Evaluate Enterprise Architecture Frameworks Using Essential Elements

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Abstract:

Enterprise architecture (EA) frameworks offer principles, models, and guidance to help one develop an EA program. Due to EA's flexible and abstract nature, there is a proliferation of EA frameworks in practice. Yet, comparison studies to make sense of them are far from satisfactory in that they lack a theoretical foundation for comparison criteria and do not meaningfully interpret the differences. In this paper, I propose a comparison approach using EA essential elements—the underlying key features of EA programs—to distinguish EA frameworks. Based on the extant literature, I identify eight elements, each with its own theoretical justification and empirical evidence. I illustrate how to use these elements to evaluate eight popular EA frameworks. The results show three ideal types of EA frameworks: technical, operational, and strategic EA. Each type has a different focus, set of assumptions, and historical context. The essential elements offer a more systematic way to evaluate EA frameworks. In addition, they shift attention from the maturity models often used in EA development to focus on particular EA elements being implemented by organizations.

Keywords: Enterprise Architecture, Essential Elements, EA Framework, EA Program.

1   Introduction

"More than double."

If there were a quick quiz on enterprise architecture (EA), "More than double" would be the answer to the question "How many EA frameworks have been introduced in the last ten years?". In 2004, when Schekkerman (2004) published his famous book on surviving the "jungle" of EA frameworks, he described in detail 14 popular EA frameworks found in practice. In 2012, when Gartner (Gall, 2012) surveyed more than 200 organizations about their EA practices, it found 33 EA frameworks. The message is clear: interest in EA has increased significantly as has the number of EA frameworks.

EA frameworks offer principles, models, and guidance to help one establish an EA program. They elaborate *what* to include in architectural documents and provide instructions on *how* to operationalize EA (Greefhorst, Koning, & van Vliet, 2006; Robertson & Blanton, 2008; Urbaczewski & Mrdalj, 2006). The established EA program would provide documentation, resource alignment, standardized policies, decision support, and resource oversight (Bernard, 2004). It is de facto enterprise architecture that produces the expected benefits. Because EA frameworks differ from each other, EA programs vary in terms of design, functionalities, and benefits.

It is important for organizations to make sense of and navigate through the "jungle" of EA frameworks to understand the design, functionalities, and benefits of the subsequent EA programs. Previous studies have compared different EA frameworks (Alwadain, Fielt, Korthaus, & Rosemann, 2011; Leist & Zellner, 2006; Liimatainen, Hoffmann, & Heikkilä, 2007; Schekkerman, 2004; Sessions, 2007; Simon, Fischbach, & Schoder, 2013). Yet, they have some limitations. First, these studies vary greatly in their focus and theoretical foundation for their comparison schemes. Some focus on specific areas such as national level frameworks (Janssen & Hjort-Madsen, 2007; Liimatainen et al., 2007), defense frameworks (Alghamdi, 2009), or research citations (Simon et al., 2013). Researchers have also used various criteria such as degree of integration and standardization (Alwadain et al., 2011; Ross, Weill, & Robertson, 2006), EA components (Leist & Zellner, 2006; Tang, Han, & Chen, 2004), or implementation degree and benefits (Liimatainen et al., 2007). Researchers have often failed to theoretically justify these criteria and chosen them based on their specific focus.

Second, these comparison studies do not meaningfully interpret the differences. While all studies have pointed out the differences between EA frameworks, none have clearly articulated whether the variations represent differences in types or in degrees. In other words, do those EA frameworks differ enough that one can categorize them into different types of distinct EA programs or do they differ insignificantly such that they reflect slightly different explanations of the same type of EA? Answering these questions is important because the answers can help managers in deciding how to implement an EA framework that fits their organizational needs and in avoiding the trap of blindly following a management fad.

In this paper, I examine how organizations can distinguish different EA frameworks and what types of EA programs these EA frameworks aim to build. To answer these questions, I review the extant EA literature and suggest eight essential elements of an EA program as comparison criteria. The essential elements provide the causal mechanisms for EA practices and explain how the practices produce intended outcomes (Bardach, 2009). They specify the benefit logics (Van den Berg & Van Steenbergen, 2006) through which architectural practices lead to business value. Using these criteria, I compare eight popular EA frameworks to understand their differences. The findings suggest these frameworks comprise three different ideal types of EA program: technical EA, operational EA, and strategic EA. These types illustrate an evolution in EA practices and indicate how certain EA elements can lead to different outcomes. The findings contribute to the discussion of EA benefits and show that, by understanding *how* organizations implement EA (i.e., what type of EA program was built), we gain a better understanding of EA benefits than if we look solely at *how well* they implement EA (i.e., the typical EA maturity model).

This paper proceeds as follows. In Section 2, I define basic concepts used in this paper: enterprise architecture, EA program, EA frameworks, and EA characteristics. In Section 3, I discuss the current approaches to compare EA frameworks and their limitations. In Section 4, I propose a comparison approach using essential elements to augment prior comparison research. Using eight popular branded EA frameworks, I illustrate how one can use these elements to make sense and distinguish EA frameworks. The analyses suggest three ideal EA types. In Section 5, I discuss the implications of EA essential elements to understanding and developing EA. Finally, in Section 6, I conclude the paper.

2   Basic Concepts

2.1   EA Definition, Program, Framework

Enterprise architecture means several things depending on whom one asks. On one hand, enterprise *architecture* can refer to the actual architectural foundation of a real-world enterprise, which comprises all the systems, their components, their relationships, and the principles that govern them (IEEE, 2000). On the other hand, *enterprise* architecture can refer to the models and documentations that describe a high-level view of an enterprise's processes and IT systems, their interrelationships, and the extent to which these processes and systems are shared (Tamm, Seddon, Shanks, & Reynolds, 2011; Zachman, 1987). The former is an actual architecture of an enterprise—a physical artifact—while the latter is an enterprise-perspective model of an organization and its systems, components, and relationships—a conceptual artifact (Ahlemann, Stettiner, Messerschmidt, & Legner, 2012).

The EA literature, in general, focuses more on the latter concepts and, thus, on enterprises' planning processes and models. This view contains several approaches that consider EA as a plan or blueprint that provides tangible documentation of an enterprise (e.g., architecture diagrams, system specifications, artifact descriptions) (GAO, 2006), as a planning process that translates business visions into changes by documenting and creating models that describe an enterprise's future state and its evolution (Lapkin, 2006), as a management philosophy that provides the organizing logic for business processes and IT infrastructure (Ross et al., 2006), or as a management program, one of many organizational functions that supports strategy planning and strategy implementation (Bernard, 2004).

In this paper, for brevity, I view enterprise architecture as a *term* that practitioners and researchers have applied to a range of "best practices"—both technical and managerial practices—to logically organize IT infrastructure and business process capabilities. Technical practices include setting standards or defining software development procedures. Managerial practices include improving the effectiveness of IT procurements or aligning IT strategy with business strategy. This definition treats EA in the most generic way without being biased by any particular perspective. EA in this view is a conceptual artifact—one that focuses on organizing and managing IT infrastructure and business process capabilities in an enterprise (Bradley, Pratt, Byrd, & Simmons, 2011; Ross et al., 2006).

In addition, when one refers to an EA observed in enterprises, it is often about the operationalized artifacts, practices, processes, and structures that embody EA principles. Iyer and Gottlieb (2004) refer to the conceptual EA components as "architecture-in-design" and the actual realization of EA as "architecture-in-operation"—doing EA work through building products and services, the running of the enterprise itself. True EA comprises both conceptual and operational components. Without conceptual principles, it lacks the *enterprise* perspective that is essential to EA. Without actual operations, EA is just good ideas on paper but dead weight to an enterprise.

To capture both the conceptual and operational aspects of EA, I focus on EA frameworks that provide principles, models, and guidance to help one develop an EA program (Cameron & McMillan, 2013; Greefhorst et al., 2006; Robertson & Blanton, 2008; Urbaczewski & Mrdalj, 2006). In my view, an EA framework not only elaborates on *what* architectural documents should include (i.e., the conceptual artifacts) but also teaches *how* to operationalize EA programs. An EA program provides EA documentation, resource alignment, standardization policies, decision support, and resource oversight (Bernard, 2004). It is de facto enterprise architecture. This definition is broader than other definitions of EA frameworks that only recognize EA frameworks as guidance to architectural documentation (Leist & Zellner, 2006; Tang et al., 2004). It also focuses on frameworks that concern *both* EA planning and operationalization rather than frameworks that only emphasize EA representation language (e.g., ArchiMate as a representation-framework), EA ontology (e.g., Zachman framework), or EA applications in a specific context (e.g., reference frameworks). In addition, using this broader definition, I later examine some of the most popular EA frameworks that are relevant to not only practitioners but also academic researchers and, thus, provide meaningful implications to the general EA audience.

Table 1. Definitions of Basic Concepts

Concept	Definition	References
Enterprise architecture	A *term* that practitioners and researchers have applied to a range of technical and managerial "best practices" to logically organize IT infrastructure and business process capabilities	Bradley et al. (2011), Ross et al. (2006)
EA program	A management program that develops and operationalizes EA models and concepts. The program provides documentation, resource alignment, standardization policies, decision support, and resource oversight. It is de facto enterprise architecture.	Bernard (2004)
EA framework	Principles, models, and guidance to help one develop an EA program. It elaborates *what* architectural documents should include and provides instruction on *how* to operationalize EA.	Greefhorst et al. (2006), Robertson & Blanton (2008), Urbaczewski & Mrdalj (2006)

2.2 EA Characteristics

EA has several distinct characteristics, and each has important implications for its adopters. First, EA has more conceptual components than technical and material components, which sets it apart from other technological practices that focus mostly on technical and material components. For example, data warehouses or enterprise systems focus on centralized databases and standardized practices. Most of EA developments involve activities at an abstract level, such as modeling activities, standardizing procedures, or coordinating decisions. Less activity involves technical and physical IT artifacts such as setting up databases or installing enterprise systems.

As a result, EA does not require intensive capital investment, but it requires intensive collaboration across business functions (i.e., it is effort intensive). Because organizations seek to achieve alignment between IT and business strategy from an enterprise perspective, they need to find support not only from top managers but also from department-level managers who contribute to EA developments and later use EA in their decision making process. With a low capital requirement but high-effort intensity, many firms overlook the necessity of EA and find it difficult to commit their time and resources (GAO, 2006).

