Enterprise Architecture for Digital Transformation

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***Abstract*— Digital transformation requires an altogether new institutional logic and effective response at a requisite organizational level. Sensing and seizing fleeting market opportunities and reconfiguring the business in line with the shifting value proposition requires increasingly specialized resources, more dynamic capabilities, and in-built resilience in the face of change. While Enterprise Architecture (EA) has been suggested to facilitate enterprise transformation, the focus has traditionally been on process standardization and integration rather than on continuous adaptation to the changing business and technological landscape. For EA to have a desired impact, more adaptive conceptualizations of EA that address the requirements of the new digital environment are called for. In this conceptual paper, we explore the implications of digital transformation on enterprise architecture. In particular, we note that existing approaches to EA address integration and coherence within a single organization but typically fall short in the face of complexities pertaining to digital ecosystems. We suggest a vertical typology of organizational capabilities and postulate that today's digital environment increasingly requires adaptive capabilities that transcend the traditional notion of dynamic capabilities. We then investigate how EA can help build flexibility and resilience in the organization.**

Keywords — enterprise architecture, digital transformation, dynamic capabilities, adaptive capabilities

I. Introduction

In today's dynamic and complex environment, change is discontinuous, unpredictable, and much faster than response [1]. In the face of this hypercompetitive environment [2], defensible strategic positions [3] or even valuable, rare, inimitable and non-substitutable resources [4] no longer provide sustainable competitive advantage. Strategy in this environment is about developing a series of temporary advantages through semi-structured strategic processes that enable dynamic strategic repositioning [5]. The competitive differentiator lies increasingly in dynamic capabilities [6][7][8]: sensing and seizing opportunities as they emerge and rapidly reconfiguring the organization to changing circumstances on an ongoing basis [7]. In moderately dynamic markets, these dynamic capabilities take the form of "detailed, analytic routines that rely extensively on existing knowledge," whereas high-velocity markets require "simple, experimental routines that rely on newly created knowledge specific to the situation" [8].

Global competition and co-operation call for networked business ecosystems that pull together co-specialized capabilities in a nonlinear fashion, eliminating barriers of time and distance. On the other hand, information technology has had fundamental consequences in organizations and the society at large: unprecedented computing power, infinity of virtual space and ubiquitous connectivity have presented enormous potential to create enterprise effectiveness, increase flexibility and to enable entirely new business models. To manage the vast complexity of the business-IT amalgam, Enterprise Architecture (EA) has been suggested as a discipline to ensure coherent structure, to make visible the underlying organizational system, and to facilitate change.

While enterprise architecture has been suggested to facilitate enterprise transformation governance [9], it has been noted that few EA frameworks provide modeling and analysis support for adaptation to fast-moving environments [10]. Traditionally, enterprise architecture has focused on process standardization and integration (e.g. [11]), not on continuous adaptation to the changing business, information, social and technological landscape. Recently, there have been calls for a reconceptualization of EA and for a new research agenda more in line with the adaptive enterprise imperative [12].

We view that just as today's complex business environment calls for a new approach to strategy, EA in a dynamic business ecosystem setting requires a qualitatively different logic that transcends its traditional premises.

Our research question is as follows:

- What are the implications of digital transformation on enterprise architecture?

The literature on organizational capabilities, competencies and resources is markedly ambiguous and inconsistent. There is a broad consensus in the literature on the dichotomy between ordinary and dynamic capabilities. The former are first-order capabilities that are generally seen to maintain the *status quo* but not to create any change, while the latter are focused on change and often described as extending, modifying or changing ordinary capabilities. This, however, is where the consensus seems to end. There is considerable "ambiguity around capability types and their competitive focus, propensity to change, and fundamental mechanisms of action" [13]. While it has long been suggested that capabilities constitute a hierarchy [14][15][16], there is little agreement on both the nomenclature and structure of these hierarchies.

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Dynamic capabilities, in particular, has become a confusing catch-all term for a wide variety of interpretations [13]. A notable attempt to disentangle the confusion is the article by Hine et al. [13], in which the authors synthesize a hierarchy of three levels of capabilities.

The structure of this paper is as follows. In Section II, we first review the history of digital disruptions, considering the notion that digital transformation transpires as a series of revolutions, wherein digitalization is taken to progressively higher institutional levels [17]. In Section III, we review broad conceptualizations of enterprise architecture [18], levels of EA [19], and the relationship between the two [12]. The role of EA in enterprise transformation and steering is discussed in Section IV. Before suggesting an integrative framework and using it to analyze the changing role of EA in the face of digital transformation, we lay a foundation for the analysis in the form of a capability hierarchy, putting forward a vertical typology of capabilities in Section V. Our contribution and the response to the research questions is provided in Section VI: what is the impact of today's digitalization on enterprise architecture. Finally, we summarize the discussion and draw conclusions in Section VII.

