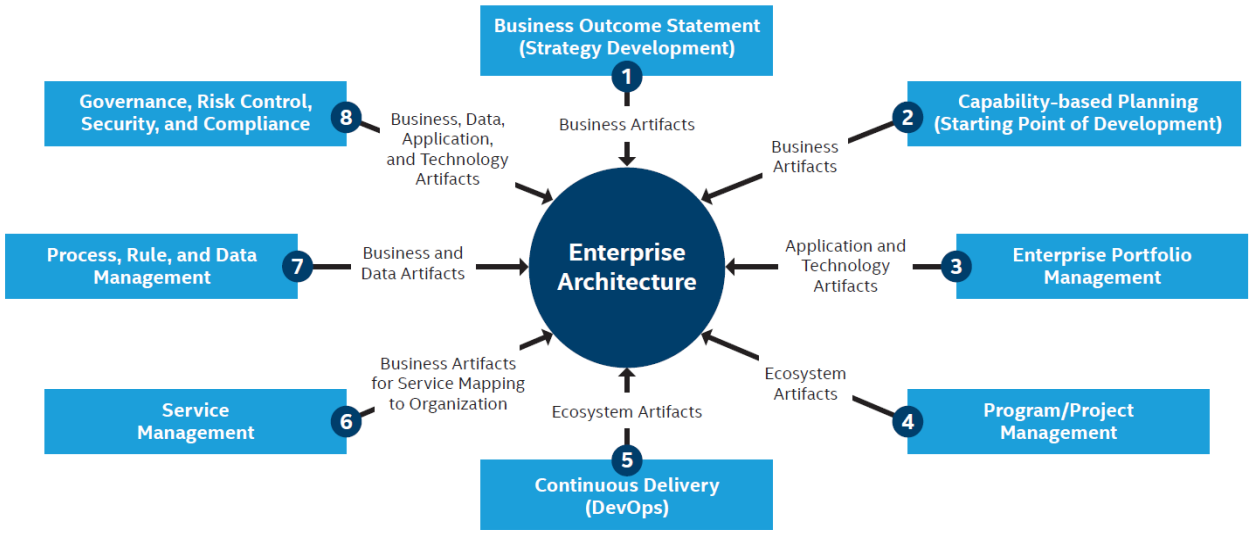


Figure 22. EA development process developed at Intel Singh (2019)

2.3.3 Organizational Impact and Results

Changing the EA approach towards Digital Transformation allowed Intel to achieve significant progress and results. This mainly reflects the ability of the company to properly handle industry disruptions and react to change in an agile way. The new EA model delivered Intel great business value through architecture simplification, modernization, and automation. A summary of the benefits and business value brought by the new EA program are listed in Figure 23:

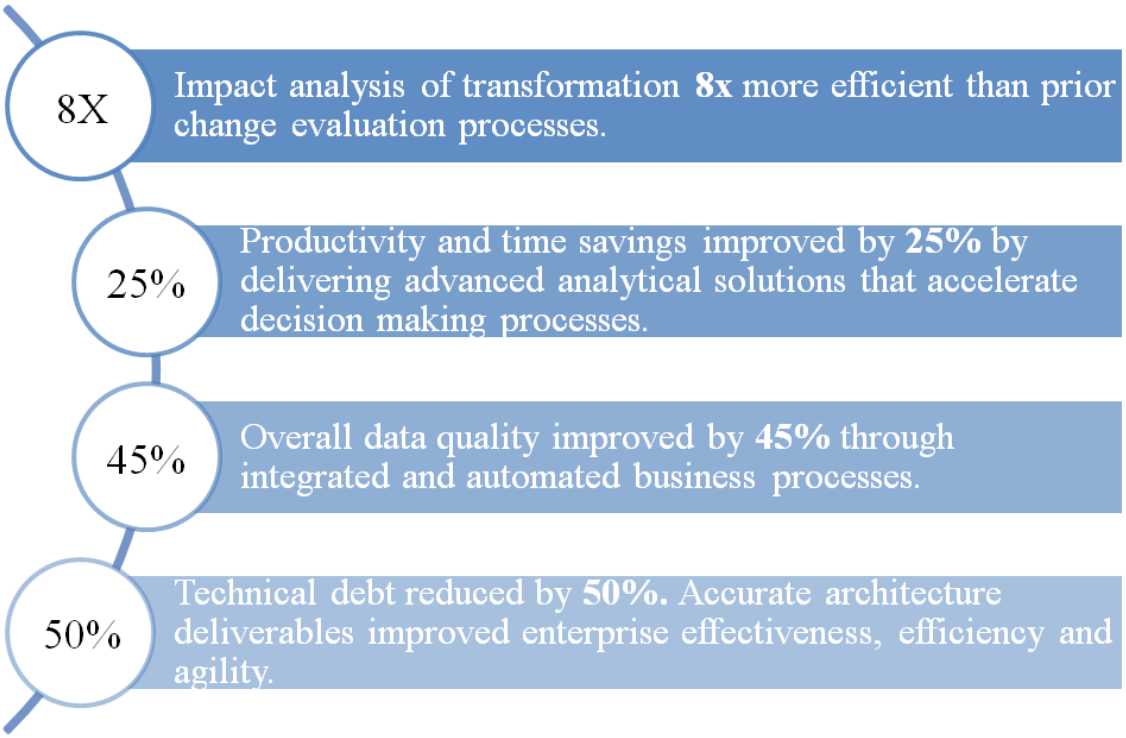


Figure 23. Business results from adopting new EA approach for DT

3 Design Analysis

After investigating the core concepts, state-of-the-art, and impact in practice in relation to the research problem, this section infers the objectives of the intended solution. Aligned to the stages of the DSRM of section 1.4, this section addresses research objective 4.a. In essence, the artifact objectives serve two purposes, first, to align requirements with solutions as part of the proposed building blocks of the EA methodology for DT, and second, to use them as evaluation criteria during the validation step of this research.

Objectives of the EA methodology for DT

Findings from the SLR, specifically the ones addressing RO1, assembled the Digital Transformation constituents to be addressed by the Enterprise Architecture practice. These elements represent the foundations and catalysts for DT, incorporated as part of the solution artifact presented in this thesis. In addition, the investigated frameworks and methods, analysed as part of the RO2, revealed a set of guidelines and directions, critical for the implementation of EA in response to DT programs. Moreover, the case study discussed in section 2.3 related to RO3, provided useful lessons and valuable insights that contribute to a better definition of the solution artifact. Figure 24, illustrates how the objectives to be achieved by the artifact, defined in section 4: Artifact Design, relate to the main research question introduced by the thesis. Consequently, the main objectives to be fulfilled by the EA framework for DT include:

3.1 Design an interdisciplinary organization

An organization that aligns business and IT into collaborative units is delivered from the analysis performed within a focus area of the reference model. The methodology presents an organizational structure that characterizes a flexible way to work and collaborate, minimizing inter-team dependencies. The new proposed interdisciplinary teams have clearly defined roles and responsibilities. The new organizational structure is aligned with the architecture principles and organizational culture promoted by the DT project.

3.2 Promote modularization and decoupled building blocks

The reference methodology conveys architecture modularity through the decomposition of social and technological elements. By adopting atomic building blocks such as services as part of the architecture development process, the artifact encourages the establishment of well-defined business boundaries, maximizes the reuse of IT assets, and limits the impact of change to other domains of the architecture.

3.3 Simplify the Enterprise Architecture cycle

The presented method avoids at all costs complexities brought by big designs up-front and simplifies the architecture development process in order to deliver a Digital Transformation

program more agile to the organization. Consequently, a minimum set of essential deliverables are documented as part of each of the stages or phases of the methodology. In addition, the artifact compiles methods, reference architectures, and models that ease the architecture development needed for DT across all domains i.e. business, application, technology, and data. Moreover, the artifact utilizes a simplified meta-model version of the ArchiMate language to reduce the complexity of architecture views part development cycle as concluded in the Intel case.

3.4 Convey business agility through architecture design

This thesis embraces the concept of architecture agility as the way in which enterprise agility is conveyed through architecture design. Through the implementation of the artifact, architecture models and social structures definitions are able to portray how business agility is materialized for the organization. These models include methods such as designing bimodal IT or two-speed architectures and structuring cross-functional teams that enable faster business services and operations of the envisioned Digital Transformation initiative. Furthermore, the proposed framework allows the definition of lightweight mechanisms or governance controls to reconcile architecture governance with the autonomy of architecture teams in charge of contributing to an overall architecture vision.

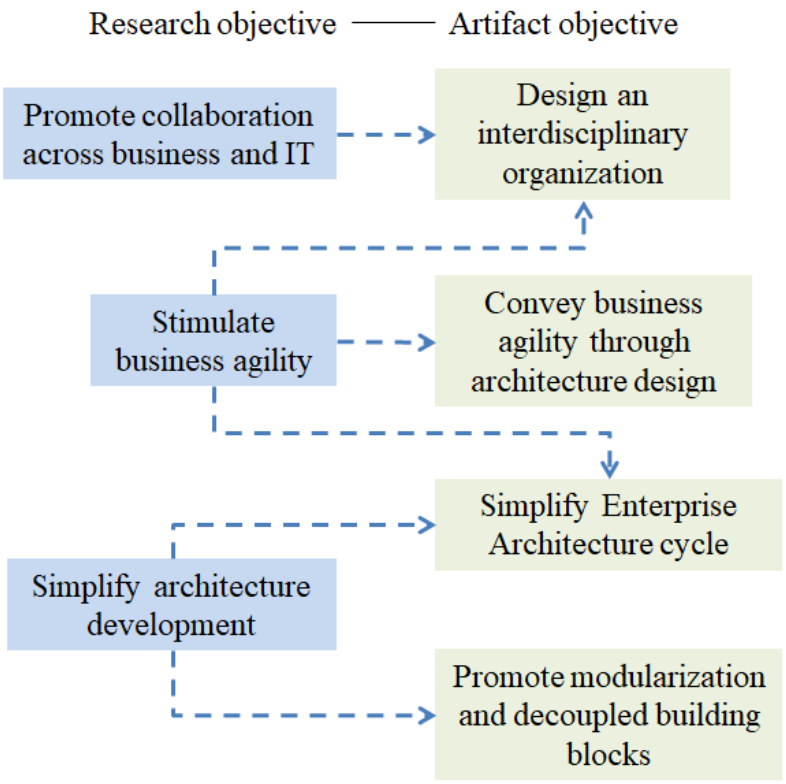


Figure 24. Artifact objectives mapped to main research objectives

4 Artifact Design

This section presents the Enterprise Architecture framework for Digital Transformation, as well as the foundations of the artifact, the architecture development cycle, activities, and intended deliverables required to convey successful Digital Transformations into organizations. In addition, the artifact compiles methodologies and practices, discussed in the literature study as part of the Enterprise Architecture development process. Ultimately, the session addresses research questions 4.b and 4.c.

Enterprise Architecture Framework for Digital Transformation

The framework reference, depicted in Figure 25, presents the building blocks and constituents to be considered for the development of Enterprise Architecture for Digital Transformation initiatives. From a top-down perspective, the drivers discussed in section 2.2.1 mark the conditions under which the goals of the artifact are defined. The goals to be attained by the Enterprise Architecture Framework for Digital Transformation (EA4DT) were described in more detail in section 3. Furthermore, the requirements represent the basic needs and properties of the framework to be materialized by architecture deliverables and guidelines, incorporated in the architecture development cycle of EF4DT later discussed in section 4.3.

The EA4DT is greatly influenced by so-called “architecture catalysts" or principles to stimulate the development of modular, agile, and evolutionary architectures, considered as critical in the context of Digital Transformation. The latter property refers to the concept of “evolvability” coined by OOAF i.e. the ability of the architecture to be changed or evolved over time (The Open Group, 2019). Therefore, the framework strives towards identifying the constraints and architectural guardrails under which the Digital Transformation program will operate.

On the other hand, agility in EA4DT is conveyed through architectural design associated with the technological and social elements of the enterprise. As a result, the framework incorporates the principles of bimodal architectures and cross-functional organizations, as well as minimizing substantially the documentation of architecture deliverables in order to shorten and accelerate architecture learning cycles. In addition, EA4DT sees no use of elaborated design before the implementation of a business initiative, therefore initial phases of the frameworks are meant to be flexible and coarse with the sole purpose to effectively convey business agility into the organization. Ultimately, the framework is guided by modular design thinking and driven by the definition of decoupled and reusable components. The concept of building blocks is defined as potentially reusable components to be combined with other building blocks to deliver architecture and solutions (Harrison, 2018). As a result, the EA4DT employs the concept of services as the core building blocks for the development of architectural solutions.

In-line with the Franke *et al.* (2009), the following sections describe essential concepts incorporated as part of the artifact i.e. principles and guidelines, the architecture development process, and finally, roles and responsibilities needed to effectively govern and manage EA4DT. As the proposed framework is delivered as a customization of ADM, additional conformance aspects required to be described from the artifact are assumed equally applicable to the TOGAF framework and not included in this document.

4.1 Framework essentials

Break the Digital Transformation vision into manageable parts: A Digital Transformation initiative as depicted in Figure 25 comprises multiple levels of extent in relation to the EA practice. In order to simplify the EA development and management while effectively delivering the DT initiative, EA4DT proposes enterprise-level and project-level scope phases. At the enterprise-level, the architecture vision and a coarse and flexible plan of action are defined, whereas at the project-level individual decisions and solutions are proposed at a granular extent.

Use services as architecture building blocks: Towards the development of flexible, loosely coupled, and highly resilient systems in-line with well-defined business functionalities, EA4DT adopts services as the foundational building blocks for architecture design. Consequently, changes or modifications in one service of the architecture only have limited impact on other services, and failures are easier to isolate, making the overall system more resilient (The Open Group, 2019).

Deliver a minimal set of essential architecture deliverables: The framework is intended to deliver only the essential set of documents and models required at each stage of the development cycle. This principle follows the maxim of LEAF to be "as minimalistic as possible" (Nandico, 2016). Additional deliverables should only be documented to cover specific stakeholders' concerns. In EA4DT, viewpoints are considered core deliverables to depict conceptual, logical, and physical service-oriented architectural decisions throughout the entire development cycle.

Design with clear business orientation: Every design and architecture decision must be made having a clear intended business value and purpose. Thus, the framework must delineate the value stream process to be offered by the Digital Transformation initiative and the possessed and required capabilities of the enterprise. As a result, the customer journey is bridged with the required capabilities. To do this, the methodology borrows the service blueprint design from OAAF and employs elements from the motivational layer of ArchiMate.

4.2 Roles, skills and responsibilities

Aligned to Franke *et al.* (2009), an important aspect to describe from EA frameworks is the main roles and responsibilities to be assigned throughout the entire architecture development process. As listed in Table 9, the proposed roles for EA4DT are stated alongside the main set of

responsibilities and specific skills required. Moreover, the stages of the designed artifact are related to the roles so that clear boundaries and authority domains are delimited. This section relies on the definitions and associations defined by the Enterprise Architecture role and skills category section of TOGAF (The Open Group, 2018).