Second, EA has high interpretive flexibility (Orlikowski, 1992) or high user involvement to constitute EA realizations. Because EA contains multiple conceptual components, it allows more subjective interpretations from users (Birkinshaw, Hamel, & Mol, 2008), which gives them the flexibility to interpret and comprehend EA in ways that most fit their needs. Subsequently, many organizations find it easier to adapt or customize existing EA models to fit their needs. Although new practices often need adjustments and customizations at some level when they are implemented, in the case of EA, its adopters experience a higher flexibility in implementing EA models. A survey from Gartner found that up to 37 percent of EA adoptions used a homemade or hybrid framework (Gall, 2012). Among the rest, no branded framework accounted for more than 8 percent of organizations. Similarly, Hjort-Madsen (2007) found that, out of 12 U.S. federal agencies, seven tried to adapt branded frameworks and two others tried to significantly modify them.

Finally, because EA contains mostly conceptual components, EA adoption is knowledge intensive and, thus, more susceptible to knowledge barriers (Attewell, 1992). Having fewer technical and material components, EA leaves proponents with abstract and theoretical principles to induce their own actionable items. Consequently, adopters face a huge knowledge burden to decipher and accumulate the necessary know-how to carry out the adoption. As a result, the adoption process can unfold over years and involve extensive interpretations and discussions.

In many cases, prospective adopters seek necessary knowledge from external sources, such as consulting firms, conferences, associations, or academic research. For example, the state of California conducted an intensive research project to combine EA best practices from consulting firms and academic research in order to morph their own version. Other organizations actively contribute to or participate in different EA communities to learn and adopt best practices. For instance, the U.S. states of Kansas and Virginia actively participate in EA developments at the National Association of Chief Information Officers (NASCIO) while adopting best practices from others. As a result of adopters' search for know-how, consulting firms, associations, or practitioner groups have increasingly introduced EA models and frameworks, which has resulted in a proliferation of EA frameworks (Schekkerman, 2004).

3 Current Approaches to Compare EA Frameworks

The flexibility and highly conceptual nature of enterprise architecture make it more susceptible to modification and adaptation during the implementation process. Furthermore, many organizations rely on external consulting firms for know-how to make sense of and implement EA. Those factors have created a proliferation of EA frameworks that different consulting firms and associations promote and a diversity of recommendations about how one should implement them.

Such proliferation raises the question of how to navigate through the "jungle" of existing EA frameworks and guidelines (Schekkerman, 2004). Making sense of diverse frameworks is critical for evaluating and choosing a framework that fits an organization's needs. Various studies have compared and contrasted different EA frameworks (see Table 2). While this body of literature is helpful in making sense of EA frameworks, they have some limitations.

First, these studies vary greatly in their focus and theoretical foundation for their comparison schemes. While some indeed compare EA frameworks (Cameron & McMillan, 2013; Leist & Zellner, 2006; Schekkerman, 2004; Sessions, 2007; Tang et al., 2004), other comparisons focus on specific areas of EA such as nation-level frameworks (Janssen & Hjort-Madsen, 2007; Liimatainen et al., 2007), defense frameworks (Alghamdi, 2009), service-oriented architecture elements (Alwadain et al., 2011; Alwadain, Korthaus, Fielt, & Rosemann, 2010), implementation patterns (Hjort-Madsen, 2007), ideologies (Lapalme, 2012), or research citations (Simon et al., 2013). In addition, these studies often do not theoretically justify their comparative framework. Depending on the research focus, researchers use different criteria, such as degree of integration and standardization (Alwadain et al., 2011; Ross et al., 2006); EA elements (Leist & Zellner, 2006; Schekkerman, 2004; Tang et al., 2004); objectives, scopes, ideologies, (Ahlemann et al., 2012; Lapalme, 2012); or implementation degree and benefits (Janssen & Hjort-Madsen, 2007; Liimatainen et al., 2007).

Second, these studies do not meaningfully interpret those comparisons. A majority of them only evaluate each EA framework based on chosen criteria but limitedly interpret the meaning of the differences (see Table 2). As such, we do not know how significantly those EA frameworks vary—in other words, to what extent the variations represent differences in types or in degrees. This question is important because, if the EA frameworks differ significantly enough to group them in different categories or types, one would expect starkly different benefits from those EA frameworks due to each type's unique purposes and assumptions. However, if they differ only incrementally or marginally based on different explanations of the same type of EA framework, one would expect less contrasting benefits from implementing different EA frameworks, and organizations could be less concerned about which EA framework they should adopt. Understanding the implications of such differences can provide the basis on which to choose an EA framework that fit organizational needs rather than blindly following fads.

Third (and related to the second point), we do not know how variations in EA frameworks can contribute to different organizational outcomes. Generally, EA practitioners and researchers believe that how well EA is implemented will affect the achieved outcomes (Ross, 2003; Ross et al., 2006; Salmans, 2010). As a result, they have proposed several EA maturity models—stages of EA evolution cycles—as a means to guide EA development (NASCIO, 2003; Ross, 2003; Salmans, 2010). However, if EA frameworks differ enough that one can categorize them into different types, organizational outcomes from EA implementation may depend not only on *how well* organizations implement EA (i.e., a typical maturity model) but also on *what type* of EA they implement. In other words, the specific EA framework and EA features that organizations choose to adopt may have a significant impact on the outcomes. To date, studies that look at the differences in EA frameworks remain mostly informative and descriptive and do not explicitly link those differences to organizational outcomes. Without such guidelines, potential adopters will find it difficult to understand and choose an appropriate EA framework.

In sum, despite the proliferation of EA frameworks, current comparison studies vary greatly in their focus and theoretical foundation for their comparison schemes. In addition, those studies fall short in articulating the meaning of those differences. In this paper, I address these limitations by proposing a comparison approach using EA essential elements (see Section 4).

Table 2. Comparison Studies of EA Frameworks

Study	Comparison scheme	Focus	EA categories
Schekkerman (2004)	Purpose, scope, principles, structures, guidance, and compliance	EA frameworks	No category provided. Only evaluation of each framework.
Tang et al. (2004)	Fundamental elements of goals, inputs, and outcomes	EA frameworks	No category provided. Only evaluation of each framework.
Ross et al. (2006)	Degree of integration and standardization	IT architecture	Business silo architecture Standardized technology architecture Optimized core architecture Business modularity architecture
Leist & Zellner (2006)	Elements of an EA development method	EA frameworks	No category provided. Only evaluation of each framework.
Urbaczewski & Mrdalj (2006)	Views, abstractions of stakeholders and coverage of the SDLC	EA frameworks	No category provided. Only evaluation of each framework.
Hjort-Madsen (2007)	EA adoption patterns	EA implementation	Accepters, improvers, and transformers
Janssen & Hjort-Madsen (2007)	EA elements and implementation scope	National EA frameworks	No category provided. Only evaluation of each framework.
Liimatainen et al. (2007)	Elements, benefits, and implementation scope of EA	National EA frameworks	No category provided. Only evaluation of each framework.
Sessions (2007)	Practical criteria for EA	EA frameworks	No category provided. Only evaluation of each framework.
Alghamdi (2009)	Criterion for defense architectures	Defense EA frameworks	No category provided. Only evaluation of each framework.
Alwadain et al. (2011)	Degree of integration of SOA elements	SOA elements	No category provided. Only evaluation of each framework.
Ahlemann et al. (2012)	Management objectives and historical development	EA evolution	EA as advanced IS engineering EA as advanced IS management EA for strategic business management
Lapalme (2012)	Ideologies, scopes, and purposes	EA schools of thought	Enterprise IT architecting Enterprise integrating Enterprise ecological adaptation
Simon et al. (2013)	Co-author network and citation analysis	EA research	EA frameworks Design and operations of EA management EA conception and modeling
Cameron & McMillan (2013)	Criteria from survey	EA frameworks	No category provided. Only evaluation of each framework.
Bernaert, Poels, Snoeck, & De Backer (2016)	Essential dimensions from EA literature	EA frameworks	No category provided. Only evaluation of each framework to develop an EA meta-model for SMEs.

4   A Comparison Approach Using Essential Elements

To distinguish EA frameworks, we need to systematically compare them. The approach must not be so abstract that one overlooks important elements but also must not be so detailed that one includes insignificant elements such that understanding the differences becomes difficult.

Because EA is a management program, one can learn a lesson on systematical comparison from policy research literature. In order to evaluate and compare different policies, Bardach (2009) suggests that one can characterize a policy by its essential and supportive elements. Essential elements provide the causal mechanisms for the intended values, while supportive elements are optional to the intended benefits of a policy. In other words, essential elements constitute the basic causal work of the policy and produce its valued results, while supportive elements can make the policy relatively better. For example, a milestone payment program would include several essential elements: defining milestones, describing milestones, and measuring and assessing the effectiveness of the milestones. On the other hand, having a one-to-one

discussion while defining milestones would be an optional and supportive element. By identifying essential elements for a policy, one can compare implemented policies for discrepancies and focus on the underlying features of a program with less risk of including features that are non-essential.

The concept of essential elements is similar to other concepts such as core features and peripheral features (Baum & Shiplov, 2006; Hannan & Freeman, 1984) or core and peripheral components (Murmann & Frenken, 2006; Tushman & Murmann, 1998). They are used to differentiate organizational behaviors and strategies. The concept also resonates with the idea of a benefit logic in EA literature (Van den Berg & Van Steenbergen, 2006), which establishes a relation between architectural practices and business outcomes. For example, deploying architectural descriptions such as reference models can reduce complexity and, thus, lead to lower maintenance costs and shorter development time, which can increase revenue. The architectural descriptions are a benefit logic that increases the success of EA.

In this paper, I argue that, by analyzing the essential elements of EA frameworks, one can better distinguish among them and address the two issues of previous studies; that is, one can: 1) show how fundamentally different EA frameworks are and whether they constitute different EA types and 2) link specific elements to actual EA outcomes and allow potential adopters to focus on the EA elements that really matter.

In Sections 4.1 to 4.2, I propose eight essential elements to make sense of and distinguish between EA frameworks. In Section 4.3, I apply these elements to compare some of the most popular EA frameworks and group them into a small number of ideal types. These different EA types suggest divergent outcomes and approaches for potential adopters.

4.1   Identifying EA Essential Elements

Prior studies suggest that an essential element needs to satisfy two conditions: 1) it must be empirically shown to produce business outcomes and 2) it must specify the causal mechanism for such outcomes to occur (Bardach, 2009; Van den Berg & Van Steenbergen, 2006). In other words, one needs to theoretically explain why the element can lead to empirically observed benefits. Thus, to identify essential elements often discussed in EA frameworks, I reviewed the academic EA literature, practitioner EA literature, and public sector EA publications. With this approach, I could examine both empirically reported EA benefits and theoretical explanations of those outcomes.