II. History of Digital Disruptions

In a recent article, Korhonen [17] suggests that digital transformation transpires as a series of disruptions. Each such revolution seems to follow a common pattern, wherein new technological innovations emerge, proliferate and enable new ways of working and trading that were not possible before. He also posits that each revolution exalts digitalization to a new institutional level, at which it brings about an order of magnitude larger impact than before. The brief history of these digital disruptions since 1950s is summarized in TABLE I.

TABLE I. Digital Transformation Transpires as a Series of Disruptions [17].

Revolution	Ascension	Enablers	Leverage
Computational Revolution	1950	Electronics + Binary computation	Management Information System
Communications Revolution	1980	Personal computer + Telecommunications	Strategic Information System
Commercial Revolution	1995	The Internet	Business Model
Collaborative Revolution	2010	Social + Mobile + Analytics + Cloud	Platform Ecosystem
Cognitive Revolution	Imminent	Cognitive technologies	Global Brain

A. Computational Revolution

The advent of general-purpose stored-program electronic digital computers in the late 1940s denoted the first digital disruption. This *Computational Revolution* [17] was enabled by the combination of electronics technology with digital computation in binary. Unforeseen computation power could be harnessed to handle larger and larger quantities of data and to address increasingly complex calculations. In the mainframe era [20] that followed, computing penetrated most functional areas in business. It enabled extracting and summarizing data from the underlying transaction processing systems to management information systems that facilitated solving structured and semi-structured decision problems of operational and middle managers.

B. Communications Revolution

The next breakthrough was the *Communications Revolution* [17], accelerated by the introduction and rapid increase in the number of personal computers in the 1980s. Rapid developments in telecommunications technologies and the proliferation of personal computers meant a paradigm shift from centralized computing to a "federal" IT structure [21]. In the distributed era that ensued, market for ICT services emerged, outsourcing abounded, and leading companies used technology to redesign their business networks [20]. Strategic information systems, built on company-specific strengths, were intended to provide competitive advantage.

C. Commercial Revolution

In the mid-1990s, the Web heralded the *Commercial Revolution* [17], wherein the very business models stemmed from the landscape-changing properties of the Internet: universal, open standards; infinite virtual capacity; reduced transaction costs; reduced information asymmetry; disintermediation; network externalities [22]. Coinciding with deregulation and new emerging markets, the onset of the Internet denoted a relentless push for lower costs, higher performance, and new innovations.

D. Collaborative Revolution

According to [17], we are currently living in the aftermath of *Collaborative Revolution*, brought about by the synergistic SMAC technologies (Social, Mobile, Analytics, Cloud) that emerged to prominence around 2010. Social media provides businesses new access to customers, and mobile technologies enable new ways to interact and communicate. Business analytics leverages "Big Data" produced by social and mobile to predict customer needs with unprecedented accuracy and speed. The Cloud provides a ubiquitous computing platform that enables and accelerates all of the above. It has transformed the development and delivery of digital services. Advantages include zero initial investment, decreasing unit cost, and usage based cost structure. Ever-smaller components of functionality can be sourced separately and composed together. Solutions can be constructed of an increasing number of pieces in various granularities. At the same time, the delivery of lowest level building blocks is concentrated in the hands of only handful global providers. SMAC technologies have together paved the way for the rise of platform economy and ecosystems. [17].

E. Cognitive Revolution

On the imminent horizon would loom the next wave of digital disruption: *Cognitive Revolution* [17]. Ushered in by cognitive technologies such as artificial intelligence, machine learning, natural language processing, or robotics, cognitive computing will "inexorably, infinitely and irreversibly transform the world as we know it" [17].

III. Conceptualizations and Levels of Enterprise Architecture

As a relatively young discipline, enterprise architecture is lacking a shared vocabulary, the discourse is relatively incoherent and fragmented, and definitions of EA range widely. Recently, there have been some attempts to make sense of the underlying structural and metaphysical underpinnings of the field. In this section, we review the seminal typology of three schools of thought on enterprise architecture [18], the tripartite model of EA [19], and a juxtaposition between the two [12].

A. Schools of Thought on EA

To make sense of the vast pluralism in the EA discourse, Lapalme [18] identifies three schools of thought on EA, each with its distinct belief system, scope and assumptions: Enterprise IT Architecting, Enterprise Integrating, Enterprise Ecological Adaptation.

The *Enterprise IT Architecting (EITA)* school views enterprise architecture as "the glue between business and IT". Focusing on enterprise IT assets, it aims at business-IT alignment, operational efficiency and IT cost reduction. It is based on the tenet that IT planning is a rational, deterministic and economic process. EA is perceived as the practice for planning and designing the architecture.

The *Enterprise Integrating (EI)* school views enterprise architecture as the link between strategy and execution. EA addresses all facets of the enterprise in order to coherently execute the strategy. The environment is seen both as a generator of forces that the enterprise is subject to and as something that can be managed. EA is utilized to enhance understanding and collaboration throughout the business.

The *Enterprise Ecological Adaptation (EEA)* school views EA as the means for organizational innovation and sustainability. The enterprise and its environment are seen as coevolving: the enterprise and its relationship to the environment can be systemically designed so that the organization is "conducive to ecological learning, environmental influencing and coherent strategy execution." EA fosters sense making and facilitates transformation in the organization.