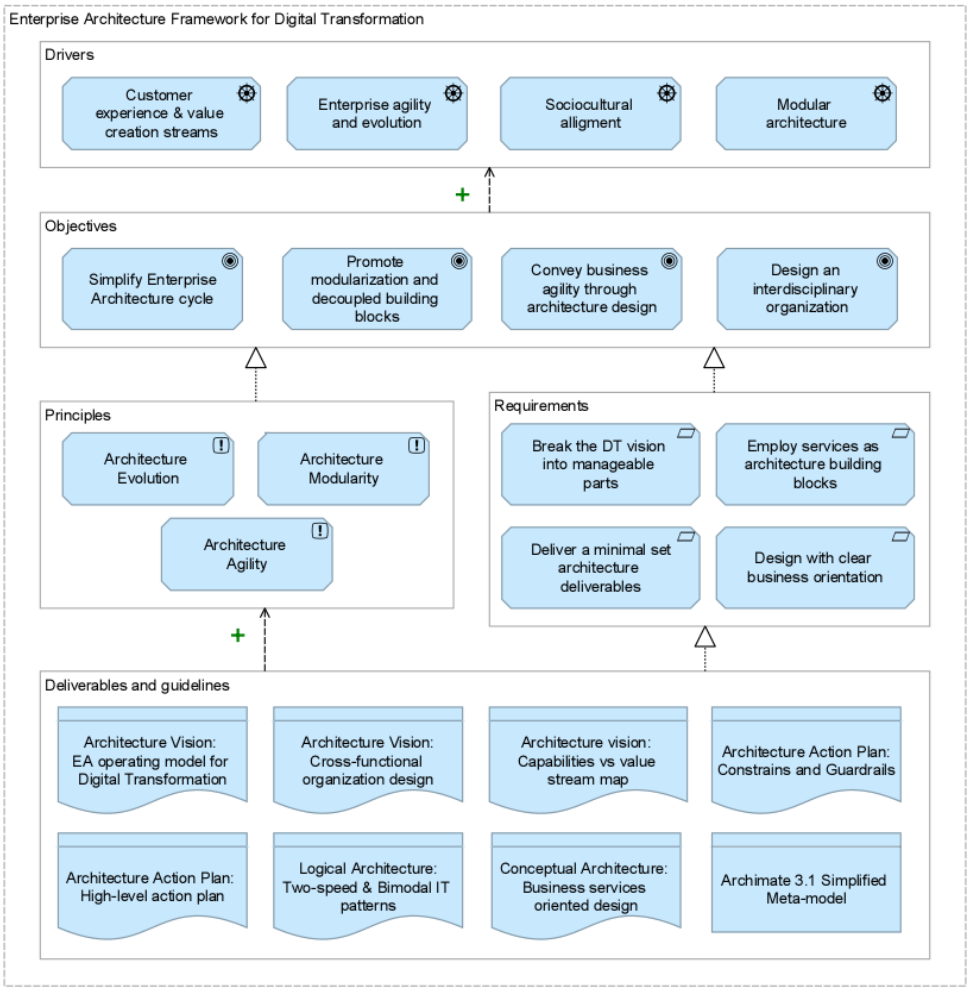


Figure 25. Enterprise Architecture for Digital Transformation

4.3 Architecture development cycle

The EA4DT incorporates a repeatable process illustrated in Figure 26 that addresses the goals and objectives of the Digital Transformation initiative. First, the cycle is enclosed by the architecture catalysts previously introduced so that all activities, deliverables, and guidelines are aligned to the constituents for EA development in order to deliver a successful Digital Transformation initiative. Once again, the EA4DT architecture development process is founded on the ADM cycle and impersonates the architecture development structure of LEAF. In the following sections, the phases of the Enterprise Architecture Framework for Digital Transformation are introduced alongside each phase's associated activities and expected architecture deliverables inputs and outputs.

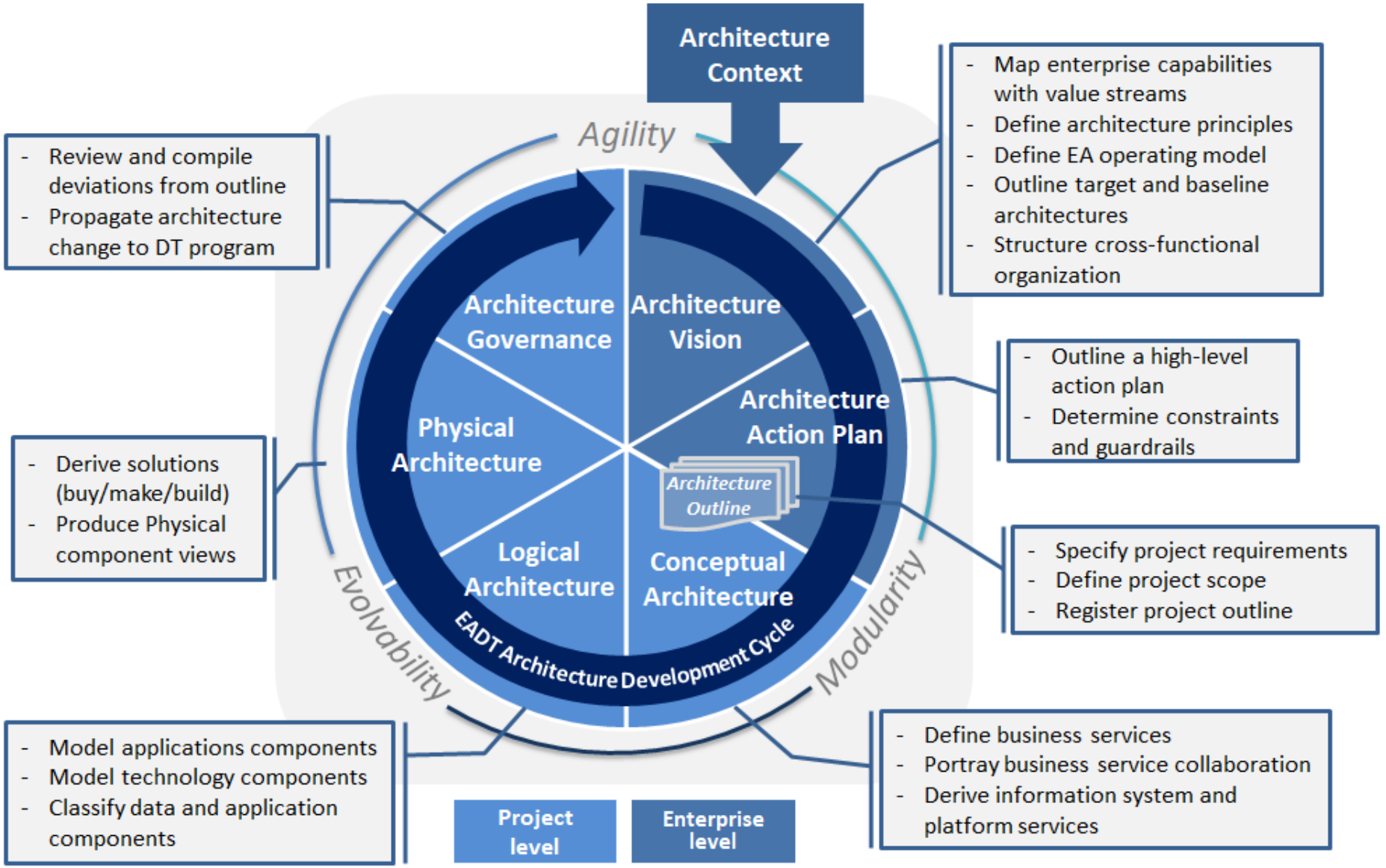


Figure 26. EA4DT Architecture Development Cycle

Table 9. EA4DT Roles, skills and responsibilities

Architecture Role		Overall responsibilities	Relevant skills	EA4DT phases
Enterprise architect		- Clarifies and agrees on architecture context with stakeholders and manages changes - Defines principles and guidelines for architecture development - Delivers high-level architecture roadmaps	- Service design and modelling - Architecture principles design - Architecture views and viewpoints design - Change management	- Architecture context - Architecture vision - Architecture action plan - Architecture governance
Project architect		- Formalize the architecture outline - Manage change at project-level - Maintain conceptual, logical and physical architecture deliverables	- Change management - Project management - Benefit analysis	- Architecture outline - Conceptual, logical and physical architecture - Architecture governance
Project Domain Architects	Business architect	- Determine business services required to realize business capabilities - Associate business objects as input/output of each business service/function	- Business modelling - Service design - Architecture views and viewpoints design	- Conceptual architecture - Logical architecture - Physical architecture
	Data architect	- Identify associated data entities to business objects flowing through IS services - Contribute to model logical service components - Promotes data stewardship and governance	- Data modelling - Architecture views and viewpoints design	
	Application architect	- Extract the required information system services from defined business services. - Model logical application components in accordance to the business structure	- Service design - Systems behaviour - Architecture views and viewpoints design	
	Technology architect	- Define technologies and platform services in support of application components - Determine COTS, cloud platforms or reuse exiting components to deploy solutions	- Service design - Systems integration - Architecture views and viewpoints design	

4.3.1 Architecture context

Digital Transformations are at all times business-driven, business-oriented, and business-centric perspective initiatives (Matt *et al.* 2015). Therefore, delineating a business strategic map that triggers the architecture development cycle of EA4DT is a critical prerequisite to conduct a successful program. The power of a Digital Transformation lies in its scope and objectives (Kane *et al.* 2015). As a result, the architecture context preparation phase is proposed by the framework. The architecture context compiles the business mission, vision, objectives, strategy, and constraints that provide the business rationale for the Digital Transformation endeavor (Nandico, 2016). In EA4DT, the Preliminary phase of ADM is embedded into the activities and considerations performed as part of the architecture context and architecture vision.

The architecture context is, in essence, the input for the architecture vision to trigger the architecture development cycle in EA4DT. In a more evolved business-value design world, this research has pointed out some methodologies that define innovative digital offerings to customers such as design thinking and job-to-be-done, These concepts are meant to be used for architectural design throughout the development cycle to avoid any kind of misalignment. Among other expected materials to be received and processed by the enterprise architect to start the architecture vision are the organization value chain and business models on a page for Digital Transformation e.g. business model canvas (Osterwalder & Pigneur, 2010) and the value proposition canvas (Osterwalder *et al.* 2014). After grasping the business idea and motivation for the Digital Transformation program the next stage begins.

4.3.2 Enterprise-level phases

4.3.2.1 Architecture vision

The architecture vision phase compiles all the required set of business tactics that will guide the intended projects for the Digital Transformation program. In addition, the enterprise architect provides a clear organization structure upon which the initiative is delimited. In contrast to ADM and in line to LEAF, the architecture vision is perceived as assigned architecture work that responds to the business request for Digital Transformation.

Main activities

- *Map enterprise capabilities with value streams:* Existing and required capabilities are mapped to value streams according to the business goals and objectives defined in the architecture context. EA4DT uses the TOGAF approach to deliver the enterprise capability model in combination with the service blueprint from OOAF The value stream and capability elements from ArchiMate serve the Enterprise Architect to produce the model.

- *Define architecture principles*: Derive the architecture principles from the architecture context. TOGAF defines a template to define architecture principles (The Open Group, 2018).
- *Define EA operating model:* Depending on the organization size and scope of the initiative an EA operating model is defined and structured. The operating model can be centralized, distributed, or federated as described in the EA at Intel case (Singh, 2019).
- *Outline target and baseline architectures:* A high-level baseline and target architecture models are outlined. As the model is strongly supported on a service-oriented design, the architecture models must depict services realized across all domains of the architecture. The layered viewpoint of ArchiMate provides a valid overview structure to portray existing services in the baseline architecture and desired ones in the target architecture.
- *Structure cross-functional organization:* According target architecture, cross-functional teams are arranged. The organization view will reflect how the services are meant to be operationalized and maintained. OAAF provides a first approach to structuring cross-functional teams. An ArchiMate model of the organizational is provided here.

Table 10. Input and output architecture deliverables for the Architecture Vision phase

Input documentation/deliverables	Output documentation/deliverables
- Business mission, vision, and goals - Business strategy models for DT initiative	- EA operating model - Enterprise capabilities value streams cross model - Architecture principles - Target architecture model - Baseline architecture model - Structure cross-functional organization

4.3.2.2 Architecture action plan

In this phase, the necessary program of works to realize the architecture vision is defined. From a TOGAF perspective, the Opportunities and Solutions and the Migration Planning phases of ADM (phases E and F) are assembled into a coarse and flexible plan of action in EA4DT, seen as the subsequent phase of the Architecture Vision (phase A) of ADM. The architecture plan of action is not an elaborate plan, however, it serves as valuable input for the portfolio and roadmap to be further detailed by project managers to address other concerns e.g. availability and knowledge of resources and investment plans.

Main activities

- *Outline a high-level action plan:* Defines an overall plan by means of transition architectures or parallel projects within a timeline to implement the envisioned architecture for DT.

- *Determine constraints and guardrails*: Identify the forces and conditions that influence the architecture evolution. Based on this, lightweight mechanisms are proposed to prevent projects from getting off track as proposed in OAAF.

Table 11. Input and output architecture deliverables for the Architecture action plan phase

Input documentation/deliverables	Output documentation/deliverables
- Architecture context - Architecture vision	- Architecture coarse plan of action - Project constraints and guardrails

4.3.3 Project-level phases

4.3.3.1 Architecture outline

The architecture outline for each project defines its contribution to the architecture vision and architecture action plan. As a result, assembling individual projects in EA4DT for the Digital Transformation program shall result in the realization of the business vision. The project architect in collaboration with the enterprise architect, determine the each project requirements in line with the architecture action plan. In conformity with TOGAF's architecture vision, the architecture outline in EA4DT also defines what is to be included, and what is excluded from the scope of the individual project.

Main activities

- *Specify project requirements:* Both the enterprise architect and the project architect specify the requirements to be fulfilled by a particular project based on the architecture action plan..
- *Define project scope:* The extent of the project is determined in collaboration between the project architect and the enterprise architect.
- *Register project outline:* An agreement in form of the architecture deliverable is signed off by the architects and the related stakeholders involved in the project.

Table 12. Input and output architecture deliverables for the Architecture outline phase

Input documentation/deliverables	Output documentation/deliverables
- Architecture action plan - Project proposal	- Architecture outline - Project update in domain model

4.3.3.2 Conceptual architecture

A strong foundation of this phase is the development of a conceptual architecture framed by service-oriented design and implementation. In EA4DT, this stage represents the identification of business activities compacted into a service to be delivered by the project. In order to outline a

consistent architecture, baseline services are also recognized so that a gap analysis can be performed based on the business objectives to be attained, always keeping in mind the architecture principles from the Digital Transformation initiative.

Main activities

- *Define business services:* Based on the project's requirements the required business services are encapsulated at a granular level based on the target architecture. According to Nandico (2016) "*business services are atomic elements of business behaviour, characterized by one goal or purpose, one activity and one role executing this activity*". Business objects are represented as input and outputs form using a business service.
- *Portray business service collaboration:* For the individual project, business services are mapped to depict their dependencies across business objects. The business, application and technology service elements from ArchiMate are meant to be utilized to produce the viewpoint.
- *Derive required information services:* Information systems services are defined in the scope of the project in line with the business services identified.
- *Derive required platform services:* Platform services are defined in the scope of the project in line with the business services and technology expectations from the Digital Transformation.

Table 13. Input and output architecture deliverables for the Conceptual architecture phase

Input documentation/deliverables	Output documentation/deliverables
- Architecture context - Architecture vision - Architecture outline	- Service gap analysis - Business service collaboration view - IS services catalog - Technology services catalog

4.3.3.3 Logical architecture

Based on the identified business services and the derived application and technology services from the conceptual architecture phase a logical organization of application components is carried-out. In addition, the data architect of the project must address concerns regarding data management and data migration to meet requirements and constraints of the target architecture of the project. The Data Architect acts as a data steward aligned to interoperability principles and governance standards such as the European Interoperability Framework to facilitate the deployment and operation of complex digital environments, a critical aspect in making a digital transformation possible (European Commission, 2015). Moreover, Domain Driven Design supports the modernization of legacy systems in progressive journeys from monolithic to modular architectures that serve Data Architects to deliver highly interoperable and independent systems.

The logical architecture represents a customization of the Information systems architecture phase of ADM focused on the scope of the project established during the architecture outline phase. However, depending on the complexity of the requirements and the scope of the project further activities and models must be delivered to address the stakeholders concerns.

Main activities

- *Model applications components:* Logical application components are modeled based on the business and information systems services in scope of the project. Further architecture decisions are made in order to modularize and reduce dependencies across application components. The application architect can rely on two-speed architecture design (Bossert, 2016) to model fast-changing elements alongside slower-release, transactional and stable architectures intended to coexist in a short-term Digital Transformation program. The Application elements from the ArchiMate standard provide the necessary elements to produce the logical architecture model for the project.
- *Model technology components:* Logical technology components are modeled to support the specified application components. Required platforms and technologies are specified as part of the mapping process. The simplified meta-model ArchiMate language provides the essential technology elements to outline the model.
- *Application classification:* In line with the interest of the DT initiative, a clear distinction is made between systems of record, systems of differentiation and systems of innovation.

Table 14. Input and output architecture deliverables for the Logical architecture phase

Input documentation/deliverables	Output documentation/deliverables
- Business service collaboration view - IS services catalog - Technology services catalog	- Application and technology component views - Data/application classification

4.3.3.4 Physical architecture

The main goal for the physical architecture is to deliver a physical technological solution for the project. The technology architect assesses solution deployments considering the architecture principles for Digital Transformation. Moreover, the evaluation process leads to the use of new technologies and infrastructure services i.e. cloud computing or COTS to achieve the desired requirements for the project as well as selecting existing platforms.