Using a research database (EBSCO), I searched for the term "enterprise architecture" in the AIS Senior Scholars' "basket of eight" (Lowry et al., 2013), management literature (*Academy of Management Journal*, *Organization Science*, *Organization Studies*, and *Administrative Science Quarterly*), and practitioner-oriented studies (e.g., *MIS Quarterly Executive*, *Sloan Management Review*, *California Management Review*, and Gartner research). In the public sector, I use publications from the CIO Council (federal-level EA) and NASCIO (state-level EA). Table 3 provides an overview. Overall, I adopted this approach for two reasons. First, others have conducted a much more extensive EA literature review that includes technical-oriented journals (see Simon et al., 2013; Lucke, Krell, & Lechner, 2010). My approach, which includes management and organization studies and practitioner writings, complements prior research. Second, because I focus on the essential elements of EA frameworks that require not only theoretical reasoning but also empirical evidence of those elements, including both academic and practitioners' writing would provide useful insight. Also note that I do not comprehensively review EA literature because others have already done so (see Simon et al., 2013; Lucke et al., 2010). However, by building on their analyses, I extend the literature by focusing on EA essential elements and empirical evidence of their impacts.

Table 3. Literature Review Sources

Academic research	Practitioner writings	Public sector publications

AIS Senior Scholars' "basket of eight":
  European Journal of Information Systems
  Information Systems Journal
  Information Systems Research
  Journal of Association for Information Systems
  Journal of Information Technology
  Journal of Management Information Systems
  Journal of Strategic Information Systems
  MIS Quarterly
 	
 Organizational studies:
  Academy of Management Journal
  Academy of Management Review
  Organization Studies
  Organization Science
  Administrative Science Quarterly
 	
 Academic writings for executives:
  MIS Quarterly Executive
  Academy of Management Executive
  Academy of Management Perspectives
	Sloan Management Review
	 California Management Review
	 Gartner
	 META Group
	 Forrester Research
	 IBM Systems Journal
	 Federation of EA Professional
	 Organization (FEAPO)
		CIO Council
		 National Association of
		 State CIOs (NASCIO)

After the first round of searching, I identified 198 publications dated from 1982-2014. In the second round, I reviewed the abstract to determine whether the publications were relevant to answer my questions. Next, for each relevant publication, I examined the content to identify what EA essential elements, key features, and concepts the publication advocated. For complex publications with more than 100 pages, I conducted the process by focusing on the abstract, executive summary, conclusion, and table of contents. I also examined the references and works cited section for other relevant publications (e.g., books, conference proceedings). By doing so, I could include important publications from other journals such as *Journal of Enterprise Architecture*, *Information Systems Frontiers*, and *Information Systems and e-Business Management*. For this round, I thoroughly examined 100 publications and retained 77 highly relevant publications for the review. Because essential elements can be multifaceted and complex, identifying them can be difficult. Based on a review of prior comparison studies, for each potential essential element, I focused on two criteria: 1) whether the articulated element includes any empirical evidence of its impacts on organizational performance and 2) whether there is any theoretical justification for how the element leads to the observed outcomes. These two criteria address the shortcomings of prior comparison research. Initially, I grouped the elements into four categories. After discussing the essential elements with other EA researchers for feedback and suggestions[1], I decided that the four categories were too abstract to substantially differentiate EA frameworks. After a few rounds of refinement, I created eight essential elements, which I describe in detail below. Table 4 lists their distribution.

Table 4. Distribution of Essential Elements in Reviewed Publications

Essential elements	Academia	Practitioner	Public Sector	Total	% occurrence
EA principles	6	10	4	20	26%
Technical EA layers	17	11	5	33	43%
Business EA layers	12	8	4	24	31%
EA development methodology	22	11	6	39	51%
EA organizing structure	15	1	4	20	26%
EA operations and monitoring	20	5	6	31	40%
EA enforcement	7	2	3	12	16%
Strategic integration	5	2	2	9	12%

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[1] I presented early versions of the essential elements at AIS conferences in 2012 and 2015

4.2 EA Essential Elements

I found eight EA essential elements common across EA publications (see Table 6). I describe them below along with the logic and empirical evidence that shows how they are essential elements of EA frameworks.

4.2.1 EA Principles (1)

One can trace the use of principles back to the early EA work in the late 1980s (Davenport, Hammer, & Metsisto, 1989; PRISM, 1986; Richardson, Jackson, & Dickson, 1990). One of the earliest EA study, the PRISM project, surveyed more than 50 large organizations on their information system architectures and concluded that principles are the most important element to ensure a successful architectural development (PRISM, 1986). The project influenced many other subsequent EA studies and practices to include EA principles as a key component of EA frameworks (Davenport et al., 1989; Greefhorst & Proper, 2011; Op't Land, Proper, Waage, Cloo, & Steghuis, 2009; TOGAF, 2009; Weiss, 2016).

EA principles or architecture principles are "declarative statements that normatively prescribes a property of the design of an artifact, which is necessary to ensure that the artifact meets its essential requirements" (Greefhorst & Proper, 2011, p. 44). They fill the gap between high-level strategic intentions and operational-level designs and, thus, form the cornerstone of EA. Because they are explicitly stated, they provide the consensus-based criteria to identify and resolve conflicts, evaluate and manage IT activities, and converge on technology directions and strategies (Richardson et al., 1990). They are similar to concepts such as strategic visions (Venkatesh, Bala, Venkatraman, & Bates, 2007) or operating models (Ross et al., 2006) because they reflect an organization's strategic intentions and business directions. However, unlike the other concepts, architecture principles provide more specific design guidelines in an organizational context. In other words, they translate and communicate high-level strategic intentions into concrete and operational-level design instructions.

Several studies provide empirical evidence of EA principles' impacts on performance. The PRISM project reported a greater success rate for organizations with defined principles than the others (PRISM, 1986). Principles-based architectures can increase information sharing, lower operational costs, increase training effectiveness (Richardson et al., 1990), reduce information duplication, and improve system efficiency (Greefhorst & Proper, 2011). Consulting firms such as Gartner recommend new chief enterprise architects to quickly develop architecture principles in their first 100 days to guide subsequent developments (Santos, Burton, & Blosch, 2016). Similarly, many EA frameworks position EA principles as one of the early components in their development process (TOGAF, 2009; Wout, Waage, Hartman, Stahlecker, & Hofman, 2010).

4.2.2 Technical (2) and Business (3) EA Layers

One task of an EA framework is to establish the different EA layers to guide IT standards and procedures (Simon et al., 2013). Extant literature advocates four common EA layers: business, application, information, and technical (or technology). Organizations often express these layers in architecture forms (documentation about processes, strategies, models, and standards) or in reference forms (taxonomy of common terms and definitions). Additionally, organizations can use the reference models to categorize and group similar processes, strategies, and models that the architectures specify.

The business EA layer examines common business organizations, strategies, and models (Simon et al., 2013). It groups business functions and related objects into clusters (or domains) that can provide commonalities and accountabilities over business processes (Versteeg & Bouwman, 2006). For example, a business architecture for a global enterprise can divide processes into geographical locations such as world level (e.g., global sales function, account management function), regional level (e.g., European product processor), and country level (e.g., domestic payment, collections, claims) (Versteeg & Bouwman, 2006). By specifying a business architecture layer, an organization shows interest in designing and managing cross-functional business processes.

The application EA layer defines the necessary applications that an organization needs to support its business processes and specifies the relationships between those applications and/or how to develop them. For example, the NASCIO EA framework suggests building the application architecture around the following constructs: an enterprise application portfolio that provides the inventory of current applications, design models that guide the development processes, and design patterns that specify pre-defined configurations for the development (NASCIO, 2004).

The information EA layer provides an organization with the enterprise information assets (structured, unstructured, or semi-structured information) needed for business processes and enterprise applications. It outlines how enterprise data and information are stored and accessed and their relationship to business processes, business management, and IT systems. For example, information architecture can specify the physical repositories for operational and analytical data (e.g., customers, products, sales) in different formats (e.g., documents, images, web) and define the schema, data flows, and logical models to map the applications to those repositories (Leganza, 2010).

The technical EA layer describes the hardware and software infrastructure that supports applications and their interactions. Technical EA includes the IT standards and structures and the relationships between technologies, which provide a blueprint for IT at different levels. For example, NASCIO defines five levels in its technical architecture: domains, disciplines, technology areas, product components, and compliance components (NASCIO, 2004). Together, these five levels make up the technical foundation for an organization.

Recently, the EA literature has increasingly distinguished between business architecture and other layers. Scholars have argued that Business architecture is a distinct layer that can differentiate EA implementations (Bouwman, van Houtum, Janssen, & Versteeg, 2011; Ulrich & McWhorter, 2010; Versteeg & Bouwman, 2006). Business architecture enables a stronger connection between IT and business strategies and signals an enterprise approach rather than a silo-technical approach. Thus, I posit the next two essential elements as:

Technical EA layers: the technical layers define the hardware and software infrastructure (e.g., technical architecture), structure and relationship of information assets (e.g., information architecture), and the repositories of enterprise applications and their relationships (e.g., application architecture). These layers define the IT foundation of an organization (Perks & Beveridge, 2003). They reduce IT complexities by outlining the interconnections between infrastructure, data, and applications (Ross et al., 2006). Studies have shown the effectiveness of these layers in improving communication, increasing system integration, identifying risks for system development (Zachman, 1987), increasing information sharing, and reducing operational costs (Perks & Beveridge, 2003; Richardson et al., 1990).

Business EA layers: the business layers define organizational structures, strategies, and models. They are clustered into domains based on their accountabilities and similarities across business processes. They serve as a basis to eliminate functional overlap and clearly outline business responsibilities (Bouwman et al., 2011; Versteeg & Bouwman, 2006). Research has shown they can clarify business strategic intentions and business relationships (Burton & Blosch, 2014; Versteeg & Bouwman, 2006) and improve organizational and system design (Burton & Blosch, 2014; Gharajedaghi, 2005; Versteeg & Bouwman, 2006).

4.2.3   EA Development Methodology (4)

One of the most commonly found essential elements of an EA framework is a development methodology that provides an outline toward developing EA, often represented in metamodels (Simon et al., 2013). An architecture methodology is a "structured collection of techniques and process steps for creating and maintaining an enterprise architecture" (Lankhorst, 2013, p. 19). A methodology can specify a formal process of an architecture's lifecycle with different development phases, what should be produced, and how the development should be conducted. For instance, the enterprise architecture planning method that Spewak and Hill (1993) propose follows a "layer cake" approach in which development activities are divided into priorities: getting started (layer 1); modeling current business and technology systems (layer 2); defining future architecture for data, applications, and technology (layer 3); and outlining an implementation plan (layer 4). The methodology can also include a transition plan to move from as-is to to-be architectures or a migration plan for a step-by-step transformation of the architecture. For example, TOGAF includes an architecture development method for EA developments that entails creating an architecture vision, establishing different EA layers, setting migration plans, creating implementation governance, and incorporating change management.

