A Thesis for the Degree of Ph.D. in System Design Management

Adaptive Integrated Digital Architecture Framework with Risk Management for Global Enterprise

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Abstract

Many global enterprises have encountered various changes, such as the progress of new technologies, globalization, shifts in customer needs and new business models. Important changes in cutting-edge IT technology with recent developments in Cloud computing and Mobile IT (such as progress in big data technology) have emerged as new trend these days. Enterprise Architecture can be effective because it contributes to the design of mid/large integrated systems, which show a major technical challenge toward the era of Cloud/Mobile IT/Digital IT in digital transformation.

This thesis aims to investigate solutions incorporated by Architecture Board in the Global Enterprise for solving issues and mitigating related architecture risks while proposing and implementing "Adaptive Integrated Digital Architecture Framework - AIDAF" and related models and approaches/platforms, which can be applied in companies promoting IT strategy using Cloud/Mobile IT/Digital IT.

This thesis can be divided into three main parts. The first part consists of chapters 1 and 2. These chapters address the background and motivation for the Adaptive Integrated EA framework proposed in this thesis, to meet with IT strategy toward Cloud/Mobile IT/Digital IT. Chapter 1 is the introduction such as the purpose, scope, and structure of this thesis, that covers the introductions of “The history of information systems towards Digital Transformation” and “Enterprise Architecture.” Chapter 2 explains the background of this thesis, such as the trend of Digital IT and the direction of Enterprise Architecture. Furthermore, problems in Enterprise Architecture toward the era of Digital IT are shown and countermeasures/solutions are also suggested in this chapter.

The second part of the thesis comprises chapter 3. In this chapter, first, the author shows the overview and positioning of Strategic Architecture Framework and related models in the era of Digital IT. Furthermore, I show the necessary elements in EA frameworks for the era of Cloud/Mobile IT/Digital IT and propose the new Enterprise Architecture framework named "Adaptive Integrated Digital Architecture Framework - AIDAF" and related models for Architecture Assessment/Risk Management and Knowledge Management on digital platform, which can solve the problems toward the era of Digital IT described in the previous chapter, while these models and frameworks are applied in companies promoting IT strategy using Cloud/Mobile IT/Digital IT.

The third part of this thesis demonstrates the application and usefulness of my proposed Enterprise Architecture Framework and several approaches/models related to this Architecture

Framework. Three case studies are presented in chapter 4, 5, 6 and 7. In chapter 4, a case study that built and practically implemented our proposed EA framework in a global pharmaceutical company is presented. This case study evaluates the effectiveness and adaptability of my proposed "Adaptive Integrated Digital Architecture Framework - AIDAF" and shows the benefits and results of this EA framework in the era of Cloud/Mobile IT/Digital IT.

Chapter 5 and 6 present two evaluations of this Architecture Framework related approaches and models. The case study in chapter 5 is focused on "Architecture Board reviews and Knowledge Management." This case study has verified the "Assessment Metamodel in Architecture Board," "Global Digital Transformation Communication model" and “Solution Collaboration Model” on digital platforms and shows the effectiveness and results of these approaches/models related to my proposed AIDAF. In chapter 6, the case study is focused on "Risk management approach for Digital Transformation" and Big Data. That case study evaluated the "STrategic Risk Management Model for digital transformation" and clarified the Strategy elements to mitigate Risks in Digital Transformation and shows results of this approach/model related to my proposed AIDAF. Furthermore, chapter 7 presents the overall evaluation of AIDAF and the discussions for AIDAF and related approaches, models.

Chapter 8 presents the conclusion and some important points from this research. This chapter summarizes the results of verifying my proposed Architecture Framework - AIDAF and related approaches/models and shows important points of this Adaptive Integrated Digital Architecture Framework - AIDAF and the related approaches/models.

List of Abbreviation

AA	Application Architecture
ADM	Application Development Method
AGATE	Atelier de Gestion de l'ArchiTEcture des systèmes d'information et de communication – An Architecture Framework for modelling computer or communication systems architecture for French Defence and military.
AIDAF	Adaptive Integrated Digital Architecture Framework
API	Application Programming Interfaces – key element for digital transformation because of an essential component in microservices, merging the old and the new IT platforms.
AUSDAF	Australian Defence Architecture Framework
BA	Business Architecture
BI	Business Intelligence
BPR	Business Process Redesign/Reengineering
CAFEA	the Common Approach to Federal Enterprise Architecture
CIO	Chief Information Officer
CISO	Chief Information Security Officer
CMC tools	Computer-Mediated Communication tools
CMMI	Capability Maturity Model Integration
COBIT	Control OBjectives for Information – related Technology
CRM	Customer Relationship Management
C4ISR	Command, Control, Communication, Computer and Intelligence, Surveillance, Reconnaissance
DA	Data Architecture
DoDAF	Department of Defence Architecture Framework
EIS	Enterprise Information Systems
ERP	Enterprise Resource Planning
FEAF	Federated Enterprise Architecture Framework
GDTC	Global Digital Transformation Communication model
GHE	Global Healthcare Enterprise
GxP	Good x Practice (validation)
IaaS	Infrastructure as a Service
IE	Internet Explorer (Microsoft)
IIS	Internet Information Services (Standard Web services for Microsoft Windows)
JDBC	Java DataBase Connectivity
KOL	Key Opinion Leaders (management)
LAN	Local Area Network
MDM	Master Data Management (platform)
MIT CISR Research	Massachusetts Institute of Technology - Center for Information Systems
MIT EA	Massachusetts Institute of Technology - Enterprise Architecture approach
MOD	Ministry of Defence (UK)

MODAF	British Ministry of Defence Architecture Framework
MVS	Multiple Virtual Storage (Operating System for IBM mainframe)
NIST	National Institute of Standards and Technology (US)
OASIS	The Organization for the Advancement of Structured Information Standards
ODBC	Open DataBase Connectivity
PaaS	Platform as a Service
PMO	Project Management Office
POS	Point of Sale
SaaS	Software as a Service
SCM	Supply Chain Management
SCM model	Social Collaboration Model
SDLC	System (Software) Development Life Cycle (process)
SNS	Social Networking Service
SOA	Service Oriented Architecture
STRMM	STrategic Risk Mitigation Model
TA	Technology Architecture
TOGAF	The Open Group Architecture Framework (EA)
TRM	Technology Reference Model
VM	Virtual Machine (Operating System for IBM mainframe)
VSE	Virtual Storage Extended (Operating System for IBM mainframe)
WAN	Wide Area Network
WWW	World Wide Web

1. Introduction

Many global corporations have experienced a variety of changes resulting from the emergence of new technologies, globalization, shifts in customer needs, and the implementation of new business models. Table 1.1 shows the history of information systems towards Digital IT. In 1970s, main frame systems had been utilized in companies. In 1980s, Office Computers were used with Workstation and PCs. In 1990s, Client Server technology had become popular in offices. In 1995, Internet emerged and came into fashion while groupwares also utilized. In 2000s, Web Computing had spread with wireless networks. In 2010s, significant changes in cutting edge IT technology due to recent developments in cloud computing and mobile IT (such as progress in big data technology), in particular, have arisen as new trends in IT. Cloud-based services and accelerated Digitized Platforms represent a growing percentage of the total IT budget of most firms in global and are shifted from existing on-premise based application systems toward the next era of Digital IT. (Nils Olaya, Jeanne W. Ross, MIT CISR research, 2015). Toward 2020, Digital Transformation is undertaken in many corporations, such as Cloud, Mobile IT applications, Big Data solutions and Internet of Things related systems these days. Furthermore, major advances in the abovementioned technologies and processes have created a "digital IT economy," introducing both business opportunities and business risks, forcing enterprises to innovate or face the consequences (Boardman & KPN 2015).
Enterprise systems (ES) are complex application software packages that contain mechanisms capable of supporting the management of the entire enterprise and of integrating all areas of its functioning (Davenport 1998, p.121). This requires Enterprise Architecture (EA) to be effective because contributing to the design of such large integrated systems would in future represent a major technical challenge toward the era of cloud/mobile IT/digital IT. Table 1.2 shows the descriptions of the perspectives (i.e. Owner's perspective, Designer's perspective, Product's perspective, etc.) of architectural representation depicted on the process of complex engineering project, as below. Table 1.2 identifies information systems analogs along with the building and airplane ones while identifying the information system model analogs along with Architect's plan of buildings and engineering design of airplanes. (Zachman 1987).

Table 1.1 The history of information systems towards Digital Transformation.

Periods	**IT Direction**	**Primary Technology**
1970	Main Frame	MVS, VSE, VM,
1980	Workstation, PC, Office Computer	Unix Workstation, PC x86 Workstation, Razer Printer, POS system, IBM AS/400, NEC System3100, Fujitsu K series.
1990	Client Server	Unix, Windows NT, NetWare, Oracle DB, DB2, ODBC, Visual Basic, C++, Ethernet LAN, WAN
1995	Internet	WWW, Netscape Navigator, IE, TPC/IP, Unix, Java, Windows95, Lotus Notes, MS Exchange, Fire Wall.
2000	Web Computing	Apache, IIS, Netscape Server, WebLogic, WebSphere, JDBC, Java Servlet, Windows2000, Wireless LAN.
2010	Cloud computing	Private Cloud (VMWare, Citrix, etc.), Public Cloud (SaaS, IaaS), Hybrid Cloud, Mobile IT.
→ 2020	**Digital IT Transformation**	**Mobile IT applications, Cloud applications (SaaS), Big Data solutions, Internet of Things, with Cloud platforms (PaaS, IaaS, SaaS)**

Table 1.2 Architectural representations depicted on processes of complex engineering project, along with analogs in buildings, airplane and information systems communities (Source: A framework for information systems architecture, IBM Systems Journal, J. A. Zachman, 1987)

Generic	Buildings	Airplanes	Information Systems
Ballpark	Bubble charts	Concepts	Scope/objectives
Owner's representation	Architect's drawings	Work breakdown structure	Model of the business (or business description)
Designer's representation	Architect's plans	Engineering design/bill-of-materials	Model of the information system (or information system description)
Builder's representation	Contractor's plans	Manufacturing engineering design/bill-of-materials	Technology model (or technology-constrained description)
Out-of-context representation	Shop plans	Assembly/fabrication drawings	Detailed description
Machine language representation	—	Numerical code programs	Machine language description (or object code)
Product	Building	Airplane	Information system

Enterprise systems (ES) are complex application software packages that contain mechanisms capable of supporting the management of the entire enterprise and of integrating all areas of its functioning (Davenport 1998, p.121). This requires Enterprise Architecture (EA) to be effective because contributing to the design of such large integrated systems would in future represent a major technical challenge toward the era of cloud/mobile IT/digital IT. Table 1.2 shows the descriptions of the perspectives (i.e. Owner's perspective, Designer's perspective, Product's perspective, etc.) of architectural representation depicted on the process of complex engineering project, as below. Table 1.2 identifies information systems analogs along with the building and airplane ones while identifying the information system model analogs along with Architect's plan of buildings and engineering design of airplanes. (Zachman 1987).

Figure 1.1 shows the relationship between city planning (Shirvani 1985) and Enterprise Information Systems – Enterprise Architecture as below. In the left side of this Figure 1.1, city planning covers various scales from the object level to the national level. The policy oriented direction shows at coarser level, while product-oriented direction shows at finer levels (Namba and Iijima 2005).

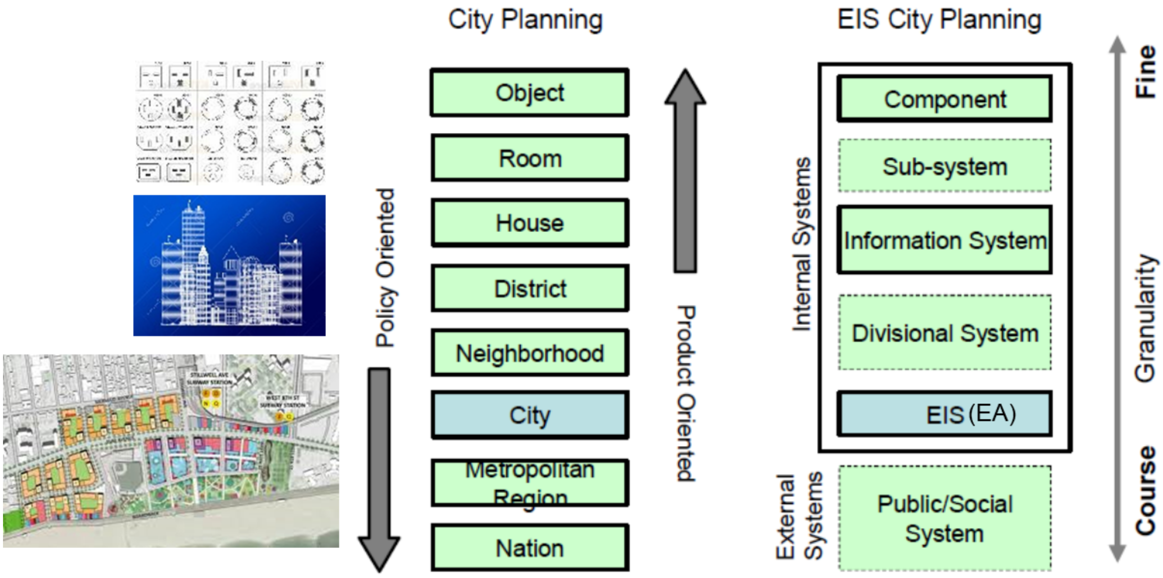

Figure 1.1 Granularity of Planning Levels for City Planning and Information Systems. (Source: City planning part was cited from Shirvani(1985))

The right side of Fig 1.1 provides the corresponding unit for EIS (EA) city planning. In terms of EIS – EA, comprehensive and interoperable characteristics correspond to coarser granularity, on the other hand, specific/analytical characteristics correspond to finer granularity (Namba and Iijima 2005). Therefore, Enterprise Architecture can correspond with City planning, while information systems can correspond with houses and buildings, and components can correspond with objects as shown in Fig 1.1.

Moreover, in terms of Enterprise Architecture, the ISO/IEC/IEEE 42010:2011 standard also recommends providing architectural descriptions of systems to manage their escalating complexity and alleviate the risks incurred during the development and evolution of these systems (Alwadain et al. 2013). From a comprehensive perspective, EA encompasses all enterprise artifacts, such as business, the organization, applications, data, and infrastructure, which are necessary to establish current architecture visibility and future architecture to produce a roadmap. EA frameworks need to embrace change in ways that adequately consider new emerging paradigms and requirements that affect EA, such as enterprise mobile IT/cloud computing (Buckl et al., 2010/ Alwadain et al., 2014). However, specific EA frameworks, e.g., The Open Group Architecture Framework (TOGAF), are criticized for their size, lack of agility, and complexity (Gill et al., 2014). On the other hand, the necessity of implementing EA in parallel in the mid-/long term (roadmaps and target architectures, etc.) in the era of cloud/mobile IT/digital IT should be emphasized in terms of promoting the alignment of IS/IT projects with management strategy/IT strategy.
In consideration of the above background information, first, this thesis addresses the aforementioned challenges by comparing the widely used EA frameworks based on the positions in each framework. As the next step, the author proposes a new Architecture Framework to meet the requirements of the digital transformation in relation to the above agility-related aspects. The proposed EA framework will be verified to support an IT strategy promoting cloud/mobile IT/Digital IT, while this thesis also presents the results of our investigation of an example case in a global healthcare enterprise (GHE), where the abovementioned EA framework is built and practically implemented. This is the only case study of related up-to-date EA toward the era of digital IT and enables us to clarify the

effectiveness, adaptability, benefits, and critical success factors of this EA Framework in the era of cloud/mobile IT/digital IT.

1.1 The purpose and scope of this research

As aforementioned in the previous section, accelerated Digitized Platforms and Cloud-based services show a growing percentage of the total IT budget of most firms in global and are shifted from existing on-premise based application systems toward the next era of Digital IT. (Nils Olaya, Jeanne W. Ross, MIT CISR research, 2015). The purpose of this research is to propose a new Architecture Framework to meet the requirements of the digital transformation and to support an IT strategy promoting cloud/mobile IT/Digital IT in corporations in global and to verify the proposed Architecture framework. Furthermore, the author of this thesis proposes several models related to this proposed Architecture framework, such as Architecture Assessment model, Communication model for Knowledge management on Digital platforms and strategic Risk Management model for digital transformation and verify these models, which will lead to the contributions of enhancing business values in global corporations as the final purpose of this research in this thesis.

On the other hand, the Open Platform 3.0 standard enables an agile digital architecture for the development of enterprise business solutions. These enterprise business solutions take advantages of IT capabilities utilizing Digital technology such as Cloud computing, Mobile IT, Big data analytics, social computing and embedded systems with sensing and/or actuation capabilities (Boardman & KPN 2015). The scope of this research for Digital IT systems and projects should be the IT Architecture covering the above elements of Digital IT.

1.2 The primary related research

The previous researches for state-of-the-art System Architecture and Enterprise Architecture are categorized as the following four types.

1. Histories and state-of-the-art progress in Architecture Frameworks
2. Alternative Approaches to Enterprise Architecture – the MIT approach
3. Service-oriented Enterprise Architecture Evolution model.
4. Adaptive Enterprise Architecture framework.

1.2.1 Histories and state-of-the-art progress in Architecture Frameworks

In the beginning, as the first type of previous research for histories in Architecture Frameworks, the Association of Enterprise Architects published the article of "The History of Enterprise Architecture: An Evidence-Based Review" in Journal of Enterprise Architecture – Volume 12, No.1 (Svyatoslav Kotusev, 2016). According to the above previous research, in 1989 the National Institute of Standards and Technology (NIST) issued the first official guidance regarding EA (Rigdon 1989). Fig 1.2 shows the NIST EA Model as below. The NIST

EA model organizes an architectural deliverable into five different architecture levels: business unit, information, information system, data, and delivery system (Svyatoslav Kotusev, 2016).

As the first type of previous researches for histories and state-of-the-art System Architecture and Enterprise Architecture, the group of ISO/IEC-JTC1-SC7 has shown the "State of the Art in System Architecture and Future Trends" in their study report (Garnier, Bérubé, & Hilliard, 2014). Fig 1.3 shows the history of Architecture Framework's Evolution as below.

First, during 1980's, the term of *Architecture Framework* emerged with the publication of the Zachman Framework for Information System Architecture. Fig 1.4 shows the "Zachman Framework for Information System Architecture" as below. This was followed by the introduction of various modelling approaches such as the "4+1 view model of software architecture" (Kruchten, 1995). At that time, the purpose was to formalize the modelling of an Information System architecture and to rapidly evolve IT system architecture design from a centralized solution.

