Analysis of Enterprise Architecture Capability Maturity Models

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บทคัดย่อ—หนึ่งในงานที่ท้าทายสำหรับการปฏิรูประบบดิจิตอลทรานส์ฟอเมชันขององค์กรคือ วิธีการที่จะเตรียมการและขับเคลื่อนการเปลี่ยนแปลง ซึ่งรวมไปถึงแพลตฟอร์มเทคโนโลยีและสภาพแวดล้อมทางธุรกิจขององค์กรทั้งหมด เพื่อบริหารจัดการความซับซ้อนของดิจิตอลทรานส์ฟอเมชันอย่างเป็นระบบ แนวคิดของสถาปัตยกรรมองค์กรจึงเป็นแนวคิดที่ถูกนำมาใช้เป็นแนวทางในการปฏิรูป อย่างไรก็ตามมีหลายองค์กรที่เริ่มดำเนินการตามแนวคิดสถาปัตยกรรมขององค์กรแต่ไม่ประสบความสำเร็จและยกเลิกโครงการหลังจากเริ่มดำเนินการเพียงไม่กี่ปี ความล้มเหลวเหล่านี้เกิดขึ้นจากปัจจัยสำคัญหลายประการ ยกตัวอย่างเช่นการขาดประสบการณ์ ความรู้ความเข้าใจในการดำเนินการในทางปฏิบัติและการขับเคลื่อนองค์กรและคนในองค์ให้เป็นไปตามแนวทางของสถาปัตยกรรมองค์กร บทความนี้ได้เสนอโมเดลประเมินสมรรถนะของสถาปัตยกรรมองค์กร เพื่อใช้เป็นเครื่องมือในการเตรียมความพร้อมในการทำดิจิตอลทรานส์ฟอเมชันภายในองค์กร โดยงานวิจัยนี้จะมีการเปรียบเทียบและวิเคราะห์แบบจำลองวัดระดับความสามารถที่ได้รับความนิยม 4 แบบจำลอง เพื่อเปรียบและวิเคราะห์ผลตามปัจจัยหลักแห่งความสำเร็จ ผลจากเปรียบเทียบจะได้แบบจำลองที่เหมาะสมสำหรับผู้เริ่มต้นใช้สถาปัตยกรรมขององค์กรเพื่อเตรียมและขับเคลื่อนดิจิตอลทรานส์ฟอเมชันอย่างเป็นระบบ

คำสำคัญ: ดิจิตอลทรานส์ฟอเมชัน, สถาปัตยกรรมองค์กร, โมเดลประเมินสมรรถนะสถาปัตยกรรมองค์กร

***Abstract*—One of the challenging tasks for organizational digital transformation is on how to effectively prepare and drive changes. These changes include not only about technology platforms but also the business environment as a whole. To systematically manage such complexity of digital transformation, the concept of enterprise architecture is normally recommended to be used. However, many organizations which started adopting enterprise architecture programmes were not very successful and then abandoned these initiatives after a few years. These failures are due to several critical factors that most early adopters of enterprise architecture are not familiar with and in many cases they are overwhelmed to deal with. This paper suggests that enterprise architecture capability maturity models should be adopted as a guiding tool to iteratively assess, prepare and implement digital transformation within organizations. In this paper, four well-known capability maturity models for enterprise architecture are compared and analyzed against a recommended set of critical success factors. A specific enterprise architecture capability maturity model is then recommended as a suitable model for any early adopters of enterprise architecture to prepare and drive organizational-wide digital transformation initiatives.**

Keywords- Digital Transformation; Digital Government; Enterprise Architecture; Capability Maturity Models

I. INTRODUCTION

During the past ten years, the concept of enterprise architecture (EA) has raised a lot of interest [1]. The EA methodology helps organizations systematically manage complexity of digital transformation. The top benefits reported include improved system integration, improved information technology (IT) governance, better coordination among the development stakeholders with common terminology, improved business efficiency and increased data integrity.

However, one of the most challenging digital transformation tasks is on how to prepare for and drive effective changes in business environment and technical platforms. As an organization grows in size and

complexity, several factors obstruct its abilities to deal with these challenges [2].