B. Levels of Enterprise Architecture

Korhonen and Poutanen [19] propound that architectural work in an enterprise be designed and built around organizational accountability levels and be divided vertically into three distinct yet interlinked architectures: Technical Architecture, Socio-Technical Architecture, and Ecosystemic Architecture. Each of these architectures would be self-contained and self-regulated with its paradigmatic function, methods, and tools.

Technical Architecture (A^T) [19] has an operational focus on reliability and present day asset utilization and is geared to present-day value realization. This is the realm of traditional IT architecture, information systems design and development, enterprise integration and solution architecture work. A^T also addresses architectural work practices and quality standards, e.g. architectural support of implementation projects, development guidelines, and change management practices. In terms of organizational structure, A^T would pertain to the technical level of organization [23][24], where the products are produced or services are provided [19].

Socio-Technical Architecture (A^S) [19] plays an important role as the link between strategy and execution. The business strategy is translated to a coherent design of work and the organization so that enterprise strategy may be executed utilizing all its facets, including IT [25][26]. A^S is about creating enterprise flexibility and capability to change rather than operational optimization: the focus on reliability is balanced with focus on validity in anticipation of changes, whose exact nature cannot be accurately predicted. A^S would pertain to the managerial level of organization [23][24], where the business strategy is translated to the design of the organization [19].

Ecosystemic Architecture (A^E) [19] is an embedded capability that not only addresses the initial design and building of a robust system but also the successive designs and continual renewal of a resilient system. The architecture must allow for co-evolution with its business ecosystem, industry, markets, and the larger society. A^E would pertain to the institutional level of organization [23][24], where the organization relates to its business ecosystem, industry, markets, and the larger society [19].

C. Relationship Between the Conceptualizations and Levels of Enterprise Architecture

One of the essays in a recent position paper on "Adaptive EA" [12] features a juxtaposition of the three schools of thought on EA [18] with the tripartite approach to EA [19] as shown in TABLE II.

TABLE II. Adaptive and Maladaptive EA [12].

	Enterprise IT Architecting (EITA)	Enterprise Integrating (EI)	Enterprise Ecological Adaptation (EEA)
Ecosystemic Architecture	"Analysis paralysis." Lock-in in the as-is.	Inadequate renewal. Failure to sense and seize opportunities. Indifference to the wider context. Adapting to but not creating change.	EA that fosters innovation and sustainability. System-in-environment co-evolution. Environment can be changed.
Socio-Technical Architecture	Clinging to "best practices" Limited view of the scope and potential of architecture. Disconnect with the strategy.	EA is the link between strategy and execution. Holistic, systemic view of the enterprise. Choosing tactics. Changing the business.	Adaptive enterprise. Business modularity.
Technical Architecture	Architectural descriptions. EA is the glue between business and IT.	EA aimed at business outcomes. Solution architecture.	Optimized core of digitized data and processes.

In the essay, it is conjectured that the EITA perspective [18] would be requisite in Technical Architecture (A^T) [19], when the environmental complexity is low. The perspective would, however, fall short at the level of Socio-Technical Architecture (A^S) [19] that pertains to 'Changing the Business' activities [27]. According to Korhonen et al. [12], "clinging to familiar 'best practices,' failing to see all facets of the enterprise, lack of appreciation of the strategic context, and limited view of the potential of architecture" can be seen as maladaptations of segmentation, dissociation, superficiality, and doomsday [28], respectively. In the face of Ecosystemic Architecture (A^E) level complexity [19], the shortcomings of EITA would be even more pronounced.

As per this view, an environment of moderate complexity would call for both A^T and A^S [19] from the EI perspective [18]. Such environment would require visibility into the organization's internal workings, intelligence on competition, as well as collaboration and mutual inquiry to foster shared understanding [12].

Finally, a highly complex environment would require response at all levels of architecture, A^T, A^S and A^E [19], and the EEA perspective [18]. According to Korhonen et al. [12], such architecture must allow for co-evolution with the business ecosystem, industry, markets, and the larger society; address the structural embeddedness among exchange partners, e.g. open-ended social contracts, information architecture of ecosystem total solutions, interorganizational interdependencies, shared destiny relationships, management of obligations, expectations, etc.; subscribe to adaptive enterprise principles (cf. [29]); and cater for business modularity on top of the optimized core of digitized data and processes [11].

IV. EA IN ENTERPRISE CHANGE AND STEERING

Enterprise change may take a myriad of forms. It may be pre-meditated and driven top-down or spontaneously self-organize bottom-up; it may be proactive in anticipation of value opportunities or reactive to value crises; it may be contained in scope and rapid in implementation, or large in scale and slow in coming. It may pertain to restructuring work, reengineering business processes, innovating new products or services, or rethinking the entire business model. In the following, we will first review Proper's [30] conceptualization of enterprise in motion and EA's role in supporting that motion. Then, we discuss how the recent EA trend of Capability-Based Planning is conducive to informed governance and steering of change, yet falls short in the face of unpredictable change that calls for sense-and-response and customer pull rather than planning and production push.