Main activities

- *Derive technology solutions:* Considering the logical architecture for application and technology services, the technology architect evaluates alternative solutions. As part of the process, the architect must choose to reuse IT assets before buy, and buy before building solutions from scratch (Singh, 2019).

- *Design physical architecture:* Selected solutions from the physical architecture must be modeled and associated to reflect the required interactions for the implementation.

Table 15. Input and output architecture deliverables for the Physical architecture phase

Input documentation/deliverables	Output documentation/deliverables
- Logical components architecture (Application and Technology)	- Physical architecture solution components - Design physical architecture

4.3.3.5 Architecture governance

The Architecture Change Management and Implementation Governance phases are simplified into the phase of Architecture Governance in EA4DT. Contracts defined for every project alongside the governance operating model established early in the development cycle, provide the necessary mechanisms to keep the realization of the project under an acceptable level of control. In addition, architecture reviews between the enterprise and project architect ensure proper change management and propagation into the DT program.

Main activities

- *Review project architecture:* In a collaborative action, the domain architects, the project architect and the enterprise architect assess the conceptual, logical and physical architecture and inspect if the requirements of the architecture outline are met.
- *Propagate changes:* Depending on the complexity of required changes and their nature, the change management process is triggered. This specific process follows the principles of the TOGAF standard for Enterprise Architecture Change Management process (The Open Group, 2018).

Table 16. Input and output architecture deliverables for the Architecture governance phase

Input documentation/deliverables	Output documentation/deliverables
- Project outline - Project's Conceptual, logical and physical architectures	- Architecture vision or project amendments

4.4 Comparison between LEAF and EA4DT

After having described the foundations, the roles, skills, responsibilities, and the architecture development cycle of EAFD, Table 17 makes a clear distinction between the presented framework and LEAF by listing the main differences of both EA approaches for Digital Transformation. The EA4DT incorporates in its development cycle key concepts found to be relevant in the process of architecting the digital enterprise in order to potentialize the architecture catalysts earlier described. Moreover, the artifact provided by this research relies on

the capabilities of the ArchiMate 3.1 standard to describe, communicate, and analyze different concerns of EA in the context of Digital Transformation. Ultimately, while both approaches share terminologies and a structure for architecture development, the EA4DT complements and reinforces LEAF with fundamental methods and guidelines retrieved from the literature in support of the core objectives of this research i.e. stimulate business agility, simplify architecture development and promote collaboration between IT and business units.

Table 17. Comparison between LEAF (Nandico, 2016) and EA4DT

Concept	LEAF	EA4DT
Modelling language	Non-proprietary (generic)	ArchiMate 3.1 (simplified)
EA operating model	Not included	*Architecture vision:* EA operating model
Architecture evolution	Architecture governance	*Architecture action plan:* Constraints and guardrails
Architecture modularity	Service-oriented approach	
Content meta-model	TOGAF-based	
Architecture agility	Agile for architecture development principles	*Architecture vision:* Cross-functional teams *Physical Architecture:* Two-speed architecture/bimodal IT
Business value design	*Architecture vision:* Enterprise value chain	*Architecture vision:* Capabilities-value streams map
Sociocultural alignment	Not included	*Conceptual vision:* Cross-functional teams
Additional Architecture references and support	Integrated Architecture Framework (Van't Wout *et al.* 2010)	OAAF (The Open Group, 2019) Two-speed IT: Bossert (2016) Bi-modal IT: Horlach, Drews & Schirmer (2016), Intel EA case (Singh, 2019) SITAM (Kassner *et al*. 2016)

5 Artifact Implementation and Validation

In this section the Technical action research and the expert opinion validation and evaluation mechanisms are carried out within an organization undergoing a Digital Transformation initiative. As a result, this segment addresses research objectives 5.a and 5.b.

5.1 Introduction to the case

Apollo Tyres Ltd is the world's biggest tyre manufacturers, with annual consolidated revenues of US$2.28 billion (March 2018), with 69% of its revenues from India, 26% from Europe and 5% from other geographies. The company has a manufacturing presence in India and Europe with approximately 5K retail dealers in India and 5,8K dealer outlets in Europe. In 2009, Apollo Tyres acquired the Dutch tire manufacturer Vredestein Banden B.V., hence, renaming the brand as Apollo Vredestein B.V. Later in 2013, the research and development (R&D) operations for Europe were established in Enschede (Netherlands), where the Vredestein global brand plant and distribution center is located. As of today, the European region is composed of 12 subsidiaries with the European headquarters office located in Amsterdam (Netherlands). Apollo Vredestein B.V. (AVBV) basically offers a twofold brand portfolio for the European market; the premium Vredestein tires brand, and the mass brand Apollo Tyres line. AVBV produces tires for different customer segments including passenger car, agricultural, and bicycle tires. The plant located in Enschede produces around 6,4M car tires and 543K agricultural tires per year. A considerable well-established partner ecosystem allows AVBV a frequent supply of tires to some recognized automobile and tractor manufacturers across the world such as Audi, Mercedes-Benz, Volvo, and John Deere.

AVBV and its products have been recognized for their quality in the industry for many years. From the IT perspective, AVBV has deployed multiple systems throughout the years to address a particular set of concerns raised by the business. However, high demands to rapidly materialize new business requirements and the increasing complexity of IT are now forcing the company to embark on well-recognized best practices and methodologies to line-up business strategy with IT solutions. In response to these concerns, the Enterprise Architecture (EA) program initiative was recently launched. The program is focused on the first stage to map business, application, and technology elements to structure the first architecture version of the organization. Desired architecture state will be further developed based on the vision and business strategy defined by top-level management and executives at AVBV.

In the meantime, the European IT division is visualizing a new data and analytics (D&A) strategy with the assistance of the recently structured Enterprise Architecture program. Some time ago, AVBV assembled the Reporting Service Team (RST) for the purpose of promoting the development of business intelligence, delivering basic descriptive analytics to multiple Business

Units (BU) of the organization. Still, new upcoming requirements and expectations from the business demand these team functions to be further developed. As a Digital Transformation initiative, the project is intended to deliver a data and analytics plan of action in-line with the interests of senior-level management. This research project is delimited by the application and validation of the Enterprise Architecture Framework for Digital Transformation for the D&A initiative. The main difficulties from the existing reporting services provided inside the organization include:

- **Limited staff and infrastructure resources:** Local resources scarce for the experimentation and deployment of new data and analytics capabilities. The current team is limited to support and develop descriptive reports to the organization.

- **Lack of business and IT collaboration:** Both BUs and IT do not collaborate for the definition of business reports. This behavior has created siloed teams that have a direct impact on reports interpretation and data literacy.

- **Lack of data and analytics vision and strategy:** The RST operates as a conventional IT-oriented division. There is little sense of data and analytics innovation and evolution, considering the great amount of business know-how the team possess.

The envisioned D&A program, intended to support critical BUs for the European division, bring the following opportunities to AVBV:

- **Explore new data and analytics technologies:** Cloud computing provides the opportunity for organizations to experiment with new technologies at a low cost. Therefore, AVBV sees the benefits of using the public cloud as a vehicle for innovation to materialize the D&A vision.

- **Develop a data-driven culture at AVBV:** Data must be considered a valuable asset as it contributes to the growth of the organization. Therefore, the D&A program provides the starting point to see its value and contribution at every level of the business.

- **Enhance decision-making processes:** Reliable insights based on high-quality data are translated into better decision-making processes for AVBV senior management.

As time was a constraint at the moment this research was performed, the validation of the project does not include the iteration of the EA4DT cycle for all the proposed projects defined during the Architecture Plan of Action phase. Instead, the validation of the Project-level phases within EA4DT contemplates a single project and its development until the Architecture Governance phase of the cycle

5.2 Implementation of the Artifact

The application of the EA4DT to the D&A initiative at AVBV is documented in this section. Therefore, the research question 5.a is addressed in this part of the document.

5.2.1 Architecture Context

After introducing the Digital Transformation initiative at AVBV for Data and Analytics, the Architecture Context compiles the business rationale that motivates the development of the Enterprise Architecture Framework for Digital Transformation. Here the goals, objectives, and scope are described, followed by the three-segment strategies defined by the organization to undertake the Digital Transformation.

5.2.1.1 Initiative scope

The D&A program contemplates the Financing, Supply Chain, and Sales departments of AVBV. Consequently, no other business units are considered to be part of this initiative. In addition, the program is intended to enhance the current descriptive reporting capabilities and offer new predictive data and analytics services for the exclusive use of the European division. As a short-term project, the D&A initiative does not incorporate the collection, storage, and analysis of unstructured data sources provided by on-going implementations associated with IoT or Big Data solutions. The D&A project, however, sets the foundations for the integration of future D&A capabilities that demand reliable infrastructure and secure platforms to support data lakes, real-time streams data ingestion, real-time streams analytics, and big data processing.

5.2.1.2 Data and Analytics strategy and principles

The D&A strategy defines three main areas that are meant to guide the initiative. As listed in Figure 27, the focus areas of the strategy include data-driven culture at AVBV, data management and governance, and robust, flexible, and secure infrastructure.

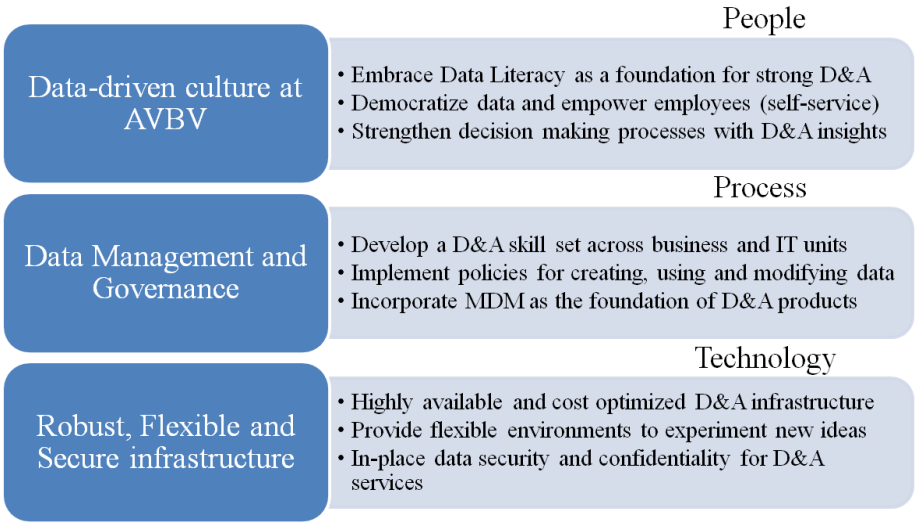


Figure 27. AVBV strategy for Data and Analytics initiative

As the initiative aims at providing enhanced internal services, AVBV includes a people, process, and technology perspective to ensure a complete view over the elements the organization requires for the D&A project to be delivered.

5.2.1.3 Business goals, objectives and requirements

Figure 28 depicts a compact view of the business goals, objectives and requirements to be achieved with the Data and Analytics project.

Improve line-of-business D&A adoption

The increasing need to empower employees and business units is vital to cope with the difficulties of having limited resources and infrastructure for delivering effective reporting services. By leveraging self-service data consumption, users across the organization are self-sufficient and licensed to elaborate reports according to their particular needs without the intervention of IT. On the other hand, effectively embracing a managed D&A solution can be achieved by diminishing shadow analytics, providing users real-time processed information that prevents them from creating ineffective data and analytics siloes.

Improve BUs decision-making

AVBV desires that BUs impacted by the D&A initiative, improve their decision-making processes based on reliable and valuable information. These can be achieved by pursuing the enrichment of data as an augmentation mechanism that assists the BUs in making more informed decisions. Moreover, improving data quality and accuracy, on the other hand, aims at identifying the validity and correctness of business information produced within AVBV to be used as an input for data and analytics. The latter is achieved by implementing a solution to manage master data of the organization.

Improve reporting services and operations

The third goal of the D&A initiative is to improve reporting services and operations. Therefore the business requires the reporting services unit to deploy cross-functional teams for enhanced Business and IT collaboration and thus, reducing the times to produce reports based on new specifications. Moreover, enhanced streamline data technologies for data ingestion, integration, processing and delivery are leveraged to rapidly transform raw data into significant business reports.

5.2.2 Architecture Vision

Once the main strategy and objectives of the Data and Analytics initiative are assembled, the architecture work begins. The main deliverables from this phase include the architecture principles, the enterprise capabilities with D&A value stream cross-mapping, the EA operating model, and both the baseline and target architecture models of the business domain. In the case of the D&A project, the models include the Reporting Services unit of AVBV.

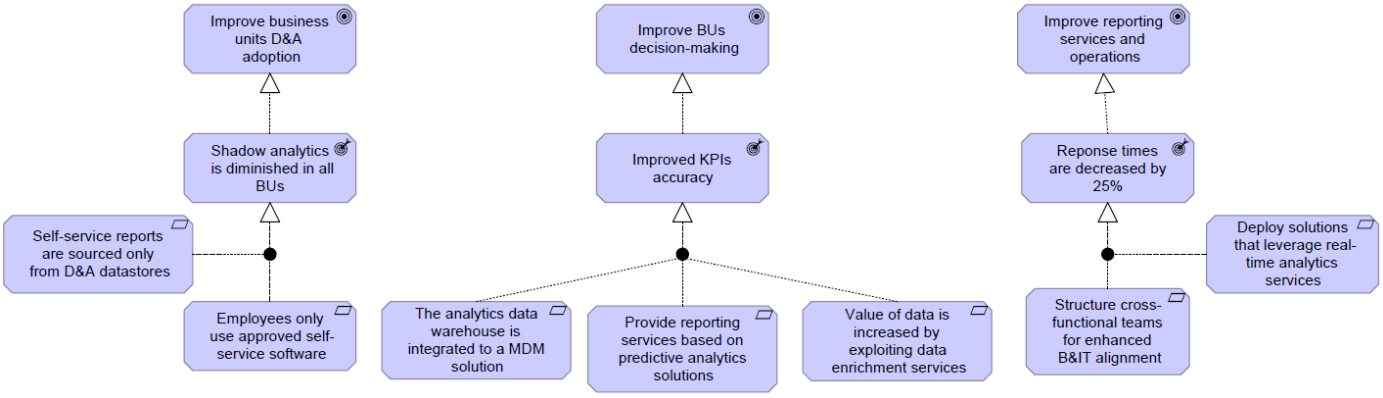


Figure 28. Goals, objectives and requirements from D&A initiative

5.2.2.1 Architecture principles

The following principles relate to the rules and guidelines that influence the decisions for architecture design and development in the context of the D&A program across business, data, technology, and applications.

- **Business principle**

Table 18. EA4DT business principle

Name	Enterprise data literacy
Statement	Information becomes a second language at every level of the organization. Business units understand the support of data and analytics to their work and IT professionals understand what their work represents to the business context.
Rationale	Data literacy provides a solid foundation for enhanced decision-making across all units of the enterprise.
Implications	Business and IT teams must collaborate at all phases of the initiative. Cross-functional teams cooperate in the design, implementation, and maintenance of the D&A program.

- **Technology principle**

Table 19. EA4DT technology principle

Name	Low-cost flexible and secure technologies
Statement	Upfront investments to support the initiative must be low with flexible and secure technologies and infrastructure used to experiment and deliver faster data and analytics services to the business departments.

Rationale	Controlled financial spending is critical for the initiative based on the use of low-cost flexible and secure technologies. Therefore, the principle stimulates the use of technologies that allow experimentation and deployment of data and analytics solutions while complying with security standards of AVBV.
Implications	Technologies and infrastructure selected for the deployment of analytics solutions must not require up-front licensing investment and annual support fees. In contrast, platforms and technologies are preferably selected on a service-based model.

- **Data principle**

Table 20. EA4DT data principle

Name	Data is a valuable asset
Statement	Created, shared and used data at all levels of the organization is indispensable and managed accordingly.
Rationale	Data is considered a key corporate resource. Positive outcomes for the business are the result of using high quality and reliable data at the right moment. Therefore, AVBV must carefully manage and use data.
Implications	Proper governance mechanisms must be put in place to prevent, detect and take action to ensure data quality and consistency. Systems of record and reference are properly aligned to the Master Data Management (MDM) strategy of the company.

