

# Enterprise Architecture in the Age of Digital Transformation

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**Abstract.** Recent advances in digital technologies are enabling enterprises to undergo transformations for streamlining business processes, offering new products and services, expanding in new areas, and even changing their business models. Current enterprise architecture frameworks are used for analysis, design, and strategy execution, helping an enterprise transition from an as-is state to a to-be state. However emerging trends suggest the need for richer models to support on-going adaptations and periodic transformations. The scope of enterprise architecture modeling needs to be expanded to include the multiple levels of dynamics that exist within any enterprise, the sense-and-respond pathways that drive change at operational and strategic levels, and the tension between centralized control and local autonomy.

**Keywords:** Enterprise architecture · Adaptive enterprise · Requirement engineering · Enterprise modeling · Digital transformation · Emerging technologies

## 1 Introduction

Modern enterprises face immense pressure to continuously grow or reinvent themselves in a fast-moving, ever-changing and integrated world. To successfully survive in such evolving and uncertain conditions, enterprises are expected to continuously adapt to changing environments [1, 2]. The nature of change may be along various perspectives such as strategic vs. operational, transformational vs. transactional, discontinuous vs. continuous, revolutionary vs. evolutionary etc., involving diverse areas such as people, culture, processes, and technology [3].

The widespread adoption of technologies, such as social media, mobile, big data analytics and cloud computing, in enterprises is enabling a change in business model, improved customer experiences, and optimized operational processes [4, 5]. Such a transformation is a significant shift from the previous *modus operandi* and results in broad-ranging and potentially disruptive enterprise-wide transformation enabling enterprises to move from a brick-and-mortar style operation to one that is more encompassing of digital technologies [6]. Digital transformation permeates industry segments, take many forms and exist at many levels within an enterprise. The focus of transformation should not be on individual systems or processes but should rather be viewed holistically and at an enterprise level. All these approaches can be considered

more conceptually and be thought of as a series of on-going transformative demands on the enterprise at an operational and strategic level.

## 2 Emerging Requirements for EA Modeling

Enterprise characteristics are traditionally captured through various enterprise architecture frameworks for the purpose of design, analysis, planning and strategy execution. As enterprises are fairly complex entities, a number of enterprise modeling techniques exist with each providing a different view of the enterprise. These modeling techniques are generally used for static as-is and to-be representations of the enterprise and are unable to support the wide range of dynamics that are present in an enterprise. They do not cater to periodic, variable and continuous change including the ability to decide between multiple alternate enterprise configurations at run-time [7]. A review of industry literature highlighting trends in digital transformation suggests the scope for enterprise architecture framework(s) to be broadened so as to consider multi-level dynamics, data-driven sensing and acting, and actor autonomy.

### 2.1 Multi-level Dynamics

Every organization relies on many processes that together ensure its success and viability. Different types of processes, for example, operational and transactions processes, planning processes, design process, innovation processes, etc., may take place over different timescales and have different frequencies of occurrence. While current enterprise architecture frameworks can model various business process, they are lacking in the ability to express and reason about the nature of the relationships among them; such as the relationship between a planning process and the process that executes the plan, or the relationship between a design process and the process that exploits the new capability, artifact, or tool produced by that design process. The relationships are important in the current context of digital transformation, as these relationships are themselves subject to change. For example, some product design decisions can be deferred closer to the time of usage by allowing customization, user configuration, or even automated personalization. Some activities may be moved from a planning process to the execution process (“run-time”) in order to take advantage of the most up-to-date data (e.g., real-time analytics from Internet of Things). We consider examples from various industry sectors.

- Banks are increasingly relying on alternate digital channels (such as mobile and internet) which function at different levels and timescales compared to the more traditional banking channels such as bank branches. Branches are heavy on processes and human interaction thus operating at a slower timescale than the internet and mobile channel. The nature of product and service offerings also varies across these channels. A seamless “omni-channel” experience to customers across all channels is becoming essential, which require careful coordination of the processes across levels of dynamics [8, 9].

- The development of mobile enterprise systems is indicative of two separate and distinct levels with different characteristics and timescales. The front-end mobile app development is characterized by quick development and deployment cycles with customers providing immediate feedback through the app store rating whereas back-end enterprise systems have longer, more cautious development cycles [10]. Thus a new business feature affecting both mobile front-end and enterprise back-end systems would be managed, developed and delivered differently based on the different enterprise levels, methodologies, tools, and timescales.
- The telecommunication industry contains numerous internal operational processes and procedures such as billing operations. Billing operations encompass multiple levels across multiple organizational departments leading to process inefficiencies and possible issues with bill accuracy [11].

These multiple levels of dynamics are not entirely evident to the casual observer nor are the boundary transitions apparent. The enterprise architect would need to understand the differentiating attributes of the levels with the placement of enterprise activities within each. The constituent activities of any process could be moved across level boundaries however there would be resulting implications which need to be understood. For example, in the case of mobile app development above, certain back-end enterprise system development activities can be made part of the mobile app development level (i.e., both front-end and back-end systems follow the same development and deployment methodology) however there might be consequences with regards to the back-end enterprise system testing and platform stability. The identification of such levels, the placement of activities within each level, the possibility of movement of the activities across level boundaries and the possible implications are considerations that have to be understood and captured by the enterprise architect.