A. Enterprises in Motion

Proper [30] generalizes all enterprise change to the notion of enterprise in motion: while the enterprise needs to bring value to its stakeholders, it also needs to constantly readjust itself in the face of experienced and/or expected value deficiencies (cf. [31]). Proper [30] distinguishes between two aspect systems of an enterprise, respectively: 1) the running system, and 2) the motioning system.

Steering the motion of the enterprise can take a number of forms: e.g. planning, managing and governing change; fostering change-oriented culture; or guiding the organization through crises. Steering comes with overhead, but is often justified by benefits due to better fit between the organization's actual and potential value generation. Proper [30] also distinguishes two additional aspect systems: 1) the producing system, and 2) the steering system. This gives us a high-level abstract view on enterprise change, depicted in Fig. 1. The running system governs the production of value for the present, and in the motioning system, the production of value for the future is steered.

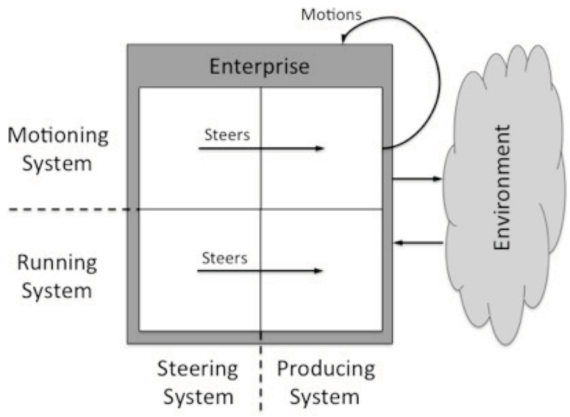

Fig. 1. Steering motion in the enterprise (adapted from [30]).

Enterprise architecture provides an important means for *informed governance* [9][32] of enterprise transformations. It comes with the necessary indicators and controls to help *transformation authorities* make informed and coordinated decisions pertaining to the portfolio of enterprise transformation efforts. Korhonen and Molnar [33] view that as opposed to enterprise-wide IT architecture that merely addresses the execution and governance of the *operational enterprise system*, enterprise architecture would facilitate the governance of transformations within the *enterprise transformation system* [32].

Proper [30] also investigates the potential role of EA to support senior management in steering enterprises in motion. He positions architectural steering (and thinking) between strategic level steering and design level steering.

B. Capability-Based Planning

A recent trend in enterprise architecture practice that facilitates informed governance and steering of change is Capability-Based Planning (CBP). CBP is a technique for planning of investments in capabilities that will help achieve the business outcomes as specified in strategy [34]. It is a powerful mechanism to ensure that the strategic business plan drives the enterprise top-down [35]. The method is focused on planning the required business improvements in terms of value-adding capability increments that represent a measurable change in the maturity of the capability.

While a capability will take an extended time to deliver, it needs to provide real business value to stakeholders as soon as

possible. To maintain momentum and to secure executive support and corporate funding, it is customary to break the capability into capability increments that deliver discrete, visible, and quantifiable outcomes. [35].

C. Adaptive Enterprise

Planned responses, however, fall short in the face of a turbulent environment. Unpredictable change calls for adaptive strategy. According to Haeckel [29], this means becoming a sense-and-response organization that is based on customer pull rather than production/marketing push. Capabilities and resources are organized in a modular fashion and dispatched on demand as opposed to scheduling them in advance. Key differences between a make-and-sell and a sense-and-response organization are exhibited in TABLE III.

According to Haeckel [29], systematic and successful adaptation can be designed around the *adaptive loop* that consists of four generic phases: 1) *Sensing* changes in the system's environment and in its internal states; 2) *Interpreting* these changes in their context; 3) *Deciding* how to respond; and 4) *Acting* on the decisions.

TABLE III. MAKE-AND-SELL VS. SENSE-AND-RESPONSE [29].

Make-and-Sell	Sense-and-response
Business as an efficient mechanism for making and selling offers to well-defined market segments with predictable needs	Business as an adaptive system for responding to unanticipated requests in unpredictable environments
Repeatable processes, replaceable parts, standard job definitions	Modular products and services, modular capabilities that are linked to create customized responses
Economies of scale	Economies of scope
Centralized planning	Decentralized decisions within a shared context
Functional and sequential activity	Networked and parallel activity
Functionally managed and optimized	Unified enterprise view
Strategy as plan	Strategy as adaptive business design

V. LEVELS OF CAPABILITIES

While it has long been suggested that capabilities form a hierarchy [14][15][16], there is considerable "ambiguity around capability types and their competitive focus, propensity to change, and fundamental mechanisms of action" [13]. In the following, we aim at untangling this confusion by identifying six levels of capabilities based on an integrative review of the literature: 1) zero capabilities, 2) routine capabilities, 3) systemic capabilities, 4) creative capabilities, 5) strategic capabilities, and 6) adaptive capabilities.

A. Zero Capabilities

With *zero capabilities*, we refer to those elementary, atomic activities in the organization that are so pedestrian that they do not provide even a short-term competitive advantage [13]. They are the minimum requirement for an acceptable level of business operations.