Some EA programs may include a roadmap as their development methodology. However, it is important to distinguish between a technology roadmap and an operational roadmap (Wout et al., 2010). A technology roadmap is a technical concept that depicts the evolution of technologies in an organization from when it is deployed to when it will be matured and retired. Such a technology roadmap should be considered part of the technical EA layers. On the other hand, an operational roadmap, or engagement

roadmap, is a process pattern that depicts how to run architectural development given an organization's specific objectives (Wout et al., 2010). It describes specific architecture contents and the engagement process for their development. Only an operational roadmap can be considered a development methodology.

A formal development methodology is essential to EA frameworks because it communicates directions and structures, provides a common vocabulary, and increases understanding of the process (Simon et al., 2013; Spewak & Hill, 1993). While all organizations usually have some plans or ideas about how to develop EA, they must formalize and materialize such plans and ideas in an organization's documents for one to count them as a developed methodology. Otherwise, the plan is not available throughout the organization and, therefore, is not communicated to others. In addition, an organization can explain the overall methodology in several documents. For instance, the EA strategy at Chubb Insurance defines the company's general direction with EA components encompassed into three major plans: a technology rationalization roadmap, an application rationalization roadmap, and a project portfolio analysis (Smith, Watson, & Sullivan, 2012).

4.2.4   EA Organizing Structure (5)

An EA program needs to define its organization and decision making rights in order to create accountabilities and establish authorities for the program. Thus, EA frameworks should provide guidance and instruction on the possible organizing structures, such as defining the roles of chief enterprise architects or the responsibilities of architectural groups. The organizing structure creates responsibilities and establishes authorities for complex coordination in EA development (Boh & Yellin, 2007; Ross et al., 2006). Various EA maturity models have identified having a formal EA structure as a key milestone that advances EA development in an organization (NASCIO, 2003; OMB, 2009; Salmans, 2010). Other studies have shown that clearly defined organizing structures increase EA usage (Winter & Schelp, 2008) and that an EA organizing structure that supports the business structure will improve EA execution (Ahlemann et al., 2012).

The EA literature often considers the organizing structure a part of EA governance. Because governance can also mean the oversight and enforcement of EA, I separate the EA organizing structure from governance as an essential element itself (see Section 4.2.6). Generally, an EA organization includes several positions, each with specific responsibilities. Table 5 lists typical roles and governance bodies in an EA organization (Ahlemann et al., 2012; CIO Council, 2001; NASCIO, 2004).

Table 5. Typical Roles and Governance Bodies in an EA Organization

Roles	Description
A Chief architect or an EA director	This role provides a single contact point for the EA program. The chief architect oversees EA development.
Enterprise architects	These architects document and maintain different EA layers.
Enterprise architecture council (EAC) or enterprise architecture steering committee	The EAC, charged with the implementation and governance of EA standards in the organization, serves as the principal oversight body. The EAC often reports directly to a senior sponsor (e.g., CIO, CFO, CEO), and the chief architect is often the chair of EAC.
Architecture review board (ARB)	The ARB comprises representatives from key functions to review and approve architecture standards, enforce standards, and provide guiding principles.
Architecture forum	The forum provides a collaborative space for architects from different business units to unite and work on a topic of mutual interest, such as infrastructure standards or network standardization. The forum is optional and formed on a voluntary basis.

4.2.5   EA Operations and Monitoring (6)

The next essential element of an EA framework includes processes to operate and monitor EA development—a core process to maintain EA results (Op't Land et al., 2009). Examples include suggesting new standards, evaluating the proposed standards, exempting agencies from certain standards, and continuously assessing the standard development processes. These processes help create EA standards that are compatible with industry standards, which enhances operational effectiveness (Boh & Yellin, 2007). They can monitor the evolution of EA practices, identify areas for improvement, and create and evaluate new IT capabilities (Ross et al., 2006). Empirical evidence has

suggested that operational processes can reduce IT complexities and increase integration (Boh & Yellin, 2007) and that maturing EA practices can lower operational costs and increase strategic agility and IT-business alignment (Bradley et al., 2012; Bradley et al., 2011).

There are different ways to establish and monitor EA operations. For example, Ahlemann et al. (2012) suggest incorporating EA into change management processes using four steps: collecting change requests, assessing changes, implementing changes, and monitoring EA. An organization can use these four steps to operate and monitor EA standards. Several maturity models have also been proposed to assess the development of an EA program (e.g., FEA maturity model, Gartner maturity model). These maturity models are useful to monitor EA development in an organization.

Organizations also vary in the degree of conducting EA operating and monitoring processes. Generally, organizations try to include local IT groups in development processes in order to balance the central-local relationship. For example, in the Veterans Health Administration—the administration of the U.S. healthcare system for veterans—the central IT unit formed EA components itself but involved local IT teams in some development activities such as populating local contents in data dictionaries and specifying local control of technologies (Venkatesh et al., 2007). In another example, Chubb Insurance created a collaborative environment in which the central IT team worked with lines of business to specify the details of new standards (Smith et al., 2012). Those dialogues helped create sustainable, long-term solutions supported by lines of business.

4.2.6   EA Enforcement (7)

In order to have an effective EA program, one needs to take steps to enforce EA values. Enforcing processes are mechanisms that incorporate EA values in organizational practices because they increase the compliance to principles and guidelines set by EA programs (Ahlemann et al., 2012; Op't Land et al., 2009; Ross et al., 2006). They contribute significantly to the overall success of EA programs because they allow one to execute EA values in actual practices (Ross et al., 2006; Schmidt & Buxmann, 2011).

To enforce EA values, most EA frameworks suggest integrating EA milestones into project lifecycles or investment lifecycles (Ahlemann et al., 2012; CIO Council, 1999). Overall, there are three modes of EA integration in the project lifecycle (Ahlemann et al., 2012). First, in an *advising* model, enterprise architects assist with and advise on project execution. Depending on projects, the architects can provide needed information, give advice, and help monitor the project execution. Second, in a *participating* model, when management support is sufficient, the enterprise architects can exercise some control over project execution, such as voting on project decisions or issuing rules for project execution. Finally, in a *managing* model, an EA team that has strong influence can actively engage in the management of project execution and even drive the implementation process (e.g., defining EA-related project goals, creating EA reporting processes).

4.2.7   Strategic Integration of EA Values (8)

Several scholars have recommended that another essential element to realize the benefits of an EA program is the integration of EA values into strategic planning processes (Ahlemann et al., 2012; Weiss, Rosser, & Blanton, 2005). These processes allow EA to enable, drive, and influence strategies and directions. EA becomes a key component of strategic planning in an organization that can transform organizational performance (Ahlemann et al., 2012; Lange, Mendling, & Recker, 2015; Ross et al., 2006). For example, chief enterprise architects can participate in strategic planning meetings, or business executives can use inputs from EA programs to determine business transformation. Doing so allows organizations to make business initiatives that exploit the capabilities created by EA. Studies have shown that the strategic integration of EA values can mediate the effects of EA infrastructure and services on organizational performance (Lange et al., 2015).

The strategic integration of EA values depends on the degree of involvement that enterprise architects have in key managerial practices (e.g., strategy planning, strategy formulation). Gartner suggests that architecting IT models is only a small part of an enterprise architect's job and that architects should spent much of their time on strategizing, communicating, leading, and governing (James, Handler, Lapkin, & Gall, 2005; Lapkin, 2005). Similarly, the dynamic enterprise architecture (DYA) framework suggests that the architectural team and business case team should constantly conduct strategic dialogues to determine business objectives (Wagter, van den Berg, Luijpers, & van Steenbergen, 2005). In general, the more

involvement enterprise architects have in strategic planning processes, the more EA values will be disseminated and integrated into organizational practices.

Table 6. Essential Elements of EA Frameworks

Element	Description	Roles and impact	Empirical evidence
EA principles	EA principles or architecture principles are "declarative statements that normatively prescribes a property of the design of an artifact, which is necessary to ensure that the artifact meets its essential requirements" (Greefhorst & Proper, 2011, p. 44). They go beyond high-level concepts such as strategic visions or operating models because they provide the specific design guidelines in an organizational context.	Explicitly stated principles provide consensus-based criteria to identify and resolve conflicts, evaluate and manage IT activities, and converge on technology directions and strategies (Richardson et al., 1990). They fill the gap between high-level strategic intentions and operational-level designs and, thus, form the cornerstone of EA (Greefhorst & Proper, 2011).	Architecture principles enhance designs for accessibility in Dutch public services, reduce duplication of information requests in the Dutch healthcare insurance, or improve system reliability and efficiency at Enexis—a Dutch energy company (Greefhorst & Proper, 2011). Principles-based architecture increases information sharing, lowers operational costs, increases training effectiveness, and increases use of central software library (Richardson et al., 1990).
Technical EA layers	Technical EA layers define the hardware and software infrastructure (e.g., technical architecture), structure and relationship of information assets (e.g., information architecture), and the repositories of enterprise applications and their relationships (e.g., application architecture).	Technical EA layers define the IT foundation of an organization (Perks & Beveridge, 2003). They reduce IT complexities by outlining the interconnections between infrastructure, data, and applications (Ross, 2003).	Technical EA layers improve communication, increase system integration, and identify risks for system development (Zachman, 1987). Technical EA layers reduce operational costs and increase information sharing (Perks & Beveridge, 2003; Richardson et al., 1990).
Business EA layers	Business EA layers define organizational structures, strategies, and models. They are clustered into domains based on their accountabilities and similarities over business processes.	Business EA layers eliminates functional overlap and outlines business responsibilities (Bouwman et al., 2011; Versteeg & Bouwman, 2006).	Clarified business strategic intentions and business relationships (Burton & Blosch, 2014; Versteeg & Bouwman, 2006) Better organizational design and system design (Burton & Blosch, 2014; Gharajedaghi, 2005; Versteeg & Bouwman, 2006).
EA development methodology	A formal methodology outlines the guideline and model of how to implement EA. Examples include a transition plan or migration plan to move from as-is to to-be architecture.	EA provides the guidance—often in meta-models on how to develop EA (Simon et al., 2013).	A formalized methodology communicates directions and structures, provides common vocabularies, and increases understanding of the process (Spewak & Hill, 1993).
EA organizing structure	Organizing structure identifies decision making rights in an EA program. For example, roles of a chief enterprise architect or an EA council.	Organizing structure creates accountabilities and establish authorities for complex coordination in EA development (Boh & Yellin, 2007; Ross et al., 2006).	Clearly defined organizing structure increases EA usage (Winter & Schelp, 2008). A right EA structure that supports organizational structures will improve EA execution (Ahlemann et al., 2012).