According to the Open Group's reports, several public and private organizations which initiated enterprise architecture programs were not very successful and then abandoned these initiatives later in a couple of years. Several reasons which result in unsuccessful EA programs are, among others, lack of high-level leadership engagement, and no alignment between the EA processes and other management practices within in the organization [3].

Another report by Gartner analyzed several factors resulting in EA pitfalls [4]. One of these pitfalls, for example, is related to the lack of appropriate measurement and communication about the programme impacts. In many cases, digital transformation and enterprise architecture initiatives are long-term endeavors. Stakeholders within the organization are often confused about its implementation due to the multi-facet involvement and its indirect value in several scenarios. Un-alignment and unclear direction during implementation also resulted in failures. This report, therefore, suggests that organizations must include measurement, documentation and communication of EA as the essential tasks in the development program. But, what about other critical success capabilities that need to be in place.

Enterprise architecture maturity models, especially those based on the capability maturity model concept, should be utilized to help organizations in measuring their maturity and guiding capacity building for successfully developing, maintaining, and utilizing EA for digital transformation. The capability maturity model can provide an effective method for organizations to assess and improve its architecture change by recommending specific critical factors and improvement [5].

In case of developing countries like Thailand, many organizations especially government agencies are in the very early stage of EA adoption during their journey of digital transformation. Some agencies have started to utilize EA frameworks such as TOGAF and the Digital Government Agency (EGA) Enterprise Architecture Framework [6]. However, one of the weaknesses is that no specific EA assessment model has been established or recommended for the country's EA development. Most of those government agencies adopting the EA frameworks haven't systematically assessed their capability to drive these initiatives.

Therefore, the objective of this paper is to propose an enterprise architecture capability maturity model suitable for organizations in developing countries like Thailand which are in the early stage of digital transformation and EA adoption. We compare and analyze several existing capability maturity models for enterprise architecture based on a recommended set of critical success factors. This paper is organized in five sections: the introduction in Section I; the background information about enterprise architecture capability maturity models described in Section II; the methodology for the comparative analysis provided in Section III; the evaluation result summarized in Section IV; and the conclusion in Section V.

II. Enterprise Architecture Maturity Model

A. Capability Maturity Model (CMM)

The most well-known maturity model, called Capability Maturity Model (CMM), was originally designed for the organization's capability of its software development process. This framework, as formulated by Software Engineering Institute, Carnegie Mellon University [7], provides organizations with guidance on how to gain visibility and control of their process for developing and maintaining of software systems. The CMM defines five maturity levels which are successive foundations for continuous process improvement. Each maturity level provides a scale for evaluating and improving software process capability with a group of key process areas. The key process areas describe how the organization matures with the necessary capability and practices in order to achieve the set of goals for each maturity level.

The CMM concepts have been extended to evaluate EA capability and other capabilities necessary for digital transformation of an organization. The main reasons to apply the CMM for assessing EA maturity capability are in its powerful mechanism for step-by-step improvement based on concrete assessment and gap analysis. These maturity models provide effective mechanisms for measuring processes through process and activity metrics and goal fulfilment. Examples of EA capability maturity models based on CMM are NASCIO EAMM, EAMMF, ACMM and DyAMM which will be elaborated further in the following sections.

B. NASCIO EA Maturity Model

For the US governments, the National Association of State Chief Information Officers (NASCIO) [8] proposed several guidelines including an EA maturity assessment model to assist state and local governments in their enterprise architecture development. The NASCIO's EA Maturity Model was developed based on the Capability Maturity Model (CMM) [9]. This maturity model can be used to assess readiness for effective enterprise architecture implementation of local governments. It also describes expected progressive benefits when the organization gradually grows in their development capacity and maturity. This assessment model consists of 8 different categories organized within 6 maturity levels. The 8 categories are as following:

Administration – It emphasizes governance roles and responsibilities. This category ensures IT resources that

shall be adequately established such that all related tasks and risks are managed appropriately.

Planning – It is to ensure that the new architecture can be used in practice and in accordance with the goals and boundaries set.