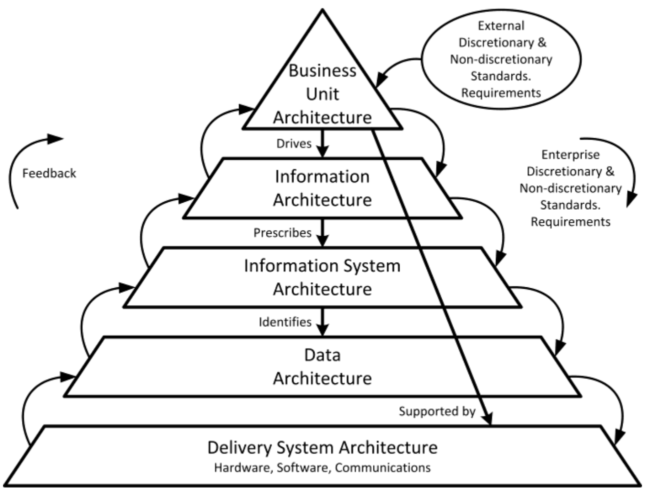

Fig 1.2 NIST EA Model (Source: Rigdon 1989, p. 138/Journal of Enterprise Architecture, Association of Enterprise Architects 2016 – Volume 12, No. 1, p. 31)

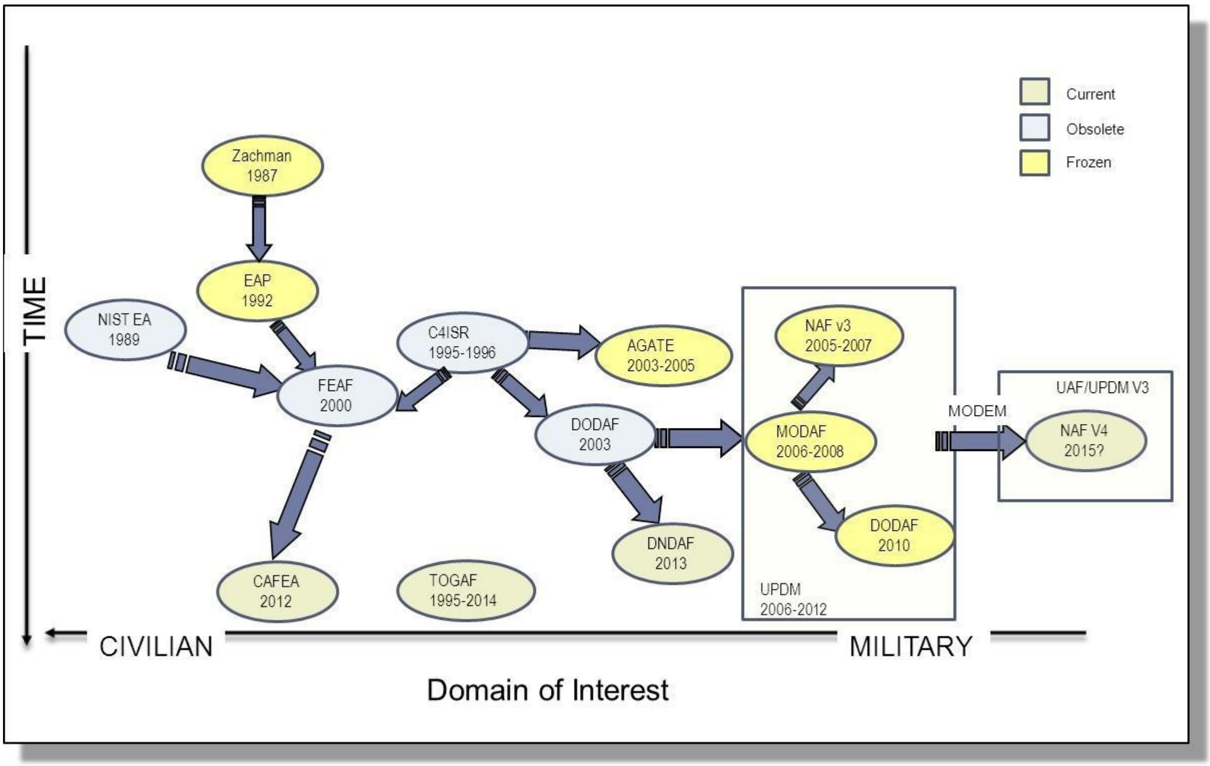

Fig 1.3 Architecture Frameworks' Evolution (Source: Architecture Guidance Study Report, ISO/IEC JTC1 SC7 Software and systems engineering, April 2014)

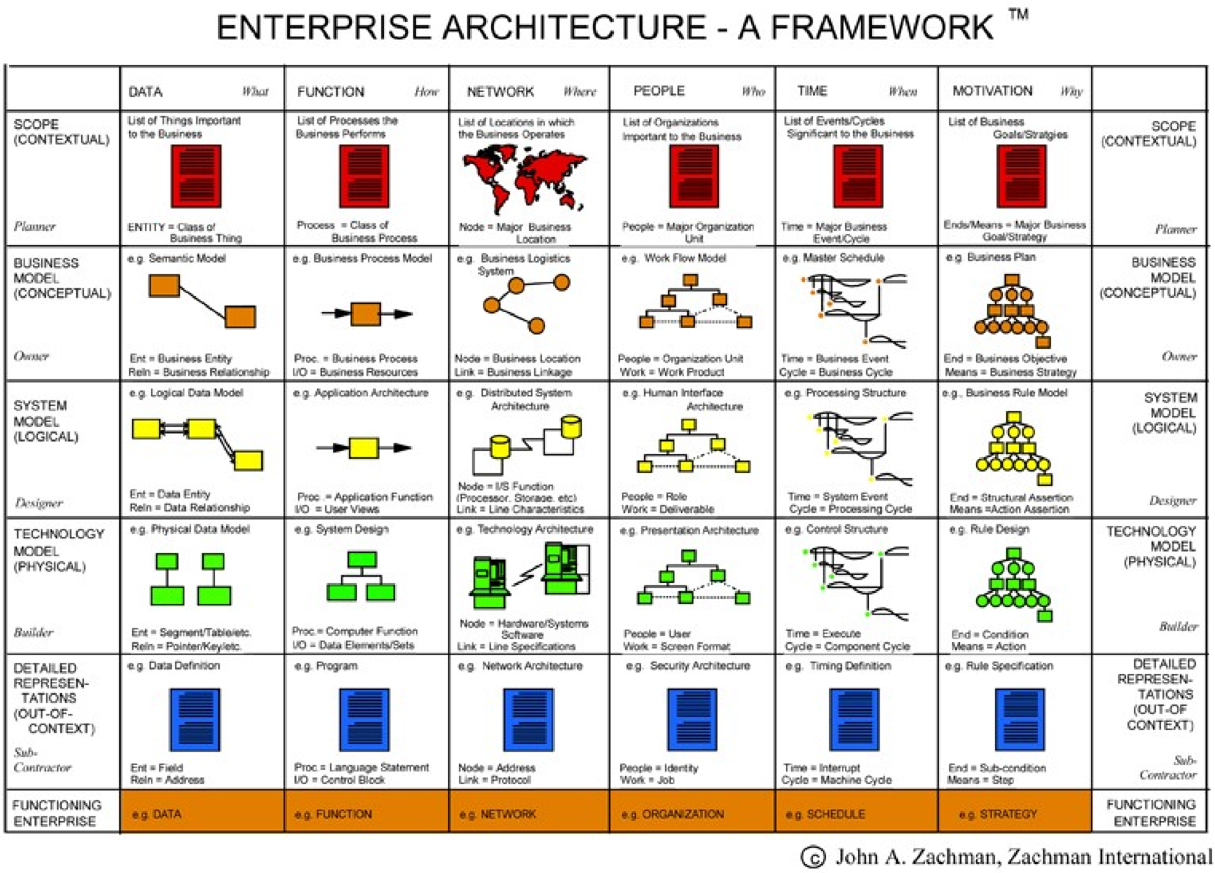

Fig 1.4 Zachman Framework for Information System Architecture (Source: Mapping EA and TOGAF ADM to the Zachman Framework, The Open Group (2002))

The first EA methodology called Enterprise Architecture Planning (EAP) was proposed by Spewak and Hill (1992). This EAP defines the following sequence of steps to practice EA:

1. Understand and document the current state of an organization.
2. Develop the desired future state of an organization.
3. Analyze the gaps between current and future states.
4. Prepare the implementation plan.
5. Implement the plan.

Although Spewak and Hill (1992) claim that EAP“creates the top two layers of Zachman’s Framework.” The Zachman Framework is seemingly mentioned just for marketing-related purposes and is not used in any real situation because the actual deliverables in EAP can hardly be mapped to the Zachman framework as claimed. For instance, the EAP methodology and its deliverables are structured four architecture domains (business, data, applications and technology), which do not map to the three columns of the Zachman Framework (what – data, how – processes, and where – locations) and do not distinguish between its top two rows (ballpark and owner’s views) (Spewak & Hill 1992). Subsequently, the EAP methodology served as a basis for many modern EA methodologies such as FEAF (Spewak & Tiemann 2006). Fig 1.5 shows the EAP methodology like "wedding cake" as below.
The US Department of Defence decided to define an architecture framework for architecture descriptions to enable analysis and decision making regarding systems' interoperability in the interface level across various "C4ISR - Command, Control, Communication, Computer and Intelligence, Surveillance, Reconnaissance" software-intensive systems. This effort led to the publication of the "C4ISR Architecture Framework" in 1996 that was later updated and entitled "DoDAF V1.0," published in 2003, while AGATE (Atelier de Gestion de l’ArchiTEcture des systèmes d’information et de communication) was promoted until 2010 by the French MOD – DGA.

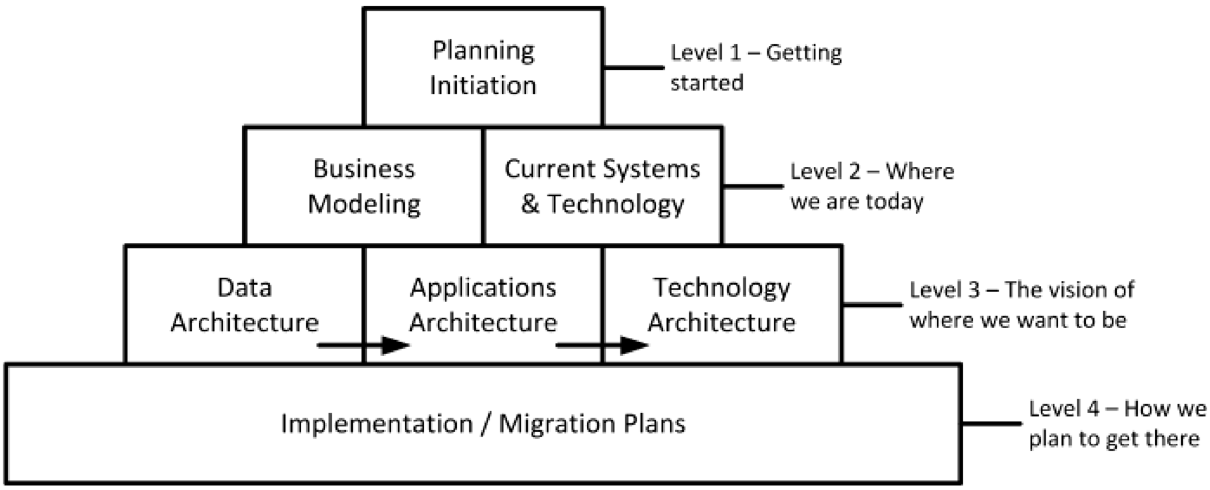

Fig 1.5 EAP methodology (Source: Spewak & Hill 1992, p. 16/Journal of Enterprise Architecture, Association of Enterprise Architects 2016 – Volume 12, No. 1, p. 31)

During this period The French military agency performed the development and evaluation programmes for defence, and the major defence acquisition programmes of systems and information system were required to document their proposed system architectures with utilizing the set of views defined in AGATE. These days, the US Department of Defence continues to require architecture data as a part of the deliverables for material development and acquisition processes. DoDAF was adapted by many other defence organizations such as the United Kingdom‘s MOD, DND/CF (Department of National Defence / Canadian Armed Forces) and NATO. The above UK's MOD defined an architecture framework named MODAF in 2006-2008 with adapting DoDAF. In 2013, DNDAF (The Department of National Defence / Canadian Armed Forces Architecture Framework) was also defined as the standard for use in all DND/CF architecture activities. DNDAF specified an approach and a set of supporting tools to develop and maintain the DND/CF Enterprise Architecture (EA). The DNDAF can provide the foundation for DND EA life cycle management covering the governance, design, building, analysis and change management of EA as well.

On the other hand, NATO also building on DoDAF and MODAF to define an architecture framework of "NATO Architecture Framework (NAF V3). NATO Architecture Framework (NAF V3) (NAF, 2007) provides some explanations on architecture kinds as shown in Fig 1.6 as below. NATO Architecture Framework (NAF) provided NATO the formalism to start up the enterprise architecture for the alliance, supporting all of NATO´s processes and Nations working together. This architecture framework is close to DoDAF, MODAF, AUSDAF (Australian Defence Architecture Framework), etc.

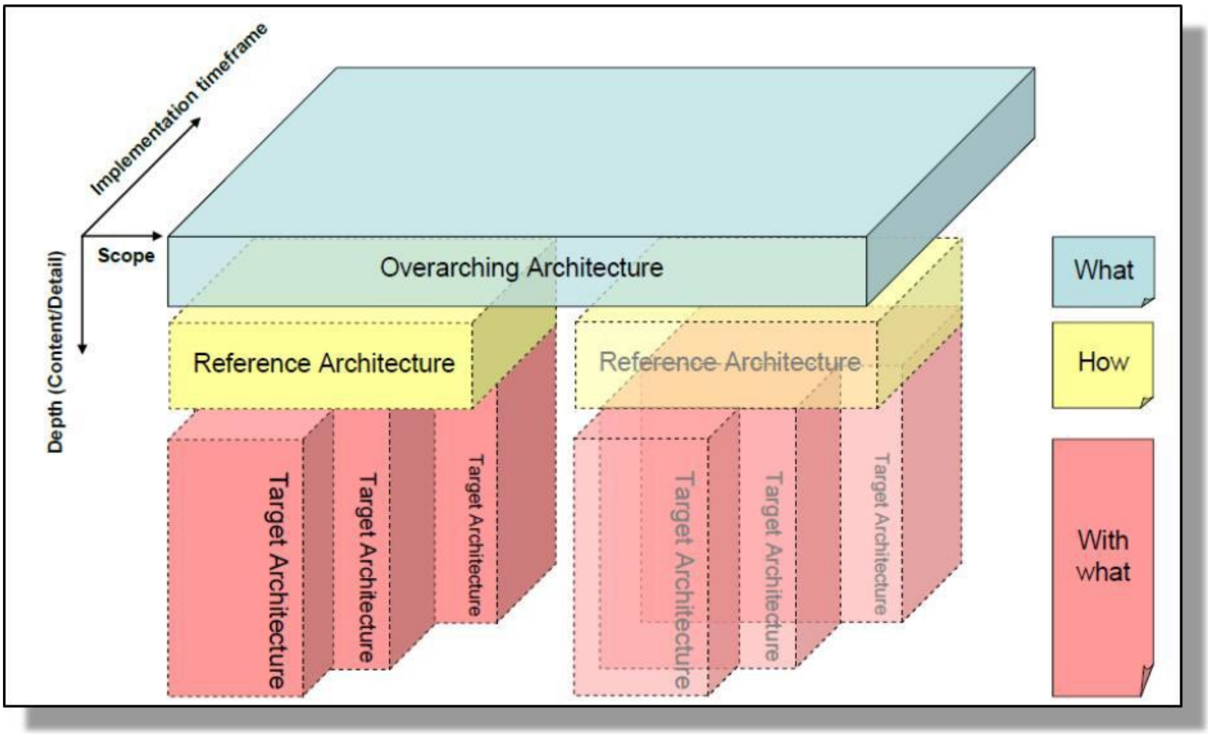

Fig 1.6 NATO Architecture Framework (NAF V3) (Source: Architecture Guidance Study Report, ISO/IEC JTC1 SC7 Software and systems engineering, April 2014)

At the same time, other industry consortium and standards bodies had been defining complementary architecture frameworks that specified methodologies for developing an architecture description for IT systems in corporations such as TOGAF's Architecture Development Methodology® (ADM) (TOGAF, 2011).

These days, utilization of architecture frameworks has evolved into a state-of-the-art practice for both civilian and military domains as depicted in Fig 1.3. As an example in September 2013, The Open Group announced that it had certified 8,500 Architects over a 12 month period on TOGAF V9 in worldwide.

In the military domain, architecture frameworks cover most of architecture descriptions, while they do not adequately cover methods. Since 2000, the US federal government had also defined a similar framework for federal EA description in the FEAF toward the CAFEA – the "Common Approach to Federal Enterprise Architecture" in 2012.

In other civilian domains, architecture frameworks are commonly used for their provided methodologies, such as TOGAF (TOGAF, 2011) to model enterprise architecture activities ,assets and deliverables. Architecting tasks are generally limited to business process modelling and making of maps and architectural charts for applications and to perform portfolio analysis and management activities (Garnier, Bérubé, & Hilliard, 2014).

1.2.2 Alternative Approaches to Enterprise Architecture – the MIT approach

As the second type of the previous research for state-of-the-art Enterprise Architecture, as an alternative one, more pragmatic EA approach was proposed by Ross et al.(2006) in Massachusetts Institute of Technology (MIT) Center of Information Systems Research. According to this kind of the previous research, Many companies tried to improve the business and IT alignment with EA frameworks of popular formal and heavyweight approaches to EA such as the TOGAF ADM (TOGAF 2011). However, many of these companies fail to proceed with EA because of the excessive rigidity and clumsiness of existing selected EA approaches (Holst & Steensen 2011; Lohe & Legner2014). The MIT approach to EA is more flexible and can help overcome the typical challenges related to the heavyweight existing EA approach. (Svyatoslav Kotusev, 2016)

The MIT approach to EA was considered and developed from research findings at Massachusetts Institute of Technology (MIT) Sloan School of Management by Ross et al. (2006). The MIT approach to EA is shown in Figure 1.7 as below. In MIT approach, As the first step, business and IT executives need to decide on the operating model in each organization, such as the necessary level of "business process integration and standardization" for delivering goods and services to customers, which can provide more clear foundation for EA development than a business strategy. As the second step, collaboratively, business and IT executives can develop the core diagram – a important EA document describing the main business and IT capabilities, corporate data, major customers and key technologies, as the description of a long term enterprise-level architectural vision (Svyatoslav Kotusev, 2016).