Table 6. Essential Elements of EA Frameworks

EA operations and monitoring	Operational and monitor processes are used to establish and evaluate EA development, such as setting up new standards, providing exceptions, and maturing EA efforts.	These processes create EA standards that are compatible with industry standards, which enhances operational effectiveness (Boh & Yellin, 2007). They also monitor the evolution of EA practices and create and evaluate new IT capabilities (Ross, 2003).	Develop EA standards reduce IT complexities and increase integration (Boh & Yellin, 2007). Maturing EA practices lower operational costs and increase strategic agility and IT-business alignment (Bradley et al., 2012; Bradley et al., 2011).
EA enforcement	Enforcing processes are mechanisms that examine EA compliance in organizational practices. For example, EA approval gates in project lifecycles.	Enforcing processes increase the compliance of organizational practices to principles and guidelines set by EA programs (Ahlemann et al., 2012).	Enforcement contributes significantly to the overall success of EA programs (Ross et al., 2006; Schmidt & Buxmann, 2011).
Strategic integration	Integration processes are mechanisms that allow EA to enable, drive, and influence organization's strategies and performance. EA values are integrated in the strategic planning. For example, EA inputs in business transformation initiatives.	EA as a key component of strategic planning in organization can transform organization's performance (Ahlemann et al., 2012; Lange et al., 2015; Ross et al., 2006).	Integration processes mediate effects of EA infrastructure and services on organizational performance (Lange et al., 2015).

4.3   Illustration Using Popular EA Frameworks

In this section, using the eight essential EA elements, I compare eight popular branded frameworks often found in practice (Bernaert et al., 2016; Schekkerman, 2004; Sessions, 2007; Tang et al., 2004; Urbaczewski & Mrdalj, 2006). While there are many EA frameworks (e.g., Accenture, TMF, SEFA, PERA, PEAF) (Gall, 2012), I focus on only frameworks that elaborate both what is to be included in architectural documents and how to operationalize EA. Such frameworks are useful in developing a successful EA program that can deliver meaningful benefits to an organization. Thus, I exclude EA frameworks that are meta-frameworks (e.g., ontology frameworks such as Zachman (1987)), representation frameworks such as ArchiMate or ARIS, or EA frameworks that are domain-specific (e.g., reference architectures such as IBM Insurance Application Architecture). In addition, because I focus on illustrating the use of essential EA elements, I select a diverse range of EA frameworks, including representative EA frameworks from the academic literature, practitioner literature, public sector, and both the U.S and E.U. scenes. The eight frameworks I selected are:

1.   The Open Group architecture framework (TOGAF). This framework inherited the work done by the U.S. Department of Defense and became one of the very first EA frameworks in the U.S. private sector.

2.   Department of Defense (DoDAF) framework. Developed by the U.S. Department of Defense in 1996, it was one of the very first EA frameworks in the U.S. public sector.

3.   Federal EA framework (FEAF). As the first and official framework developed by the U.S. CIO Council, it encourages EA development in federal agencies. The FEAF has inspired many other national EA frameworks such as the Finnish national EA framework (Liimatainen et al., 2007).

4.   Gartner framework. Built by the consulting firm Gartner, it has been popular in the U.S. private sector, especially after Gartner's bought out one of its competitors, the META Group.

5.   MIT framework. Created by MIT's Center for Information Systems Research (CISR), academics and practitioners have widely used this framework.

6.   The generic enterprise reference architecture and methodology (GERAM). The framework is one of the popular EA frameworks in Europe. It was developed as a project to compile several other methodologies in enterprise integration (Bernus, Mertins, & Schmidt, 2006; Bernus & Nemes, 1996; Bernus, Nemes, & Schmidt, 2013).

7. The dynamic enterprise architecture (DYA). The Dutch consulting firm Sogeti developed this framework. It is included in the curriculum of one of the few available master of enterprise architecture programs in Europe (Van den Berg & Van Steenbergen, 2006; Wagter et al., 2005).

8. The integrated architecture framework (IAF). The consulting firm Capgemini created this framework, and many European companies have used it. It adopts the experience of more than 3,000 EA projects, and it is one of the highly used EA frameworks in a recent EA survey (Gall, 2012).

I collected publications for each framework from their websites, their archived websites from the Internet archival database[2], and research databases. Overall, I collected more than 100 documents that totaled to over 7,000 pages. These documents provided a good understanding of the frameworks and their evolution. I classified each framework based on the eight essential elements of an EA framework proposed above. For each framework, I read through the relevant documents and identified evidence that indicated an essential element. Typically, I identified an element by going through the table of contents, introduction section, executive summary, or overall framework diagrams. For example, reading through the table of contents could indicate whether a framework included technical and business layers. For elements that needed further investigation such as the eighth element (integration of EA values), I searched through the text for direct evidence or for clarification. For instance, the MIT framework elaborated on different mechanisms (e.g., engagement model, linking mechanisms, and learning and exploitation) to introduce and incorporate EA in high-level strategic planning (Ross et al., 2006). Appendix A provides a detailed comparison of the eight frameworks and the supporting evidence.

For each framework, I assessed the existence of each essential element by examining whether I could find explicit evidence of the element described in the framework (level 3), some limited or implicit evidence (level 2), or little to no evidence at all (level 1) (see Table 7). I reviewed and discussed the assessment with another senior researcher experienced with the EA literature to validate my assessment. I then qualitatively categorized them by deciding how each framework differs from the others. In addition, I compared them through a cluster analysis (see Appendix B for details). The result of the cluster analysis is aligned with my qualitative evaluation, and both analyses suggest three ideal EA types. Each ideal type has its own focus, assumptions, and historical context.

Table 7. Comparison of Popular EA Frameworks

Elements	Technical EA		Operational EA			Strategic EA		
	DoDAF	GERAM	FEAF	TOGAF	IAF	MIT	Gartner	DYA
EA principles	1	2	3	3	3	2	3	3
Technical EA layers	3	3	3	3	3	1	3	3
Business EA layers	2	1	3	3	3	3	3	3
EA methodology	3	3	3	3	3	3	3	3
EA organizing structure	2	2	3	3	3	3	2	3
EA operations and monitoring	2	3	2	3	2	3	2	3
EA enforcement	2	3	3	3	3	3	2	3
Strategic integration	1	1	1	1	2	3	3	3

Note: 1 = little to no evidence, 2 = some evidence, 3 = plenty of explicit evidence.

4.3.1 Technical EA

Frameworks of this type include the DoDAF or GERAM framework. They focus on establishing an enterprise's IT foundation. These frameworks see enterprise architecting as a job of the IS/IT organization in which they need to identify the necessary IT components of the enterprise to reduce complexities and increase standardization (Ahlemann et al., 2012). These frameworks emphasize an enterprise's technical

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[2] The Wayback Machine—an Internet archival database (http://archive.org).

aspects by identifying technology components that are necessary for the enterprise operations. They pay less attention to the business aspects and often assume the business inputs for EA development rather than specifying how business aspects contribute to the development process. The frameworks also lack overall principles that guide the architectural development.

Historically, the technical EA type started in the early history of the EA field and became dominant mostly during the 1990s. Early writings often focused on "information system architecture" rather than "enterprise architecture" (PRISM, 1986; Sowa & Zachman, 1992; Zachman, 1987). Because EA and enterprise-level architecting concepts were relatively new at the time, many frameworks of this type emphasize the establishment of technical EA layers, methodology, and structure to allow organizations to transform from an "as-is" to a "to-be" IT architecture, to reduce IT complexity, and to integrate IT components across the enterprise (Sessions, 2007). These frameworks often overlook or under-emphasize business and strategic elements such as EA principles or strategic integration. Some frameworks attend to governance issues such as organizing structure, monitoring, and enforcement, but such consideration is not a norm among frameworks of this type.

4.3.2   Operational EA

Operational EA frameworks include TOGAF, FEAF, and IAF frameworks. They focus on an enterprise-wide and holistic approach toward EA development and stress the development of not only technical but also business EA layers. Unlike technical EA, these frameworks emphasize the importance of defining EA principles early in the development process, and they often define a business architecture—the documentation of key business processes—which, in turn, determines the details of subsequent EA layers such as application, information, and technical architecture. These frameworks focus less on technical issues (e.g., complexity, redundancies) and more on establishing an IT foundation for smooth and effective operations (Ahlemann et al., 2012) or effective strategy execution (Lapalme, 2012). They see EA as the glue between business and IT to execute business objectives effectively. Thus, operational EA frameworks emphasize not only IT artifacts and models but also IT planning, implementing, and controlling from an enterprise perspective.

Historically, operational EA frameworks emerged around 2000 when EA professionals realized that the pure technical modeling approach of technical EA frameworks was not sufficient to bring about EA's expected outcomes (Ahlemann et al., 2012). As IT investment increases and an enterprise recognizes the necessity of IT, there is an increasing need to involve non-IT stakeholders in the IT decision making process. Several studies and reports at that time pointed out critical EA success factors such as having business values as guidance to EA development (El Sawy, Malhotra, Gosain, & Young, 1999), obtaining top management support and involvement (GAO, 2002, 2003), and putting business leaders as the primary stakeholder and target audience for EA (Lindström, Johnson, Johansson, Ekstedt, & Simonsson, 2006). As a result, EA principles, business EA layers, governance mechanisms, accountability, and enforcement processes are important elements to this type of EA framework.

4.3.3   Strategic EA

Frameworks that fit into this type include the MIT, Gartner, and DYA framework. The rise of strategic EA frameworks began in the mid-2000s and continues today. These frameworks view EA as one of the many management and strategic planning tools that allow organizations to take advantage of their IT investments. These frameworks focus on using and exploiting the IT capabilities of the built IT foundation. Thus, frameworks in this type are not particularly interested in establishing EA layers or documenting and specifying requirements—although those activities are still a part of EA professionals' jobs—but more in the application of EA values and principles to guide and drive organizational transformation. For example, the MIT framework does not mention what EA layers one needs to develop, and Gartner stresses that what EA framework an organization chooses is not as important as using and adapting it to their needs (Robertson & Blanton, 2008).

These frameworks see EA as a link between strategy and execution to effectively implement and drive enterprise strategies (Lapalme, 2012; Ross et al., 2006). EA is part of the enterprise strategic plan to create and maintain competitive advantages (Bradley et al., 2011; Ross & Beath, 2006; Venkatesh et al., 2007). Thus, compared to other types, strategic integration is a significant element of this type of framework. The DYA features a strategic dialogue between the architectural team and business case team to determine business objectives (Van den Berg & Van Steenbergen, 2006; Wagter et al., 2005), and the Gartner and MIT frameworks both stress how EA is a part of the strategic planning process that

enable business capabilities (Ross et al., 2006). These frameworks emphasize how to design comprehensive and enterprise-wide solutions that improve organizational efficiency and transform organizational processes.