Framework – It composes of several components that support the development of enterprise architecture. They are defined as standards for operations such as processes, forms and templates.

Blueprint – It is about the documents including diagrams and corresponding descriptions which give the EA architect or related stakeholders an overview perspective of all important concepts, the logical elements and the physical components, their attributes and their interrelationship over the organization with meaningful information.

Communication – This category emphasizes that all EA artifacts and standards are established and communicated for the team to reference and use.

Compliance – It is about working according to published standards, processes, models and other EA elements. Compliance must be reviewed periodically to assure that the business, IT programs and services are operated effectively.

Integration – This category defines the ability of internal or external organization to support for cooperation and integration to the greatest benefits of the organization.

Involvement – It is about support of all stakeholders in the organization such as executives, managers, and employees to involve in the on-going EA programme.

The maturity levels of NASCIO have six different stages, from Level 0 to Level 5. The key characteristics of each level are following:

Level 0 – No Program: There is no architectural framework in place at this level of maturity.

Level 1 – Informal Program: The enterprise architecture framework and standards have been imposed and are operated but informally. Ad-hoc operations and contribution by individuals are still the key nature of the organization at this level.

Level 2 – Repeatable Program: The organization has defined its foundation architecture and standards. Their usages are being tracked and verified. The processes are repeatable and reusable templates are starting to be developed.

Level 3 – Well-Defined Program: In this level, the EA framework is clear. The standards, associated templates and their tailoring guidelines have been established and used accordingly within the organization. The established framework align and synchronize the development of all business and architecture domains. Business processes, practices and performance metrics in all process areas are tracked, monitored and reported.

Level 4 – Managed Program: The quantitative management is practiced within the organization where performance metrics are collected, analyzed and acted upon. These quantitative data are used to predict performance and to provide better understanding of their process capabilities.

Level 5 – Continuously Improving Vital Program: The systematic and continuous improvement mechanism is institutionalized within the organization. The targets for effectiveness and efficiency based on business goals have been established. Improvement activities have been continuously carried out based on knowledge of the impact changes which are related to the corresponding processes.

C. US DoC ACMM Framework

An Architecture Capability Maturity Model (ACMM) was developed by the United States Department of Commerce as a tool to conduct internal architecture assessments for organizations [10]. The ACMM is a framework that represents the key components of productive EA processes. The target of ACMM is to identify weak points and provide guidelines to improve the whole-of organization processes for increasing the success of enterprise architecture initiatives.

ACMM has divided into two parts. The first part is about the six maturity levels of enterprise architecture and the second part describes enterprise architecture characteristics of operating units' processes at different maturity levels. We can describe each maturity level and its nine enterprise architecture elements as following:

Level 0 – None: No enterprise architecture program exists in the organization.

Level 1 – Initial: The organization has published and applied informal enterprise architecture, or a preliminary enterprise architecture process is underway.

Level 2 – Underdevelopment: Enterprise architecture process is under development.

Level 3 – Defined: Defined enterprise architecture including detailed written procedures and technical reference models are established.

Level 4 – Managed: Managed and measured enterprise architecture process is established.

Level 5 – Optimizing: Systematic continuous improvement is carried out within each enterprise architecture process.

This model suggests that there are nine critical elements that must be managed. They are enterprise architecture process, architecture development, business linkage, senior management engagement, operating unit participation, communication, cyber-security, governance, and IT investment/acquisition strategy.

The criterion of each key element should be intensified or improved when the architecture is matured for a higher level. For example, let us consider the business linkage in Level 1 and Level 2. In Level 1, the business linkage could be minimal, or the architecture may have an implicit linkage to business strategies or

business drivers. But in Level 2, the linkage of the EA to business strategies must be explicitly defined and established.

The architecture maturity of an organization will be at one of these six levels (0-5). Each architecture maturity must fulfill all these nine EA elements but with different intensities. If it satisfies or achieves only some of those nine elements, it will not reach that maturity level but it could be staying at the lower level.