- **Application principle**

Table 21. EA4DT application principle

Name	Technology independence
Statement	Applications employed as part of the initiative are not bound to any specific technology and therefore can operate in a variety of platforms and infrastructure.
Rationale	Independence of applications from specific technologies facilitates the development, upgrade, and migration of the application components required for the D&A initiative.
Implications	The applications are deployed under wide-open standards and allow portability between different platforms and IT infrastructures.

5.2.2.2 Enterprise Architecture operating model

Given the size of the organization and the scope of the initiative, a centralized EA model is chosen for the D&A program to be delivered at AVBV. The EA operating model presented in Figure 29 depicts the EA team under the Head of IT Europe. Consequently, the lead enterprise architect, the project architect, and each of the domain architects (data, business, application, and technology) report directly to this organization. For the purpose of executing architecture governance, the Enterprise Architect and project architect collaborate to review changes and potential deviations from each of the projects defined in the Architecture plan phase of EA4DT. Ultimately, each business unit manager i.e. the head of Sales, the head of Supply Chain, and the head of Finance work hand in hand with domain architects to develop architecture work and essential deliverables according to each individual project.

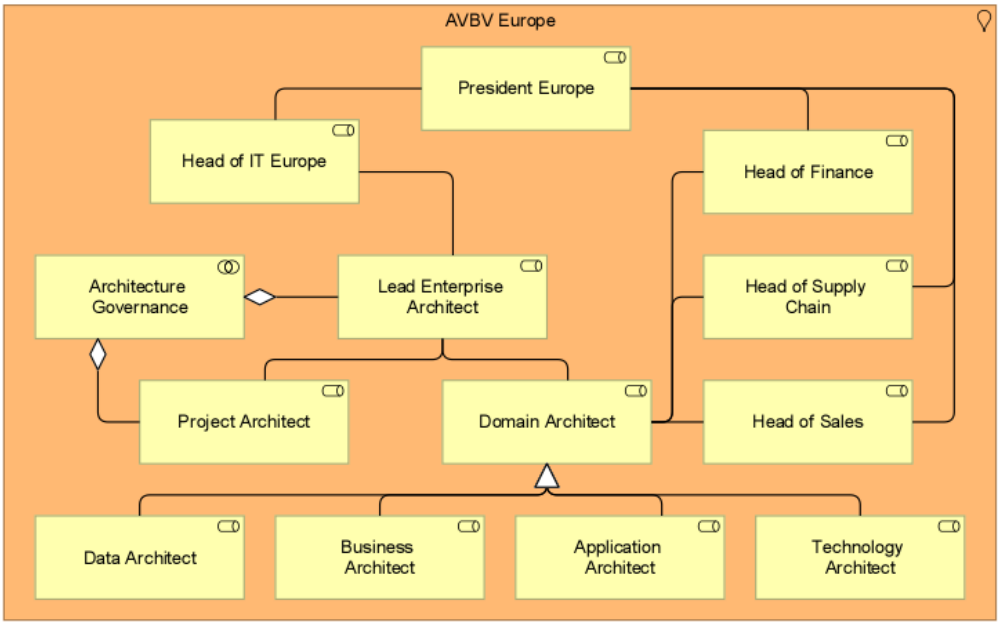


Figure 29. EA Operating model for D&A

5.2.2.3 Enterprise capabilities with D&A value stream cross-mapping

Enhanced business decisions are made based on the execution of the Data and Analytics continuum value stream detailed in Figure 30. The sequence incorporates the key set of activities to deliver analytics from end-to-end of the enterprise. Each of the stages of the data and analytics continuum map the required and missing capabilities that create an overall result for each of the stakeholders of the initiative. As a first step, data acquisition (data capture) represents the collection of data at the source i.e. systems of record or systems of reference. Next, the organization of data in a centralized repository is performed with the prior employment of data profiling, cleansing, integration, and transformation capabilities. Master Data Management and data enrichment create superior value in the analytics continuum as they provide the ability to ensure data uniformity, stewardship, and semantic consistency as well as data augmentation.

Later, data is analyzed by leveraging data preparation, predictive analytics techniques, and data mining. At the end of the value stream, data is delivered and effectively distributed to all the relevant stakeholders. Table 22 lists capabilities as defined by the DAMA guide to Data Management Body of Knowledge DAMA-DMBOK Guide (Mosley *et al*. 2009) and other relevant sources.

Table 22. Data and analytics capabilities definitions and references

Capability	Source	Definition
Data Transformation	DAMA-DMBOK Guide (Mosley *et al*. 2009)	Embodies the process of standardization and mapping of data entities to corresponding target representation upon identification of data errors.
Data Integration		The data management function for consolidation data from multiple sources and ensuring consistency across controlled redundant data with a "golden version".
Data Profiling		Provides the capability to perform statistical analysis and assessment of the quality of data values. It also involves the exploration of relationships that exist across value collections and data sets.
Data Cleansing (Quality)		Focuses on activities that correct and enhance values of data elements. Correction activities are pushed to source systems whenever possible.
Master Data Management (MDM)		MDM is the process of defining how master data is created, integrated and used throughout the enterprise. Master data is an authoritative, most accurate data available about key business entities.
Predictive Analytics		Is the capability to perform what-if analysis that allows an organization and its users to create and test models based on actual data, and then project future results.
Data Mining		Refers to a technique in the area of data analytics. It mainly focuses on revealing patterns in data using various algorithms.
Descriptive Analytics	Gartner, Inc. (2020)	Represents the manual examination of data or content characterized by traditional BI and visualization techniques e.g. pie, bar charts, line graphs, tables or generated narratives.

Capability	Source	Definition
Data Visualization	Gartner, Inc. (2020b)	A way to represent information graphically, highlighting patterns and trends in data, helping the user to achieve quick insights.
Data Delivery	Gartner, Inc. (2017b)	Refers to the optimal point of impact to where data is delivered, whether to support human activities, embedded analysis into business processes or support predictive analytic activities.
Data Migration	IBM (2019)	The process of transferring data from one computing or storage environment to another.
Data Enrichment	Allen & Cervo (2015)	The process of enhancing existing information by adding missing or incomplete data. Typically, data enrichment is achieved by integrating external data sources.

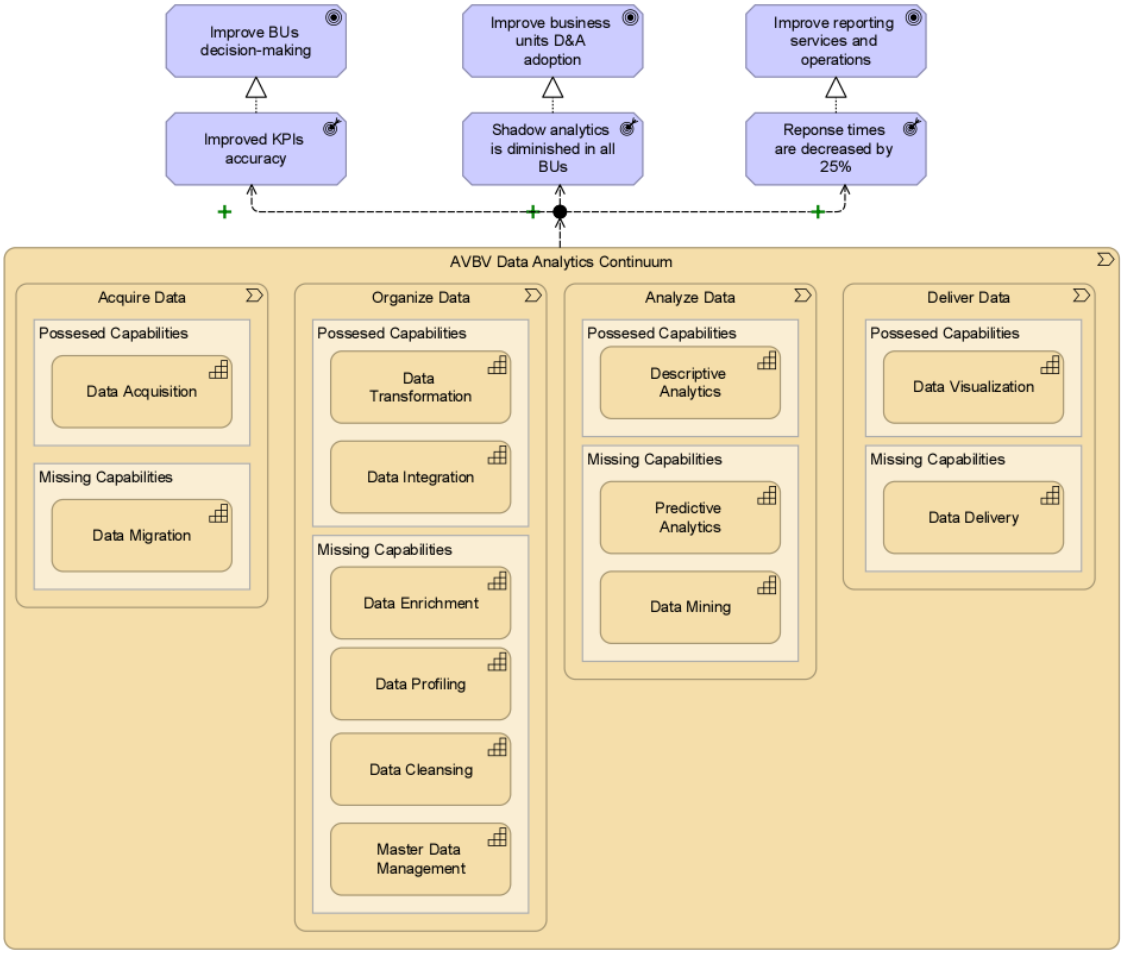


Figure 30. Data and Analytics capabilities with value streams mapping

5.2.2.4 Baseline architecture

***CONFIDENTIAL* (AVBV internal use only)**

Figure 31. Baseline architecture from Reporting Services AVBV (*Confidential*)

5.2.2.5 Target architecture

The envisioned architecture illustrated in Figure 32 introduces several modifications across the business, application, and technology domains aligned with each of the stages of the analytics continuum value stream. As a result, proper collection, cleansing, profiling, preparation, and delivery of data is handled and the identified missing capabilities are now embodied. From a bottom-up perspective, the target architecture will continue to retrieve structured data from the original source databases by reusing the business logic contained within the ETL data integration component. However, to ensure data quality and consistency of key master records e.g. Customer, Product, Supplier, Material, and Account, heavily utilized by D&A services, a master data repository and integration layer environment is blended. The MDM component acts as an authoritative data governance mechanism to control master records across all data sources.

The layer on top of the AVBV infrastructure leverages a critical set of technological components in response to the missing enterprise capabilities for advanced and predictive analytics. In line with the architecture principles, the technology architect has seen an opportunity to employ Cloud Computing as the backbone of the new analytics platform deployment and a solid foundation for future implementations to support Big Data analytics for unstructured data. The latter would also allow AVBV to deploy resilient distributed architectures. Furthermore, the Cloud infrastructure allows the deployment of the columnar-store OLAP database, ideal for hosting the data warehouse repository (DWH instance). Data migration to the new environment from the local infrastructure will be required. A front-end application (BI server) supports online access and business logic required to build and publish the dashboards containing the relevant information to each report. For predictive analytics to be effectively conveyed, a runtime environment that supports statistical computing and data mining (Advanced Analytics server) are also merged into the solution architecture. Thus, models for regression (linear or nonlinear), classification, association, or clustering can be implemented depending on the prediction concerns applicable to each business unit. To enable online web access to the predictive analytics results hosted in the Advanced analytics server (Data mining DB), a web application must be deployed.

To increase the value of D&A services, data enrichment is leveraged by provisioning an additional Data Preparation server where external APIs are consumed. Useful services for data enrichment in the context of AVBV might include, for example, real-time weather and traffic conditions to be used by predictive models for order shipment and stock provisioning. Prior to merging data with the analytics repository, a preparation process is triggered to ensure only the required values and metadata are included in the prediction datasets. For security and

performance purposes the Data mining DB and the DWH instance are hosted in different computing environments. Hence, computing resources are not shared and intrusive processes are avoided. Moreover, secure network connectivity between local and cloud infrastructure is addressed by using Virtual Private Networks (VPN) with the use of server-side or client-side encryption mechanisms.

At the top layers including the Application and Business architecture domains, the self-service reporting client will continue to provide self-service reporting functionalities for well -defined operational and strategic business planning processes. Moreover, the application services for predictive analytics reports supply the critical functionalities to a new business analytics planning process. The last-mentioned brings together BU teams and IT by means of the assisted decision-making collaboration. Ultimately, the Web IDE application component (Integrated Delivery Environments) realizes predictive analytics development services to the organization. As a result, continuous business analytics development processes are performed by joint collaboration between three newly created roles: Data scientists, Business and Information Analysts. Data scientists employ data mining algorithms on extracted datasets to produce predictive analytics reports, whereas Information and Business Analysts personify a mixed role of business and IT skills to constantly improve descriptive and predictive business analytics. Further descriptions for each of the elements of the Target Architecture are detailed in the Conceptual Architecture phase.

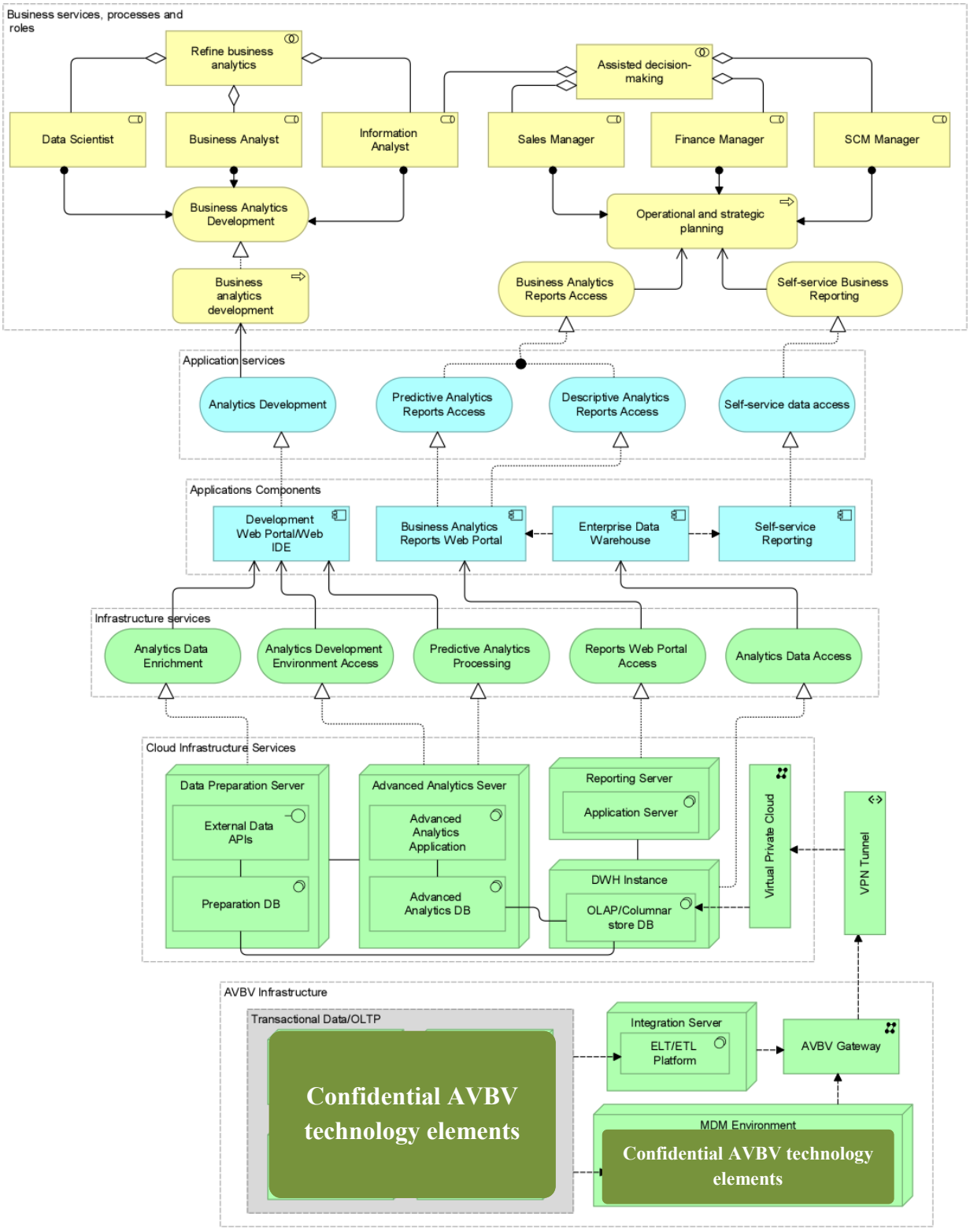


Figure 32. Target architecture from Data and Analytics AVBV

5.2.2.6 Cross-functional organization

An essential part of architecting the digital enterprise lies in decomposing the organization and outline boundaries that minimize inter-team dependencies (The Open Group, 2019). Figure 33 depicts the cross-reference between business and IT units required to deliver the Data and Analytics project. Therefore, teams are built by assigning a responsible for each intersection point specialized in a particular business-oriented purpose e.g. sales, supply chain, or finance. As a result of this proximity between IT and business experts, business requirements are delivered faster and efficiently. The Master Data Management team does not follow this pattern as their responsibilities include the management of business data entities across the entire enterprise.