B. Routine Capabilities

With *routine capabilities*, we refer to first-level capabilities [13] that "reflect an ability to perform the basic functional activities" [15]. These are static routines that the organization does at any given time given its stock of factors of production [14]. They are focused on everyday subsistence tasks of the organization using current resources [13]. These capabilities have some impact on the competitiveness [13].

C. Systemic Capabilities

Systemic capabilities are focused on change and use less-patterned routines and more specialized resources than routine capabilities (cf. [13]). These dynamic functional capabilities [13] pertain to "repeated process or product innovations, manufacturing flexibility, responsiveness to market trends and short development cycles" [15]. The notion is also in line with the definition of organizational capability by Helfat and Peteraf [36]: "the ability of an organization to perform a coordinated set of tasks, utilizing organizational resources, for the purpose of achieving a particular end result."

D. Creative Capabilities

Creative capabilities are about organization-specific creative ability – "the more metaphysical strategic insights that enable firms to recognize the intrinsic value of other resources or to develop novel strategies before competitors" [15]. These dynamic learning capabilities [13] operate to extend, modify or create ordinary capabilities (cf. [16]). The concept is commensurate with notions such as distinctive competence [37][38] or core competence [39].

E. Strategic Capabilities

Strategic capability refers to the organization's ability to use its creative capabilities. As such, the notion is comparable to that of organizational capability as defined by Moingeon et al. [40] and Kangas [41]. A specific type of such capability is the capacity to learn ([42], cited in [40]). Teece, Pisano and Shuen [6] refer to this capacity to renew competences to achieve congruence with the changing business environment as dynamic capabilities.

F. Adaptive Capabilities

While strategic capabilities provide competitive advantage in moderately turbulent environments, highly turbulent environments call for *adaptive capabilities* that enable the organization to quickly respond to and effectuate change in its environment to ensure its effectiveness in the shifting context. This resilience does not only pertain to recovery, flexibility, or crisis preparedness, but also to a capacity for continuous innovation [43]. In some cases, the inherent limits of the organization's resilience are reached and it must completely transform to maintain its existence of function in a new stability domain [44].

Adaptive capabilities enable quick creation of new knowledge (cf. [8]) and improvised response to rapid, unpredictable, and novel events (cf. [45]). As high uncertainty, high risk environments do not allow time to respond effectively, these capabilities often rely on the network [46].

VI. Enterprise Architecture for Digital Transformation

A. Integrative Framework

Our research question was: "What are the implications of digital transformation on enterprise architecture?"

Based on the theoretical review above, we can approach this question by conceptualizing digital transformation as an evolutionary series of digital disruptions (cf. [17]). We reason that enterprise architecture could then be most adaptively viewed from the Enterprise Ecological Adaptation perspective (cf. [18]). It would not only need to address the Technical (A^T) and Socio-Technical (A^S) levels of architecture, but also the Ecosystemic Architecture (A^E) (cf. [19]).

We further posit that exaltation of digital transformation to the level of business ecosystems and industries would mean that competitive advantage would require what we call adaptive capabilities. As shown in TABLE IV. we also postulate that the next wave of digital disruption, manifesting at the global societal level, would bring about the need of generative capabilities – the capacity to proactively and endogenously create the future – but do not elaborate on this type of capabilities in the context of this paper.

TABLE IV. Progressive Institutional Logics Along Strategy, Capabilities, and Enterprise Architecture

Capabilities	Institutional Level	Nature of EA	Levels of EA
Generative Capabilities[a]	Global societal	Enterprise Ecological Adaptation	$A^E + A^S + A^T$
Adaptive Capabilities	Ecosystem		
Strategic Capabilities	Business / Organization	Enterprise Integration	$A^S + A^T$
Creative Capabilities	Functions		
Systemic Capabilities	Work systems		
Routine Capabilities	Processes	Enterprise IT Architecture	A^T
Zero Capabilities	Activities		

[a] Speculative level, not elaborated in this article

In line with Proper [30], we postulate that in each "enterprise in motion": 1) There are *steering capabilities* and *producing capabilities* pertaining to the Steering System and Producing System, respectively; 2) Zero capabilities and routine capabilities (see Section V) belong to the Running System; 3) Creative and strategic capabilities pertain to the Motioning System; 4) Systemic capabilities constitute boundary capabilities between the Running and Motioning Systems (see Fig. 2).

While we appreciate the applicability of Proper's [30] model (Section IV) in the scope of a single organization, we would argue that higher order capabilities would transcend this remit. We postulate the Generative System (see Fig. 2) that governs the constitution and co-adaptation of the system of systems at the ecosystemic level. Extrapolating the reasoning above: 5) Adaptive and generative capabilities pertain to the Generative System; 6) Strategic capabilities constitute boundary capabilities between the Motioning and Generative Systems.