Table 8 provides a profile of these ideal EA types. These ideal types are related to each other and represent an evolution from technical to operational and, lately, strategic EA frameworks. Yet, they have distinct focuses and are built on different assumptions. In Section 5, I discuss the implications of these ideal EA types to EA literature and practices.

Table 8. Profile of Ideal EA Types

	Technical EA (prior to 2000)	Operational EA (since 2000)	Strategic EA (since 2006)
Examples	DoDAF, GERAM	FEAF, TOGAF, IAF	MIT, Gartner, DYA
Focus	Focuses on technical aspects. Aims to reduce IT complexities and increase IT standardization.	Focuses on technical and business aspects. Aims to establish an enterprise IT foundation and align IT-business strategy.	Focuses on the applications of EA values and principles to enable and drive business initiatives. Aims to strategically exploit IT capabilities.
Assumption	EA is a job of the IT organization.	EA needs involvement of non-IT stakeholders.	EA team should be part of strategic formation processes.
Distinctive element	Technical EA layers.	EA principles and business EA layers	Strategic integration of EA values.

5   Discussion

It has been more than ten years since Schekkerman (2004) discussed how to survive "in the jungle of enterprise architecture frameworks", and, since then, the number of existing EA frameworks has more than doubled. Yet, few studies have attempted to make sense of this terrain and to help organizations navigate EA frameworks (Alwadain et al., 2011; Cameron & McMillan, 2013; Leist & Zellner, 2006; Liimatainen et al., 2007; Schekkerman, 2004; Sessions, 2007; Simon et al., 2013). Further, existing studies lack a theoretical foundation for their comparison schemes and fall short in determining whether the observed variations represent different EA types or variations of the same type.

To address those limitations of prior literature, this study reflects on the extant EA literature and suggests eight essential elements that one can use to distinguish the existing frameworks. The concept of essential elements is similar to concepts such as core and peripheral features found in policy research and organizational studies (Bardach, 2009; Baum & Shiplov, 2006; Hannan & Freeman, 1984; Murmann & Frenken, 2006; Tushman & Murmann, 1998). These essential elements allow organizations to systematically compare the essence of each EA framework to the others. Through comparing eight popular branded EA frameworks, I identified three ideal types of EA frameworks, each with its own assumptions and focus. By understanding the different types and their characteristics, organizations could make better decisions in adapting or creating their own framework.

5.1   Using Essential Elements to Evaluate and Choose Appropriate EA Frameworks

The proposed essential elements provide a way for organizations to evaluate and choose appropriate EA frameworks that fit their needs. From Table 8 and Appendix A, one can see that each EA framework has its own strengths and weaknesses. For example, GERAM may provide great tools and support for establishing technical representations of the enterprise, but other frameworks such as TOGAF or IAF could provide better guidance on methodology, operations, monitoring, and enforcement processes. The ideal types also show key elements that distinguish EA frameworks. Unlike technical EA, operational EA frameworks include the development of *EA principles* and *business EA layers* in order to have a holistic architecture design process, to include non-IT stakeholders in the development process, and to focus on the business-IT relationships. Compared to operational EA, strategic EA frameworks emphasize the *strategic integration of EA values* in order to make EA an enabler for business initiatives. Understanding what essential elements make one framework substantially depart from the others would inform managers in choosing an appropriate framework for their needs.

While it is always tempting to go for the most advanced and recent EA type (i.e., strategic EA), organizations may have to use an incremental approach and start from technical EA and mature their EA programs over time. Lack of necessary resources, know-how, or managerial support can prevent a radical transformation from no EA to a strategic EA program (Ross et al., 2006). Thus, by knowing the key essential elements, organizations can better focus their limited resources and develop an appropriate plan to mature EA. For example, starting with technical EA, organizations can choose to focus on technical reference models, technical taxonomy, and solution architectures to reduce IT complexity and redundancy. Next, they can develop overall architecture principles, design a business architecture, and involve business partners more intensively with the EA development process. They can use the success from technical EA to motivate and attract business managers to accept EA practices. As the technical EA program matures into an operational EA program, the EA team can start focusing on integrating EA values into strategic initiatives to eventually evolve into a strategic EA program.

5.2   Essential Elements and EA Development

The essential elements and ideal EA types that I propose here contribute to prior research on EA development (Bradley et al., 2011; Tamm et al., 2011). Specifically, they shift attention from the maturity models often used in EA development to a focus on the particular EA elements that organizations implement. In reality, most organizations use a best-of-breed approach in which they combine several branded EA frameworks to create their own (Gall, 2012). As a result, they need to understand which EA elements they can combine and how they contribute to organizational benefits. I strongly encourage future research to investigate both essential and supportive elements implemented by organizations and how various configurations lead to organizational benefits. Because there is no one-size-fits-all solution in EA implementation, the essential elements that I propose here provide the first step toward understanding what other "sizes" exist and how they are connected to different outcomes.

This research prompts the question of whether different types of IT organizations favor a particular type of EA framework. For example, operational and strategic EA frameworks encourage interconnection between business processes and organizational units. While the benefits are potentially alluring, these types of frameworks require organizations to establish business EA layers along with enterprise-wide mechanisms to enforce and collaborate across business functions (Bouwman et al., 2011). In most cases, that means changes in organizational structure, increased centralization of IT activities, and increased uniformity of IT standards. For organizations that have a more decentralized IT structure and culture, these changes may not be welcome or, worse, may be perceived as a threat to the autonomy of business units. Therefore, Ross et al. (2006) suggests that organizations first identify their operating model; that is, establish their strategic vision before creating enterprise architecture. Companies that envision a business model with low standardization and low integration may prefer a technical EA framework. Following this logic, one can also imagine that operational and strategic EA frameworks, or essential elements of those frameworks, can only be applied in organizations in which the need for change is urgent or the central IT organization has enough power to drive the necessary change. For organizations with insufficient support from top-level managers or with weak power in the central IT organization, adopting an operational or strategic EA framework may be met with hostile opposition (Bui, 2015). To practitioners, the lessons here imply a need to choose and adapt essential elements that fit their organizational needs and avoid the trap of blindly following a management fad.

5.3   Limitations

This study has several limitations. I analyzes only eight EA frameworks, and we need further studies to test the generalization of the proposed ideal types with additional frameworks. In addition, other essential elements might be used for the classification. Identifying essential elements, as I explain above, can be a complex and subjective process (Bardach, 2009). To account for this, I have carefully articulated the essential elements with empirical evidence found in practice and laid down the theoretical reasons to support the essential elements I selected. The identified EA types also share similarities with other types that other methods have identified (Lapalme, 2012; Simon et al., 2013). However, I encourage future studies to extend the essential elements are.

Further, this study does not assess the quality of essential elements in each framework but rather the extensive coverage of essential elements. Frameworks maybe substantially different in how they approach to those elements. For instance, while both TOGAF and FEAF has a formal development methodology, I do not know which framework has a better methodology based on the different

methodology artifacts that they suggest (e.g., transition plan, engagement plan). Such evidence would require one to systematically compare the framework operationalization and empirical evidence of their implementation. I encourage future research to consider such comparison of the quality of essential elements in different frameworks.

6   Conclusion

This research provides a framework for organizations to make sense of and navigate through the "jungle" of EA frameworks. Unlike previous studies, I use EA essential elements to systematically distinguish the EA frameworks and interpret the meaning of the differences. At a minimum, I hope the identified elements and the ideal types of EA frameworks here will aid managers who are looking for a way to adapt and invent their own EA foundation.

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References

Ahlemann, F., Stettiner, E., Messerschmidt, M., & Legner, C. (2012). *Strategic enterprise architecture management: Challenges, best practices, and future developments*. New York: Springer.

Alghamdi, A. S. (2009). Evaluating defense architecture frameworks for C4I system using analytic hierarchy process. *Journal of Computer Science, 5*(12), 1075-1081.

Alwadain, A., Fielt, E., Korthaus, A., & Rosemann, M. (2011). Where do we find services in enterprise architecture? A comparative approach*. In *Proccedings of the 17th Americas Conference on Information Systems*.

Alwadain, A., Korthaus, A., Fielt, E., & Rosemann, M. (2010). Integrating SOA into an enterprise architecture: A comparative analysis of alternative approaches*. In *Proceedings of the 5th IFIP International Conference on Research and Practical Issues on Enterprise Information Systems*.

Attewell, P. (1992). Technology diffusion and organizational learning: The case of business computing. *Organization Science, 3*(1), 1-19.

Bardach, E. (2009). *A practical guide to policy analysis: The eightfold path*. Washington, DC: CQ Press.

Baum, J. A. C., & Shiplov, A. V. (2006). Ecological approaches to organizations. In S. R. Clegg, C. Hardy, T. B. Lawrence, & W. R. Nord (Eds.), *The Sage handbook of organization studies* (pp. 55-110). Thousand Oaks, CA: Sage.

Bernaert, M., Poels, G., Snoeck, M., & De Backer, M. (2016). CHOOSE: Towards a metamodel for enterprise architecture in small and medium-sized enterprises. *Information Systems Frontiers, 18*(4), 781-818.

Bernard, S. A. (2004). *An introduction to enterprise architecture*. Bloomington, IN: Author House.

Bernus, P., Mertins, K., & Schmidt, G. (2006). *Handbook on architectures of information systems* (vol. 2). Berlin, Heidelberg: Springer.

Bernus, P., & Nemes, L. (1996). A framework to define a generic enterprise reference architecture and methodology. *Computer Integrated Manufacturing Systems, 9*(3), 179-191.

Bernus, P., Nemes, L., & Schmidt, G. (2013). *Handbook on enterprise architecture*. Berlin, Heidelberg: Springer.

Bidan, M., Rowe, F., & Truex, D. (2012). An empirical study of IS architectures in French SMEs: Integration approaches. *European Journal of Information Systems, 21*(3), 287-302.

Birkinshaw, J., Hamel, G., & Mol, M. J. (2008). Management innovation. *Academy of Management Review, 33*(4), 825-845.

Boh, W. F., & Yellin, D. (2007). Using enterprise architecture standards in managing information technology. *Journal of Management Information Systems, 23*(3), 163-207.

Bouwman, H., van Houtum, H., Janssen, M., & Versteeg, G. (2011). Business architectures in the public sector: Experiences from practice. *Communications of the Association for Information Systems, 29*(1), 411-426.

Bradley, R. V., Pratt, R. M. E., Byrd, T. A., Outlay, C. N., & Wynn, D. E., Jr. (2012). Enterprise architecture, IT effectiveness and the mediating role of IT alignment in US hospitals. *Information Systems Journal, 22*(2), 97-127.

Bradley, R. V., Pratt, R. M. E., Byrd, T. A., & Simmons, L. L. (2011). The role of enterprise architecture in the quest for IT value. *MIS Quarterly Executive, 10*(2), 73-80.