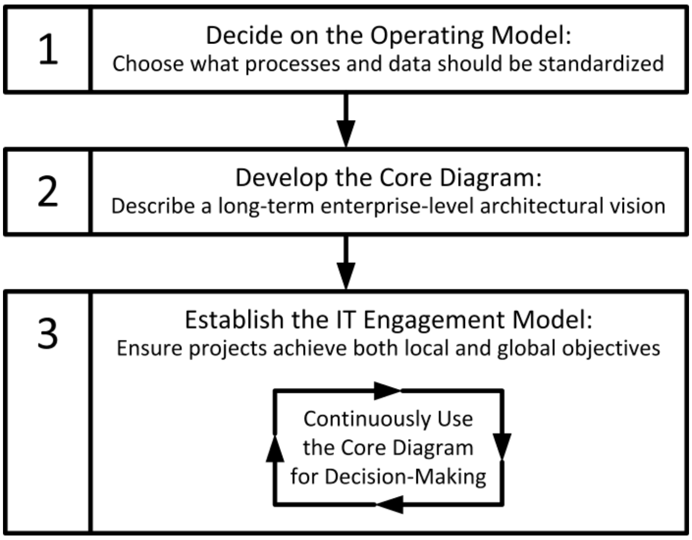

Fig 1.7. The MIT Approach to EA (Source : Journal of Enterprise Architecture, Association of Enterprise Architects 2016 – Volume 12, No. 4, p. 9)

Finally, business and IT executives will design and implement the IT engagement model such as the system of governance structure assuring that business and IT projects achieve both local and company-wide enterprise objectives. The IT engagement model includes three essential elements as below.

1. Enterprise-level IT governance – top management decision-making process/framework including the core diagram
2. Project management – controlled project delivery methodology with necessary checkpoints
3. Linking mechanisms – processes and committees ensuring the communication between enterprise-level decisions and project-level activities

The aforementioned core diagram is continuously used in concrete project-level decisions through the linking mechanism with business and IT managers on various organizational levels. Hence, through the MIT approach to EA, each IT project can attain both local and global objectives, and they can move to a company towards the desired long-term architectural vision (Svyatoslav Kotusev, 2016).

1.2.3 Service-oriented Enterprise Architecture Evolution model

As the third type of the previous research for state-of-the-art Enterprise Architecture, Alwadain proposed and theorised about Enterprise Architecture Evolution model in Service Oriented Architecture (SOA). Alwadain investigated EA evolution using the morphogenetic theory (Archer, 1995), a critical realism-based theory, to comprehend the evolution process triggered by SOA introduction. This theory provides a useful conceptualisation for the investigation of organisational changes, especially involving technological changes (Alwadain, 2016). As a result of the above research, they conceptualised the EA evolution process by distinguishing three phases: (1) architectural conditioning (due to an organisation's pre-existing EA), (2) architectural interaction (e.g., SOA introduction) and (3) architectural elaboration (outcomes of EA evolution).

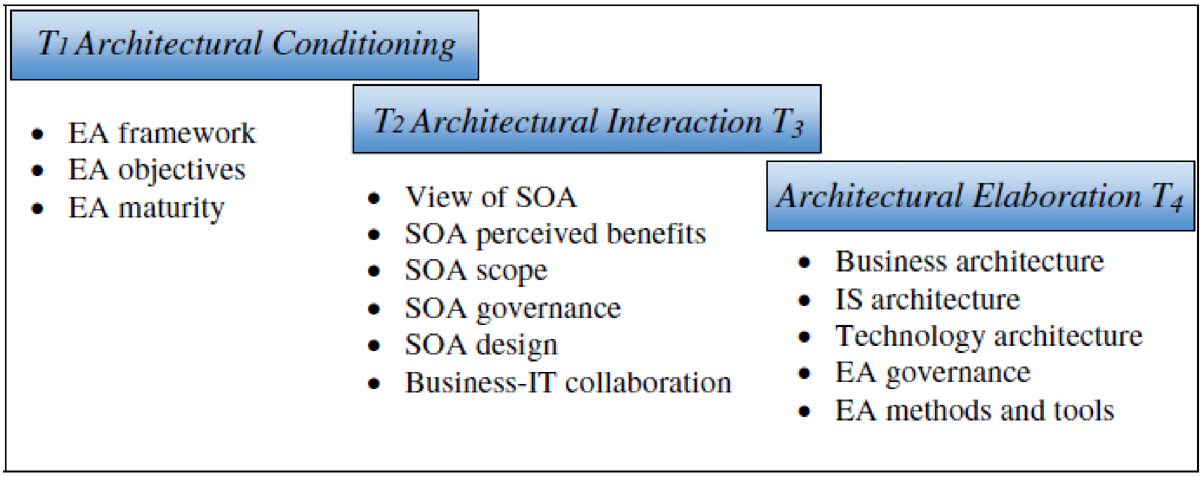

Fig 1.8 Service-oriented EA Evolution theoretical model for SOA integration (Source: Data & Knowledge Engineering ,Elsevier, Alwadain et al. (2016))

Furthermore, they developed the model into more detail (the following Fig 1.8) based on a literature review and explorative interviews as described in previous work (Alwadain et al. 2014). Fig. 1.8 shows this detailed model of Service-oriented EA Evolution for SOA integration as below.

For the Architectural Elaboration (T4), five possible levels of EA evolution outcomes were identified: Business Architecture, Information Systems Architecture, Technology Architecture, EA governance, and EA methods and tools. Simultaneously, they identified three conditional generative mechanisms regarding Architectural Conditioning (T1): EA framework, EA objectives and EA maturity, and six generative mechanisms concerning Architecture Interaction (T2–T3): View of SOA, SOA perceived benefits, SOA scope, SOA governance, SOA design and Business-IT collaboration (Alwadain et al. 2014).

The above scope of change under this investigation is limited to SOA introduction as the trigger of EA evolution. Other aspects of causing changes for EA evolution, for instance, new corporate strategy, emerging technologies such as Cloud/Mobile IT/Digital IT were outside the scope of this research (Alwadain et al. 2016).

1.2.4 Adaptive Enterprise Architecture framework

As the fourth type of the previous research for state-of-the-art Enterprise Architecture, Gill proposed and verified the "Adaptive Enterprise Architecture framework" in the case study of Australian Government partially as Cloud adoption strategy for IT environment (Gill et al. 2014). The Adaptive Enterprise Architecture framework (known as the Gill framework) is a meta-framework that enables support by specifying the situation and tailoring an adaptive EA function and framework. It is based on adaptive enterprise service system logic expanding on the SoS (System of Systems) and Agility, service science approach (Gill, 2013). This adaptive EA framework is defined from the viewpoint of integrating cloud-computing elements, and broadly speaking is composed of two main layers: an external layer (Context, Assessment, Rationalization, Realization, and Un-realization) and an internal layer (Defining, etc.) (Gill et al., 2014).

1.3 Thesis structure

This thesis comprises 8 chapters. Chapter 1 is the introduction such as the purpose, scope, and structure of this thesis. Furthermore, this thesis can be divided into three main parts as shown in Fig 1.8. The first main part consists of chapters 2. This chapter addresses the background and motivation for the "Adaptive Integrated Digital Architecture Framework – AIDAF" proposed in this thesis, to meet with IT strategy toward Cloud/Mobile IT/Big Data/Digital IT. Chapter 2 explains the background of this thesis, such as the trend of Digital IT and the direction of Enterprise Architecture. Furthermore, problems in Enterprise Architecture toward the era of Digital IT are shown and countermeasures/solutions are also suggested in this chapter.

The second main part of the thesis comprises chapter 3. In this chapter, the necessary elements in EA frameworks for the era of Cloud/Mobile IT/Big Data/Digital IT are shown, and the author proposes the new Enterprise Architecture framework named "Adaptive Integrated Digital Architecture Framework - AIDAF" and related models for Architecture Assessment/Risk Management and Knowledge Management on digital platform, which can solve the problems toward the era of Digital IT described in the Chapter 2.

The third main part of this thesis demonstrates the application, use and value of my proposed Enterprise Architecture Framework and several approaches/models related to this Architecture Framework - AIDAF. Three case studies are presented in chapter 4, 5 and 6. In chapter 4, a case study that built and practically implemented our proposed Digital Architecture Framework - AIDAF in a global pharmaceutical company is presented. This case study evaluates the effectiveness and adaptability of my proposed "Adaptive Integrated Digital Architecture Framework - AIDAF" and shows the benefits and results of this Architecture framework – AIDAF in the era of Cloud/Mobile IT/Digital IT.
Chapter 5 and 6 present two evaluations of this Architecture Framework related approaches and models. The case study in chapter 5 is focused on "Architecture Board reviews and Knowledge Management on Digital platforms." This case study has verified the "Assessment Metamodel in Architecture Board" and "Global Digital Transformation Communication model" on digital platforms and shows the effectiveness and results of these approaches/models related my proposed AIDAF. In chapter 6, the case study is focused on "Risk Management approach for Digital Transformation" and Big Data. That case study evaluated the "STrategic Risk Management Model for digital transformation" and clarified the Strategy elements to mitigate Risks in Digital Transformation and shows results of this approach/model related my proposed AIDAF. Furthermore, chapter 7 presents the overall evaluation of AIDAF and the discussions for AIDAF and related approaches, models.
Chapter 8 presents the conclusion and some important points from this research. This chapter summarizes the results of verifying my proposed Architecture Framework - AIDAF and related approaches/models and shows important points of this Digital Architecture Framework - AIDAF and the related approaches/models.
As the above briefing, this thesis consists of 8 chapters, and Fig 1.9 shows the relationship with each chapter in this thesis as below. Especially, as the constitution of this thesis, the

chapters 4 to 7 evaluate and verify the "AIDAF and related approaches, models" hypothesized in this thesis.

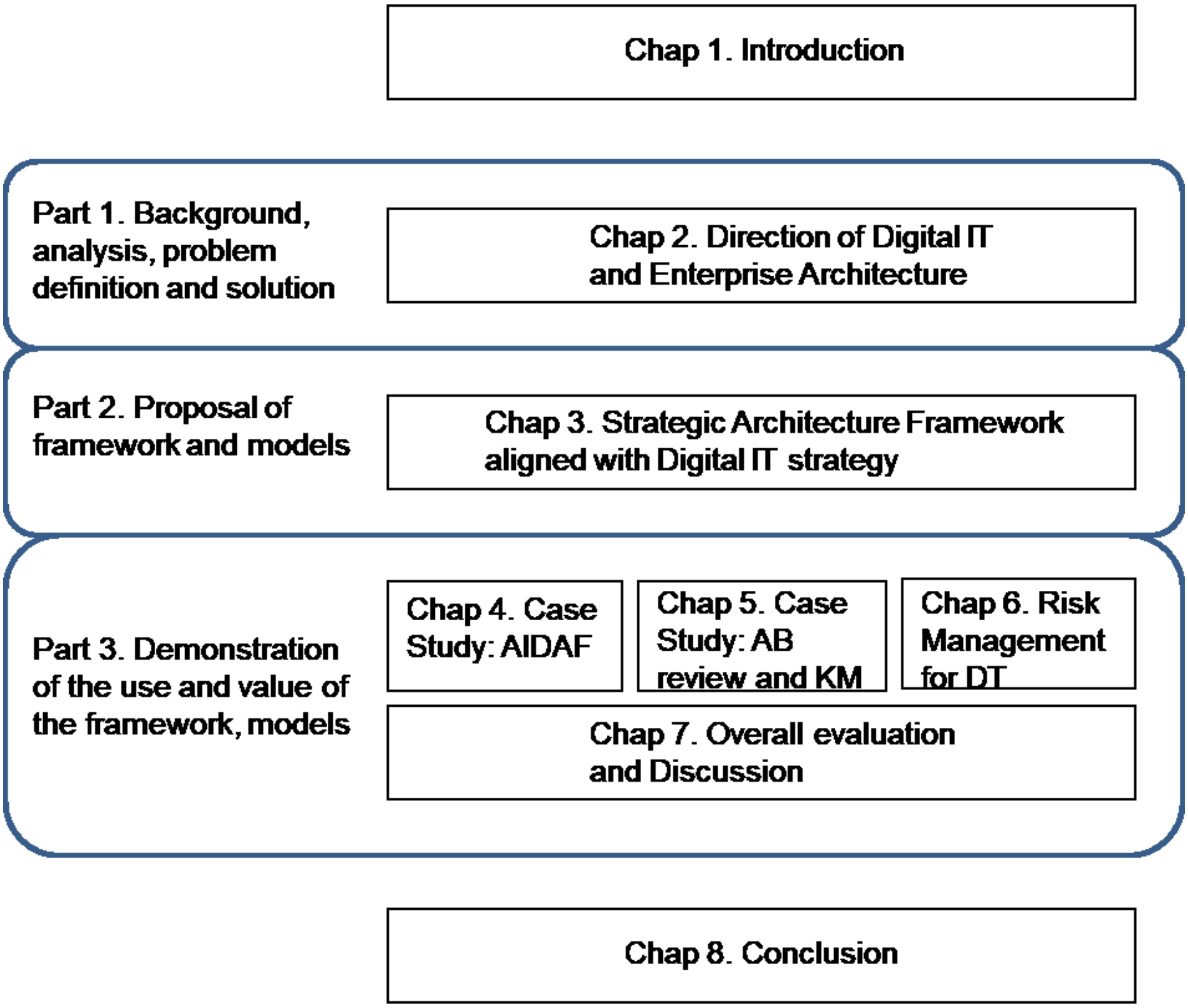

Fig 1.9 Structure of the thesis

2. Direction of Digital IT and Enterprise Architecture

As In the past ten years, EA has become an important method for modeling the relationship between the overall image of corporate and individual systems. In ISO/IEC/IEEE42010:2011, architecture framework is defined as "conventions, principles, and practices for the description of architecture established within a specific domain of application and/or community of stakeholders." Furthermore, in the TOGAF (2011) technical literature, it is defined as "a conceptual structure used to develop, implement, and sustain an architecture." In addition, EA visualizes the current corporate IT environment and business landscape to promote a desirable future IT model (Buckl et al. 2010). EA is required as an essential element of corporate IT planning; it is not a simple support activity (Alwadain 2013), and it offers many benefits to companies, such as coordination between business and IT, improvement in organizational communication, information provision, and reduction in the complexity of IT (Tamm et al. 2011). In order to continue to deliver these benefits, EA frameworks need to embrace change in ways that adequately consider the emerging new paradigms and requirements that affect EA, such as the paradigm of Cloud computing or enterprise mobility (Alwadain et al. 2014).

Mobile IT computing is an emerging concept in general that uses Cloud services provided over mobile devices (Muhammad & Khan 2015). In addition, Mobile IT applications are composed of Web services. There is not much literature that discusses EA integration with Mobile IT and the relationship between the two; however, integration with SOA has been discussed greatly. Many organizations have invested in SOA as a crucial approach for achieving agility as an organization that can manage rapid change (Chen et al. 2010). In the meantime, there has been a recent focus on Microservices architecture, which allows rapid adoption of new technologies, such as Mobile IT applications and Cloud computing (Newman 2015). This paper considers both perspectives.

In terms of Cloud Computing, mobile devices also widely use Cloud computing capabilities, and many Mobile IT applications also operate with SaaS Cloud-based software (Muhammad & Khan 2015). There is literature that concerns the integration and relationship between EA and Cloud computing, but it is scarce. Although Cloud computing formats consist of three general services— SaaS, PaaS, and IaaS—under the current EA framework, there is merely a modeling of only this computing format and the business components managed by this company. Considering recent dynamic moves in business and the characteristics of Cloud computing, it is necessary for companies to link the service characteristics (those similar to the above Mobile IT characteristics) of EA and Cloud computing (Khan & Gangavarapu 2009). It is said that the traditional EA approach requires months to develop an EA that allows Cloud technology in order to realize a Cloud adoption strategy, and organizations will demand adaptive enterprise architecture to iteratively develop and manage an EA adaptive to the Cloud technology (Gill et al. 2014).

In addition, the Open Platform 3.0 Standard was developed and approved by The Open Group, and it focuses on emerging technological trends, such as Cloud computing and Mobile IT, that create new business models. In this environment, many basic architecture models are noted, including Mobile IT/Cloud computing. Furthermore, the core elements of mobile devices, applications, device management, and application management, as well as those of Cloud computing, which are SaaS, PaaS, and IaaS, have been proposed (Boardman & KPN 2015). On the other hand, the pubic standards group OASIS (MacKenzie et al. 2006) has introduced the SOA Reference Model, which presents SOA core elements of service and service interface.

2.1 Directions of Cloud/Mobile IT

2.1.1 Cloud Architecture

In NIST Cloud computing definition highlights three Cloud service models: SaaS, PaaS, and IaaS (Gill 2015). Figure 2.1 shows the "high-level architectural components of Cloud computing from an enterprise point of view." The architectural components shown in Figure 1 are divided into two types: "Service-based" enclosed in an oval and "Resource-based" enclosed in a rectangle. Although the "Service-based" component is used by "Cloud computing consumers," the "Resource-based" component supports the "Service-based" (Khan & Gangavarapu 2009) component.

PaaS is a platform hosted at IaaS. PaaS includes both system software and Integrated Development Environment (IDE), in addition to a programming language, test tools, Web, application, database and file servers, and integrated utilities and infrastructure software (Gill 2015). As shown in Figure 2.1, the PaaS key architectural component is the "Development Resource" including development platforms. In addition, "Service-based" components include "Composition" (software components, utilities to build applications) and "Execution" (application on the platform to run) (Khan & Gangavarapu 2009).

SaaS is a software application developed and deployed, or run, by the underlying PaaS. The SaaS interface can be accessed through client and API interfaces (Gill 2015). As shown in Figure 2.1, the main SaaS "Resource-based" component is "Application Resources," which includes virtualization and middleware. Although "Service-based" components have "Application Objects" (modules, process logic, and databases), the "Processing" components change "customer's data" into "output" (Khan & Gangavarapu 2009).

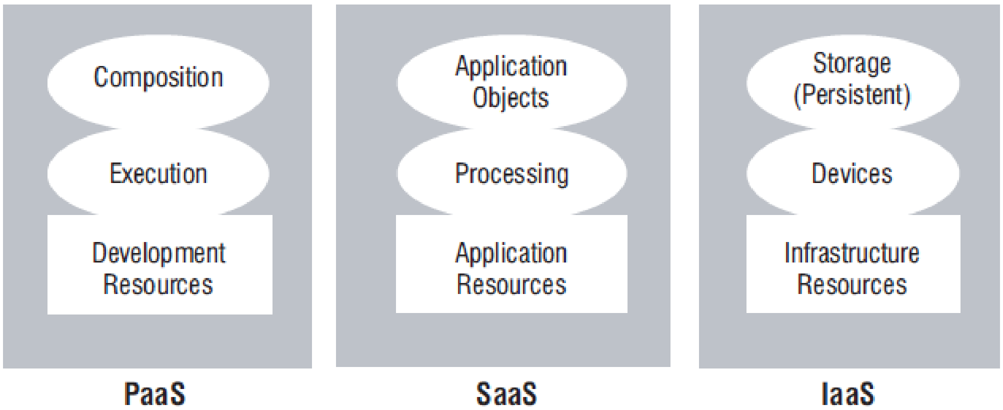

Figure 2.1. High-level architectural components of Cloud computing from EA perspective (Source: Cutter IT Journal, November 2009).