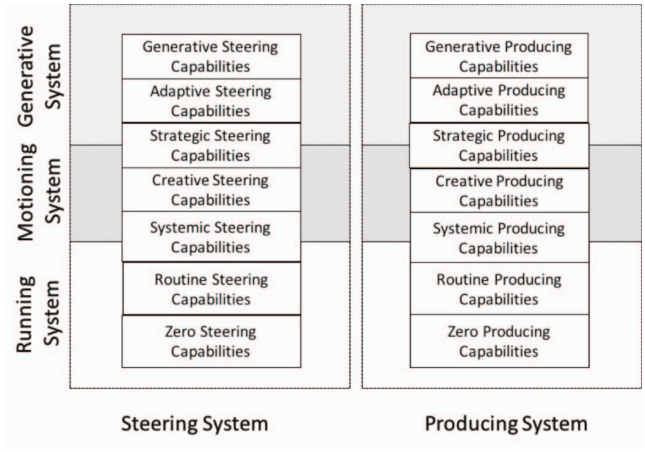

Fig. 2. Classification of capabilities.

Enterprise transformation is driven by experienced and/or expected value deficiencies, e.g. losses of value or failure to meet anticipated gains of value [31]. These value deficiencies cannot be properly addressed through steering of the Running System [33]. Creating new value calls for motioning the enterprise and steering this motion in the Motioning System: radically redesigning business processes, developing new products/services, or changing the business model altogether.

While the traditional enterprise-wide IT architecture facilitates enterprise transformations within the operational enterprise system, informed governance of more value creation oriented enterprise transformations would call for the extended conceptualization of enterprise architecture [33]. The CBP approach [34] appears to help informed and coordinated decision-making related to the portfolio of enterprise transformation efforts (cf. [9]). While the CBP and other business architecture oriented approaches address integration and coherence within a single organization and are applicable at the level of Socio-Technical Architecture [19], they would merely seem to subscribe to the Enterprise Integration school of thought [18] and thereby fall short in the face of complexities pertaining to digital ecosystems. The Ecosystemic Architecture [19] would seem to call for a sense-and-response approach [29] that transcends traditional EA.

B. Digital Transformation Dissected

As per Section II, the latest digital disruption is about elevating digitalization from the enterprise level to that of the ecosystem. In the light of Section V, this digital transformation, as casually called, would denote a shift from the level of strategic capabilities to the level of adaptive capabilities. TABLE V. exhibits the manifestation of different aspects of digital capability at the enterprise-strategic and ecosystem-adaptive level, respectively.

Whereas the commercial revolution of the 1990s had enabled radically new digital business models, the ongoing digital transformation sees the emergence of the platform as a business model. Compared to the platforms of the pre-platform age, the digital platforms of today are customer-oriented, vibrant, robust, dynamic, co-operation-based, and often open source and standards-based [48]. Well defined

boundary resources will drive platform utilization. Technical (e.g. SDKs, APIs) and social (e.g. responsibilities of parties, monetization models) boundary resources form together the foundation for a successful platform. It is important to recognize that apart from being a platform owner there are multiple ways of gaining from platform economy as an ecosystem player.

TABLE V. MANIFESTATION OF COLLABORATIVE REVOLUTION ALONG DIFFERENT ASPECTS OF DIGITAL CAPABILITY

Aspect of Digital Capability	Enterprise-Strategic Level	Ecosystem-Adaptive Level
Digitization of Business	Digital business model	Digital platform business model
Digitization of Work	Integrated digital enterprise	Digital ecosystem
Collaboration and Connectivity	Technology-enabled collaboration	"Plug-and-play" digital connectivity; Smart contracts
Customer Engagement	Service co-production; predictive analytics driven business design and multi-channel engagement	Responding to customer needs through prescriptive analytics and optimization (near) real-time; Augmented reality; Intelligent assistants
Information Management	"Analytics 2.0" [47]: predictive Big Data analytics; Data Science	"Analytics 3.0" [47]: analytics and optimization embedded into operational business decisions; Data aggregation as a business
Technology Management	Cloud environment, data center architectures, distributed storage and computation technologies	Stream computing; Container technology; Internet of Things
Resource Use	Predominately internal resources or recources from external providers	Resources combined freely from vast selection of service or functionality providers

At the enterprise-strategic level, the management of digital information, information technology, and information products must be intertwined into an integrated digital enterprise that implements the digital business model. At the ecosystem level, these digital businesses must additionally be co-adaptive and nimbly respond to and effectuate environmental change.

In terms of collaboration and connectivity, simple relationships between two or few organizations are being supplanted by distributed partnerships within vast networks. Not only do digital technologies of today enable collaboration, but they also allow for standards-based "plug-and-play" interoperability and smart contracts (notably with blockchain technology). Hence, to fully exploit this development, enterprises should structure their architectures flexible and easily adaptable.

Customers have long been involved in co-production of services and experiences in design time, and predictive analytics have informed business design. However, digital data trails are increasingly being analyzed to data-enrich offerings in a real-time, closed-loop fashion. The customer experience will be enriched with augmented reality features and artificial intelligence powered intelligent assistants.