D. Enterprise Architecture Management Maturity Framework (EAMMF)

The United States Government Accountability Office has published the Enterprise Architecture Management Maturity Framework so called EAMMF [5], to aid organizations in developing, maintaining, and using enterprise architecture. The purpose of this maturity model is to provide a flexible progress benchmark mechanism against the plan.

The framework consists of three related components: (1) seven maturity stages; (2) four attributes that are critical success factors of organizations; (3) fifty-nine elements of core enterprise architecture management.

Each of the seven maturity stages indicates key enterprise architecture management conditions. The higher stage reflects that the organization must build its capability based upon the previous stage. This maturity model suggests to the organization the step-by-step development roadmap for gradually building the organization's maturity for EA-based digital transformation. Brief descriptions of these seven maturity stages are as following.

Stage 0) Initiating EA Awareness: Awareness of an EA programme is just initiated. The organization may not have any concrete plans to develop and establish EA yet.

Stage 1) Creating EA Institutional Commitment and Direction: The organization at this stage initiates a foundation for an EA programme.

Stage 2) Building the Management Foundation for EA Development and Usage: In this stage, the organization develops an EA management foundation based on the strategic leadership and the commitment built in Stage 1.

Stage 3) Establishing Initial EA Versions: The organization at this stage analyzes and develops preliminary versions of enterprise architectures of the organization.

Stage 4) Completing and Using an Initial EA Version for Targeted Results: The first version of enterprise architecture and its migration plan for transitioning from the current architecture to the target architecture have been endorsed by the executive committee.

Stage 5) Expanding and Evolving the EA and Its Use for Institutional Transformation: The development scope of enterprise architecture has been expanded to cover the whole-of organization.

Stage 6) Continuously Improving the EA and Its Usage to Achieve Corporate Optimization: The mechanism for continuous improvement of EA and its usage has been established. Its improvement cycle has been systematically implemented.

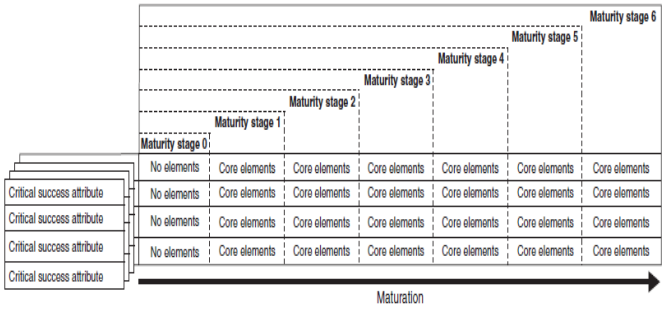

Figure 1. A Framework for Assessing and Improving Enterprise Architecture Management (EAMMF)

The four critical success attributes define and categorize different supporting mechanisms of 59 core elements. They are referred to as EA Management Action Representation, EA Functional Area Representation, Office of Management and Budget Capability Area Representation, and EA Enabler Representation. Each of these attributes give the organization the perspective on which directions to be focused on the framework's core elements.

The fifty-nine core elements are used together with the EA practices, structures, activities, and conditions. The EA program provides suggestion to the organization for progressing to the higher level of EA management maturity. This framework thereby increases the chances of realizing an EA's institutional value when properly employed based on the unique facts and situation of each organization.

E. The Dynamic Architecture Maturity Matrix (DyAMM)

The Dynamic Architecture Maturity Matrix (DyAMM) is part of the Dynamic Architecture (DyA) method. The DyA [11] is an EA method that describes the vision on the development and maintenance of architecture through a dynamic approach. DyAMM is used as an EA maturity assessment tool. The input for this maturity matrix is delivered by maturity assessments containing questions relevant to the EA maturity.

DyAMM [11] is different from other maturity models, apart from the aspect of improvement and prioritization. In most cases the classic maturity models contain only five separate maturity levels, whereas this maturity matrix has a more fine-grained approach.

Goal-oriented and evolutionary development of architectural functions is the key emphasis of this framework [12]. This maturity model can be adopted as a tool to incrementally develop architectural functions. Eighteen focus areas of architectural implementation and practices are recommended in this model. These focus areas were collected from real experience of many organization's enterprise architecture practices. Each focus

area is categorized into several levels of maturity. These maturity levels are positioned against each other in the matrix.