IaaS provides a pool of computing, network, storage, memory, and other related infrastructure resources located in a particular facility. IaaS accommodates PaaS and SaaS (Gill 2015). As shown in Figure 2.1, the IaaS key architectural component is "Infrastructure Resources," which includes servers, disks, devices, and CPUs. With regard to the other two "Service-based" components, IaaS includes "storage of consumer's data" (permanent data storage) and "devices" (using the physical computing resources of networks, servers, and CPU power). In network components, there are also low-level architectural components of bandwidth, routers, and switches (Khan & Gangavarapu 2009).

2.1.2 SOA and Microservices

SOA and *Microservices* vary greatly from the perspective of service characteristics (Richards 2015). In this section, we explain these characteristics.
SOA is a collaborative design approach for multiple services to offer various capabilities; its design approach has been used for large monolithic applications (Newman 2015). In terms of service types and roles in SOA, there are extremely clear and formal service classifications. The SOA architectural pattern, shown in Figure 2.2, defines four basic types (Richards 2015). Business services are abstract, high-level services that define the core business operations performed at the enterprise level, with XML, Web Services Definition Language (WSDL), etc. Enterprise services are concrete, enterprise-level services that implement the functionality defined by business services. As shown in Figure 2.2, middleware components bridge abstract business services and corresponding actual enterprise services. Enterprise services are generally shared across an organization (Richards 2015).
Application services are application-specific services bound to the specific application context. Application services provide specific business functions not seen at the enterprise level, and they can be directly called through dedicated user interfaces or enterprise services.
Finally, infrastructure services are those services that implement nonfunctional tasks, such as auditing, security, and logging, almost similar to the Microservices architecture. In SOA, it is possible to call infrastructure services from application or enterprise services (Richards 2015).

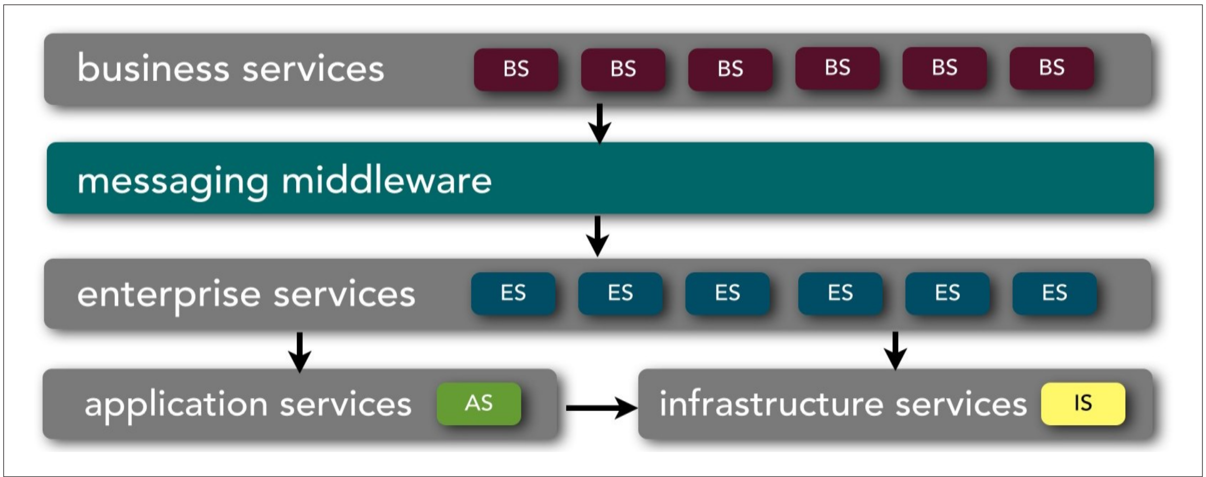

Figure 2.2 SOA taxonomy (Source: Microservices vs. Service-oriented architecture, O'Reilly, November 2015)

Microservices are the approach to distributed systems that promote the use of finely grained services with their own lifecycles. Such services collaborate together while integrating new emerging technologies to solve the potential problems of many SOA implementations (Newman 2015). Microservices architecture is identified as the optimal architecture for Cloud-hosted solutions. Composed of multiple cooperating Microservices, Microservices architecture is enabled by Mobile IT applications, the Web, and by mounting wearable devices that will become popular in the future (Familiar 2015).
Microservices categories differ decisively from SOA service categories. Microservices architectures have limited service taxonomy in terms of service type classification. As shown in Figure 2.3, Microservices are mainly composed of only two service types.
While functional services support specific business operations and functions, infrastructure services support nonfunctional tasks, such as authentication, permissions, auditing, logging, and monitoring, because infrastructure services are not external facing, but are recognized as "private shared services" that can be used internally only for other services. Functional services can be accessed externally and are generally not shared with other services (Richards 2015). Microservices allow early adoption of new technology, such as Mobile IT applications and Cloud computing (Newman 2015). Composed of multiple cooperating Microservices, it can be implemented as a Mobile IT application (Familiar 2015).

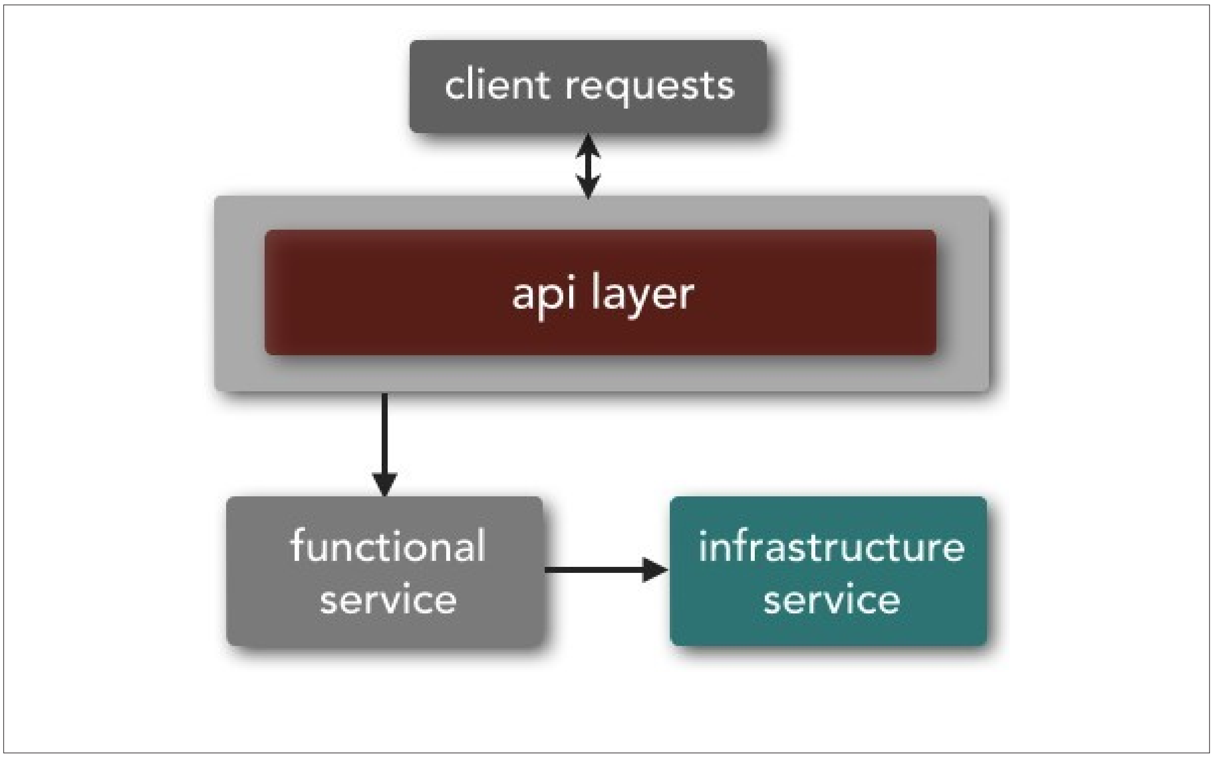

Figure 2.3. Microservices service taxonomy.

2.2 Specific Application Layer on Cloud/Mobile IT – Big Data

2.2.1 Big Data

The New computing trends require data with far greater volume, velocity, and variety than ever before. Big data is utilized in ingenious methods to predict customer buying behaviors, detect fraud and waste, analyze product opinion, and react quickly to changes in business conditions (a driving force behind new business opportunities) (Chappelle 2013). The term “big data“ refers to data that is so large, it is difficult to process using currently-available IT systems. There is a growing opportunity for analysis, visualization, and distributed processing software to enable users to extract useful information from such data (Boardman et al. 2015). Sources of big data include the following.

- Corporate data in SQL databases
- Data in cloud-based SQL or NoSQL databases
- Data provided by social networks
- Data provided by sensors or object identifiers in the internet-of-things (IoT)

Big data applications may include visualization functionality for effective user presentation of analytical results. Furthermore, big data applications should leverage web services that make the results of their analyses available to other applications through APIs; objects in the IoT can be data generators (Boardman et al. 2015).

Existing big data reference architectures have been shepherded by NIST, which helped create the big data interoperability framework, including a reference architecture volume. The strengths of a NIST reference architecture include strict vendor neutrality, while providing clear definitions of big data terminology across many domains (US Department of Commerce 2015). Figure 2.4 shows this NIST Big Data Reference Architecture (NBDRA).

The NBDRA represents a big data system comprised of five logical components connected by interoperability interfaces (i.e., services). These include “System Orchestrator,” “Data Provider,” “Big Data Application Provider,” “Big Data Framework Provider,” and “Data Consumer.” Moreover, two fabrics envelop those five components: “Management” and “Security and Privacy” (US Department of Commerce 2015).

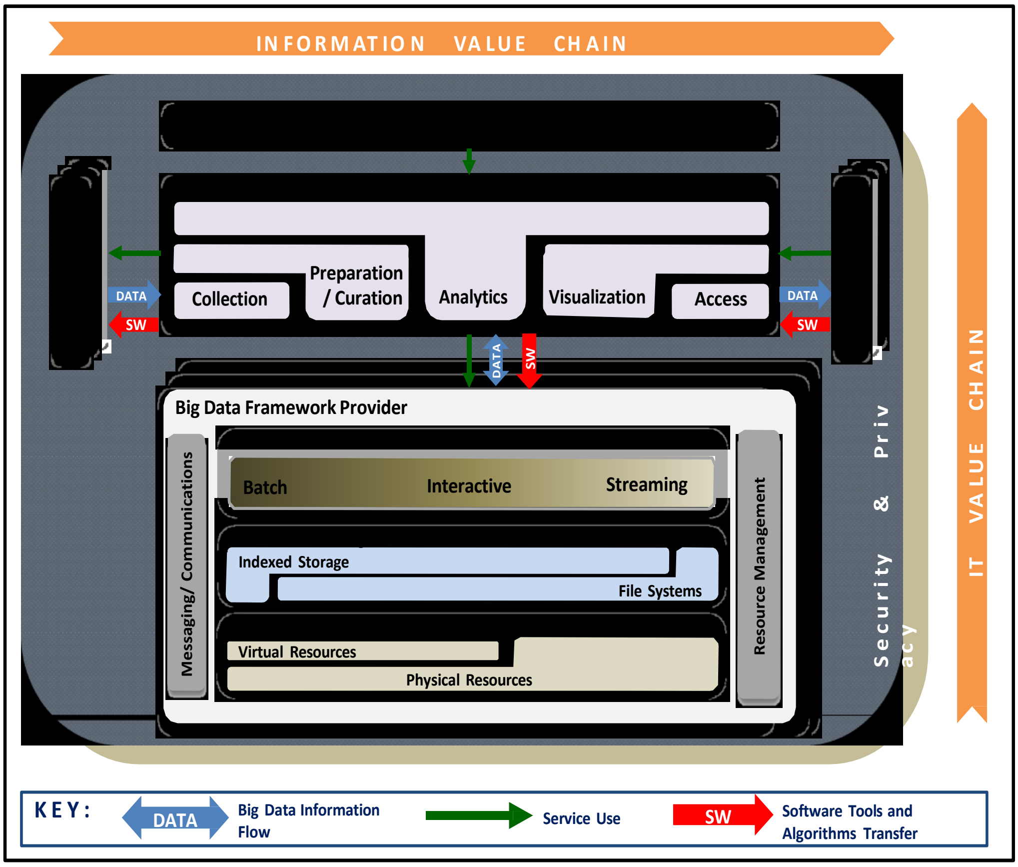

Figure 2.4: NIST Big Data Reference Architecture (NBDRA)

The NBDRA is organized around two axes showing two big data value chains: the information (horizontal axis) and the IT (vertical axis). Along the information axis, value is created by data collection, integration, analysis, and application of these results into the value chain. Along the IT axis, value is created by offering networking, infrastructure, platforms, application tools, and other IT services for hosting and operating Big Data to support required data applications. The intersection of both axes is the Big Data Application Provider component, indicating that, in both value chains, data analytics and its implementation provide value to Big Data (US Department of Commerce 2015). The "DATA" arrows in Figure 2.4 show the flow of data between the main components. The "SW" arrows show transfer of software tools for processing Big Data. The "Service Use" arrows show software programmable interfaces (US Department of Commerce 2015).

LinkedIn, for example, collects data from users and offers services, such as skill endorsements or newsfeed updates to users based on data analysis. Additionally, Twitter uses collected data for real-time query suggestion (Pääkkönen, Pakkala 2015). Therefore, most solutions exist in the Big Data Application Provider component and should be categorized as Specific Application Layers on Cloud and Mobile IT platforms. Technology vendors such as Oracle (2014), IBM (Mysore et al. 2012), and Microsoft (2012) have also developed Big Data Reference Architectures (Kein, Buglak et al. 2016). These vendors publish practical Reference Architectures for Big Data toward EA practitioners in corporations and other groups. Most companies already use analytics for forms, reports, and dashboards based on structured data

from operational information systems that conform to pre-determined relationships. However, Big Data cannot follow this structured model. The streams are all different and have difficulty establishing common relationships. However, this diversity and abundance can provide opportunities to learn and develop new ideas to support business transformation (Chappelle 2013).
The architectural challenge is to bring the above two paradigms together. Therefore, rather than Big Data becoming a new technology silo, organizations should share a unified information architecture to leverage all types of Big Data for promptly satisfying business needs. Oracle provides a practical Big Data Reference Architecture to face the challenges depicted in the Figure 1 of the previous white paper of (Chappelle 2013), which provides a conceptual view of the Big Data Analytics Reference Architecture, designed to provide a high-level architecture description of the Big Data and Analytics solution (Chappelle 2013).
The above Big Data and Analytics Reference Architecture concentrates the following three important aspects.

- “*Unified Information Management*” corresponds to the need to manage information holistically, as opposed to governed business silos independently, such as with “High Volume Data Acquisition,” which acquires high volumes data with some discards, and “Multi-Structured Data Organization and Discovery,” which organizes data of different structures into a common schema.
- “*Real-Time Analytics*” can contribute to businesses by leveraging information and analysis with prevailing events using “Interactive Dashboards” to react to information and to drill down root cause analyses of situations.
- “*Intelligent Processes*” can execute business processes more effectively and efficiently, using analysis such as “Optimized Rules,” “Recommendations,” and “Performance/Strategy Management.“

The middle/lower layer of Figure 1 depicted in the previous white paper of (Chappelle 2013) represents “Information,” in which Big Data and Analytics architecture incorporates many different types of data, such as “Operational Data,“ “Content,“ and “External/Analytical da-ta.” In the lower layer of Figure 1 depicted in the previous white paper of (Chappelle 2013), “Deployment“ options are presented for deployment of architecture components, such as “Public Cloud,” “Private Cloud,” and “Managed Services” (Chappelle 2013). Hence, Big Data can be categorized as specific application layers on cloud and mobile IT platforms.

2.3 EA Frameworks– TOGAF, FEAF, Adaptive EA, etc. - with the integration of Cloud/Mobile IT

To start, the first step is to select an EA framework for this research. The criteria for this selection are: (A) widely used and highly evaluated EA frameworks and (B) an EA framework that supports Mobile IT/Cloud computing and Web service elements. According to a survey in the Journal of Enterprise Architecture (2013), from the perspective of the "widely used" criterion, TOGAF, Zachman, Gartner, Federal Enterprise Architecture

Framework (FEAF), and DoDAF are the most widely used EA frameworks, and it was decided that TOGAF, FEAF, and DoDAF are "highly evaluated." Furthermore, according to Microsoft (2007), Zachman, TOGAF, FEAF, and Gartner are the most commonly used EA frameworks.

In this paper, the second criterion for EA framework selection is integration with the elemental framework of Mobile IT/Cloud computing and Services (part of SOA). From the perspective of integrating the elements of Mobile IT and strongly directly linked Cloud computing, Gill et al. (2014) argued that FEAF, TOGAF, Zachman, and the Adaptive Enterprise Architecture framework (Gill 2013) are suitable. In addition, TOGAF, FEAF, DoDAF, and the British Ministry of Defence Architecture Framework (MODAF) are discussed from the perspective of integration with SOA elements, which have Web services (Alwadain 2013; Federal CIO Council 2008; US Department of Defense 2009).

In addition, because the Gartner framework is limited to commercial use, complete access is not possible and it is therefore outside of our scope (Franke et al. 2009). Moreover, because the Zachman framework does not provide an enterprise architecture process for implementing and operating an enterprise architecture capability (Gill 2015), this is also out of our scope at this time.

What follows is an explanation of the five EA frameworks, selected in the above steps, that were the subject of a comparative survey in this research for the thesis.

2.3.1 TOGAF (The Open Group Architecture Framework)

As TOGAF is a framework for developing enterprise architecture with a detailed method and supporting tools, developed and maintained by members of The Open Group. Architecture Development Method (ADM) is the core of TOGAF. Fig 2.5 shows this ADM in TOGAF9 as below. It describes a step-by-step approach to developing Enterprise Architecture (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al. 2014). TOGAF is not attached to government enterprises. It is a generic and comprehensive framework that can be tailored for the development of effective enterprise architecture capability for technology-enabled enterprise adaptation (Gill 2015). With regard to the remaining parts of TOGAF, "the content framework" provides a conceptual meta-model for describing architectural artifacts. "The enterprise continuum" is a virtual repository for storing architectural models and architectural descriptions. "The TOGAF reference models" are divided into the TOGAF Technical Reference Model and the Integrated Information Infrastructure Reference Model (Buckl et al. 2009; The Open Group 2009c).

Web Service/SOA elements in TOGAF are found in its meta-model and discussed further in its documentation (The Open Group 2009b, 2009c). TOGAF has three layers. First, in the business architecture, a business service is identified in the meta-model. In the application architecture, application and information system services are represented in the meta-model. In the technology architecture, a platform service is identified in the meta-model (Alwadain 2013). There is a specific notation of the Mobile IT Category, particularly in the Mobile Device part of "Enterprise Security View" and "Communication Engineering View" under the content framework Technology Architecture portion. In addition, there is mention of the APIs under Application Architecture and Technology Architecture in ADM and TRM. In TOGAF, a service interface is identified as part of all three architectures of business, application, and technology, whereas there is no element of a Cloud Category (Masuda, Shirasaka, & Yamamoto, 2016).