At the enterprise level, enterprise-wide integrated data governance is required to continually reconfigure the organization along with its co-evolution with the ecosystem [49]. Big Data is sourced from the organization's internal transaction systems as well as from external sources such as the social media platforms, sensors of various types, and captures of audio and video recordings. True data aggregation from multiple internal and external sources will be possible for the first time. Predictive analytics models are used to forecast the future. At the ecosystem level, information management must enable operational analytics [50], wherein analytics and optimization are embedded into operational business decisions that must be executed immediately.

In terms of technology, enterprise-level Big Data requires distributed database and computing technologies: public or private cloud computing environments, virtualized data center architectures, parallel data processing, "in memory" and "in database" analytics, and new database technologies geared to relatively unstructured data. At the ecosystem level, social media, mobile computing, and Internet of Things have further increased the volume, velocity, and variety of data. On the one hand, the technical architecture must deal with unstructured data discovery over very large data sets that may have very high latency. On the other hand, adaptive analytics activities bring the analytics to a conversation level and require very low latency [51]. To achieve real-time, or "decision-time" [50], analytics, the architecture must also enable stream computing: real-time identification, data synthesis, and scoring. Whereas only ten years ago most enterprises preferred having their IT operations on premises, the trend is now towards public clouds. Now container technology allows enterprises to shift their applications or even individual functions from one cloud service provider to another.

At the enterprise-strategic level, the use of resources is predominately characterized as resource planning that combines internal and external resources. The cycle of change is typically longer, and the use of external resources is based on relatively static contracts. At the ecosystem level, the ever smaller pieces of resources (e.g. services, functionality) are combined more freely, dynamically, and temporarily. This calls for a good understanding of available resources and ability to utilize them both technologically and economically.

C. *Enterprise Architecture. Now.*

As suggested in [19], the EA methods and tools for Ecosystemic Architecture would be different from those of Technical or Socio-Technical Architecture (i.e. the traditional scope of EA). It would also be based on the ontological and epistemological premises of the Enterprise Ecological Adaptation school of thought on EA [18] rather than Enterprise Integration or Enterprise IT Architecting school. In the following, we outline, in broad strokes, how some faculties

of such adaptive enterprise architecture in a multi-organization digital ecosystem might look like.

Pivotal in this surmise is the notion of adaptive capability as outlined in Section V. The organization must sense and respond to the shifting context in all phases of the adaptive loop [29]: 1) real-time surveillance of external and internal environments (*sense*); 2) continuous evaluation of the organization's value proposition, value creation, and value appropriation (*interpret*); 3) ability to make decisions (*decide*); 4) ability to reconfigure and orchestrate infrastructure and services across the ecosystem (*act*).

TABLE VI. CHANGING ROLE OF EA AND TECHNOLOGICAL CATALYSTS ALONG DIFFERENT PHASES OF THE ADAPTIVE LOOP

Phase in Adaptive Loop	Changing Role of EA	Essential EA Faculties	Technological Catalyst
Sense	From time-consuming up-front data gathering and modeling to up-to-date real-time informational representation of the enterprise	Surveillance; Technology watch; Business watch	Stream computing; Intelligent sensors; Mobility / Connectivity
Interpret	From gap analysis of "as-is" vs. "to-be" to analytics-based prescriptions	Impact analyses and simulations; Pattern recognition	Real time prescriptive analytics
Decide	From centralized planning, prediction and analysis to principles-based decentralized experimentation and adaptation	Architectural principles; Distributed decision making; Commitment management	Technological decentralization
Act	From monolithic enterprise architecture to modular and flexible ecosystem architecture	Flexible and adaptible framework; Boundary resources; Ecosystem management; Probing	Modular digital ecosystem

Enterprise architecture would support digital capability throughout the adaptive loop, providing a systematic means for early identification and fast response to important trends and events both inside and outside an enterprise (cf. [50]). In the following, we discuss how EA can support the four phases of the adaptive loop.

Sense: Haeckel [52][29] likens information-driven business to the fly-by-wire systems of modern fighter airplanes. Just as computer systems distill essential information for pilots and translate their responses into a multitude of actions, adaptive organizations are managed by wire: leveraging technology to sense and make sense of information and to enact pertinent actions more effectively. The sensing is achieved through technology and business foresight, continuous surveillance of signals, identification of events, data synthesis, and scoring. Stream computing and intelligent sensors are but some examples of new technologies that augment the organization's sensing. An important feature of adaptive enterprise architecture is that it is updated in "real time" rather than periodically.

Interpret: Real-time, or "decision-time" [50], operational analytics is embedded into virtually all business decisions at the front lines of operations. The digital data trail is analyzed to provide prescriptive recommendations that support decision-making. To validate the foresight insights, enterprise architecture can be used to run impact analyses and simulations on hypothetical change scenarios. The relationship between cause and effect in a complex environment is non-linear [53]. Patterns emerge, but any attempts to inspect, categorize or analyze them in a structured way are futile. However, deep learning on big data sets can potentially be leveraged to recognize patterns in enterprise-in-environment dynamics and make them visible.