Bui, Q. N. (2015). Increasing the relevance of enterprise architecture through "crisitunies" in U.S. state governments. *MIS Quarterly Executive, 14*(4), 169-179.

Burton, B., & Blosch, M. (2014). Business architecture is not optional for business-outcome-driven EA. *Gartner.* Retrieved from https://www.gartner.com/doc/2863320/business-architecture-optional-businessoutcomedriven-ea

Cameron, B. H., & McMillan, E. (2013). Analyzing the current trends in enterprise architecture frameworks. *Journal of Enterprise Architecture, 9*(1), 60-71.

CIO Council. (1999). *Federal enterprise architecture framework version 1.1*. Retrieved from http://www.whitehouse.gov/omb/e-gov/FEA

CIO Council. (2001). *A practice guide to federal enterprise architecture*. Retrieved from http://www.whitehouse.gov/omb/e-gov/FEA

Davenport, T. H., Hammer, M., & Metsisto, T. J. (1989). How executives can shape their company's information systems. *Harvard Business Review, 67*(2), 130-134.

El Sawy, O. A., Malhotra, A., Gosain, S., & Young, K. M. (1999). IT-intensive value innovation in the electronic economy: Insights from Marshall Industries. *MIS Quarterly, 23*(3), 305-335.

Gall, N. (2012). Gartner's 2011 global enterprise architecture survey: EA frameworks are still homemade and hybrid. *Gartner.* Retrieved from https://www.gartner.com/doc/1887220/gartners--global-enterprise-architecture

GAO. (2002). *Enterprise architecture use across the federal government can be improved*. Retrieved from http://www.gao.gov/new.items/d026.pdf

GAO. (2003). *Leadership remains key to agencies making progress on enterprise architecture efforts*. Retrieved from http://www.gao.gov/products/GAO-04-40

GAO. (2006). *Enterprise architecture: Leadership remains key to establishing and leveraging architectures for organizational transformation*. Retrieved from http://www.gao.gov/products/GAO-06-831

Gharajedaghi, J. (2005). *Systems thinking: Managing chaos and complexity: A platform for designing business architecture* (2nd ed.). Burlington, MA: Elsevier.

Greefhorst, D., Koning, H., & van Vliet, H. (2006). The many faces of architectural descriptions. *Information Systems Frontiers, 8*(2), 103-113.

Greefhorst, D., & Proper, E. (2011). *Architecture principles: The cornerstones of enterprise architecture*. Berlin, Heidelberg: Springer.

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Englewood Cliffs, NJ: Prentice Hall.

Hannan, M. T., & Freeman, J. (1984). Structural inertia and organizational change. *American Sociological Review, 49*(2), 149-164.

Hjort-Madsen, K. (2007). Institutional patterns of enterprise architecture adoption in government. *Transforming Government: People, Process and Policy, 1*(4), 333-349.

IEEE. (2000). *IEE recommended practice for architectural description of software intensive systems (IEEE standard 1471-2000)*. Retrieved from https://standards.ieee.org/findstds/standard/1471-2000.html

Iyer, B., & Gottlieb, R. (2004). The four-domain architecture: An approach to support enterprise architecture design. *IBM Systems Journal, 43*(3), 587-597.

James, G. A., Handler, R. A., Lapkin, A., & Gall, N. (2005). Gartner enterprise architecture framework: Evolution 2005. *Gartner.*

Janssen, M., & Hjort-Madsen, K. (2007). Analyzing enterprise architecture in national governments: The cases of Denmark and the Netherlands*. In *Proccedings of the 40th Hawaii International Conference on System Sciences.*

Lange, M., Mendling, J., & Recker, J. (2015). An empirical analysis of the factors and measures of enterprise architecture management success. *European Journal of Information Systems, 6*(1), 1-21.

Lankhorst, M. (2013). *Enterprise architecture at work: Modelling, communication and analysis* (vol. 3). New York, NY: Springer.

Lapalme, J. (2012). Three schools of thought on enterprise architecture. *IT Professional, 14*(6), 37-43.

Lapkin, A. (2005). Gartner's enterprise architecture process and framework help meet 21st century challenges. *Gartner.* Retrieved from https://www.gartner.com/doc/486650/gartners-enterprise-architecture-process-framework

Lapkin, A. (2006). Gartner defines the term "enterprise architecture". *Gartner.* Retrieved from https://www.gartner.com/doc/493639/gartner-defines-term-enterprise-architecture

Leganza, G. (2010). Topic overview: Information architecture. *Gartner.* Retrieved from http://www.chrismills.com.au/files/205PDF/Information_architecture_overview.pdf

Leist, S., & Zellner, G. (2006). Evaluation of current architecture frameworks. In *Proccedings of the ACM Symposium on Applied Computing.*

Liimatainen, K., Hoffmann, M., & Heikkilä, J. (2007). *Overview of enterprise architecture work in 15 countries.* Ministry of Finance, Finland.

Lindström, Å., Johnson, P., Johansson, E., Ekstedt, M., & Simonsson, M. (2006). A survey on CIO concerns: Do enterprise architecture frameworks support them? *Information Systems Frontiers, 8*(2), 81-90.

Lowry, P. B., Moody, G. D., Gaskin, J., Galletta, D. F., Humpherys, S. L., Barlow, J. B., & Wilson, D. W. (2013). Evaluating journal quality and the association for information systems Senior Scholars' journal basket via bibliometric measures: Do expert journal assessments add value? *MIS Quarterly, 37*(4), 993-993.

Lucke, C., Krell, S., & Lechner, U. (2010). Critical issues in enterprise architecting—a literature review. In *Proceedings of the 16th Americas Conference on Information Systems.*

Murmann, J. P., & Frenken, K. (2006). Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy, 35*(7), 925-952.

NASCIO. (2003). *Enterprise architecture maturity model version 1.3.* Retrieved from http://www.nascio.org/

NASCIO. (2004). *Enterprise architecture development tool-kit v3.0.* Retrieved from http://www.nascio.org/

OMB. (2009). *Improving agency performance using information and information technology (enterprise architecture assessment framework v3.1).* Retrieved from https://www.whitehouse.gov/omb/e-gov/FEA

Op't Land, M., Proper, E., Waage, M., Cloo, J., & Steghuis, C. (2009). *Enterprise architecture: Creating value by informed governance.* Berlin, Heidelberg: Springer.

Orlikowski, W. J. (1992). The duality of technology: Rethinking the concept of technology in organizations. *Organization Science, 3*(3), 398-427.

Perks, C., & Beveridge, T. (2003). *Guide to enterprise IT architecture.* New York, NY: Springer.

PRISM. (1986). *Dispersion and interconnection: Approaches to distributed systems architecture.* Retrieved from https://c.ymcdn.com/sites/www.globalaea.org/resource/collection/EAAC3D6C-D447-451C-AC5F-6E1DC7788D42/PRISM_Report.pdf

Richardson, G. L., Jackson, B. M., & Dickson, G. W. (1990). A principles-based enterprise architecture: Lessons from Texaco and Star Enterprise. *MIS Quarterly, 14*(4), 385-403.

Robertson, B., & Blanton, C. E. (2008). Enterprise architecture frameworks: Just choose one and use it. *Gartner.*

Ross, J. W. (2003). Creating a strategic IT architecture competency: Learning in stages. *MIS Quarterly Executive, 2*(1), 31-43.

Ross, J. W., & Beath, C. M. (2006). Sustainable IT outsourcing success: Let enterprise architecture be your guide. *MIS Quarterly Executive, 5*(4), 181-192.

Ross, J. W., Weill, P., & Robertson, D. C. (2006). *Enterprise architecture as strategy: Creating a foundation for business execution.* Boston, MA: Harvard Business School Press.

Salmans, B. (2010). EA maturity models. In L. A. Kappelman (Ed.), *The SIM guide to enterprise architecture* (pp. 89-95). Boca Raton, FL: CRC Press.

Santos, J., Burton, B., & Blosch, M. (2016). The enterprise architect's first 100 days. *Gartner*. Retrieved from https://www.gartner.com/doc/3243420/enterprise-architects-days

Schekkerman, J. (2004). *How to survive in the jungle of enterprise architecture frameworks*. Victoria, Canada: Trafford Publishing.

Schmidt, C., & Buxmann, P. (2011). Outcomes and success factors of enterprise IT architecture management: Empirical insight from the international financial services industry. *European Journal of Information Systems, 20*(2), 168-185.

Sessions, R. (2007). Comparison of the top four enterprise architecture methodologies. *Microsoft.* Retrieved from https://msdn.microsoft.com/en-us/library/bb466232.aspx

Simon, D., Fischbach, K., & Schoder, D. (2013). An exploration of enterprise architecture research. *Communications of the Association for Information Systems, 32*(1), 1-72.

Smith, H. A., Watson, R. T., & Sullivan, P. (2012). Delivering an effective enterprise architecture at Chubb Insurance. *MIS Quarterly Executive, 11*(2), 75-82.

Sowa, J. F., & Zachman, J. A. (1992). Extending and formalizing the framework for information systems architecture. *IBM Systems Journal, 31*(3), 590-616.

Spewak, S. H., & Hill, S. C. (1993). *Enterprise architecture planning: Developing a blueprint for data, applications and technology*. Wellesley, MA: QED Publishing Group.

Tamm, T., Seddon, P. B., Shanks, G., & Reynolds, P. (2011). How does enterprise architecture add value to organisations? *Communications of the Association for Information Systems, 28*(1), 141-168.

Tang, A., Han, J., & Chen, P. (2004). A comparative analysis of architecture frameworks. In *Proceedings of the Software Engineering Conference* (pp. 640-647).

TOGAF. (2009). *The open group architecture framework (TOGAF) version 9 "enterprise edition"*. Retrieved from http://www.opengroup.org

Tushman, M. L., & Murmann, J. P. (1998). Dominant designs, technology cycles, and organizational outcomes. *Research in Organizational Behavior, 20*, 231-266.

Ulrich, W., & McWhorter, N. (2010). *Business architecture: The art and practice of business transformation*. Tampa, Florida: Meghan-Kiffer Press.

Urbaczewski, L., & Mrdalj, S. (2006). A comparison of enterprise architecture frameworks. *Issues in Information Systems, 7*(2), 18-23.

Van den Berg, M., & Van Steenbergen, M. (2006). *Building an enterprise architecture practice: Tools, tips, best practices, ready-to-use insights*. Sogeti, Netherlands: Springer.

Venkatesh, V., Bala, H., Venkatraman, S., & Bates, J. (2007). Enterprise architecture maturity: The story of the Veterans Health Administration. *MIS Quarterly Executive, 6*(2), 79-90.

Versteeg, G., & Bouwman, H. (2006). Business architecture: A new paradigm to relate business strategy to ICT. *Information Systems Frontiers, 8*(2), 91-102.