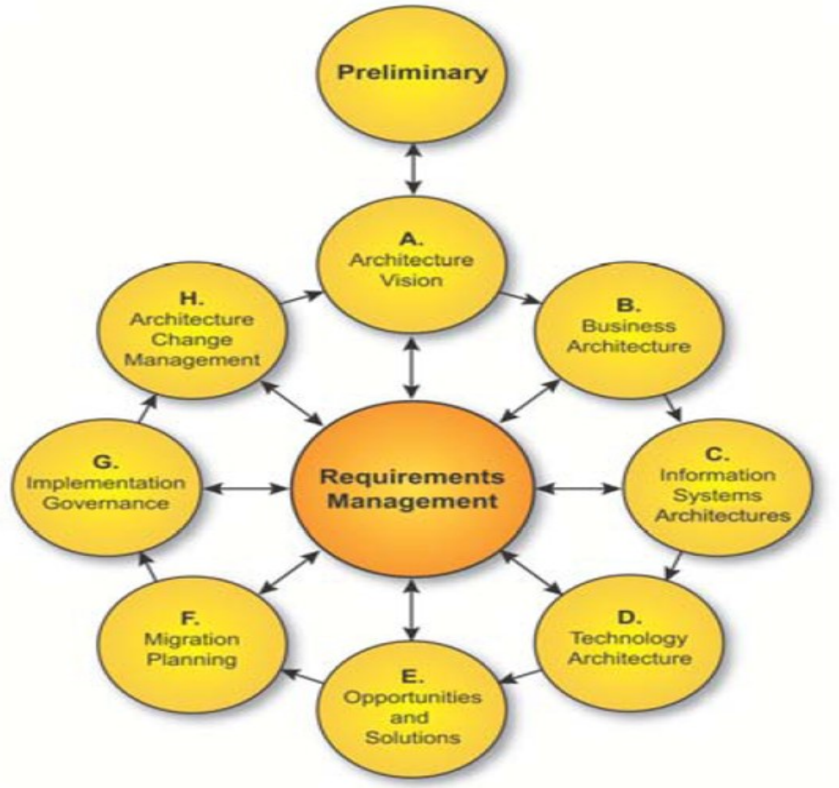

Fig 2.5. The Architecture Development Method (ADM) in TOGAF9 (Source: The Open Group (2009c))

2.3.2 FEAF (Federal Enterprise Architecture Framework)

FEAF (Federal Enterprise Architecture Framework 2013) is a comprehensive framework for developing and maintaining the enterprise architecture capability of the Federal Government. FEAF provides a common and standardized approach and principles for developing and sharing architecture information between agencies (Gill 2015). Fig 2.6 shows the structure of this FEAF as below. FEAF was developed by the US Federal Chief Information Officers Council (Federal CIO Council 2008). The core of FEAF is a Collaborative Planning Methodology (CPM) and Consolidated Reference Model (CRM). CRM specifies six interrelated reference models: Performance Reference Model (PRM), Business Reference Model (BRM), Data Reference Model (DRM), Application Reference Model (ARM), Infrastructure Reference Model (IRM), and Security Reference Model (SRM) (Gill 2015). The reference models are intended to standardize terms and definitions in EA contexts and improve sharing and collaboration across the entire federal government (Federal CIO Council 2008).

First, with regard to FEAF Mobile IT Category elements, Mobile Devices appear in SRM and IRM meta-models and in ARM and BRM. APIs are produced in the ARM meta-model and DRM (Federal Enterprise Architecture Framework 2013). With regard to FEAF Cloud Category elements, Cloud Computing is produced in IRM meta-models, and SaaS, PaaS, and IaaS are noted in IRM Cloud First Initiatives. Furthermore, Cloud Computing is noted in ARM and SRM (Federal Enterprise Architecture Framework 2013). Concerning FEAF Web Service/SOA elements, Business Service appears in the BRM meta-model, DRM, and ARM.

Application Service is noted in ARM, Enterprise Service in BRM, and Infrastructure Service in IRM (Federal Enterprise Architecture Framework 2013). Service Consumer and Service Provider are also identified in BRM (Federal Enterprise Architecture Framework 2013; Federal CIO Council 2008). Moreover, Application Interface appears in ARM meta-models (Federal Enterprise Architecture Framework 2013), and Service Interface is noted in ARM (Federal CIO Council 2008).

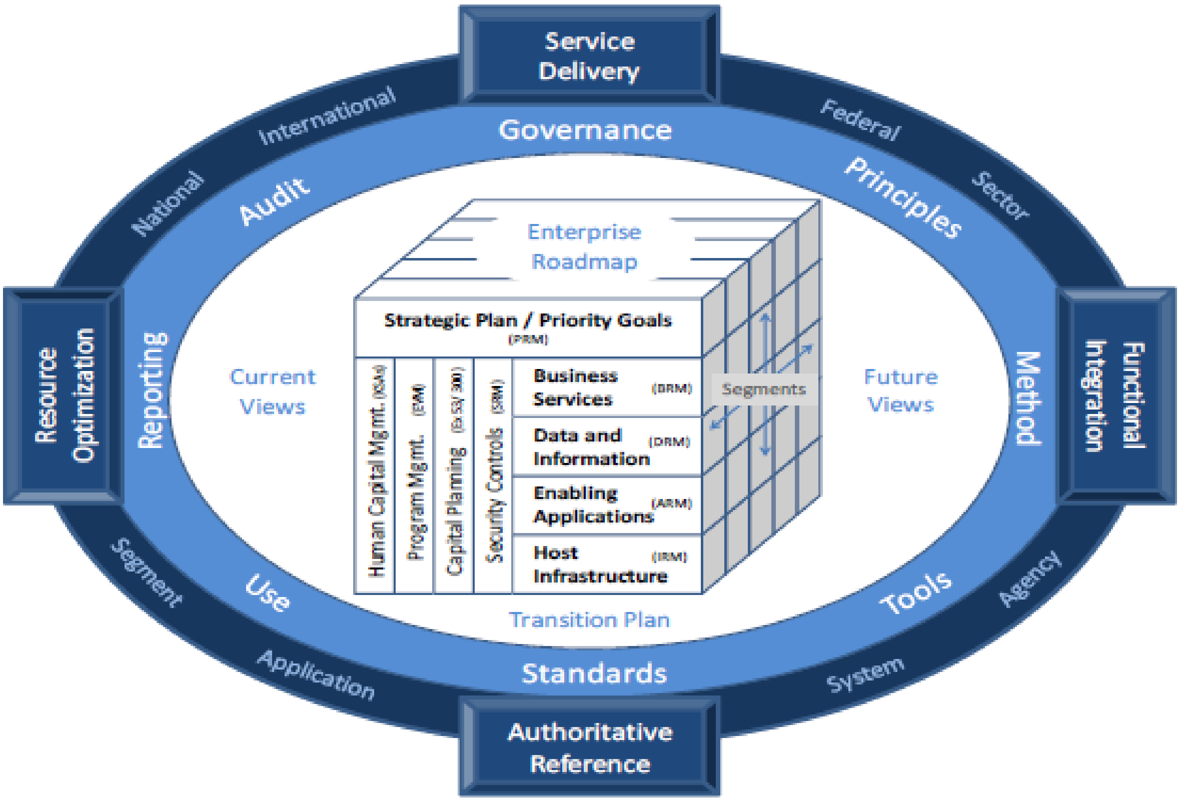

Fig. 2.6 Structure of the FEAF (Source: Federal Enterprise Architecture Framework Version 2 (2013))

2.3.3 DoDAF (Department of Defense Architecture Framework)

DoDAF is an architecture framework for the United States Department of Defense and defines a standard approach for describing, presenting, and integrating DoD architecture. DoDAF provides the guidance and rules for developing architecture descriptions in order to show a common denominator for understanding, comparing, and integrating Systems of Systems (SoS), and interoperating and interacting architectures (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al. 2014). DoDAF provides a six-step architecture development process: Define Architecture Use, Define Architecture Scope, Define Required Architecture Data, Manage Architectural Data, Analyze Architecture Data, and Document Architecture (according to the intended architecture use or needs). Fig 2.7 shows the "DoDAF 6-step Architecture Process" as below.

The DoDAF meta-model is structured around the interoperability of processes and systems (Gill 2015). DoDAF v2.0 has different layers (viewpoints): Systems Viewpoint (SV), Service Viewpoint (SvcV), Data & Information Viewpoint (DIV), Operational Viewpoint (OV), Standards Viewpoint (StdV), Capability Viewpoint (CV), Project Viewpoint (PV), and All Viewpoints (AV) (US Department of Defense 2009). DoDAF provides a concrete EA process, meta-model, models, viewpoints, etc. (Gill 2015).

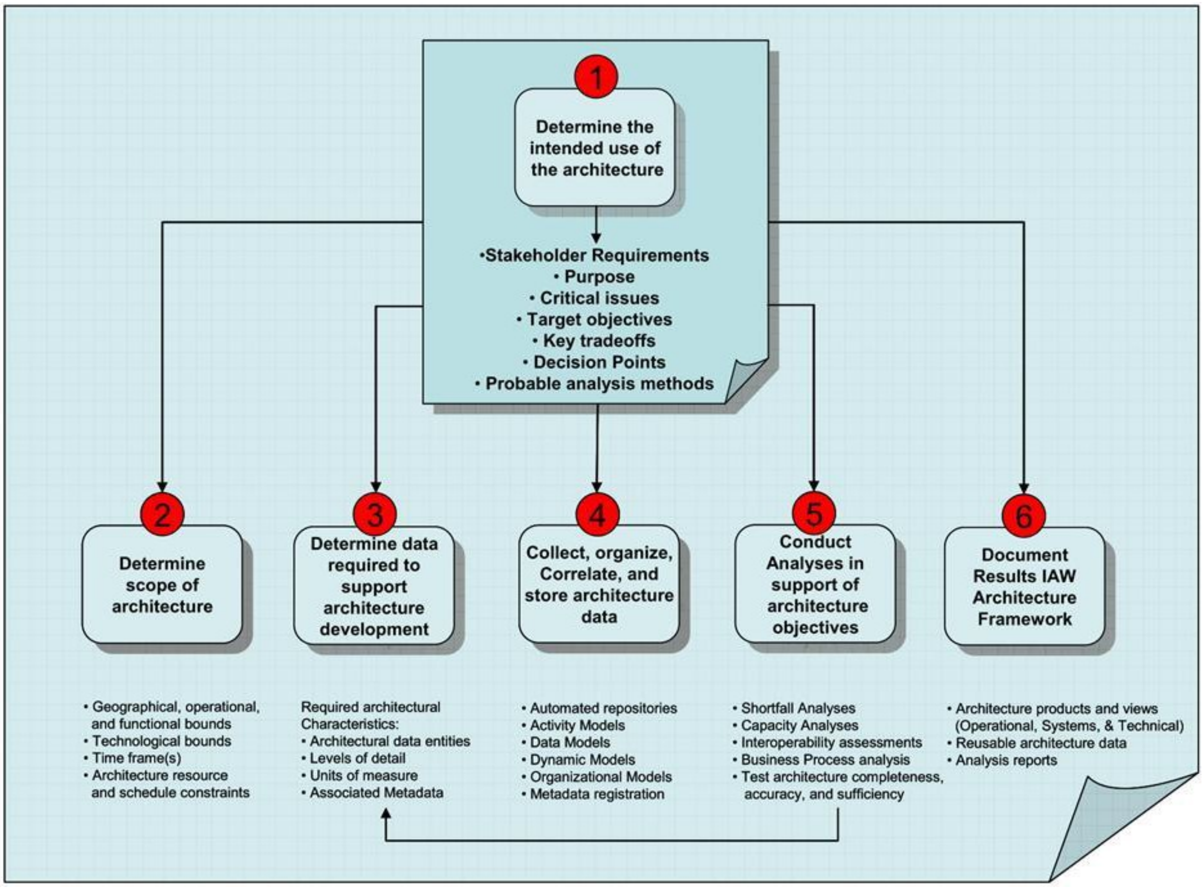

Fig. 2.7 DoDAF 6-step Architecture Process (Source: Architecture Guidance Study Report, ISO/IEC JTC1 SC7 Software and systems engineering, April 2014)

First, with regard to Mobile IT Category elements in DoDAF, Mobile Devices are mentioned under CV. Concerning Cloud Categories in DoDAF, SaaS is noted in SvcV and CV. In addition to PaaS and IaaS, Cloud Computing is also addressed under CV. With regard to Web Service/SOA elements in DoDAF, in the DoDAF generic meta-model, a service (including business and software services), a service port and performer (both service consumer and provider) are identified. The main viewpoint that has Web Service/SOA elements is SvcV. However, these elements appear in other viewpoints, such as AV and CV, when mapping services to capabilities (Alwadain 2013).

2.3.4 MODAF (British Ministry of Defence Architecture Framework)

MODAF defines a normalized way of conducting Enterprise Architecture, and it was originally developed by the UK Ministry of Defence (MOD). The UK's MOD defined an architecture framework named MODAF in 2006-2008 with adapting DoDAF. Fig 2.8 shows the “MODAF Architecture Process” as below. MODAF is an internationally normalized EA framework developed by MOD to support Defence planning and change management activities (ISO/IEC JTC 1/SC7 Architecture Guidance, Garnier et al. 2014). MODAF provides a consistent set of rules and templates, known as views, that present a textual and graphical visualization of an area of the business. Each view provides a special perspective of the business in order to meet various stakeholder concerns. The views are divided into seven categories: strategic, operational, service-oriented, systems, acquisition, technical, and all views. MODAF includes a meta-model that defines the relationship between all data in all the views (UK Ministry of Defence 2010a).
With regard to Mobile IT Category elements in MODAF, although Mobile Devices are noted in strategic and system viewpoints, the focus is from a Mobile Network perspective. Moreover, there are no Cloud Category elements in MODAF. Web Service/SOA-related elements identified in the MODAF models are service, service interface, and service consumer in the service-oriented viewpoint (UK Ministry of Defence 2010b). In addition, there is note of Application Services under the service-oriented viewpoint (Masuda, Shirasaka, & Yamamoto, 2016).

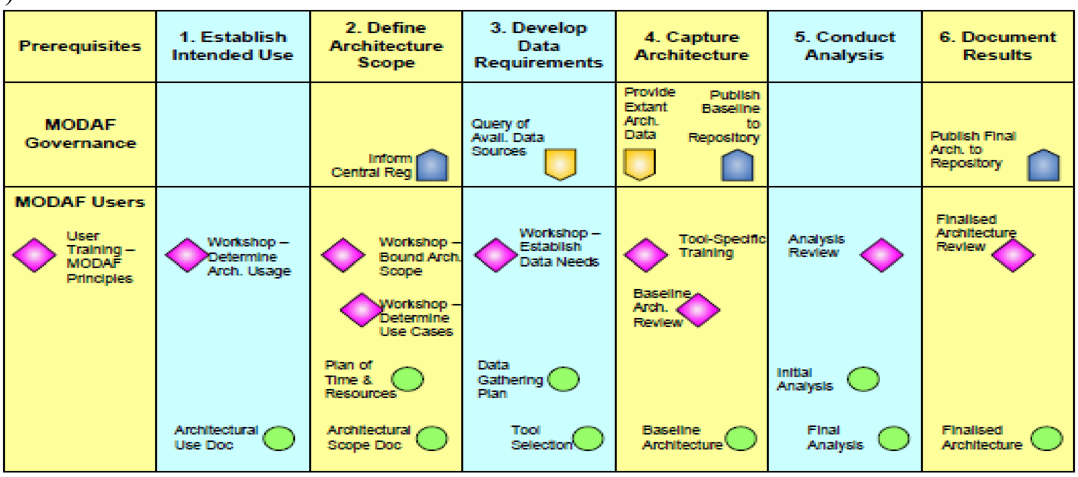

Fig. 2.8 MODAF Architecture Process (Source: MOD Architecture Framework (MODAF), UK Ministry of Defence, October 2010)

2.3.5 Adaptive Enterprise Architecture Framework

The adaptive enterprise architecture framework (also known as the Gill Framework) is a meta-framework that can be used to support the tailoring of a situation-specific adaptive enterprise architecture capability or framework (Gill 2013). Fig 2.9 shows the "Adaptive Enterprise Architecture Framework" as below. This framework provides support for developing and managing adaptive or agile enterprise architecture in a modern context, including adaptive Cloud technology-enabled enterprise architecture. This framework has its foundation on the new "adaptive enterprise service system" theory, which extends the SoS, agility, and service science approaches for defining, operating, managing, supporting, and adapting a modern enterprise as an "adaptive enterprise service system" (Gill 2013). This framework has two main layers: outer and inner. The outer layer presents five adapting capabilities (i.e., context awareness, assessment, rationalization, realization, and un-realization) to guide the continuous adaptation of the adaptive enterprise architecture as an adaptive enterprise service system in response to internal and external changes. The inner layer assists in defining, operating, managing, and supporting the complex enterprise as an adaptive enterprise service system in response to changes or requirements reported by the outer layer (Gill et al. 2014).

First, with regard to Mobile IT Category elements in an Adaptive EA framework, there is note of Mobile Devices and APIs in Cloud EA Capability. With regard to Cloud Category elements in the Adaptive EA framework, SaaS, PaaS, and IaaS reside in the Adaptive Cloud EA Model, and the Cloud Interface is described in the Adaptive Cloud EA—the model for the federated adaptive enterprise Service Information System (SIS). Furthermore, concerning Web Service/SOA elements in an Adaptive EA framework, Business, Application, Information, Infrastructure, and Platform Services reside in the Enterprise Service System meta-model and Cloud EA Model (Service Mapping—External View) and the Service-based Mobile application is described in Cloud EA Capability. Moreover, Business Interface resides in the Business Architecture Model (Internal View) of Cloud EA Capability (Masuda, Shirasaka, & Yamamoto, 2016).