Decide: Simple rules [5][54] expedite decision-making to flexibly seize attractive and unexpected opportunities as they arise [55]. Architectural principles provide a powerful simple-rule-like vehicle to effectively guide design decisions, while preventing analysis paralysis [56]. On the other hand, unexpected external events are diverse in nature, have a large impact, and are difficult to address and to dispatch to the right decision layer [57]. To ensure that the analytics-enabled foresight has an impact, enterprise architecture should help communicate the generated insights directly to the decision-makers at different organizational levels. The dynamic dispatching of issues could be facilitated with a proper commitment management system [29] that coordinates the behaviour of people in accountable roles.

Act: In the face of digital transformation, a key capability is to rapidly develop new IT solutions to keep on par with the fast-paced competitive environment. Innovation is not just about inventing entirely new products and services within the organization, but innovation is increasingly distributed across organizational boundaries. Solutions are composed of smaller, co-specialized components [58] and increasingly sourced as services. The EA shall help manage interdependencies between organizations. Modularity in product, service and organization designs 'glues' together loosely coupled parts and begets strategic flexibility, but it requires standardized component and organization interfaces, lest adaptive coordination becomes prohibitively difficult [59]. A clear set of social and technical boundary resources is requisite for a well-functioning platform, and enterprise architecture can be of great help in managing these boundary resources. On the other hand, EA shall support "planned spontaneity" and impromptu activities in the face of unanticipated environmental events and crises, rapid reconfiguration of operational capabilities, and individual initiative that calls for creativity and intuition (cf. [45]). In this setting, patterns can be elicited by creating probes, and the desirable patterns can then be amplified and undesired ones attenuated [53].

VII. DISCUSSION AND CONCLUSIONS

Digital transformation is about fully utilizing new technological possibilities to create value and competitive advantage. To customers, this is essentially manifested in

enhanced or entirely new products and services. This transformation has often a profound impact on the business model, operating model, organizational structure, and key resources of the organization. EA must support this transformation through evaluating and reconfiguring the value creation and value capture mechanisms of the enterprise.

Innovation and agile development require an entirely different mindset than traditional application development. This apparent cultural and even psychological discrepancy has forced several enterprises to establish a separate innovation unit, while the traditional IT units continue to maintain the legacy. However, there is a real danger that having a separate innovation unit leads to separate solutions. Unless these solutions are integrated into the operating core, there is a considerable risk of ending up with a scattered, difficult-to-reconfigure production environment and rising costs.

Winter [16] argues that dynamic capabilities typically involve long-term commitment to specialized resources. In less turbulent environments, these investments might not be justified. While we acknowledge the possibility of over-investing in a less turbulent environment, we would argue that today digital transformation is present in virtually every industry. Preparing for the turbulence should be a priority for all, at least for information-intensive enterprises. Therefore, rather than resorting to ad-hoc solutions and decision-making, adaptive capabilities and flexible structures should be systematically developed and managed.

In the past, EA has predominantly been a practice within the IT organization and focused on modeling the IT landscape from Enterprise IT Architecting [18] perspective. Business leaders have not been embracing these technical practices. In some organizations, EA has been used to promote a common understanding and shared meanings at the enterprise level, thus subscribing to the Enterprise Integrating school of thought [18]. Lapalme's [18] Enterprise Ecological Adaptation is still largely just a conceptualization, but in the age of digital transformation, there is a clear need to embrace the new logic of EA. In this paper, we have attempted to outline this logic.

Digital transformation is often run as a separate program or unit within an enterprise. We view, however, that in this case the full potential of digital transformation cannot be leveraged. Instead, it should be fully integrated with every level and function of operation in the enterprise. Digital disruption will affect organizations thoroughly, and responding to constant change requires action at all levels of the enterprise. Managing the whole infrastructure and services sourced from several providers is an essential capability for a successful enterprise.

Since the functionality of dynamic capabilities can be duplicated across enterprises, their value for competitive advantage lies in the resource configuration that they create, not in the capabilities themselves [8]. However, we argue that the current development of platform economy allows dominant players to seize the market through customer accumulation and to foster generativity for network effects. Competitive advantage lies in the speed in which adaptive capabilities are exercised to achieve market dominance and new competitors are prevented from entering the market.

In conclusion, sustainable competitive advantage in highly turbulent environments calls for in-built organizational flexibility and resilience. The capability to sense, interpret, decide and act based on real-time information seems to be of particular essence. This requires an up-front design of adaptive capabilities and respective enabling structures and mechanisms. EA bears potential to support such adaptive capabilities, but it needs to be reconceptualized from Enterprise Ecological Adaptation point of view (cf. [18]). It has to be borne in mind, however, that capability development is highly path-dependent. Achieving higher level capabilities requires first mastering the lower ones. Enterprise architecture can also play an essential role in facilitating the evolution to higher level capabilities.

The literature is relatively scant in the area of adaptive EA in the digital transformation context. We hope that this study makes a small step towards better understanding of EA's changing role in the digital platform ecosystems. However, further research, particularly empirical studies, and conceptualization of the theme is required.

VIII. REFERENCES

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