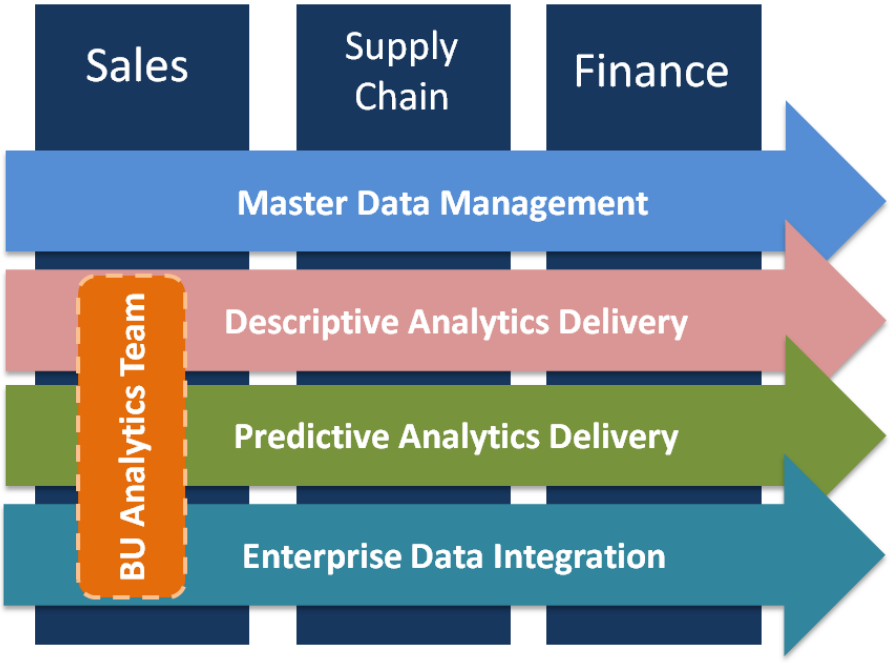


Figure 33. Business and IT cross-reference teams for D&A program

The organizational structure view provided in Figure 34 illustrates the teams and roles associated with each business unit for the D&A program.

- **Business analyst:** Responsible for ensuring that business reports, including descriptive or predictive, are built according to use-case requirements. Provides extended business knowledge to assist in the development of descriptive and predictive business reports.

- **Information analyst:** Ensures data is structured and available for distribution and access across the repositories created for descriptive reports. Supports new requirements for the creation or modification of descriptive business reports.

- **Data integration specialist**: Provides technical integration support to existing or new sources of information across all layers of the technology architecture.

- **Data scientist:** In charge of implementing prediction algorithms or advanced analytics techniques to deliver predictive business reports based on business requirements.

- **Data architect:** Manages and provides access to master data repositories for analytics purposes. The data architect belongs to a Data Management Service organization, in the case of AVBV, the Center of Excellence (CoE).

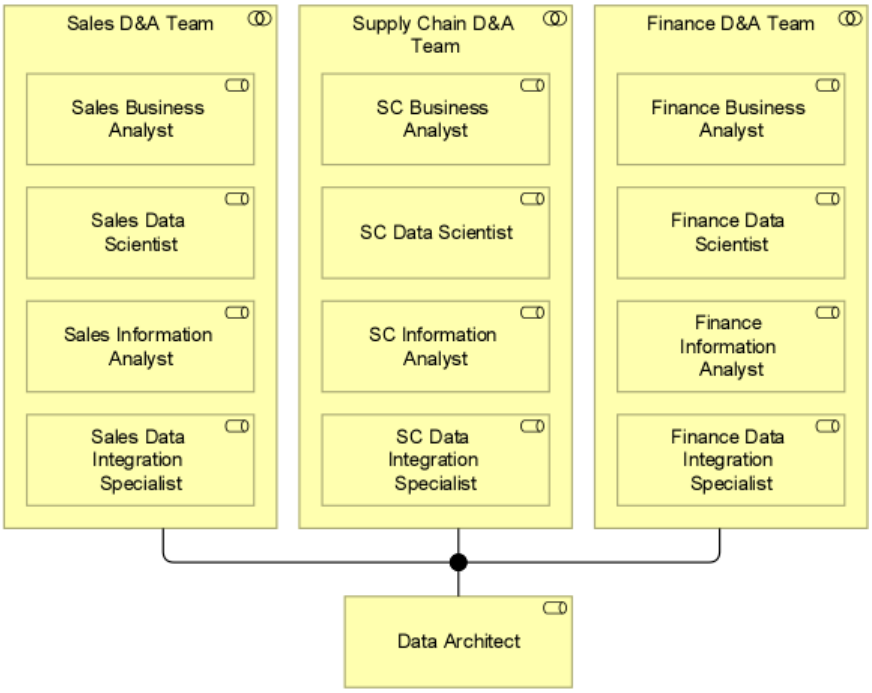


Figure 34. Roles and teams structure for D&A operation

5.2.3 Architecture Action Plan

The architecture action plan for AVBV presents the necessary individual projects to realize the Architecture Vision introduced in the previous section. The derived work packages were extracted by analyzing the Target Architecture blueprint and the D&A strategy provided in the Architecture context section. It is important to highlight that the development and implementation of all the projects are required for the successful delivery of the D&A initiative for the European division of AVBV.

5.2.3.1 High-level action plan

The action plan for the Data and Analytics program for AVBV is composed of four major individual work packages or projects. The execution of these individual projects contributes to the realization of the Architecture Vision. Figure 35 provides a concise view of the project structure of the D&A initiative.

- **Master Data Management:** Consists of all the activities related to the integration of systems of records or reference to the Master Data repository. Furthermore, it exposes the required services for the delivery of Master Data consumed by the D&A environment. At the moment this thesis is written, the Center of Excellence (CoE) team has already begun with the design and implementation of the MDM solution for AVBV globally.

- **Provision Data and Analytics Services:** It involves the deployment of the new platforms that supply the required set of functionalities for both descriptive and predictive analytics. This involves the conceptual design and logical association between the application and technological components that materialize the desired business services of the target architecture. Furthermore, the project outlines the optimal solutions for deployment based on the initiative's architecture principles defined. The project must be developed without compromising the ongoing reporting services operations at AVBV.

- **Data Analytics Design and Implementation:** In here, the actual implementation of advanced analytics solutions takes place to provide enhanced descriptive and predictive reports for business units. According to the individual requirements for each department, predictive techniques are implemented such as data mining algorithms or statistical models with the support of programming languages (Python or R). Separated access to high-quality refined datasets from the descriptive data analytics repository (data warehouse) is utilized for the implementations. This particular project will require further analysis and design from a Data Architecture perspective with defined business requirements and expectations for delivered predictive analytics results.

- **Information security:** In line with the business and architecture principles and overall D&A strategy, the information security project includes all the activities related to implementing the required mechanisms to provide security at all levels of the architecture. Since the D&A program has a strong foundation on the use of data, the work package must secure data in all its states i.e. data at rest, data in motion, and data in use. Ultimately, the Infrastructure and Cloud team must review and make certain that all implemented solutions are compliant to corporate and external regulations.

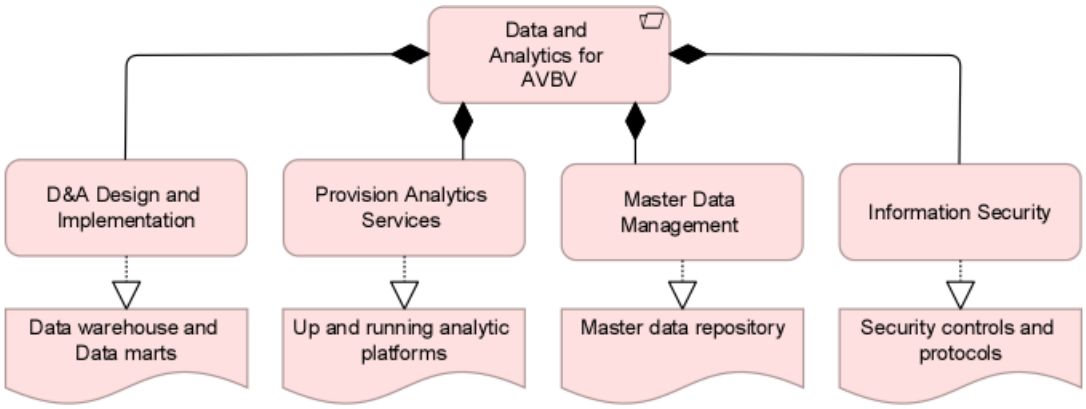


Figure 35. Defined projects and expected deliverables for D&A program

5.2.3.2 Architecture constraints and guardrails

To facilitate architecture evolution the following set of constraints and guardrails are described for the D&A initiative. Constraints classified in Table 23 describe both the technical and business limitations that influence the ability for the architecture to change over time.

Table 23. Constrains definition and classification for architecture program

Constrain	Description	Type
Transactional systems remain On-premise	Transactional databases and core data sources will remain deployed locally under the domain of AVBV infrastructure.	Technical
Low impact platform migration	As IT resources are scarce, software solutions and service platforms must be chosen on a cost-effective basis with little or no impact on migration activities from current implementations.	Business
IT resources are justified on business outcomes	AVBV's main business is to produce and sell tires not implementing IT, therefore any additional resources must be justified by tracing back its contribution to the organization.	Business

On the other hand, proposed architecture guardrails are meant to be lightweight mechanisms enforced by an oversight team for the project, in the case of the D&A program, the Architecture Governance review board composed by the Lead Enterprise Architect and the Project Architect. Therefore the principal architecture guardrails for the project are:

- **Employ reference architectures:** Project teams are expected to employ reference architectures as part of the development of the logical and technological architecture models. Best practices can involve practitioner-based or literature-based reference architecture models. As part of the D&A project the SITAM reference architecture

(Kassner *et al.* 2016) retrieved from literature is considered as a point of reference for the technological foundations of both logical and physical architectures.

- **CoE team support:** AVBV's corporate Center of Excellence (CoE) must assist architecture teams with additional best practice and industry recommendations. Any decision that deviates from the desired architecture state must be discussed with the CoE and therefore justified with evidence on the architecture reviews.

5.2.4 Architecture Outline

The Architecture Action Plan introduced in the previous section presented four main projects required to be executed in order to realize the Data and Analytics vision. For validation purposes, this research project only examines one of the suggested projects for the remaining phases of the EA4DT development cycle. Based on the short-term results it provides and its relatively low dependency to other projects, the Provision Data and Analytics Services project is selected as the candidate to further elaborate on the architecture outline and its associated conceptual, logical, and technical architectures.

5.2.4.1 Project requirements

To effectively validate the contribution of the Provision Analytics Services project to the architecture vision and consequently to the business requirements, the following project requirements are defined into a granular level.

- **Deploy descriptive analytics access service:** The project must ensure the deployment of the new descriptive analytics portal for internal use of the BUs part of the D&A initiative. Functionalities of the service exceed current capabilities offered by Athena.

- **Deploy prescriptive analytics access service:** The project delivers a service for managers form the Finance, Sales, and Supply Chain departments to consume predictive analytics reports based on specific business requirements.

- **Enable self-service reporting data access service:** Each of the BU is granted access to the particular data structure or data mart for the development of self-service business reports. The service does not involve access to data sources that process results for predictive analytics.

- **Provision predictive analytics development service:** An application service is enabled for the implementation of business analytics for predictive purposes. The service is intended to serve only the business analytics development process introduced by the target architecture.

5.2.4.2 Selected project scope

The Provision Data and Analytics Services project is outlined by the deployment of required components and platforms in a cloud environment that enable access and consumption of descriptive and predictive analytics reports. Moreover, the project includes the definition and design of development services for predictive analytics implementations. Associated activities to its future implementation involve the migration of automated processes (ETL jobs) and databases (current data warehouse) to the selected cloud platforms.

The project does not include the design of predictive models according to individual business requirements. For this specific concern, the Predictive Analytics Implementation project must be executed. The definition of integration mechanisms for master data consumption must be delivered as part of the Master Data Management project. Ultimately, the project does not evaluate detailed network and security mechanisms for local to cloud data center interconnectivity as it falls into the Security and Compliance project.

5.2.5 Conceptual Architecture

Based on the requirements and the scope established at the Architecture Outline for the Provision Data and Analytics Services, the Conceptual Architecture phase gets kicked-off. In this phase, the exposed business services are described and associated with key business objects, processes, and roles. As a result, assembled business activities and teams portray a cross-functional collaboration required to deliver and maintain the business service within AVBV. Later on, information and technology services in support of business services are listed and described.

5.2.5.1 Business analytics development service

The first of the three business services for the Provision Data and Analytics Services project addresses the development of business analytics reports for the Business Units involved in the D&A initiative. Table 24 describes the main characteristics of the business service. Furthermore, Figure 36 portrays the business services and its associated elements.

Table 24. Business analytics development service definition

Characteristic	Description
Business objective	The service aims at providing an internal business function to deliver analytics reports based on detailed business specifications or requirements.
Business process	The business analytics development process compiles the set of activities required to collect, develop, and deploy the reports accordingly.

Characteristic	Description
Business roles	Data Scientist, Information Analyst, Business Analyst (roles descriptions provided in section *Architecture vision: Cross-functional organization*)
Business objects	*Analytics Business Report:* Represents the expected outcome from executing the business analytics development business process.
	Analytics Report Specification: Embodies the business requirements or specifications required to begin the business analytics development process.
Information Systems service	The Analytics Development service enables a collaborative advanced analytics environment in support of business roles in charge of delivering predictive reports implementations.
Technology services	*Predictive Analytics Processing:* Represents the exposed technology function for processing the implemented algorithm or technique to obtain predictive results to present in a report.
	Analytics Development Environment Access: Enables access to a collaborative platform for the implementation and development of advanced analytics.
	Analytics Data Enrichment: Allows the business to gain more insights by adding value to data through the use of third-party authorized data provider services.

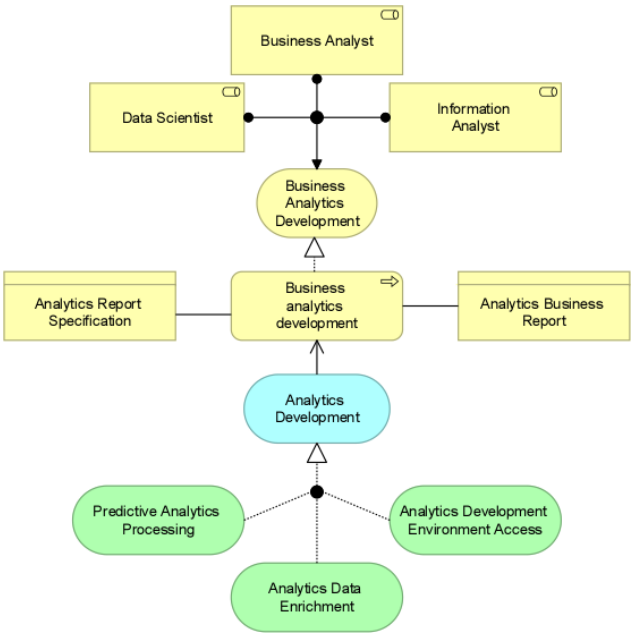


Figure 36. Business analytics development service collaboration view

5.2.5.2 Business Analytics Reports Access

The second business service is centered on enabling access to business analytics reports to entitled business units. Table 25 describes the main characteristics of the business service. Furthermore, Figure 37 portrays the business services and its associated elements.