As illustrated in Figure 2, the maturity levels of each focus area are depicted by the letters A to D, indicating increasing levels of maturity. Notice that the number of maturity levels may differ for each focus area, i.e. varying from two to four. Most focus areas are distinguished within these three levels of A-C.

Scale / Area	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Development of architecture		A			B			C						
Use of architecture			A			B				C				
Alignment with business		A				B				C				
Alignment with the development process			A				B		C					
Alignment with operations					A			B			C			
Relation to the as-is state					A				B					
Roles and responsibilities				A		B					C			
Coordination of developments							A			B				
Monitoring				A		B		C		D				
Quality management								A		B			C	
Maintenance of the architectural process							A		B		C			
Maintenance of architectural deliverables					A			B					C	
Commitment and motivation		A					B		C					
Architecture roles and training				A		B			C			D		
Use of an architectural method				A						B				C
Consultation			A		B				C					
Architectural tools							A				B			C
Budgeting and planning				A							B		C	

Figure 2. The Dynamic Architecture Maturity Model

The maturity level of each focus area is associated with one to four yes/no questions. The determination of the focus area level is done by answering these questions. Only if all questions associated with a maturity level are answered confirmatively, the associated maturity level can be said to be achieved. Figure 3 shows example questions associated with the level A of the focus area Use of Architecture. In total, there are 137 questions associated with the matrix.

Nr.	Question
9	Is there an architecture that management recognizes as such?
10	Does the architecture give a clear indication of what the organization wants?
11	Is the architecture accessible to all employees?

Figure 3. Questions to measure maturity level A for the focus area Use of Architecture

III. METHODOLOGY

This paper adopts a comparative methodology for analyzing the four well-known EA maturity models against on a set of critical success factors (CSFs) for enterprise architecture initiatives [13] [14]. The criteria for selecting critical success factors is based upon the total quality management concept which indicate issues that must be carried out for successful implementation of enterprise architecture.

Referring to a publication by Tanja Ylimaki [15], critical success factors for implementing enterprise architecture initiatives have been extensively analyzed. The CFSs summarized in the mentioned paper were suggested as critical components for organizations to achieve high quality EA initiatives and enable successful digital transformation. These critical success factors are particularly essential for organizations with less experience in enterprise architecture and digital transformation. The twelve critical success factors are as following:

1) **Scoping and Purpose:** The scope and objective of enterprise architecture initiatives for driving digital transformation must be clearly articulated and established. The scope and objective must be holistically aligned with business vision/goals and mission of the organization. The long-term political will for enterprise architecture and digital transformation must be established.

2) **Communication and Common Language:** The scope of enterprise architecture and digital transformation is an enterprise-wide and long-term change initiative. The common understanding among all stakeholders in the organization is essential. The common vocabulary and language must be developed and widely used within the organization. The shared vision, knowledge, implementation actions, and their potential and actual impacts must be clearly communicated for the whole-of organization.

3) **Business Driven Approach:** EA plans and development aligned with business requirements and management is essential. Every EA element must be linked and traceable to the business strategy indicating clear alignment between business and IT.

4) **Commitment:** Ongoing commitment from both high-level management and all key personnel will ensure effective leadership engagement, adequate resources, implementation and operations towards successful outcomes.

5) **Development Methodology and Tools Supported:** Enterprise Architecture is a strategic planning and implementation which transforms vision into effective practices. For the development of enterprise architecture and digital transformation, it requires several methods and tools to enable and support these change initiatives. The tools and methods used aim to guide the analysis, design, implement and control the organizational transformation from the as-is conditions to the target architectures systematically.

   Development methodology and tools supported should be structured, well-defined, documented and used including, for example, processes, guidelines, best practices, drawing standards and other means to support the quality of architectures, as well as to track architectural decisions and changes.