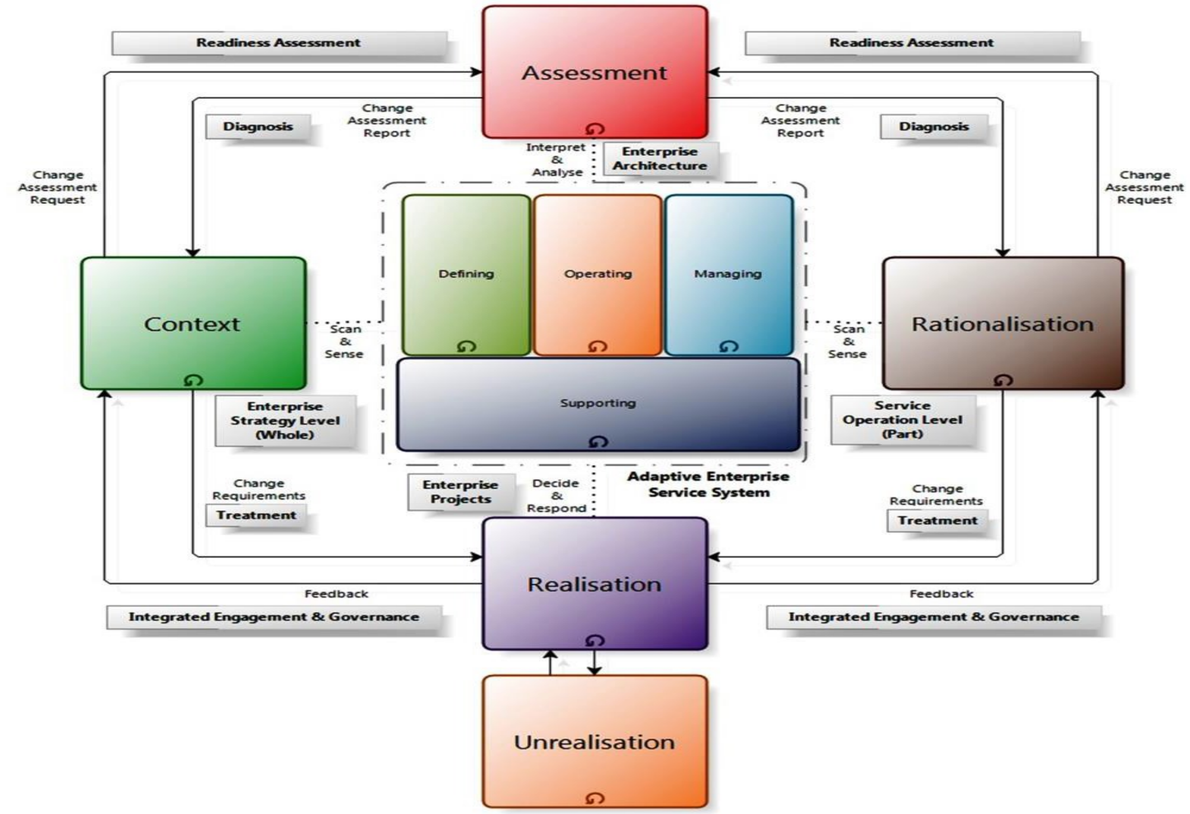

Fig. 2.9 The Adaptive Enterprise Architecture Framework (Source: Agile enterprise architecture: a case of a cloud technology-enabled government enterprise transformation. Proceeding of the 19th Pacific Asia Conference on Information Systems (PACIS 2014), Gill)

2.4 EA Framework Analysis

2.4.1 Comparison of Mobile IT/Cloud Integration in EA Frameworks

The five selected EA frameworks are compared based on the key elements of Mobile IT/Cloud computing and Services in order to present an overview of the status in terms of the Mobile IT/Cloud elements and the position of these elements in the layers (viewpoints) of the five frameworks. Discussions and conclusions based upon this comparison are presented in the following sections(Masuda, Shirasaka, & Yamamoto, 2016).

First is the Mobile IT Category. The Mobile IT-related elements are identified in all frameworks. For instance, mobile device is found in the FEAF meta-models in IRM and SRM, and FEAF documents in BRM and ARM. Moreover, mobile device is identified in the TOGAF, DoDAF, MODAF, and Adaptive EA framework documents. An API is found in the FEAF meta-model in ARM, and FEAF documents in DRM. Furthermore, an API is presented in the TOGAF and Adaptive EA framework documents. However, *Mobile Device Manager* and *Mobile Application controller* are not found in all frameworks(Masuda, Shirasaka, & Yamamoto, 2016).

Second is the Mobile IT-related Cloud computing category. Many elements of "Mobile IT-related Cloud computing" that involve SaaS, PaaS, and IaaS are found in the meta-models of Adaptive EA framework. Moreover, SaaS is identified in the FEAF document in IRM, and

DoDAF documents. PaaS and an IaaS are used in the FEAF document in IRM and DoDAF document. Furthermore, other Cloud-related elements are identified in the FEAF meta-model in IRM and FEAF documents in ARM and SRM, and in the DoDAF document. Moreover, in the Adaptive EA framework documents, a Cloud Interface is found(Masuda, Shirasaka, & Yamamoto, 2016).

Third is the Services category. The service is identified in all frameworks, but it varies remarkably in the details. For instance, a generic service element is found in the meta-models of DoDAF, MODAF, and Adaptive EA framework, whereas a business service is recognized in the meta-models of TOGAF, FEAF, and Adaptive EA framework, and in the DoDAF documents. In addition, an application service is identified in the TOGAF and Adaptive EA framework meta-models, and in the FEAF, DoDAF, and MODAF documents. Furthermore, an Information System service is found in the TOGAF and Adaptive EA framework meta-models, and an enterprise service is identified in the FEAF and Adaptive EA framework documents. Moreover, an infrastructure service is presented in the Adaptive EA framework meta-model, and in the TOGAF and FEAF documents, whereas a platform service is used in the TOGAF and Adaptive EA framework meta-models. From the perspective of Microservices and Application, Information System, and Platform services, etc. in SOA, these are equivalent to Functional services. Service-based Mobile Application is not found in all frameworks, with the exception of Adaptive EA framework. In terms of Microservices, Infrastructure service in SOA is equivalent to infrastructure service, whereas Business service in SOA is close to Microservices(Masuda, Shirasaka, & Yamamoto, 2016).

Fourth is the Actors category. In the Adaptive EA framework meta-model, an actor is identified in the business layer and in the TOGAF and FEAF documents in BRM and SRM. A service consumer is presented in the MODAF meta-model and in the TOGAF, FEAF, and Adaptive EA framework documents. Moreover, a service provider is used in the TOGAF and MODAF documents, and FEAF documents in BRM, whereas a performer that could be a service provider or consumer is presented in the DoDAF meta-model and documents(Masuda, Shirasaka, & Yamamoto, 2016).

Table 2.1 Mobile IT/Cloud elements in EA frameworks

EA Frameworks		TOGAF 9			FEAF					DoDAF v2.0		MODAF		Adaptive EA	
Layers (views) Mobile IT/Cloud elements		**Business**	**Information Systems**	**Technology**	**BRM**	**DRM**	**ARM**	**IRM**	**SRM**	**Capability View**	**Services View**	**Strategic /System Viewpoint**	**Service Oriented Viewpoint**	**Enterprise Service System**	**Cloud EA Capability**
Mobile IT Category (TA)	Mobile Device			*	*		*	**	**	*		*			*
	API		*	*		*	**								*
	Mobile Device Manager														
	Mobile Application Controller														
Mobile IT-related Cloud Category (TA)	SaaS							*		*	*				**
	PaaS							*		*					**
	IaaS							*		*					**
	Cloud Interface														*
	Other						*	**	*	*					**
Services Category (AA)	Service									*	**		**	**	**
	Business Service (micro service)	**			**	*	*				*			**	**
	Application Service (functional service)		**				*			*	*		*	**	**
	IS Service (functional service)		**											**	**
	Enterprise Service (functional service)				*									*	
	Infrastructure Service (infrastructure service)			*				*						**	**
	Platform Service (functional service)			**										**	**
	(Service based) Mobile Application														*
Actors Category	Actor	*			*				*					**	**
	Service Consumer	*		*	*								**	*	
	Service Provider	*	*	*	*								*		
	Performer									*	**				
Interfaces Category	Business Interface														**
	Application Interface						**								*
	Infrastructure Interface														*
	Service Port										**				
	Service Interface	*	*	*	*		*						**	*	

Fifth is the Interfaces category. A Business Interface is identified in the Adaptive EA framework meta-model. Moreover, Application and Infrastructure interfaces are found in the Adaptive EA framework documents. However, in the DoDAF meta-model, it is called a service port, whereas in the TOGAF, FEAF, Adaptive EA framework documents, and MODAF meta-models, it is called a service interface(Masuda, Shirasaka, & Yamamoto, 2016).

2.4.2 Analysis of Cloud/Mobile IT Integration in EA Frameworks

The analysis from previous sections resulted in several beneficial findings. First, the Mobile IT element is recognized in the frameworks. A mobile device and/or API were identified in most layers (viewpoints) of TOGAF, FEAF, and Cloud EA Capability of Adaptive EA framework. Moreover, only the mobile device was found in DoDAF and MODAF. On the other hand, all frameworks did not include the elements of a Mobile Device Manager and Mobile Application controller at the current time, which can lead to difficulties for making proper architecture models/guidelines for Mobile IT to promote EA(Masuda, Shirasaka, & Yamamoto, 2016).
Second, most frameworks have elements of Cloud computing related to Mobile IT, with the exception of TOGAF and MODAF. All the elements of Cloud computing related to Mobile IT, such as SaaS, PaaS, and IaaS, are included in FEAF, DoDAF, and Adaptive EA framework meta-models. Because the US government agency promotes the IT strategy called "Cloud First," where shared services become suitable for budget reduction and optimization with common sense approaches, Cloud IRM defined in FEAF has the elements of SaaS, PaaS, and IaaS. In terms of DoDAF, SaaS is found in the description of "DoDAF Meta Model for Services", whereas PaaS, IaaS, and SaaS are identified in the description of "service-centric IE capability." The Cloud interface is identified only in Adaptive EA framework. Because all frameworks do not have the Cloud Interface indispensable for implementation of the Hybrid Cloud-based system in companies, with the exception of the Adaptive EA framework, it is obvious that few model-defining Hybrid Clouds appropriate for companies exist in EA frameworks. Therefore, it will be considered that the corporation adopting TOGAF, etc. can adopt the integrated framework with the Adaptive EA framework supporting elements of Cloud computing to meet the shift to Cloud computing environments in future. In addition, concerning the Zachman framework, Zachman has published an Official Newsletter specific to the Cloud Category that mentions a definition of Cloud computing within Physical and Detailed Views (Zachman 2011). Moreover, Laplante et al. (2008) defined SaaS within an entire view of contextual, conceptual, logical, physical, detailed, and functioning(Masuda, Shirasaka, & Yamamoto, 2016).
Third, all frameworks have a service element, but some differences are observed by examining further and comparing systematically. A business service is included in most EA frameworks. An application service is also included in most frameworks. However, the IS, enterprise, and platform services are less frequent. Each of these is covered in one framework and the Adaptive EA framework. Although the Platform service is presented in TOGAF and Adaptive EA framework, the infrastructure service is used in these frameworks as well as FEAF—they have similar semantics. Furthermore, it is apparent that TOGAF has a clear categorization and representation of services in all their layers (viewpoints). A Service-based Mobile Application is found only in the document of the Adaptive EA framework. On the other hand, few service elements described as Microservices are found in all frameworks at the current time(Masuda, Shirasaka, & Yamamoto, 2016).

Fourth, the actor element is included in the frameworks. An actor as a generic element is discovered in TOGAF to represent both the service provider and consumer. The separation of the provider from the consumer in two elements is only observed in FEAF (Alwadain 2013). In Adaptive EA framework, only service consumer is found in two elements. The actor element is similar to many of the other elements in terms of terminology discrepancy, regardless of whether a generic actor element is used to represent both the provider and consumer (Alwadain 2013).

Fifth, all frameworks have an interface element, but some differences are identified by comparing them. In terms of the service interface, all frameworks contain interfaces as part of SOA. However, interface-related elements are represented through different terms in the various frameworks. For example, in DoDAF, the term "service port" was chosen instead of "service interface" (Alwadain et al. 2014). Adaptive EA framework includes business, application, infrastructure, and service interfaces(Masuda, Shirasaka, & Yamamoto, 2016).

Furthermore, it appears that the presented frameworks can generally or partially accommodate the elements that constitute the categories of Mobile IT/Cloud computing and services as part of SOA. However, there are few elements of Mobile IT and related Cloud computing, which is beneficial to the definitions of architecture models/guidelines/processes in Mobile IT and related Cloud computing to promote EA in corporations. In specific, in terms of the Mobile IT Category, the existing EA frameworks have not supported the essential mechanisms of this one to date because most elements, such as Mobile Device Management, Mobile application, and its controller, are not included in all EA frameworks at the current time. We concluded that there should be a problem where there is no element useful for defining proper architecture models/guidelines/processes in Mobile IT and related Cloud computing in all frameworks to promote EA(Masuda, Shirasaka, & Yamamoto, 2016).

2.4.3 Results of EA Framework Analysis

In this section, five EA frameworks were investigated and compared in terms of Mobile IT/Cloud computing and Service elements. They all supported service elements at different levels and almost all included the elements of Mobile IT/Cloud computing, even if partially. However, although only Cloud computing elements were found in the Adaptive EA framework and FEAF meta-models, which led to architecture models/guidelines/processes for Cloud computing, there were few elements of Mobile IT and related Cloud computing effective for making appropriate architecture models/guidelines/processes in Mobile IT and related Cloud computing to promote EA in corporations. For instance, there was no element of Cloud Interface in the meta-models of all frameworks, which is essential for defining a Hybrid Cloud system, whereas there was no element of Mobile Device Manager, Mobile Application controller, or Mobile Application in the meta-models of all frameworks. The problem to be solved is that there is no effective element for making appropriate architecture models/guidelines/processes in Mobile IT and related Cloud computing in all frameworks to promote EA that can lead to business contributions, cost reductions, and profit increase in corporations. For the purpose of coping with these matters with regard to Mobile IT/Cloud computing integration in EA frameworks, we propose to establish "TOGAF Guidelines for Mobile IT" and "TOGAF Guidelines for Cloud computing," "TOGAF Guidelines for

Microservices" as "TOGAF Guidelines for SOA" was published several years ago. Moreover, we are hopeful that the architecture reference models for Mobile IT/Cloud computing will be established in DoDAF in the future. On the other hand, it will be useful for the architecture meta-models of Mobile IT and Microservices to be defined in the Adaptive EA framework in the future(Masuda, Shirasaka, & Yamamoto, 2016).
The contribution of the paper is that, to the best of our knowledge, this is the first paper to compare EA frameworks with a focus on the Mobile IT/Cloud computing elements integrated into those frameworks. Moreover, this study will be the first step in understanding and improving the integration of Mobile IT/Cloud computing with Service in EA. This study will be the preparation for defining appropriate architecture models/guidelines/processes in Mobile IT and related Cloud computing to promote EA as a very important factor of IT Governance in corporations for the future. On the other hand, for practical reasons, although the study referred to the relationships and interactions among the elements of Mobile IT/Cloud computing and Service, it could not analyze their relationships in EA frameworks because of space restrictions. Future research needs to look beyond existing literatures to better identify the role of Mobile IT/Cloud computing with services for EA in order to define architecture meta-models in Mobile IT and related Cloud computing. It can be proposed as a good option that a company having applied TOGAF or FEAF etc. can adopt the integrated framework with the Adaptive EA framework supporting elements of Cloud computing to meet the trend shift to Cloud computing/Mobile IT environments from now onwards. Future research needs to verify these proposed EA frameworks, such as surveys and case studies, while being able to consider utilizing quantitative analysis/methodologies to clarify the practical values of these proposed EA frameworks in an applicable manner. Furthermore, the IoT (Internet of Things), which is an important category of Digital IT, also has architecture elements similar to Mobile IT/Cloud. The IoT consists of IoT devices such as sensor/control/RFID tags and Web service APIs, according to the definitions of models related to the IoT and also to big data analytics in Open Platform 3.0 Standard. Moreover, the IoT can involve the SaaS Cloud model as software becomes more deeply integrated in the machines around us (Loukides and Bruner 2015).
Further research is required to explain the differences in the integration approaches that could be generalized to new emerging concepts, such as Mobile IT/Cloud computing, that need to be integrated in the EA frameworks (Masuda, Shirasaka, & Yamamoto, 2016).

2.5 Problems and Solutions

2.5.1 Problems' structure and their factors in Digital Transformation and Enterprise Architecture

As results of investigations regarding problems in Digital Transformation and related Enterprise Architecture in global corporations and previous research in Australia and worldwide, the author considers the following 7 kinds of factor's categories in their problems' structure.

[1] Factor of Architecture Strategy and Governance

[2] Factor of Business Architecture
[3] Factor of spanning Business Architecture and Application Architecture, their dependencies
[4] Factor of spanning Application Architecture and Technology Architecture, their dependencies
[5] Factor of Data Architecture
[6] Factor of spanning Data Architecture and Technology Architecture, their dependencies
[7] Factor of Technology Architecture

Therefore, there are a lot of cross-functional problems in Digital Transformation and EA, that will lead to the loss of profits because of less strategic alignments and non-standardization in application, technology and data. Fig 2.10 shows the results of the author's investigation regarding problems' factors and grouping them as below.

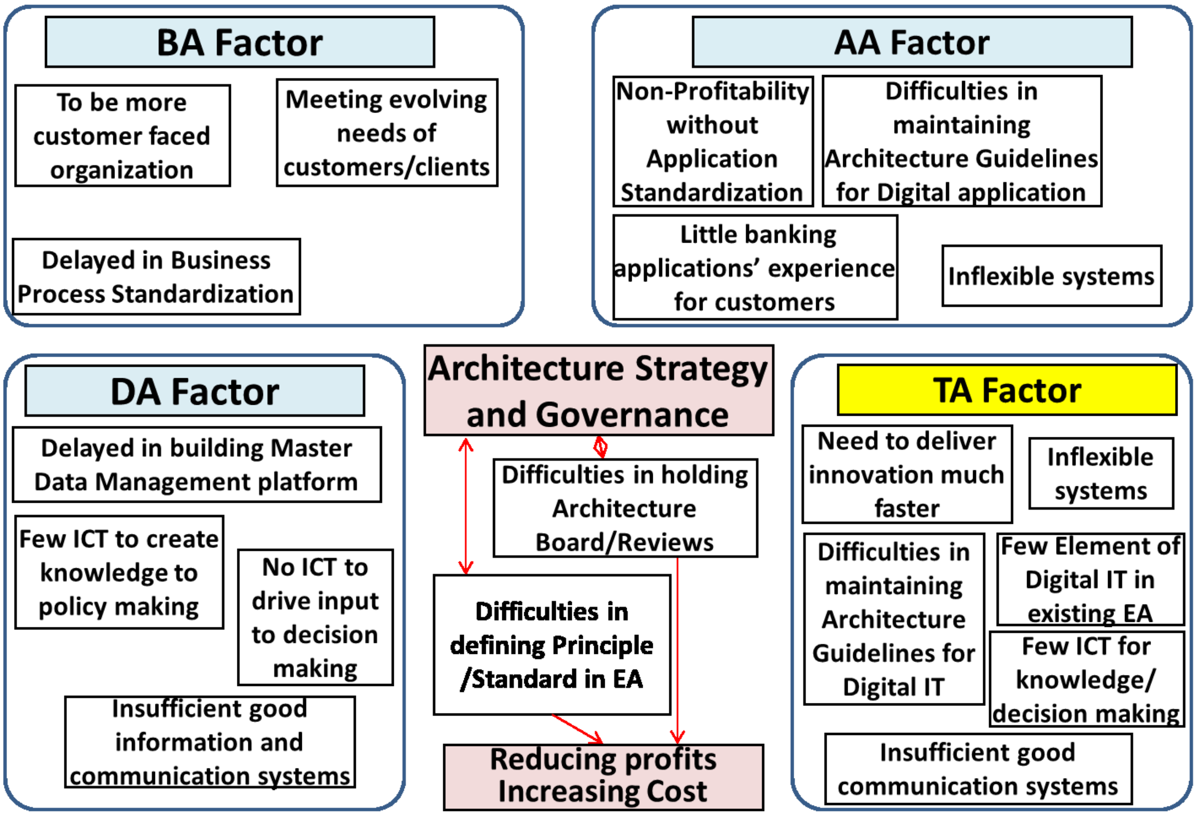

Fig. 2.10 Problems' structure in Digital Transformation and EA

2.5.1.1 The Factor of Architecture Strategy and Governance

One of critical factors to problems in Digital Transformation and EA should be the factor of "Architecture Strategy and Governance" especially in global corporations. In the case study of global pharmaceutical company, the author faced with difficulties in holding global Architecture Board and performing Architecture reviews in the global level, with applying TOGAF (Masuda et al. 2017). The factor of Architecture Governance had an affect on this problem. Furthermore, the author faced with difficulties in defining each principle and standard as a global organization in the case study of global pharmaceutical company (Masuda et al. 2017). The factor of Architecture Strategy had an affect to these kinds of problems. Finally, these problems in Architecture Strategy and Governance will lead to the reduction of profits in global corporations.