Table 25. Business analytics reports access service definition

Characteristic	Description
Business objective	The services essentially provide access to business actors to business analytics reports fabricated and maintained by the Business Analytics service.
Business process	No business services realize this business service. However, it serves the Operational and Strategic planning business process of authorized BUs.
Business roles	*SC/Finance/Sales Manager:* Represent the main users of the business service demanding continuous access to published predictive and descriptive business analytics reports.
Business object	*Analytics Business Report:* Represents the business object provided by the business service and used throughout the Operational and strategic planning process.
Information Systems service	*Predictive Analytics Reports Access:* Provides the application user interface to access predictive analytics reports.
	Descriptive Analytics Reports Access: Provides the application user interface to access descriptive analytics reports.
Technology services	*Reports Web Portal Access:* Exposes the technology functionality that allows the web portal to be deployed through a web interface. The platform provides a single pane of glass for both predictive and descriptive business report access.

5.2.5.3 Self-service Business Reporting

The third business service is associated with providing business reports access through a self-service reporting model. Table 26 describes the main characteristics of the business service. Furthermore, Figure 37 portrays the business services and its associated elements.

Table 26. Self-service business reporting service definition

Characteristic	Description
Business objective	The business service stimulates data democratization. Processed business datasets are exposed to the business units for self-service reporting purposes.
Business process	*Analytics Business Report:* Represents the business object provided by the business service and used throughout the Operational and strategic planning process.
Business roles	*SC/Finance/Sales Manager:* Represent the main users of the service demanding continuous access to business datasets through self-service reporting mechanisms.
	Information Analysts: Assist business users in the elaboration of self-service reports and strengthen data literacy across AVBV.
Business object	*Analytics Business Report:* Represents the business object provided by the business service and used throughout the Operational and strategic planning process.
Information Systems service	*Self-service data access:* Connect processed data marts with business users that require self-service reporting capabilities.
Technology services	*Data Marts Data Access:* Provides the technology platform to access specific segments of data according to business profiles.

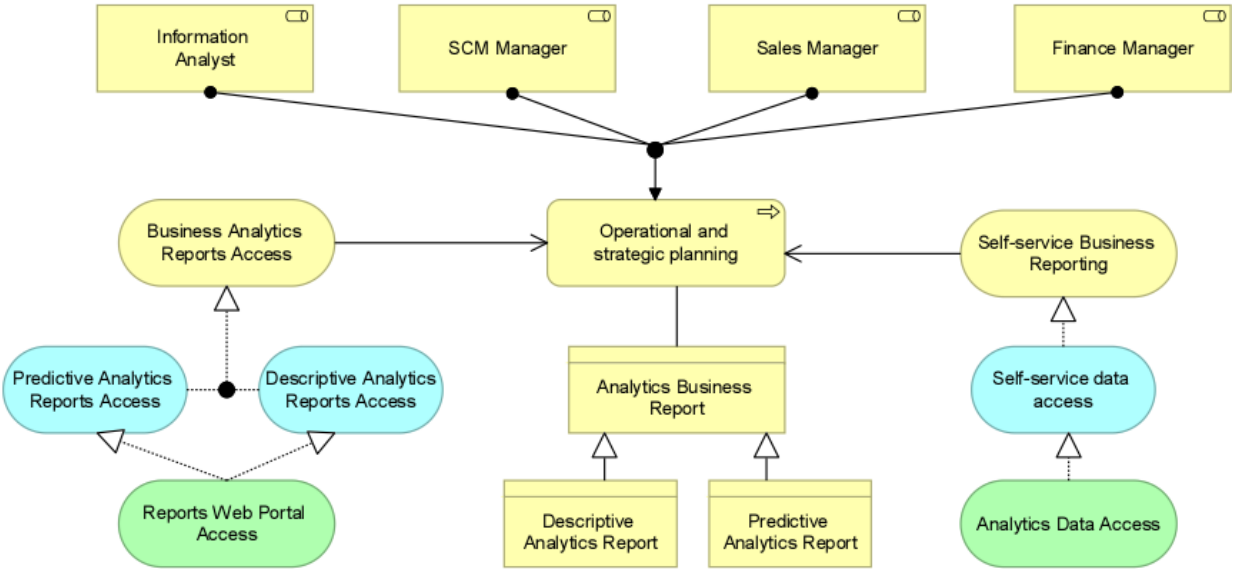


Figure 37. Business analytics reports access and self-service business reporting services collaboration view

5.2.6 Logical Architecture

Once the conceptual architecture phase is completed, the logical architecture defines the underlying information systems and technology in support of the application services to be consumed by the business. A critical part of the logical architecture involves structuring the technical elements into a two-speed IT configuration to allow the evolution of fast-paced services critical for the D&A initiative while supporting traditional mission-critical back-end systems. The following activities further describe the deliverables of the logical architecture phase.

Application and Technology Design

According to Figure 38, the information systems or applications to be deployed to support the D&A analytics are essentially split into two fronts: the fast speed and the transactional architecture. In the fast-speed front, applications can change at a considerably higher rate than the transactional ones, i.e. they can be modified faster and even replaced if needed in order to comply with business services defined in the conceptual architecture. On the other hand, the transactional segment includes information systems that are more reliable and deliver the highest quality.

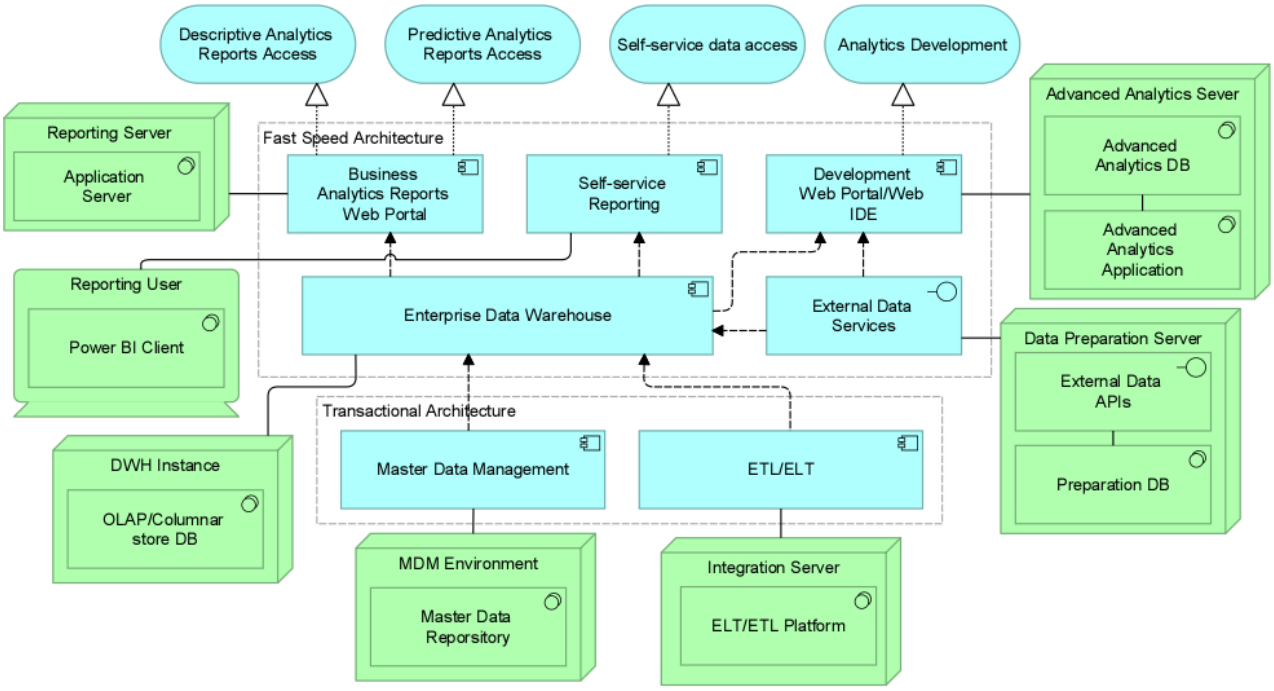


Figure 38. Logical application and technology components view

As listed in Table 27, each system is classified into a system of record, a system of differentiation, and a system of innovation simplifying the process of modeling application and associated components. Ultimately, generic technological components are associated with the application elements in order to extend the reach of the viewpoint and address stakeholder's concerns from the technical perspective.

Table 27. Application components classification

Application	Description	Classification
Business Analytics Reports Web Portal	Front-end application where users access to both descriptive and predictive reports produced by the analytics development service	System of differentiation
Self-service Reporting	Reporting client tool employed by users to produce customized reports from defined data marts	System of differentiation
Development Web Portal/Web IDE	Web development environment where predictive analytic results are executed and subsequently published to the Business Analytics Reports Web Portal	System of innovation
Enterprise Data Warehouse	Consolidated enterprise repository where multiple sources of structured information are integrated for analysis purposes.	System of differentiation
External Data Services	Represents an interface to trusted external data services to be integrated with internally generated data and provide richer reports (both descriptive and predictive)	System of innovation
Master Data Management	Embodies the application repository that contains master business entities to be delivered to the D&A data warehouse.	System of record
ETL/ELT	The intermediary system that extracts, transforms and loads transactional data from multiple sources into a denormalized data model in the data warehouse.	System of record

5.2.7 Physical Architecture

After defining the application and technical elements, the Physical Architecture is presented. In line with the interest of senior management as described in the Architecture Context phase, the physical architecture leverages emerging technologies i.e. cloud computing for deploying the required infrastructure and platform services to be supported by the D&A initiative at AVBV

Technology Solutions Model

The diagram presented in Figure 39, represents the physical technological configuration to comply with the requirements of the D&A initiative. The architecture model in this phase is divided into two main segments: Azure Infrastructure Services and the local AVBV infrastructure. An additional layer is presented for external data services integrations. The purpose of the latter is to leverage external data services provided through secure APIs to

consume data from external providers and enrich the defined data models for both descriptive and prescriptive analytics. Regarding the local AVBV infrastructure physical technology components, transactional data (OLTP) databases will remain on-premises as they represent the data repositories of the most critical systems in support of the operations of the plant in Enschede. Moreover, the Master Data Governance solution to be deployed as part of the MDM project will also remain in AVBV's local infrastructure due to hard dependencies to other local systems and applications.

On the other hand, the Azure Infrastructure services comprise all the platforms required to support the integration, transformation, ingestion and delivery of data. The components include the Azure Data Factory service, Microsoft SQL Server RDBMS for data preparation and data consolidation (data warehouse), SQL R services, ultimately, the power BI console service. All the services will be hosted in Microsoft's public cloud in the first iteration of the methodology, as a way to experiment and define the right technologies as the architecture continues to evolve. The connection between the local infrastructure of ABVB and Azure must be delivered by using Expressroute as a mechanism to guarantee both reliable and stable connections between the platform deployed on-premises and the ones deployed as cloud services. The selection of Azure as the initial cloud service provider was greatly influenced by senior management and their interests of leveraging their existing investment with the company for other technology projects.

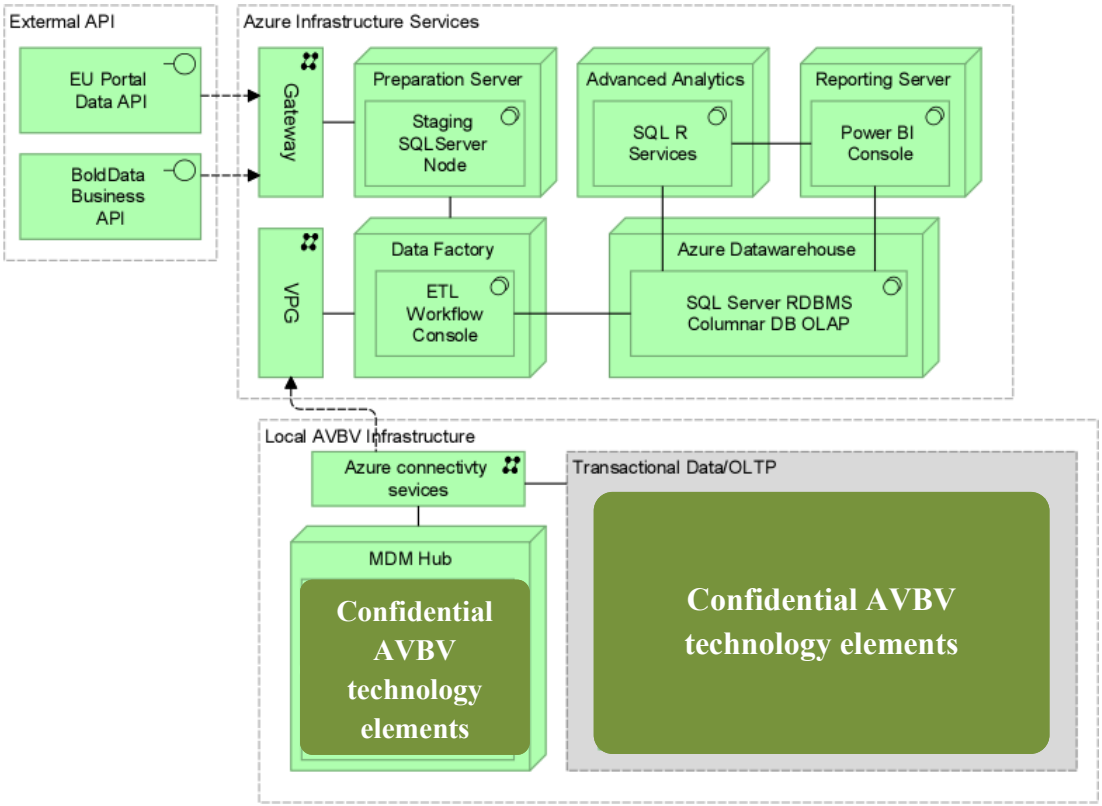


Figure 39. Technology components configuration view for D&A

5.2.8 Architecture Governance

As part of the EA4DT development cycle, the architecture governance phase compiles identified changes from the conceptual, logical, and physical architecture to be propagated across to the architecture vision documentation. For the Provision Data and Analytics Services project, alterations or modifications to the envisioned target architecture are justified, documented, and propagated.

5.2.8.1 Modifications at the Enterprise-level

After having analyzed the proposed conceptual, logical and physical architectures and review the requirements defined for the Provision Data and Analytics Services project in the architecture outline phase, there is only one identified fundamental change from the technology perspective to be propagated into the target architecture. The nature of the change does not require an entire redefinition of business and application services across the entire architecture. Therefore, only the physical architecture introduced a modification and the target architecture model is updated.

Figure 40 depicts the new target architecture at the Enterprise-level that portrays the introduced technical alteration. At the technical level, the current implementation of the ETL component deployed on a legacy technology within AVBV local infrastructure is highly customized and not capable to be reused and connected to the MDM project. Therefore, the decision led to the entire replacement of such a component into a cloud service that enables compatibility with the Master Data Governance and ensures portability with technology independence in line with the architecture principles earlier defined for the D&A initiative. As a result, the integration component between both transactional and master data to be transformed and delivered into a data warehouse will be undertaken by a cloud service platform. Ultimately, by experimenting with these technologies additional changes may arise for the entire architecture model, however, as the scope of this validation does not include the actual implementation of these cloud platforms services, these alterations are not yet identified and reported for the Provision Data and Analytics Services project part of the Data and Analytics program.

5.2.8.2 Modifications at the Project-level

The conceived architecture models for the conceptual, logical, and physical phases portray a granular view of the envisioned target architecture with their respective definitions and relationships to other architectural components. However, part of accelerating the learning cycles in EA4DT means testing and experimenting with the defined set of technologies to effectively assess the business value. Therefore post-designing architectural activities include the implementation, through small experiments, of the selected technology components followed by feedback sessions for architecture redesign based on the experiment results. Aligned to the scope of this thesis project, no experimentation was performed and therefore no modifications at the project level were defined. If any, changes at the project-level do not pose any amendments to the architecture vision in EA4DT.