6) **EA Models and Artifacts:** The enterprise architecture models in several domains, e.g. business architecture, information systems architecture, and technology architecture, are the

means to communicate the current situations and also the proposed target environments for stakeholders' consultation. It is very essential that the issues, the endorsed plan, business and architectural requirements, and models conveying coherent and concise pictures of the organization are documented and made available for all key stakeholders.

7) **EA Governance:** Governance provides the management and organizational aspects of architecture. It implies the mechanism on how the organization makes decision, manages its architecture process, sets priorities of work, and manages resources.

8) **Project and Program Management:** EA development is usually conducted through projects therefore project management skills play the crucial role in the project success.

9) **Assessment and Evaluation:** Assessment and evaluation of EA is undertaken as a part of the EA governance. The EA evaluation is a challenging task since it normally takes years before the effects and consequences of, for instance, an architectural decision, can be measured.

10) **IT Investment and Acquisition Strategies:** IT investment and acquisition strategies refer to the extent to which the EA influences the IT investment and acquisition strategy of the organization.

11) **Skilled Team, Training and Education:** EA development requires effective teamwork among the key stakeholder groups e.g. architects, business domains, top management, and business partners.

12) **Organizational Culture:** While developing an EA, the organizational culture should also be taken into consideration aiming at good organizational and cultural fit because in many cases cultural changes are inevitable. Especially, the organization's readiness to develop and utilize the EA is the important factor. It includes aspects like attitudes towards changes by the management and the employees. The communication environment and risk management among others must be managed and monitored.

	Maturity Models			
Critical Success Keys	NASCIO EA 3.1	EAMMF	ACMM	DyAMM
Scoping and Purpose	1	2	1	1
Communication and Common Language	2	2	2	2
Business Driven Approach	2	2	2	2
Commitment	1	2	1	2
Development Methodology and Tools Supported	0	2	2	2
EA Model and Artifacts	2	2	2	0
EA Governance	2	2	2	0
Project Program Management	2	2	1	1
Assessment and Evaluation	2	2	1	0
IT Investment and Acquisition	1	2	2	2
Skilled Team, Training and Education	2	2	0	2
Organizational Culture	0	2	1	0
Percentage (100)	70.83	100.00	70.83	58.33

In this paper, we evaluate and analyze all mentioned EA maturity models against these 12 CSFs. If the detail in each model matches with each specific CSF, we mark the point to 2. If the detail in the model has partially matched with that CSF, we mark its point to 1. If the detail in the model does not match with that CSF, we mark the point to 0.

After the evaluation, we transform the comparative result into the weight scores.

IV. Evaluation Result

The comparative evaluation of the four maturity models are shown in Table 1 as the weight-score table. The evaluation result indicates that the NASCIO EA maturity model has the score of 70.83%, EAMMF 100%, ACMM 70.83% and DyAMM 58.33%.

TABLE I. **WEIGHT-SCORE TABLE OF THE MATURITY MODELS**

V. Analysis and Conclusion

According to the comparative evaluation described in the previous section, it can be concluded that the EAMMF provides the best overall assessment framework and guidelines since it covers all critical factors for successful EA implementation. EAMMF is considered as a suitable EA capability maturity model for the organizations especially in developing countries or countries that are in the early stage of EA adoption and early stage of digital transformation since those organizations need a more detailed and specific guidelines to assess and gradually build their capability.

The missing success factors in NASCIO and ACMM, for example, are about unclear detailed actions in some maturity levels. The weak point of DyAMM is that it does not provide a clear explanation about the state of each individual maturity level. DyAMM, EAMMF and

NASCIO EA consist of similar components. Their differences can be seen in the number of levels, categories and statements; and the detail in which they are described.

In developing and early EA-adoption countries like Thailand, most organizations especially government agencies have less experience in EA implementation for organizational-wide digital transformation. The clear and detailed guidelines for conducting assessment and specific capacity building recommendations are very much needed. Organizations should incrementally prepare all components that are the critical success factors for implementing the digital strategy. The digital transformation initiative requires all necessary enterprise architecture blueprints such as policy, governance, people, process, information, applications and IT infrastructure. The appropriate capability can reduce the risks of development failures and missing goals of organizational-wide digital transformation initiatives.

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