2.5.1.2 The Factor of Business Architecture

The factor of Business Architecture is also important among critical factors to problems in Digital Transformation and EA. In the case study of global pharmaceutical company, the author faced with the delayed situation in business process standardization in global (Masuda et al. 2017). On the other hand, Telstra CIO mentioned that they need to help make the large organization a more customer-faced one (K. Walsh, 2012). Demand management in the factor of Business Architecture (BA) had a bearing on this kind of problem. The factor of Business Architecture had an affect on these kinds of problems in Digital Transformation and EA.

2.5.1.3 The Factor of spanning Business Architecture and Application Architecture, their dependencies

The factor of spanning Business Architecture (BA) and Application Architecture (AA) with their dependencies should be also most important one among critical factors to problems in Digital Transformation and EA. Coca-Cola Amatil CIO commented that they need to stay profitable and to keep meeting the evolving needs of its customers and clients. Furthermore, Commonwealth Bank CIO mentioned that little had been done since 1960 to improve the banking applications' experience for customers (K. Walsh, 2012). The factor of spanning Business Architecture (BA) and Application Architecture (AA) had affects to these kinds of problems in Digital Transformation and EA. Fig 2.11 shows the interdependency of problems' structure between architecture domains in Digital Transformation and EA, covering the above interdependency between BA and AA as below.

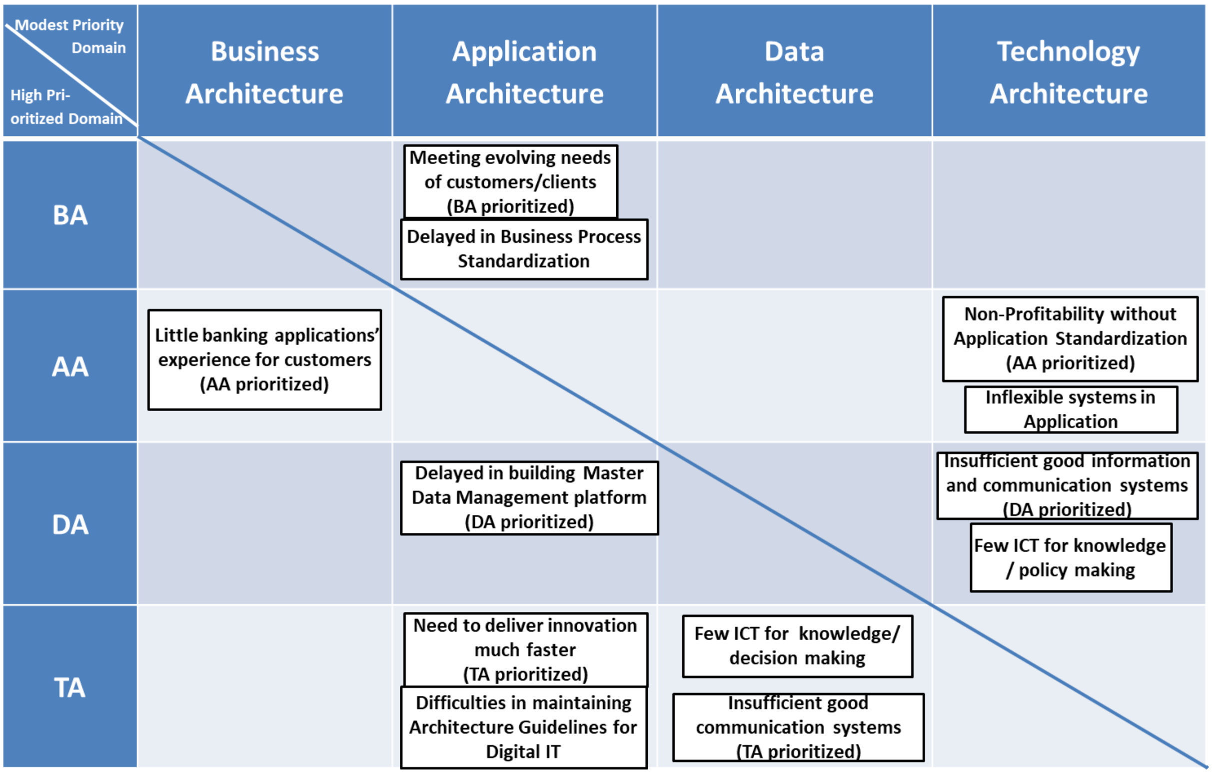

Fig. 2.11 Interdependency of Problems' structure between Architecture Domains in Digital Transformation and EA

2.5.1.4 The Factor of spanning Application Architecture and Technology Architecture, their dependencies

The factor of spanning Application Architecture (AA) and Technology Architecture (TA) is the most critical one to problems in Digital Transformation and EA. ING Direct CIO mentioned that it should be important to enable them to deliver innovation much faster than they could before, with more cost-efficiency with application standardization. In the case study of global pharmaceutical company, the author had difficulties in developing/maintaining Architecture Guidelines for Cloud/Mobile IT application systems in global level (Masuda et al. 2017). Moreover, Commonwealth Bank CIO commented that the systems were inflexible in application and technology (K. Walsh, 2012). The factor of spanning Application Architecture (AA) and Technology Architecture (TA) with their dependencies had affects to these kinds of problems in Digital Transformation and EA. Also, Fig 2.11 shows the interdependency of problems' structure between AA and TA in Digital Transformation and EA as above.

2.5.1.5 The Factor of Data Architecture

The factor of Data Architecture will become more important as a critical factor to problems in Digital Transformation and EA while Big Data solutions are prevailing more. In the case study of global pharmaceutical company, the author met the situation that the project of building the Master Data Management platform had not proceeded in global (Masuda et al. 2017). The factor of Data Architecture had a bearing on this kind of problem in Digital Transformation and EA.

2.5.1.6 The Factor of spanning Data Architecture and Technology Architecture, their dependencies

The factor of spanning Data Architecture and Technology Architecture will also become more important as critical factors to problems in Digital Transformation and EA. Australian Government CIO commented that good information and communication systems should be vital to efficient, effective government. Furthermore, Australian Government CIO mentioned that ICT should be critical to creating knowledge to inform policy making, to drive input to decision making (K. Walsh, 2012). The factor of spanning Data Architecture and Technology Architecture with their dependencies have affects to these kinds of problems in Digital Transformation and EA. Fig 2.11 shows the interdependency of problems' structure between Data Architecture and TA in Digital Transformation and EA as above.

2.5.1.7 The Factor of Technology Architecture

The factor of Technology Architecture is also critical factor to problems in Digital Transformation and EA. In the case study of global pharmaceutical company, the author found out that there were few elements of Cloud/Mobile IT/Digital IT in existing EA framework such as TOGAF, FEAF and DoDAF, etc. (Masuda et al. 2016). The factor of Technology Architecture have affects to the problems in Digital Transformation and EA.

2.5.2 Solutions to cope with Problems in Digital Transformation and Enterprise Architecture

If the author of this thesis mentions prior notice basis, the solutions proposed and verified in this thesis, which should consist of AIDAF with related 5 kinds of agility elements and four kinds of models, can correspond to the above problems in Digital Transformation and EA. Fig 2.12 shows the relationship between the above solutions and problems in Digital Transformation and EA ,while the left side of problem items show architecture domains related to each problem and the right side of problem items show problem categories applicable to each one as below.

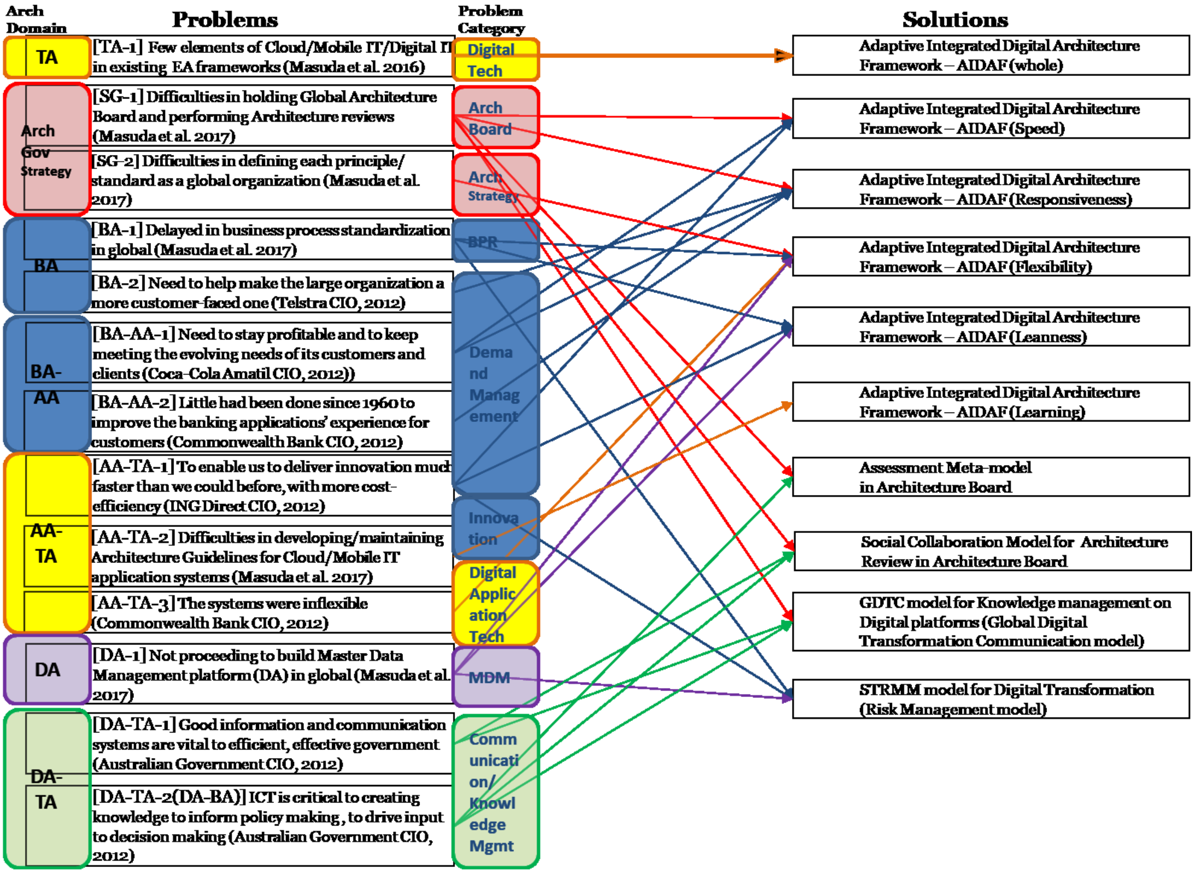

Fig. 2.12 The relationship between Problems and Solutions for Digital Transformation and Enterprise Architecture (Source: The Australian Business Review, July 2012/ Masuda et al. 2017)

The solutions in Fig 2.12 will be explained and proposed in the next chapter in this thesis. Furthermore, each solution in Fig 2.12 will be evaluated and verified in the following chapter 4 to 7 in this thesis.

3. Strategic Architecture Framework aligned with IT strategy promoting Cloud/Mobile IT/Digital IT

The purpose of this chapter is to propose an "Adaptive Integrated Digital Architecture Framework - AIDAF" to meet the requirements of the digital transformation in relation to the above agility-related aspects. The proposed EA framework should support an IT strategy promoting cloud/mobile IT/Digital IT on the basis of what our prior research suggested. Moreover, the author proposes an architecture assessment model, global communication/knowledge management model and risk management model related to the above AIDAF in this chapter.

3.1 Overview of Strategic Architecture Framework in the era of Digital IT (AIDAF covering related models)

3.1.1 Overview and positioning of AIDAF and related models

For the purpose of proceeding with IT strategy promoting Cloud/Mobile IT/Digital IT/Big Data, I introduce strategic architecture approach and framework in the era of Digital IT in this research. This approach and framework suits the requirements of Digital IT related application systems, that needs the agility elements, while coping with each life cycle defined in SDLC (System Development Lifecycle). According to the definitions of agility elements published by Gill (2014), agility elements consist of "Speed," "Responsiveness," "Feasibility," "Leanness" and "Learning." The following Fig 3.1 illustrates the overview of Strategic Architecture Framework in the era of Digital IT (AIDAF covering related models) while the
vertical axis shows "Digital Agility" and the horizontal axis shows SDLC in Fig 3.1.

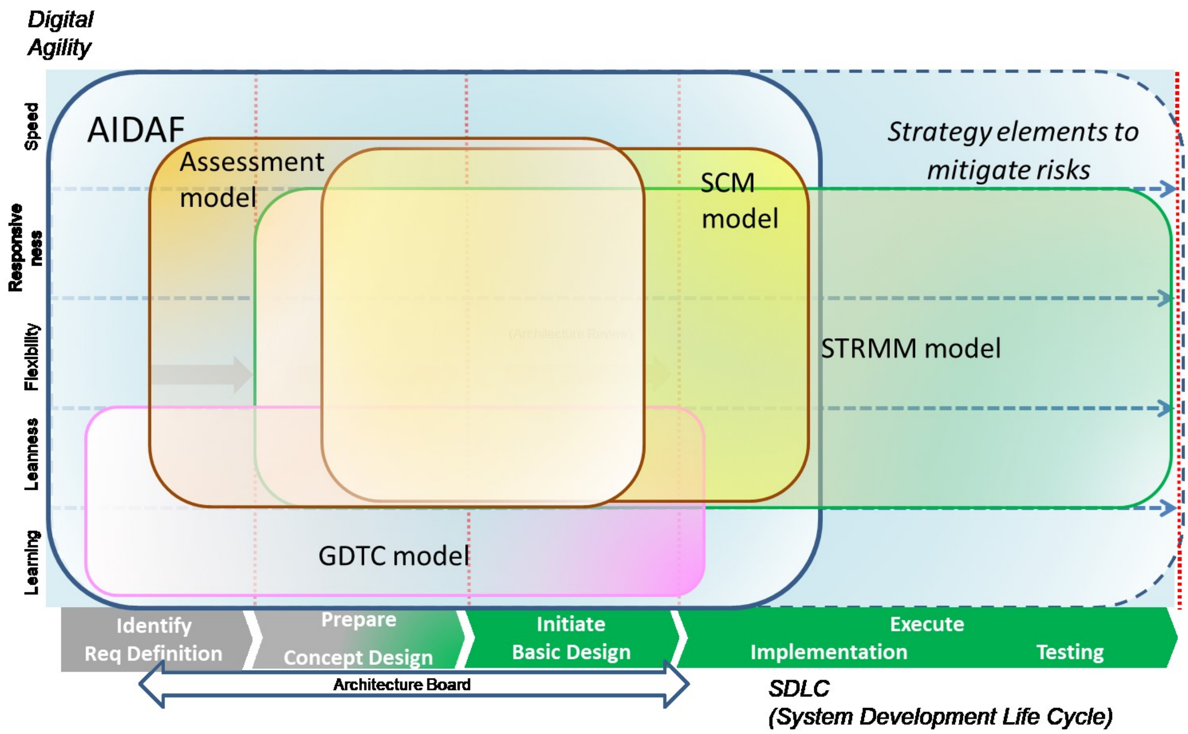

Figure 3.1 Overview of Strategic Architecture Framework in the era of Digital IT (AIDAF and related models)

The author proposed an "Adaptive Integrated Digital Architecture Framework - AIDAF" supporting all elements of Digital Agility, and the author proposed and divided related models, involved in AIDAF, into several ones: 1) Adaptive Integrated Digital Architecture Framework – AIDAF, 2) Assessment meta-model in Architecture Board, 3) GDTC model for global communication on enterprise portal, 4) Social Collaboration Model for Architecture Review in Architecture Board, 5) STrategic Risk Mitigation Model for Digital Transformation, with Strategic elements to mitigate risks.

First, the "Adaptive Integrated Digital Architecture Framework - AIDAF" is the overall Architecture Framework that will support and promote an IT strategy toward the Digital IT. This Architecture framework can be applied in most of phases from "Requirement Definition" to the mid of "Implementation" in SDLC. In this Architecture framework, Architecture Board can be held on short term basis to respond to business user's requirements flexibly with lean structure of architectural processes and deliverables, while developing and utilizing Architecture Guidelines for Digital IT architectures with learning basis.

The scope of dotted line in Fig 3.1 shows the AIDAF in the phases from the latter of "Implementation" to "Testing," where mechanisms of architecture change management need to be fully defined and processed in AIDAF. At the current time, projects related to architecture changes can be submitted and reviewed in Architecture Board partially, however, appropriate mechanisms of Architecture Change Management should be defined and developed in AIDAF to cover the above scope formally.

Second, the "Assessment meta-model in Architecture Board" is covered in AIDAF and the one that can perform Architecture Review regarding solution architectures of new IS/IT projects on the basis of a defined evaluation criteria. This Assessment model will support the

Architecture Board reviews in the early phases from the mid of “Requirement Definition” to “Basic Design” in SDLC, that can be held on short term basis to respond to business user’s requirements flexibly with lean structure of architectural deliverables such as target architectures, current architectures and roadmaps.

Third, “GDTC model for global communication on enterprise portal” is the effective knowledge management process and model on digital platforms for Architecture Board reviews and involved in AIDAF. This model can be applied in the early phases from the “Requirement Definition” to “Basic Design” in SDLC with the lean structured processes on digital platforms involving Architecture Guidelines for Digital IT architectures on learning basis.

Fourth, “Social Collaboration Model for Architecture Review in Architecture Board” is the Architecture model on digital platforms for Architecture Board reviews, covering Business Architecture, Application Architecture and Technology Architecture, and this model is covered in AIDAF as well. This model can be applied in the phase from the mid of “Conceptual Design” to the early “Implementation” in SDLC with the lean structured processes on digital platforms to respond to business user’s requirements flexibly on short term basis.