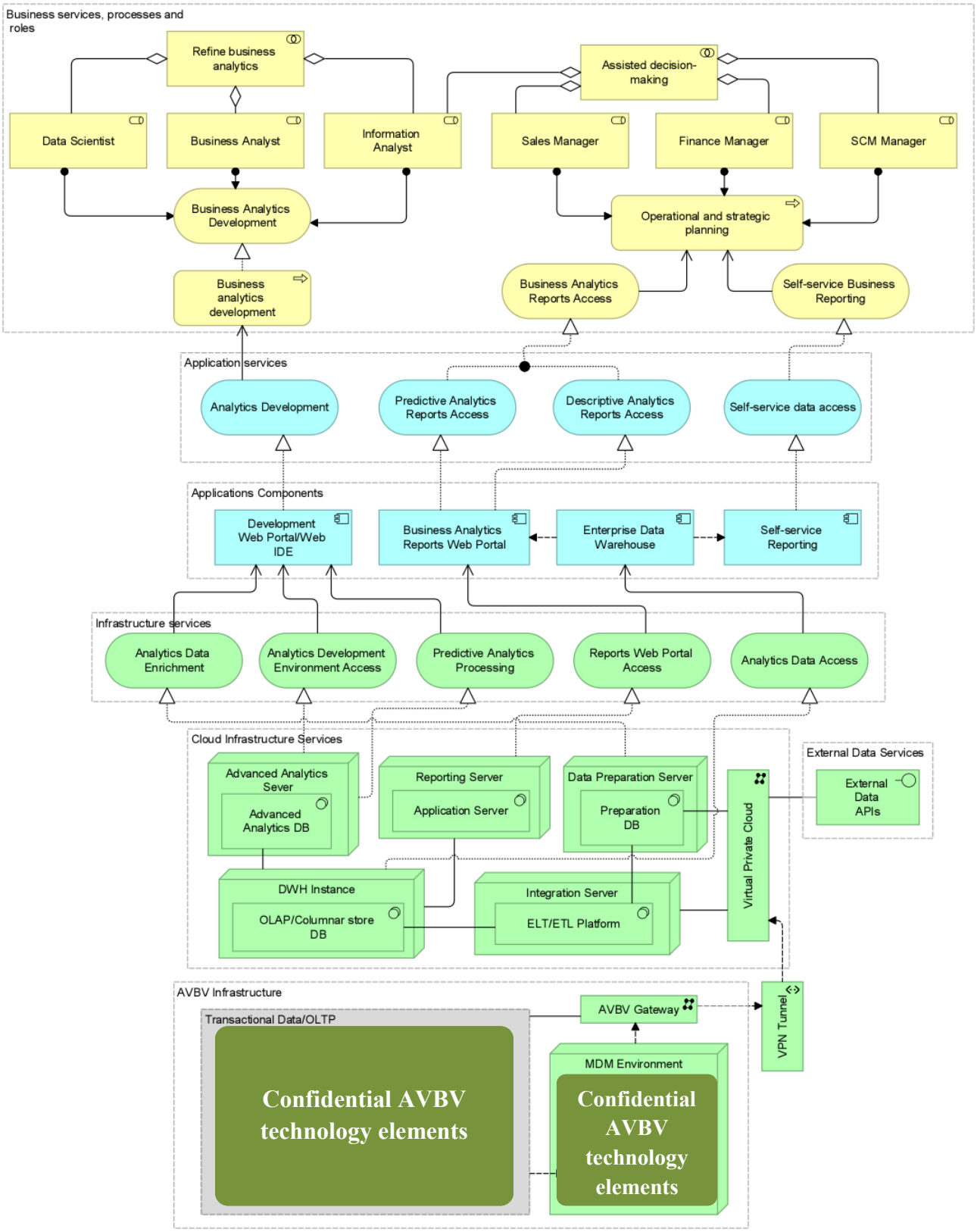


Figure 40. Modified Target Architecture design for D&A initiative

5.3 Artifact evaluation

In the second stage of the validation, results from applying the EA4DT into the Data and Analytics project were evaluated by two business architects part of the IT European division and one IT architect from the corporate division of AVBV. A round of expert opinion semi-structured interviews was performed preceded by the presentation of the methodology and the results obtained throughout the entire architecture development cycle. This subsection of the validation phase addresses the research objective 5.b.

Expert opinion evaluation model

The approach carried out for the evaluation of the EA4DT consists of three interviews with employees of AVBV that aim to validate if the designed artifact satisfies and addresses the main research question considering the results provided by the Technical Action Research case. This research method for validation is known as expert opinion for design science research (Wieringa, 2014). Based on their experience in the field of Enterprise Architecture, a solid comprehension of the presented artifact, and the results provided by implementing the methodology to the Data and Analytics initiative, positive and negative opinions are documented.

The validation method serves as a vehicle to filter out poor design choices made by the main researcher of this thesis and suggests the incorporation of potential new elements into the artifact. Interviews were conducted in 20 to 30 minutes one to one sessions, where multiple open questions were posed regarding two major areas, the problem relevance, and the practical and implementation relevance. In line with Hevner *et al.* (2004), the proposed areas take into consideration the utility, quality, and efficacy of the artifact in relation to the main objective of this research. Once again, before performing the interviews, participants were already familiarized with the artifact and the results from the first validation phase, i.e. implementing the artifact into the D&A initiative.

5.3.1 Problem relevance

The problem relevance questions aim at evaluating with experts three major objectives around the principal research question introduced by this thesis in the context of a Digital Transformation project. These objectives include stimulating business agility, simplifying the architecture development process, and promoting collaboration across business and IT social structures. Furthermore, these main objectives are linked with their associated artifact objective, presented in section 3: Design Analysis, with the sole purpose of tracing back artifact objectives to the main research objective. Table 28 classifies the problem each of the problem relevance questions according to their research concept and artifact objective.

Table 28. Problem relevance questions for expert evaluation interviews

Objective: Stimulation of business agility	
Artifact objectives	**Question**
1. Design interdisciplinary organization	Do you consider that designing a cross-functional organization (architecture vision) portrayed how agility can be transferred to the business? Why?
2. Convey business agility through architecture design	Do you consider that designing two-speed and bimodal IT architecture patterns (logical architecture) portrayed how agility can be transferred to the business? Why?
3. Simplify the architecture development cycle	Do you consider the artifact embraces faster learning cycles through the delivery of simple enough architecture models in contrast to other big designs upfront EA approaches? Why?
Objective: Promote collaboration across business and IT social structures	
Artifact objectives	**Question**
1. Design interdisciplinary organization	Do you consider that the alignment of social structures employed within EA4DT (architecture vision) enables greater collaboration between business and IT for the D&A initiative? Why?
Objective: Simplification of the architecture development process	
Artifact objectives	**Question**
1. Promote modularization and decoupled building blocks	Does the EA4DT incorporates the essential set of deliverables to simplify the architecture development process for a Digital Transformation initiative? If not, which do you consider are missing?
2. Simplify the architecture development cycle	Do you consider the simplified version of the ArchiMate metamodel for EA4DT serves the purpose of keeping architecture products simple throughout the entire architecture development cycle? If not, what concepts should be included?
	Does the utilization of services as decoupled building blocks promote modularization within EA4DT, therefore simplifying the architecture development process? Why?

5.3.2 Practical and Implementation relevance

The practical and implementation relevance questions aim at registering the expert's predictions for the implementation and adoption of the framework among the IT division of AVBV. The proposed relevance questions include:

a) Do you consider that the method can be applied to other Digital Transformation initiatives inside and outside of AVBV (e.g. smart manufacturing)?

b) How do you classify the complexity of using and applying the EA4DT to any other Digital Transformation endeavour (very simple, simple, intermediate, complex, or very complex)? Why?

c) Do you consider the designed artifact only to be applicable to a specific set of emerging digital technologies (e.g. Big data analytics and IoT)?

5.3.3 Interviews with practitioners

The following subsections compile the most relevant pieces of information extracted through the individual sessions performed with three interviewees from AVBV. The results are included for both the problem and the practical and implementation relevance areas of concern.

5.3.3.1 Interviewee 1

Date	July 2nd, 2020
Role	IT supervisor with more than 10 years of experience in the area of Business and IT architecture. Works alongside a team of specialists in AVBV in Europe including application development, architecture, end-user devices, and infrastructure management and security. Focused on transforming the business with new emerging digital technologies and help AVBV embark on a successful journey towards Digital Transformation.

Problem relevance

The inclusion and design of cross-functional teams are essential for providing faster and highly cohesive delivery environments in response to the challenges brought by highly dynamic business requirements. Although cross-functional teams were evaluated sometime in the past at AVBV, they were not defined based on particular business purposes in contrast to what has been shown in the D&A initiative project. Moreover, the two-speed architecture models from the Logical architecture phase in EA4DT are considered pertinent for portraying business agility through architectural design in contrast to traditional approaches used within AVBV that represented entire IT architectures models as a "single package". These experiences resulted in many delays for any particular project, and the way the EA4DT addresses it may result in

segmented but faster project fulfilment. In the context of the D&A initiative, this addresses the concern from senior management to provide different reports across multiple levels of the organization. Finally, simplification brought by the artifact will allow faster learning cycles with quicker stakeholder feedback iterations. The segmentation into smaller projects proposed by the artifact will allow the team to avoid working on big-bang projects and focus more on short-term tangible results.
In relation to the second research objective, the presented cross-functional organization (part of the architecture vision in EA4DT) creates a social structure in AVBV that lessens team isolation and enables closer cooperation between business and IT social structures of the enterprise. The presented models, however, did not reflect the way in which roles with the same skill sets, e.g. Information analysts from the Supply Chain and the Sales department cooperated as they may need to address business requirements that overlap between two internal departments from AVBV. This calls for additional views or architecture designs to address these particular concerns.

The validated framework in the context of the Digital Transformation initiative at AVBV, from a simplification of the architecture development process perspective, includes what needs to be considered essential for architecture development. The simplified conceptual, logical, and physical architecture models are crucial when explaining senior management, for instance, what is the budget is spent on. The suggested deliverables facilitate the understanding of what has to be implemented by the current IT staff of the organization. Moreover, the use of modular and decoupled building blocks such as services elements utilized by the framework will allow AVBV to detect flaws and reduce impacts from modifying architecture structures at later stages of the cycle. In line with the strategic vision of the D&A initiative for AVBV, the suggested services would require a more granular definition and segregation considering the short-term requirements and desired state of the company in the long run (predictive analytics services).

Practical and Implementation relevance

The framework could be employed for other project endeavors, prescribing the essential building blocks alongside a methodology that provides guidance for other organizations to embark on successful Digital Transformation journeys. The strength of the framework lies in the concept of experimentation as a way to deliver incremental business value to the organization, coping with highly volatile business requirements. In addition, the framework could be embraced as a highly relevant tool for organizations with a smaller size and budget compared to AVBV, where simplicity is a must as they continue to move towards larger-scale implementations.

Regarding the utilization of the artifact with other emerging digital technologies, the framework is rather best practice-based than a technology-bounded approach, which makes it flexible to be used for any other digital strategies e.g. industry 4.0. Ultimately, the EA4DT level of complexity is in between simple and complex based on a variety of concerns around implementation,

usability, and adoption from the IT team. The artifact also needs to include focus areas that tackle other critical issues from Digital Transformation projects such as risk management and cost/benefit analysis.

5.3.3.2 Interviewee 2

Date	July 3rd, 2020
Role	Information Technology professional with more than 15 years of experience in the field of infrastructure and network engineering. Supports the delivery of IT projects to multiple service units across the organization. Has a strong orientation for assembling interdisciplinary teams and bringing IT and business units even closer to deliver upcoming projects for AVBV.

Problem relevance

In the context of the D&A initiative, the presented structure of a cross-functional organization alleviates long-standing issues associated with the lack of communication and alignment between the Reporting Services Team and the dependent business teams i.e. the Sales, Supply Chain and Finance units. The adoption of both fast and slow cycle IT architectures embodied through architecture designs will definitely allow the organization to embrace quick wins when implementing the technology services. In addition, the methodology introduces a promising approach to simplify architecture deliverables, however, from the perspective of the company, current staff employees will push back the new methodology as it does not align with the traditional way of working, ergo complicating the transition towards new ways of working.

On the other hand, promoting collaboration across business and IT social structures can be perceived as a very loose terminology given the code environment of AVBV. The methodology only covers a superficial aspect of what building an interdisciplinary organization represents for the business i.e. collaboration tooling, digital cooperation across multiple projects or initiatives, enterprise-wide cross-functional teams design, certainly this aspect of the methodology has to be extended to effectively promote collaboration across business and IT.

Regarding the simplification of the architecture development process, the presented artifact is fairly complete and can be at the core of a much larger framework to be adopted globally at AVBV. From an external point of view, there are still some focus areas to be considered including Governance, Enterprise Portfolio Management, and Service Management on a global scale if this was not the case of a Digital Transformation for AVBV. The framework strongly focuses on the delivery of something new into the architecture space that can be applied in the case of greenfield or startups companies. Moreover, the usage of small containers and services leveraged by the framework has its merits but it can at to some extent become complex. There needs to be a governance mechanism to provide effective oversight and up to date status of all

the proposed services, both conceptually and logically, for the D&A initiative as it continues to grow and evolve.

Practical and Implementation relevance

The artifact is flexible enough to be implemented in organizations that seek EA capabilities for the design and development of other digital endeavor footprints such as smart manufacturing by mapping the needs of the business to the focus areas introduced by the methodology. Furthermore, EA4DT can be very difficult to implement at an organization such as AVBV due to its strong traditional mentality of avoiding change at every single level (cultural, social, and technological), which is completely opposite to what has been introduced by this research project. Finally, the presented solution can be implemented as part of any other digital endeavor, where any internal or external offering from the organization has been transformed into a digital product exposed through the consumption of services.

5.3.3.3 Interviewee 3

Date	July 9th, 2020
Role	Technology architect with over 20 years of experience in the areas of business analytics and enterprise applications in the manufacturing, media analytics, consumer goods, and IT industries. In charge of guiding the organization to successful Digital Transformation implementations for Industrial Internet of Things (IIoT) by leveraging digital emerging technologies such as Machine Learning, and Artificial Intelligence.

Problem relevance

In the context of the D&A initiative as presented by the EA4DT, the cross-functional organization creates synergies between Technology and Business. It also creates strong integration for the flow of information between various business units. In the absence of a cross-functional organization, technology may implement what might seem unnecessary for business, thereby discarding the project implemented or delaying the use of technology due to changes demanded later on by the organization. Designing a cross-functional organization ensures that everyone is in agreement with what is being done while implementing company-wide architectures (EA) or Digital Transformation, thus conveying agility to the business. Furthermore, timely communication is the key to any successful project. The alignment of social structures as portrayed by the artifact enable stakeholders to stay updated on the project progress. In relation to simplicity, the project-level phases in EA4DT ease the development of EA for the D&A program, however, the enterprise-level phases can become complex for EAM when managing multiple projects for large-scale DT initiatives. The Architecture Action Plan and Architecture outline phases must further be complemented with methods and practices from Portfolio and Project Management disciplines.

On the other hand, the two-speed and bimodal architecture patterns influence business agility depending on the maturity level of the transactional and stable slower-cycle speed systems of the organization. Regardless of the IT logical structure, there will always be dependencies between the two segments of the architecture, thus delaying the implementation of customer-facing applications and systems of innovation for the Digital Transformation project. For instance, data creation, modification, and usage is an essential part of the overall architecture that breaks the barriers of the bimodal pattern. Therefore a clearer strategy to decommission legacy systems of record to introduce MDM for data governance is an important concept to be considered as part of the logical architecture phase. Lastly, faster learning cycles to be attained by the EA4DT will depend on the scope of the Digital Transformation initiative and the size of the organization that is going after it. For example, banking systems focus on big designs as reliability and security of data are important while many startups, including high growth companies like Netflix and Uber, experiment a lot with technology and stay agile with architecture. In the case of a Digital Transformation for a company, it is always good to look at the complete design of EA, to ensure all parts are well integrated.

Practical and Implementation relevance

The proposed artifact is generic and flexible for its utilization for other Digital Transformation endeavors according to the expert judgment. In addition, the EA4DT is definitely a cleaner and simpler way of delivering Digital Transformation compared to other traditional approaches based on the experience in the field and undergoing initiatives being developed at AVBV. As a final remark, the highlight of the EA4DT according to the interviewee was the incorporation of decoupled services as building blocks for architecture development as they portray the strongest components of any modern and scalable architecture. From a technical perspective, they enable controlled upgrades, patch management, testing, and integration. The new norm of decoupled blocks is absolutely service-oriented, where each decoupled block may have further decoupled services running as microservices, thereby making management of software components extremely easy for a large enterprise.