Wagter, R., van den Berg, M., Luijpers, J., & van Steenbergen, M. (2005). *Dynamic enterprise architecture: How to make it work*. Hoboken, NJ: John Wiley & Sons.

Weiss, D. (2016). Developing effective enterprise architecture principles. *Gartner.* Retrieved from https://www.gartner.com/doc/497000/developing-effective-enterprise-architecture-principles

Weiss, D., Rosser, B., & Blanton, C. E. (2005). Enterprise architecture improves IT planning synergies. *Gartner.*

Winter, R., & Schelp, J. (2008). Enterprise architecture governance: The need for a business-to-IT approach. In *Proccedings of the ACM Symposium on Applied Computing* (pp. 548-552).

Wout, J. v. t., Waage, M., Hartman, H., Stahlecker, M., & Hofman, A. (2010). *The integrated architecture framework explained: Why, what, how*. New York: Springer.

Zachman, J. A. (1987). A framework for information systems architecture. *IBM Systems Journal, 26*(3), 276-292.

Appendix A: Detailed Comparison of Popular EA Frameworks

Table A1. Detailed Comparison of Popular EA Frameworks

Elements	DoDAF	GERAM	FEAF	TOGAF
EA principles	N/A	Use design principles to develop solutions. Lack of overall architecture principles.	Architecture principles that govern the development, maintenance, and use of EA. They map to the organization's IT visions and strategic plans.	Develop architecture principles in the preliminary phase to govern the development and implementation processes. TOGAF view these principles as a subset of IT principles, a more narrow view of EA principles.
Technical EA layers	DoDAF meta models provide vocabulary and specifications for various technical aspects such as information and data, resource flows, capabilities, etc.	GERA identifies human, process, and technology concepts of enterprise integration.	A set of reference models of IT resources (technical, data, and service component).	Architectural domains include data, application, and technology architecture provide technical models and taxonomy.
Business EA layers	The operational viewpoint provides better understanding of the business models and operations of the enterprise. The meta models specify organizational structure and some business logics; however, they are technical oriented and limited.	N/A	Segment Architecture focuses on cross-cutting business areas. Business reference model outlines relationships of lines of business.	Business Architecture defines business strategy, governance, organization, and key business processes.
EA development methodology	Architecture development provides a six-step process of EA development.	EEM describes the process of enterprise engineering.	The transition processes explain how to move from as-is to to-be architecture.	The architecture development method provides a step-by-step approach to EA.
EA organizing structure	The configuration management component specify authority and responsibilities of EA teams but lack details on relationships with other functions.	Define human roles and their capabilities and qualities but lack the description of interrelationships and responsibilities.	Enterprise roadmap defines roles and responsibilities of EA stakeholders. Integrated governance model shows relationship between multiple agencies and EA.	The architecture capability framework defines the structures, processes, roles, responsibilities, and skills for EA development
EA operations and monitoring	The configuration management component requires the use of implementation and evaluation process but no specific details.	PEMs and GEMCs provide reference models and modelling constructs for EA development.	Some details on EA development processes. Has a mature level assessment framework to evaluates EA progress	A change request process is included to adjust requirements. The architecture maturity model describes architectural evolution.
EA enforcement	The architecture and standards review group oversees compliance but it is unclear how it should be set up.	EEM associates with project management techniques to plan, budget, control, and terminate projects.	The performance improvement lifecycle is centered on architectural compliance.	Compliance assessments are conducted as part of the governance process.

Table A1. Detailed Comparison of Popular EA Frameworks

Strategic integration	No explicit evidence. While strategic information is discussed as guiding EA, no clear indication on the role of EA in setting strategic directions.	N/A	N/A	Not prominent. Strategic inputs are drivers for EA and there is a business transformation readiness assessment but it is unclear how EA drives business.

Elements	IAF	MIT	Gartner	DYA
EA principles	Architecture principles set the general characteristics of the desired architecture	Operating model, a high-level strategic vision, must be defined before EA development to specify the strategic intents and directions.	EA principles need to be defined early to support consistent decision making and drive enterprise change.	Architectural principles are developed during the Strategic Dialogue to guide EA development.
Technical EA layers	Information systems, technology, and information architecture document technical concepts.	N/A	The Information, Technology, and Solution architecture capture technical requirements.	Include technical and information architecture to develop technical foundation.
Business EA layers	Business architecture describes processes, organizations, people, and resources. It focuses on creating business requirements, grouping criteria, and implementation guidelines.	Operating model defines core business processes, shared data, key linking technologies, and key customers.	Include business architecture which represents business processes and business concerns.	Include business architecture which outlines the products and services offered, the processes and required structure to deliver those products and services.
EA development methodology	IAF engagement roadmaps describe how to run an architectural engagement.	A detailed discussion on how to develop EA using operating models, EA, and engagement model.	Gartner EA process model is a logical approach to EA development	A DYA process that defines how to develop EA
EA organizing structure	The function and design authority is discussed, especially the role of design authority in business units.	IT governance defines decision rights and accountability.	Define principles for decision rights but lack details.	Governance is part of the DYA model. Discussion of architectural team, its responsibilities, and competencies.
EA operations and monitoring	Some details with discussion of IAF with other development methods. Lack of an evaluation framework	The IT engagement model with linking mechanisms to execute EA. Has an EA maturity model with management practices for each maturity stage.	Lack of concrete guidance but use an adaptive approach to develop EA that fits local contexts.	Has development processes using three strategies.
EA enforcement	IAF guidelines provide requirements for the realization of the architecture. The enforcement authorities of design authority are also discussed.	IT engagement model links project level activities with overall EA principles	Implicitly assumed in their governance model.	Monitoring is part of the governance set up. Architectural evaluation should be part of project reports.

Table A1. Detailed Comparison of Popular EA Frameworks

Strategic integration	Enterprise transformation is somewhat discussed, and IAF outcomes are discussed in relation to business management.	Matured EA will increase strategic agility and create new capabilities. Strategic directions lead EA development.	EA is part of IT planning process, driving strategies and agendas.	Strategic dialogue between the architectural team and business case team to determine business objectives.

Appendix B: Cluster Analysis of EA Frameworks

To understand the type of EA that EA frameworks aim to build, I performed a cluster analysis using SPSS, a commonly used and accepted statistical software. Cluster analysis is a multivariate technique that classifies groups with small intra-cluster distance and large inter-cluster distance (Hair, Black, Babin, & Anderson, 2010); thus, it was appropriate for my purpose.

I first checked the data for inter-object similarity using correlational measures (Table B1). Overall, most variables had no correlation with the others. The "EA development methodology" element did not have any variation since all frameworks include a formal methodology. Thus, I omit them in the correlation table. There was no multicollinearity reported.

Table B1. Correlation Measures

Element	1	2	3	4	5	6	7
EA principles	1						
Technical EA layer	.267	1					
Business EA layer	.635	-.204	1				
EA organizing structure	.548	-.293	.696	1			
EA operations and monitoring	0.000	-.378	-.180	.258	1		
EA enforcement	.408	-.218	.104	.745*	.577	1	
Strategic integration	.286	-.459	.509	.174	.135	-.078	1
*. Correlation is significant at the 0.05 level (2-tailed). I omit the "EA development methodology" element because it has a constant value.							

Next, I performed a hierarchical cluster analysis using Ward's method for cluster formation and squared Euclidean distance for similarity measure (Hair et al., 2010). Social science and EA research have used this approach for cluster analyses (Bidan, Rowe, & Truex, 2012). To analyze the clusters, I used the agglomerative coefficients and the dendogram—a visual representation of the clusters. While initially I could interpret two clusters, I decided to select a three-cluster solution because it gives more theoretical interpretation (Figure B2). To verify and "fine tune" the cluster solutions, I conducted a non-hierarchical analysis using k-means cluster (Hair et al., 2010). The hierarchical analysis suggested a k value of 3, and I used data means from the hierarchical cluster analysis as the initial seeds (as opposed to random seeds). The final result showed no change in the cluster membership, indicating reliable results.

To interpret and profile the cluster solutions, I conducted an ANOVA analysis with cluster membership as the independent variable and the essential elements as the dependent variables. Table B2 presents the results. Among the essential elements, I found that three significantly contributed to the cluster formation: "EA principles", "business EA layers", and "strategic integration". This result aligns with theoretical justifications that argue that these elements have significant impacts on organizational performance (Ahlemann et al., 2012; Bouwman et al., 2011; Greefhorst & Proper, 2011; PRISM, 1986; Ross et al., 2006; Versteeg & Bouwman, 2006). I discuss their significance in Section 5.
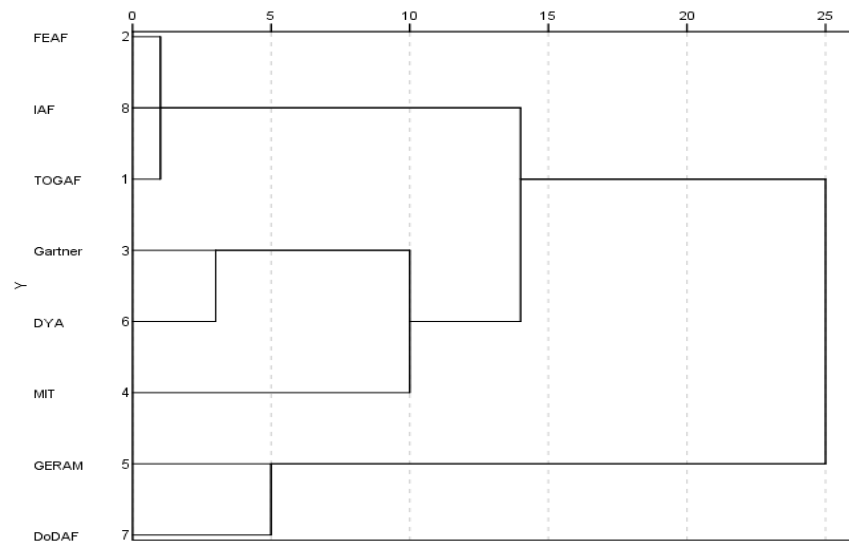
Figure B1. Cluster Dendogram

Table B2. Cluster Profile

Element	Mean values			F	Sig
	Technical EA	Operational EA	Strategic EA		
EA principles	1.5	3	2.67	6.071	0.046
Technical EA layers	3	3	2.33	0.781	0.507
Business EA layers	1.5	3	3	16.875	0.006
EA organizing structure	2	3	2.67	4.531	0.075
EA operations and monitor	2.5	2.33	2.67	0.227	0.805
EA enforcement	2.5	2.67	3	0.714	0.534
Strategic integration	1	1.33	3	23.281	0.003

About the Authors

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