Fifth, “STRMM model for Digital Transformation” is the risk mitigation model with Architecture Board toward the digital transformation while involved in AIDAF. This model can be applied in the full life cycle and phases from the mid of “Requirement Definition” to the “Testing” in SDLC with the lean structured processes for Architecture reviews, while responding to the questions and requests from the risk’s stakeholders flexibly. Furthermore, in Digital Transformation, Strategy elements to mitigate risks can be effective mainly in the execution phase of SDLC and will sometimes support the all elements of Digital Agility, while covered in AIDAF.

Finally, the AIDAF will support the all elements of Digital Agility, and STRMM model will be applied in all phases from “Requirement Definition” to “Implementation” and “Testing” as shown in Fig 3.1. Therefore, in terms of the overall assessment in Chapter 7, the AIDAF will be evaluated from standpoints of all elements of Digital Agility, and the STRMM model covered in AIDAF will be evaluated in terms of full lifecycle in SDLC.

3.1.2 Research Strategy

In the previous section, as the "Architecture Framework and Risk Management approach fitting to the strategy of promoting cloud/mobile IT," we proposed an "Adaptive Integrated Digital Architecture Framework - AIDAF" covering related models such as “STrategic Risk Mitigation Model for digital transformation” on the basis of previous research in this field. The above framework needs to cover the necessary EA elements for the era of cloud/mobile IT/digital IT, while the above model should be applied in full lifecycles of SDLC.

Moreover, as a research strategy of this thesis, the author shows strategic research questions to verify this "Adaptive Integrated Digital Architecture Framework - AIDAF" toward the requirements and overall elements of Digital Agility in the era of cloud/mobile IT/digital IT and to ensure the effectiveness of the proposed models involved in the Architecture framework, such as “STrategic Risk Mitigation Model for digital transformation” in overall full lifecycles of SDLC. Next, we evaluate these strategic research questions corresponded to the case study of a Global Healthcare Enterprise (GHE), which is a research-based global company with primary focus on pharmaceuticals. Being the largest pharmaceutical company in Asia and an industry leader, this GHE prioritizes the future direction of Digital Healthcare as an important element of corporate strategy; therefore, this case study of the GHE is among the only advanced cases of EA implementation toward the era of Digital IT, especially in the field of digital healthcare.

RQ1: How can our proposing EA framework covering related models solve problems in the era of cloud/mobile IT/digital IT?

RQ2: How can an "Adaptive Integrated Digital Architecture Framework - AIDAF" meet the requirements and elements of Digital Agility in the era of cloud/mobile IT/digital IT?

RQ3: How can the "STRMM model" be effective for mitigating risks for Digital Transformation in terms of full lifecycle in SDLC?

Then, the author who actually led the project to build and implement this EA, carried out the case study within a global pharmaceutical company, where we built and implemented the “Adaptive Integrated Digital Architecture Framework - AIDAF,” by focusing on real developments and progress histories. Moreover, we evaluate the aforementioned research questions using this case study of the global pharmaceutical company, as a research strategy of this thesis(Masuda, Shirasaka, Yamamoto, 2017).

On the basis of the above research, we clarify the challenges, benefits, and critical success factors of this Architecture framework covering related models for EA practitioners in the following chapter 7.

3.2 Necessary Elements and Requirements in EA Frameworks for the era of Cloud/Mobile IT/Digital IT

3.2.1 Necessary elements in Enterprise Architecture Framework for the era of Cloud/Mobile IT/Digital IT

When considering the necessary elements of the EA framework for the era of cloud/mobile IT/digital IT, the EA should have the ability to accommodate agility-related elements. However, the TOGAF is criticized for its size, lack of agility and complexity (Gill et al. 2014). Table 3.1 contains the results of efforts to identify the elements defined in each of the architecture domain categories and agility-related elements in all subject EA frameworks below. In Table 3.1, TOGAF9, FEAF, MIT EA, and our proposed "Adaptive Integrated EA framework" are included as all-subject EA frameworks(Masuda, Shirasaka, & Yamamoto, 2017). Moreover, the author of this thesis has named this EA framework suitable for the era of Digital IT as "Adaptive Integrated Digital Architecture Framework – AIDAF"(Masuda et al. 2017). DODAF and MODAF were excluded from this Table 3.1 because these frameworks do not contain a specific description of agility-related elements.(US Department of Defense, 2009; UK Ministry of Defence, 2010a/2010b) In addition, because the Gartner framework is limited to commercial use, complete access is not possible and it is therefore outside of our scope (Franke et al. 2009). Moreover, because the Zachman framework does not provide an enterprise architecture process for implementing and operating an enterprise architecture capability (Gill 2015), this is also out of our scope at this time. Moreover, when describing the review criteria of "elements in each Architecture Domain Category" in the Table 3.1, we referred to the definitions of each element in the EA framework development project (in this case the global pharmaceutical company) because there were no specific definitions for these elements in existing EA frameworks. On the other hand, regarding the review criteria of "agility-related elements" we referred to the definitions of agility elements published by Gill (2014).

First, all the elements of each architecture domain such as Business Architecture (BA), Application Architecture (AA), Data Architecture (DA), and Technology Architecture (TA) are identified in TOGAF9 (The Open Group, 2009c). On the other hand, agile-related elements can be realized by extension by IT4IT, although there is no specific description regarding agile-related elements such as "leanness" and "learning" in TOGAF9 itself.

IT4IT can be used to cover the agile-related elements that would extend the capabilities of TOGAF, whereas the logical service model defined in IT4IT should be equivalent to parts of the adaptive EA framework (The Open Group, 2017).

Second, all the elements of each architecture domain (BA, AA, DA, and TA) are also identified in FEAF (Federal Enterprise Architecture Framework 2013). However, in terms of agile-related elements, there is no specific description regarding "speed," "leanness," and "learning" defined in Table 3.1. "flexibility," which may be realized by extending SOA and "responsiveness," is identified in the PRM (Performance Reference Model) in FEAF itself.(Federal Enterprise Architecture Framework 2013)

Table 3.1: Elements of each Architecture Domain and Agility in EA frameworks

EA Frameworks			TOGAF 9	FEAF	MIT EA	AIDAF (Adaptive Integrated Digital Architecture Framework)
Necessary elements of EA for Cloud/Mobile IT/Digital IT		Review Criteria				
Elements of each Architecture Domain Category	BA – High level	Business process policy	o (definable)	o (definable)	o (definable)	o (definable)
	BA - Detailed level	Business function chart Business Process flow	o (definable)	o (definable)	× (none)	o (definable)
	AA – High level	Application optimization policy	o (definable)	o (definable)	o (definable)	o (definable)
	AA – Detailed level	Application function chart, Application user location & Communication diagram	o (definable)	o (definable)	× (none)	o (definable)
	DA – High level	Data Integration Policy	o (definable)	o (definable)	o (definable)	o (definable)
	DA – Detailed level	Standard Logical Data model, Standard Interfaces, BI/DWH Specifications	o (definable)	o (definable)	× (none)	o (definable)
	TA – High level	Technology Platform Integration Policy	o (definable)	o (definable)	o (definable)	o (definable)
	TA -Detailed level	Technology Standard, Technology Reference Model, Logical diagram	o (definable)	o (definable)	× (none)	o (definable)
Agility related Elements	Speed	Rapid flexible response of enterprise in timely manner	Extensible with IT4IT RA (Requirement to Deploy)	× (none) No specific description	-Faster develop in stage 4 (Business Modularity)	o (definable) -Accommodates expected or unexpected changes rapidly by short-term cycle
	Responsiveness	Appropriate responses to deal with changes while sensing situations	Extensible with IT4IT RA (Detect to Correct)	- Service Responsiveness in Performance Reference Model	-IT responsiveness improve in stage 2(Standardize) & 4	o (definable) - scans, senses and reacts properly to expected and unexpected changes by short-term cycle
	Flexibility	Adapt to changing complex business demands in defining Principles in EA.	Extensible with IT4IT RA (Requirement to Deploy)	Extensible with SOA (Service Oriented Architecture	-"Foundation for execution" is this base.	o (definable) -Able to define Principles flexibly
	Leanness	EA operation with optimal /minimal resources without compromising quality	× (none) No description	× (none) No description	-Optimal core business process and data in stage 3	o (definable) -With optimal EA deliverables, focus on reducing waste and cost without compromising on quality
	Learning	EA using up-to-date knowledge/experience with continuous growth/adaptation	× (none) No description	× (none) No specific description except for education systems	-Management Practice in stage 4 accelerate learning	o (definable) -With knowledge sharing, focuses on enterprise fitness, improvement, transformation and innovation.

Third, all high-level elements of each architecture domain, such as the "business process policy" in BA, "application optimization policy" in AA, "data integration policy" in DA and "technology platform integration policy" in TA, are identified in the MIT EA (Ross et al., 2006). However, almost none of the detailed elements in each architecture domain (BA, AA, DA and TA) are found in the MIT EA (Yamamoto, 2017). On the other hand, descriptions regarding the agility-related elements of "speed," "learning," and "responsiveness" are found in stage 4 of the "business modularity" section in the MIT EA, and a description of "responsiveness" is also found in stage 2 of "technology standardization." A description concerning the agility-related element of "leanness" is found in stage 3 of "optimized core" and the description of the agility-related element of "flexibility" is found in the "foundation for execution" in the MIT EA (Ross et al., 2006)

Forth, all the elements of each architecture domain (BA, AA, DA, and TA) should be identified in the Adaptive Integrated EA framework proposed in this study, because this EA framework is designed to include long-term principles and target architectures in addition to an adaptive EA framework. Moreover, descriptions regarding all the agility-related elements of "speed," "responsiveness," "flexibility," "leanness," and "learning" are identified in both the adaptive EA framework (Gill, 2015) and the proposed Adaptive Integrated EA framework.

Based on the above comparison, the "Adaptive Integrated Digital Architecture Framework - AIDAF" we propose in this study should have capabilities for all the elements of each of the architecture domain categories and all of the agility-related elements defined in Table 2, to address the limitations of TOGAF9, FEAF, and MIT EA(Masuda, Shirasaka, & Yamamoto, 2017).

3.2.2 Requirements in Enterprise Architecture Framework for the era of Cloud/ Mobile IT/Digital IT

According to the Fig 2.12 of Problems and Solutions in Chapter 2, several kinds of requirements in Enterprise Architecture Framework in the era of Digital IT are identified.

First, in terms of Architecture Strategy and Governance, there should be the requirement of holding architecture board and reviews in global organization, etc, while defining each principle/standard in global ones for EA framework and models in the era of Digital IT. For the purpose of coping with the above requirements, I can propose “Adaptive Integrated Digital Architecture Framework – AIDAF” from standpoints of speed, responsiveness and flexibility of agility-related elements described in the previous section, and “Assessment model,” “Social Collaboration Model” and “Global Digital Transformation Communication model” in the following sections.

Second, according to the Fig 2.12, from standpoints of Business Architecture (BA) and Data Architecture (DA), there should be the requirement of coping with delays in standardization projects of Business Processes and Master Data Management platforms flexibly. In the following sections, the author can propose “Adaptive Integrated Digital Architecture Framework – AIDAF” from standpoints of flexibility, leanness of agility-related elements described in the previous section, and “Strategic Risk Mitigation Model” to minimize the related risks.

Third, according to the Fig 2.12, in terms of Business Architecture (BA) and Application Architecture (AA), there should be the requirement of coping with the difficulties of demand managements for Digital IT systems and projects. In the following sections, the author can propose “Adaptive Integrated Digital Architecture Framework – AIDAF” from standpoints of speed, responsiveness and leanness of agility-related elements described in the previous section, and “Strategic Risk Mitigation Model” to minimize the related risks.

Forth, as described in the section of 2.5, from standpoints of Application Architecture (AA) and Technology Architecture (TA), there should be the requirement of keeping up with the rapid progress of Digital application technologies for Cloud/Mobile IT/Big Data/Digital IT. In the following sections, the author can propose “Adaptive Integrated Digital Architecture

Framework – AIDAF" from standpoints of learning, speed and flexibility of agility-related elements described in the previous section.

Finally, according to Fig 2.12, from standpoints of Data Architecture (DA) and Technology Architecture (TA), there should be the requirement of good communication systems with knowledge management for the decision making. The author can propose "Assessment model," "Social Collaboration Model" and "Global Digital Transformation Communication model" for this requirement in the following sections.

3.3 Adaptive Integrated Digital Architecture Framework - AIDAF

3.3.1 Proposal of Adaptive Integrated Digital Architecture Framework - AIDAF

The preliminary research of this study promoted the strategic use of cloud / mobile IT. This suggests that corporate entities that implement EA by having applied frameworks such as TOGAF and FEAF, could adopt a framework that enables the integration of an adaptive EA framework to provide further support for cloud elements as one possible solution. Accordingly, this study proposes an "Adaptive Integrated Digital Architecture Framework – AIDAF" based on this suggestion for an EA framework that can even be used by corporate entities to promote a cloud / mobile IT strategy. Figure 3.2 illustrates the proposed model of the AIDAF. The proposed model is an EA framework integrating an adaptive EA cycle in the lower part of the diagram with TOGAF or a simple EA (framework) [1] for different business division units in the upper part of the diagram.

The adaptive EA cycle in the proposed model makes provision for initiation documents (including conceptual architecture designs) for new cloud / mobile IT related projects that are continuously drawn up on a short-term basis (monthly, etc.). This begins with the Context Phase, which is prepared for referencing the Defining Phase (architecture design guidelines related to all types of security / cloud / mobile IT consistent with the IT strategy) in line with the needs of business divisions. In the next phase of the assessment / architecture review, the architecture committee / organization reviews the architecture by focusing on the conceptual design portion of the initiation documents for this IT project. In the Rationalization Phase, the stakeholders and Architecture Board differentiate/decide upon information systems that will be replaced by the proposed new information system structure or that are no longer necessary and can be abandoned. In the Realization Phase, this project team begins to implement the new IT project agreed upon as a result of deliberating these issues/action items. This enables the corporate entity to adopt an EA framework capable of flexibly adapting to new cloud / mobile IT projects that continuously occur, and which are composed of these four phases.

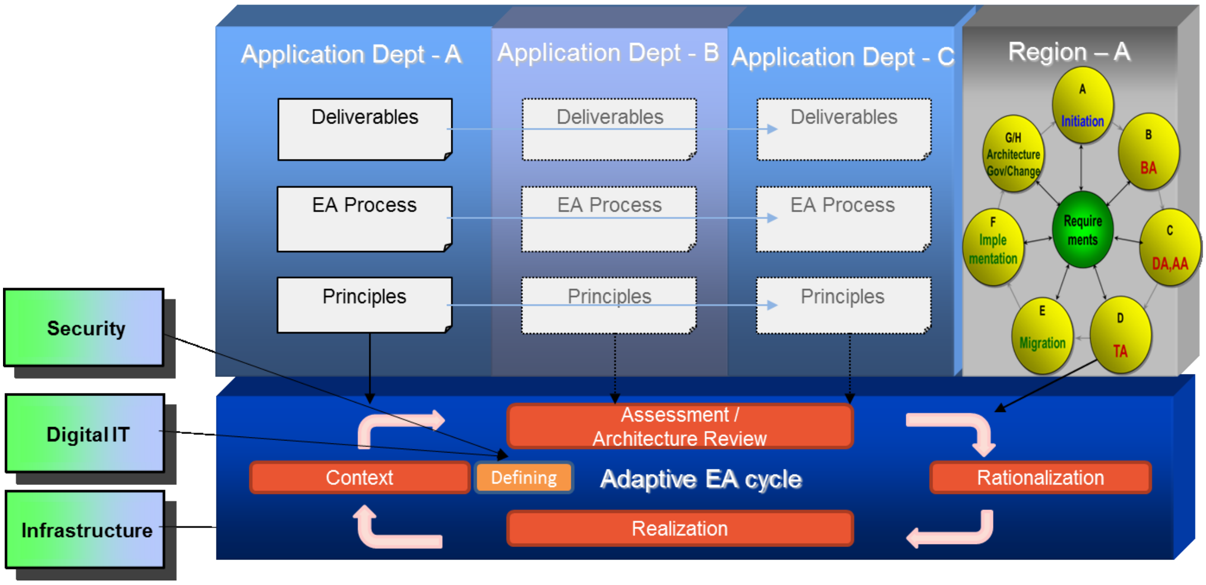

Figure 3.2 AIDAF proposed model (ex : TOGAF and Adaptive EA framework, etc.)

Moreover, the "TOGAF" and "simple EA (framework)" based on an operational division unit in the top part of the Figure 3.2 is able to respond to differing policies and strategies in business divisions from a mid-long-term perspective. This part of the framework has a structure that can select the above EA framework in line with the characteristics of business division unit operational processes and future architecture. This part also enables application. Further, the framework should align EA guiding principles with the definitions of these principles for business divisions to ensure consistency between the adaptive EA cycle in the lower portion of this Figure 3.2 and the "TOGAF" and "simple EA (framework)" in the upper portion. Furthermore, in the defining phase, the architecture committee / organization promotes the appropriate architectural design of each of the new cloud/mobile IT related systems by developing/publishing the architectural guidelines for security/cloud/mobile IT, etc. to achieve alignment with the IT strategy(Masuda, Shirasaka, & Yamamoto, 2017).

3.3.2 Research Methodology

In the previous section, as an "EA Framework fitting to the strategy of promoting cloud/mobile IT," we proposed an "Adaptive Integrated Digital Architecture Framework - AIDAF" on the basis of previous research in this field. The proposed framework needs to include the necessary EA elements for the era of cloud/mobile IT/digital IT.

Moreover, we present research questions to verify this "Adaptive Integrated Digital Architecture Framework - AIDAF" toward the requirements in the era of cloud/mobile IT/digital IT and to ensure the effectiveness of this proposed EA framework. Next, we evaluate two research questions corresponded to the case study of a Global Healthcare Enterprise (GHE), which is a research-based global company with primary focus on pharmaceuticals. Being the largest pharmaceutical company in Asia and an industry leader, this GHE prioritizes the future direction of Digital Healthcare as an important element of corporate strategy; therefore, this case study of the GHE is among the only advanced cases of EA implementation toward the era of Digital IT, especially in the field of digital healthcare.

RQ1-1: How is an "Adaptive Integrated Digital Architecture Framework - AIDAF" developed to meet the requirements in the era of cloud/mobile IT/digital IT?

RQ1-2: How can our proposing EA framework solve problems in the era of cloud/mobile IT/digital IT?

Then, the author who actually led the project to build and implement this EA, carried out the case study within a global pharmaceutical company, where we built and implemented the “Adaptive Integrated Digital Architecture Framework - AIDAF,” by focusing on real developments and progress histories. Moreover, we evaluate the aforementioned research questions using this case study of the global pharmaceutical company(Masuda, Shirasaka, Yamamoto, 2017).

On the basis of the above research, we clarify the challenges, benefits, and critical success factors of this EA framework for EA practitioners in the following chapter 7.