6. Conclusions

This research introduces the Enterprise Architecture Framework defined by fundamental building blocks of architecture agility, modularity, and evolvability with a core methodology that guides organizations embark on Digital Transformation endeavors. After validating and implementing the proposed framework in the context of the Data and Analytics initiative at Apollo Vredestein B.V., the usefulness of the artifact was evaluated and demonstrated. This section presents the limitations of this research, as well as its contribution and future work to be undertaken.

6.1 Research objectives revisited

As stated in section 1.3: Research Objectives, the main research question for this thesis is:

How to lead organizations towards successful Digital Transformations by means of an Enterprise Architecture framework that stimulates business agility, simplifies architecture development, and promotes collaboration across business and IT units?

Based on the main research question multiple research objectives were established. The following subsections revisit and summarize the findings for each research objective in order to answer the main research question.

6.1.1 Research Objective 1 (RO1): Contrast the structure of the Enterprise Architecture practice with the anatomy of Digital Transformations.

This research has studied the nature of the Enterprise Architecture practice in relation to the phenomenon of Digital Transformation. Based on the definition of Gartner, Inc. (2020c) and Reis *et al.* (2018) a Digital Transformation is an exercise of digital optimization and IT modernization to leverage new emerging digital technologies to enable major business improvements and influence all aspects of customers' life. On the other hand, Enterprise Architecture refers to the organizing logic of internal and external social and technical elements in order to maintain and review the whole operation of an enterprise. The relationship between Enterprise Architecture and Digital Transformation lies in the integration of digitalization projects through the design, exploration, and implementation of emerging technologies such as IoT, Big Data Analytics, Cloud Computing that materialize valuable digital capabilities for an organization.

After examining extensively the body of knowledge compiled in section 2.2: Systematic Literature Review, elements were found to be inherent in Digital Transformations in contrast to the Enterprise Architecture discipline. These elements include agile architecture delivery, highly dynamic customer-oriented service alignment, value streams design, and ultimately, complete

business instead of IT focus. The categorization and analysis of these elements resulted in the definition of five essential core components to be contemplated by current EA practice in relation to Digital Transformation endeavors. The core components include the social alignment of the enterprise, customer experience, and value creation streams, architecture agility, architecture evolution, and architecture modularity. As a result, these components represent the building blocks of the designed artifact introduced in this thesis.

6.1.2 Research Objective 2 (RO2): Identify the state-of-the-art regarding Enterprise Architecture practice to support the realization of Digital Transformation initiatives.

The state-of-the-art with regard to Enterprise Architecture approaches that best provide a basis for Digital Transformations compiled a set of frameworks, tools, methodologies, and techniques explored in section 2.2.2: Enterprise Architecture practices for Digital Transformation. Among the most important approaches; The Open Group Agile Architecture Framework™ (OAAF), the Adaptive Integrated Digital Architecture Framework (AIDAF), and the Lightweight Enterprise Architecture Framework (LEAF) integrate key concepts aligned to the identified core components of RO1 including architecture agility, modularity, and evolution. This research highlights the contribution of the TOGAF framework and its core methodology (ADM) as the foundations for undertaking Enterprise Architecture for Digital Transformations in two of the three examined approaches, those being AIDAF and LEAF.

In addition to the frameworks mentioned above, the research examined various methodologies, techniques, reference architectures, and tools that contributed to a specific set of concerns for organizations embarking on Digital Transformation projects. These approaches range from the definition of bimodal architectures, such as two-speed IT in which IT components are divided in predictable and explorative elements to respond effectively to agile transformations, to the use of hypergraphs to use formal mathematical analytical methods for discovering misalignments among IT strategies, information systems, and information architectures. As a result, multiple instruments were explored as part of this thesis, hence stressing the importance of improving the current state of the Enterprise Architecture practice in relation to Digital Transformations.

6.1.3 Research Objective 3 (RO3): Elaborate on how the Enterprise Architecture practice is delivered in organizations that have embarked on Digital Transformation initiatives.

This study also analyzed in section 2.2.2.3: EA and industries undergoing Digital Transformations how a variety of industries are relying on Enterprise Architecture to deliver Digital Transformations into the organizations. Among the industries analyzed for this study, the banking, manufacturing, logistics, and healthcare sectors are employing different mechanisms to support enterprise transformation as part of their digital strategy. The studied methods for developing EA for DT involve mapping digital capabilities across socio-technical structures of the enterprise including processes, technology, and people, the utilization of industry specialized

IT reference architectures (e.g. SITAM), and the extension of EA meta-models for smart manufacturing implementations.

The case study reviewed in section 2.3: Case Study EA for Digital Transformation at Intel provided an overview of the Enterprise Architecture approach taken by Intel on their journey towards successful Digital Transformation. In the first place, the company reformulated the EA approach by taking advantage of the ADM cycle from TOGAF focusing on the virtues of capability-based planning followed by Enterprise Portfolio Management, CI/CD, Service Management, and ultimately Governance and Risk Management. Moreover, Intel introduced a new EA operating model as part of the solution in order to obtain C-staff level buy-in and support for the transformation program. The interdisciplinary structure of the operating model involved multiple solution groups across the value streams or business and operation teams across the organization. The implementation of the new EA approach at Intel for the Digital Transformation strategy permitted the company to reduce the technical debt, improve the overall enterprise data quality, and boost the company's productivity.

6.1.4 Research Objective 4 (RO4): Design an Enterprise Architecture framework for Digital Transformation.

Results extracted from both the Systematic Literature Review and the analysis of the case study, with respect to the Enterprise Architecture approach for Digital Transformation embraced by Intel, facilitated the definition of core objectives, described in section 3: Design Analysis, to be attained by the designed artifact introduced in this thesis. Consequently, the identified artifact objectives were associated with the main research objectives which involve the stimulation of business agility, the simplification of architecture development and the collaboration across business and IT units, so that validation results were able to trace back the contribution from the proposed artifact to the main research objectives. The artifact objectives comprise the design of an interdisciplinary organization, the utilization of modular and decoupled building blocks, the simplification of the architecture development cycle, and the employment of architecture models and designs to convey business agility.

The Enterprise Architecture Framework for Digital Transformation (EA4DT) described in section 4: Artifact Desing introduces the essential building blocks and architecture catalysts, based on the results from RO1, RO2, and RO3, for stimulating the development of modular, agile and evolutionary architectures considered as fundamental in the context of Digital Transformation initiatives. The artifact also includes a cycle-based architecture development process following the principles of breaking the DT vision into manageable parts, utilizing services as foundational architecture design building blocks, embracing a minimalistic maxim for delivering architecture products, and ultimately design with clear business orientation. Moreover, the 8 stages cycle of the EA4DT is greatly influenced by the TOGAF content metamodel, the structured methodology of Lightweight Enterprise Architecture Framework (Nandico, 2016), the

two-speed, and bimodal architecture approaches from Bossert (2016) and Horlach, Drews & Schirmer (2016), and the digital and agile transformation architecture concepts of The Open Group Agile Architecture Framework (The Open Group, 2019). Ultimately, The EA4DT addresses the main research question by enclosing the methodology around the architecture catalyst previously mentioned so that all activities, deliverables, and guidelines are aligned to the constituents for EA development in order to deliver a successful Digital Transformation into the organization. Moreover, the cycle-based approach absorbs the virtues of all the examined body of knowledge grouped into the following areas of concern:

Stimulation of business agility

The EA4DT conveys business agility to the organization in multiple ways. First, through architecture designs by leveraging methods such as two-speed and bimodal IT in the Logical Architecture phase to differentiate faster release cycles from slower stable transactional architectures that coexist in an organization for a given Digital Transformation. Furthermore, the artifact brings closer together social elements of the enterprise by designing a cross-functional organization in the Architecture Vision phase. Due to the proximity of these interdisciplinary teams, business requirements are meant to be delivered faster and efficiently. Lastly, the enforcement of essential deliverables across the entire methodology in EA4DT contributes to the acceleration of the architecture learning cycles.

Simplification of architecture development

To simplify the delivery of architecture work, the EA4DT defines phases to be undertaken at the enterprise-level and at the project-level perspective. Thus, enabling the definition and execution of smaller work packages and avoiding complexities brought by committing to big designs upfront across all stages of the architecture development cycle. Moreover, the framework follows at each stage of the cycle a minimalistic view for delivering architecture products while keeping solutions simple according to the established business and architecture principles.

The EA4DT relies on the ArchiMate modeling language and uses a simplified version of its metamodel as described in section 2.1.4: EA modelling support tools and notation, following the recommendations from BizzDesign (2018), for portraying all the architecture models suggested throughout the entire development cycle. Ultimately, the adoption of services as decoupled building blocks for designing architectures promotes modularization within EA4DT, thus simplifying the process for developing architecture products in the context of Digital Transformations projects.

Promote collaboration across business and IT units

As part of the Architecture Vision phase, the EA4DT introduces cross-functional teams that are in charge of maintaining and supporting the envisioned Digital Transformation program. The framework presents a social structure that moves away from traditional organizational models and aligns business and IT into highly cohesive delivery units aiming at reducing inter-team dependencies. The foundations of designing a cross-functional organization in EA4DT belong to the concept of architecting the agile transformation in OAAF described in section 2.2.2.1: Architecture frameworks.

6.1.5 Research Objective 5 (RO5): Demonstrate and evaluate the Enterprise Architecture framework for Digital Transformation in an organizational context.

The Technical action research study employed in this research served as a mechanism to validate the artifact in the field. As described in section 5.2: Implementation of the Artifact, the Data and Analytics (D&A) initiative at Apollo Vredestein B.V. acted as the problem context in which the EA4DT was validated. The implementation of the EA4DT produced the required set of architecture deliverables aligned to the business goals, objectives, and requirements of the D&A program stated in the Architecture Vision phase of the methodology. Similarly, the executed and documented activities through the entire cycle produced key architecture products in line with the main objectives of this research which included the enterprise capabilities value stream cross-mapping and the cross-functional organization design at the Architecture Vision phase, the flexible high-level project composition plan of the Architecture Action Plan phase, the service-oriented architecture models depicted in the Conceptual Architecture phase, the two-speed application and technology design at the Logical Architecture stage, the hybrid cloud IT configuration from the Physical Architecture phase, and ultimately, the management of change at the Architecture Governance stage.

The results from applying the artifact to the real-world project were presented to three experts in the areas of business and IT architecture in section 5.3: Artifact evaluation. The evaluation process registered the designed artifact contribution to the research problem and to the practical and implementation relevance according to the interviewees. As foreseen by the experts during the interview sessions, the artifact contributes to the stimulation of business agility mainly through the adoption of concepts such as two-speed and bimodal architectures as well as the formation of cross-functional teams that will allow the organization to embrace quick wins when implementing the proposed digital services. Furthermore, the EA4DT simplifies the architecture development process mostly by following a service design pattern and committing to a reduced version of the ArchiMate standard. However, there is a tradeoff, the notion of simplicity in EA4DT is only recognized in the project-level phases of the methodology and it is perceived as a complex practice at the enterprise level stages for large-scale Digital Transformation architecture endeavors. Lastly, the promotion of collaborative business and IT units through the alignment of

social structures as part of the Architecture Vision phase in the D&A is considered among the experts as a differentiator element in EA4DT from other EA approaches. Nevertheless, for this element to be successfully implemented in AVBV, the enterprise culture transformation must be addressed first.

6.2 Contribution

Considering the overall impact of this research delineated in section 1.6: Practical and Scientific relevance, and the obtained evaluation results presented in section 5.3: Artifact evaluation, three main contributions are identified. First, from a theoretical standpoint, this thesis contributes to scholars of the Business and Information Technology discipline by introducing a novel approach to develop Enterprise Architecture for Digital Transformation. The artifact assembles the fundamental building blocks to embrace modular, agile, and evolutionary architectures based on the results of a systematic literature review and the examination of a case study of a well-recognized organization. Additionally, this study has conducted a Technical Action Research to provide significant insights into how the proposed artifact contributes to Digital Transformation initiatives by leveraging new techniques incorporated into a new Enterprise Architecture methodology.

Secondly, academics could employ the proposed artifact for analyzing the business impact of aligning social, cultural, and technological elements critical for delivering Digital Transformations into organizations. Disciplines such as DevOps exemplify the importance behind embracing new ways to arrange social elements to leverage strong collaboration and agility in organizations. This framework has integrated the virtues of designing a cross-functional and interdisciplinary organization as part of the architecture development methodology in contrast to traditional EA approaches.

Ultimately, from a practical perspective, this study has validated the suggested framework and its core methodologies in a real-world Digital Transformation project. The D&A initiative for AVBV provided the appropriate environment to assess the usefulness of absorbed concepts from other architecture frameworks or methods that were either presented only at a theoretical level or were recently published where no real-world implementation cases existed. Therefore, this study has served as a point of reference for the validation of such approaches with their particular benefits and drawbacks in relation to practice. In general, experts interviewed at the evaluation stage of this research have appraised the framework with a positive tone, especially with respect to providing a well-founded Enterprise Architecture approach to address the particularities of Digital Transformation efforts in practice.

6.3 Limitations

Despite the fact that the study has addressed the main research question and associated research objectives as well as contributing to both scientific and practitioner communities, it is still subject to limitations. The EA4DT focuses on the development of Enterprise Architecture for Digital Transformation at a very high level, excluding key best practices for successful digital initiative implementations such as leadership and communication as indicated by McKinsey & Company (2018). Though the designed artifact contributes to the success of Digital Transformations it is still bound to the organizing logic of business, information systems, and technology in the context of Digital Transformations.

On the other hand, this research has undertaken an Enterprise Architecture approach for Digital Transformation focused entirely on design and planning maneuvers, cutting out implementation activities. As a consequence, the research is limited to derived predictions from executing the validated framework in the problem context, leaving potential new challenges uncovered. Moreover, while the designed framework introduces core building blocks and principles, as well as the methodology for developing EA for DT according to the literature analysis, it overlooks other relevant practice aspects e.g. capability maturity assessments, portfolio, service, and risk management. This limitation was corroborated by the interview evaluation sessions detailed in section 5.3: Artifact evaluation.

Finally, this research has adopted a simplified version of the ArchiMate metamodel aligned with the recommendations from Singh (2019) and BizzDesign. (2018). As a result, the considered elements and relationships were found sufficient for designing and modeling architecture viewpoints across the entire development method. However, the latter observation cannot be generalized to all the Digital Transformation initiatives. This simplification becomes a limitation when portraying future viewpoints of the D&A initiative at AVBV that could potentially require other passive, active, or behavioral elements from the ArchiMate metamodel which are not included in this research.

6.4 Future research

As mentioned in the limitations section, further research is required to improve the proposed Enterprise Architecture Framework for Digital Transformation and thus, provide a more comprehensive approach to support new digital initiatives. Future research efforts must strive towards:

- The integration of microservices and domain-driven design into Enterprise Architecture development. This research has relied on the virtues of the service-oriented design for architecting Digital Transformations, however, new emerging technologies such as cloud

computing-native architectures implement countless pieces of business logic embedded into services that reflect business behavior to internal and external customers of the organization. Therefore, the framework should incorporate a mechanism for modeling new required business services into large-scale loosely coupled microservices, hence stimulating the development of modular architectures.

- The inclusion of a maturity model for Digital Transformation that provides a complete EA capability assessment. This includes areas of examination such as the architecture development process, documentation of artifacts and standards and their connection to business strategies and drivers, the involvement of senior management, availability of EA content, governance processes, increased business agility, and reduced complexity. A potential approach to be further studied and attached to the artifact is the OAAF maturity model introduced by The Open Group (2019).

- Analyzing the adoption of risk, service, and portfolio management practices as part of the architecture development process for Digital Transformations. Despite the fact that Digital Transformation encourages risk-taking according to literature, practitioners have indicated that the framework still needs to address risk control for regulatory proposes across all the domains of the Enterprise Architecture approach. Furthermore, project and portfolio management practices should be further studied to provide an exhaustive approach on how to pivot between strategy and realization of a Digital Transformation project. These concepts were encapsulated in the Architecture Action Plan and Architecture outline phases in EA4DT, however, their level of involvement is rather simplistic.

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