## 2.2 Data-Driven Sensing and Acting

Enterprise change is being influenced by both the internal adoption of technologies and the general pervasiveness of digital technologies in the environment that they operate in. The enterprise needs to “observe” and be aware of such situations based on which it would initiate and undertakes activities of adaptation and change. Such paths of change can be analyzed in terms of sense-and-response loops through which the enterprise continuously adapts and improves [12]. In the sensing part the enterprise would (proactively or reactively) determine the cause and need for change. In the responding part, the enterprise would determine the best possible alternate for change. Sensing and responding take place in processes that exist at different levels of dynamics and timescales. For example the sensing part can happen at machine-scale time (through the use of automated data driven systems) with the acting part existing in human-scale (through managerial decision making). Such data-driven sense-and-respond loops for ongoing enterprise transformation already exist in multiple industries.

- Big data analytics is helping banks make conscious decisions in identifying areas where investment should be made towards the digitization of business operations thus

helping banks manage their limited budgets more effectively. Analytics help identify inefficient business processes which are then optimized and improved upon [8, 13].

- The retail industry relies heavily on big data analytics to sense short-term and long-term trends that loom on the horizon. These are then acted upon by the responding side by at an operational and strategic level. Sensing aspects include customers demanding a better shopping experience, increasing competition because of technology improvements, entry of non-traditional competitors, changes in the supply chain etc. [14]; these changes would have to be sensed, understood and appropriate actions taken which would be operational or strategic in nature.
- The healthcare industry is using big data and predictive analytics to produce new innovation in biometrics and bioinformatics. This is in addition to using machines for generating preliminary diagnoses which aid and guide physicians in patient diagnoses and treatment regime [15].

Enterprise architects need to have methods that can help them sketch out such linear paths or cyclic loops as they exist in any enterprise, the various levels and timescales that they transition through, the interactions that the paths may have with other paths or enterprise objects, the sensory inputs to the sensing part and the corresponding balance that the responding part should bring.

### 2.3 Actor Autonomy Review

Enterprises are complex and collaborative environments with a multitude of human and non-human (system) actors. Each actor possesses their own intentions, goals and objectives which may or may not align with those of other actors or even the enterprise itself. Thus there exists a certain degree of actor autonomy within the overall enterprise. Any enterprise transformation would typically be a disruptive exercise and one that would positively, as well as, negatively affect actors. The expectation is that while the overall enterprise would benefit from such a transformative exercise, it may go against the individual interests of some actors. As before, enterprise actors can exist across the various enterprise levels and even participate in sense-and-respond loops. For an individual actor, their objectives and goals may also span these levels. The actor interests may, at times, align with enterprises hierarchies and divisions whereas on other occasions it may cut across those structures. Actors may support or oppose the goals of any transformative exercise and even change states between the two. Opposition to enterprise objectives may manifest itself as change rigidities in the enterprise.

- Financial institutions have a level of actor autonomy in order to counteract threats from new entrants in the financial services sector. Fintech startups and technology companies (like Google and Apple) are offering competing financial products and services which are eroding into the profitability margins of traditional banks [9]. As a result, banks are digitizing their core products like credit cards, loans and payments to better compete with these entrants. They can better do so if there is some level of distributed autonomy in the enterprise so that digitalization efforts can be executed and delivered independent of other enterprise divisions and inherent enterprise rigidities.

- The ultimate goal (i.e., the implementation of a required business feature) of a mobile enterprise system is the same yet the front-end mobile and the back-end enterprise systems have significant autonomy with defined integration points for the successful completion of this business objective [10]. This allows both areas to maintain distinct culture, processes, methodologies, software tools and environment that are more conducive to their particular needs.
- The retail industry provides an excellent example for *decreasing* actor autonomy in the case of online vs. retail stores. Traditional retailers are attempting to provide a more uniform shopping experience across both segments (i.e., an omni-channel experience) but having two separate segments with significant actor autonomy would not produce the desired end-result [14]. So while the execution specifics between both segments may differ, there is a certain consolidation of actor autonomy with respect to higher level objectives.

Enterprise architects would have to be able to depict actor autonomy, actor objectives and goals, boundaries of actor influence, multiple levels at which these objectives and influences span and interactions between actors. They would also want to show any alignment (or misalignment) of actor objectives with the enterprise-level objectives.

### 3 Conclusions and Future Work

Transforming enterprises as a response to on-going digital change demands is rather difficult and needs to be considered in a structured manner particularly as enterprises are complicated entities with multifaceted social, process and technological elements; all of which can determine the success or failure of any adaptation exercise. The nature, complexity and texture of any enterprise adaptation may vary significantly and can cut across multiple industry segments. Current enterprise modeling approaches will need to be extended to better acknowledge and support today's highly dynamic environments. Enterprise architects would be expected to be more involved in the strategizing, planning and execution of digital transformation so that they can correctly design and devise the various alternate to-be configurations.

In [7] we attempted a preliminary characterization of an adaptive enterprise. We are exploring methods and techniques from diverse areas, including requirements engineering, system dynamics, and management frameworks, to contribute towards a framework for adaptive enterprise architecture. We envision a framework that would assist enterprises to deal with on-going adaptation demands such as those posed by digital transformation. We wish to understand the nature and texture of such enterprise "adaptiveness" requirements and the ways to capture the as-is and to-be adaptiveness characterization of the enterprise. Additions and enhancements to existing enterprise modeling techniques would be considered for assisting with visualization and analysis of these requirements. On the sensing side, the awareness requirements would be monitored and evaluated on an on-going basis for satisfaction of enterprise adaptive objectives. On the responding side, any dissatisfaction of these requirements results in the selection and implementation of a suitable to-be alternative that enables the

enterprise to adapt to changing circumstances. The alternative(s) would be selected while considering the tradeoffs between various factors existing at a social, contextual, process, and technological level.

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