Systems Approaches in the Enterprise Architecture Field of Research: A Systematic Literature Review

Jarkko Nurmi, Mirja Pulkkinen(✉), Ville Seppänen, and Katja Penttinen

Faculty of Information Technology, University of Jyvaskyla, P.O. Box 35, 40014 Jyväskylä, Finland
{jarkko.nurmi,mirja.pulkkinen,ville.r.seppanen, katja.penttinen}@jyu.fi

Abstract. This study explores the use of the systems approaches (systems thinking and systems theories) as the theoretical underpinnings for Enterprise Architecture (EA) research. Both the academic and the practitioner communities have maintained an interest in EA due to its potential benefits, promising for the recent technological and business advances. EA as a research area is, however, characterized by diversified views depicted in different definitions of the concept, and no acknowledged common theoretical foundation. A number of prior studies have noticed this gap in the EA field of research, and called for a strengthening of the theory of EA. Variegated systems approaches have been suggested as a theory base. The aim of this study is to examine if, and to what extent the systems approaches could provide a common theoretical foundation. We contribute with a systematic literature review on the state-of-art of systems approaches in EA research. We find that the systems approaches are, indeed, frequently referred to in the EA studies. However, as of yet, the application of these theories appears to be fragmented, and the approaches are rarely systematically used in empirical studies. We discuss the findings, reflecting to the types of theory and the use of theory in our area of research.

Keywords: Enterprise architecture · Systems thinking · Systems theory Systems approaches · Literature review

1 Introduction

Enterprise architecture (EA) appears to maintain some interest in research. This might be due to the potential solutions it offers to some of the present problems organizations face with the current emerging technologies and growing complexity [33]. EA presents a tool for alignment between business and IT, an issue still judged as one of the top three management concerns [34]. Further, some evidence of business benefits attained with this approach have been brought up recently [49].

Definition of enterprise architecture varies by its use [6, 32, 39, 55]. However, we start out by defining EA loosely as an approach to manage, plan and develop enterprises and their IT. As a unit of analysis, enterprises or organizations, that, even if

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networked or federated and thus depending on their environments, have some decision-making authority over their own resources and their goal setting (See e.g. [22]; Definition 2.7). The need for an architectural approach to the management of the business-IT alignment emerged with the diffusion of IT and the emergence of networking technologies already decades ago [6]. Technology developments today keep driving the need, giving new emphasis to the vision: "enterprise analysis tools that are growing in importance and are likely to become mandatory for any business that continues to grow and evolve" [62]. This outlines the need for an approach to apply to at least medium or large size organizations. The need appears in the context of the use of IT in organizations. The term 'enterprise architecture', was coined later, and its focus has been enlarging to cover also the strategic planning [27, 42], to support the business and IT alignment [6, 44].

Various systems approaches are applied in EA research, and the idea of viewing enterprises as systems finds support in the related research areas. In management science, the research of management and organizations, systems theory used to have a strong resonance [15], summarized in a related special issue of the Academy of Management Journal [1], however, the interest appearing to fade over time [3].

For EA, an early example of systems theory use is the Systemic EA Method (SEAM) [59]. Recently, Santana et al. [46] conducted a literature review and a description of EA network analysis that sees enterprises as complex networks. Fu et al. [16] discussed complexity cybernetics in relation to EA, and, based on an analysis of 33 papers, concluded that despite growing interest, neither EA cybernetics, nor other systems approaches have been yet established as a theoretical foundation for studies in this field. Lapalme [32] encourages taking on the systems thinking and system-in-environment paradigms for the evolving EA approach.

The need for an acknowledged theoretical foundation for EA has been noted by previous research [e.g. 7, 25, 26]. Several other studies [e.g. 19, 21] have discussed the systems nature of an enterprise, and researchers have noted a need to strengthen the theoretical roots of enterprise architecture as well as to study its relations to other fields, such as systems thinking [5, 33]. For example, Kappelman and Zachman [28] point that "[…] the EA trend of applying holistic systems thinking, shared language, and engineering concepts, albeit in the early stages of their application, is here to stay". Furthermore, [42] state the "importance of systems thinking and, especially, of adopting the open systems principle, for managing EA design and evolution".

The aim of this study is to find indications, if, and to what extent, the systems approaches could provide a common theoretical foundation for EA. We conduct a systematic literature review to answer the research questions:

- RQ1: To what extent different systems approaches are already in use in EA research?
- RQ2: What aspects of theory do the systems approaches cover in earlier studies?

The remainder of this paper is structured as follows: First, the concept of enterprise architecture is presented in Sect. 2. Next, Sect. 3 presents and briefly discusses the systems approaches, and the elements shared across the different approaches. Additionally, we take a look into the significance of theory for a research area. In Sect. 4, the research method of this study, the systematic literature review (SLR) protocol is

presented. Sections 5 and 6, respectively, present the analysis and discussion of the SLR results. Finally, we conclude with some remarks on the state-of-art account of the systems approaches to the field of EA, and questions opening for future research.

2 Enterprise Architecture as an Evolving Research Area

Some work regarding the various definitions of EA already exists. For example, Schönherr [48] discusses a total of 126 references from 1987 to 2008 and concludes that majority of these do not define EA in a comprehensive way. Different language communities are discussed by Schelp and Winter [47]. Rahimi et al. [42] and Saint-Louis et al. [45] conducted comprehensive systematic literature reviews in order to find definitions of EA, and Kappelman et al. [29] discuss the development of EA definition. Also, Korhonen et al. [31] discuss the possible reconceptualization of EA. While these studies make valid contributions, the nature of the complex field of enterprise IT and systems is still not captured in a single definition for EA, even if the need is pointed to by several authors [e.g. 45].

In the field of information systems (IS) research, the area to which IT in an organizational setting is foremost related to, the basic unit of analysis is traditionally an information system. EA, however, as an approach is suggested to cope with the planning and management of a number of systems within an enterprise. The unit of analysis thus is the enterprise, or organization, with numerous systems that is naturally leading to the idea of *a system of systems*. As a baseline theory, the systems thinking, and related theories thus seem to come close.

According to Romero and Vernadat [43], EA, in the form of the EA frameworks, has historically been developed parallel in two different communities – the IS, and the industrial engineering community [6]. Bernus et al. [5] state that EA originates in the disciplines of management, IS and engineering. In IS and management science, the work of e.g. Zachman [63], and Spewak and Hill [51] have been seminal. Within the engineering community, the focus is to engineer the information and material flows of the whole enterprise – hence the term enterprise engineering (EE) [6]. Later, the scope of the engineering community extended to cover the whole enterprise and its business networks, including e.g. supply chain [43] and to further rationalize and specify the focus on essential elements of EA [41]. Ambiguity concerning the definition of EA may be partly due to its origins, and Bernus et al. [5] point, that there is a gap between originally intended scope and the present-day scope of EA. However, for the engineering communities (software, systems and enterprise engineering), the "system of systems" engineering (SoSE) the systems nature of the research area is self-evident [17]. We acknowledge this as a related area, but not included in our study.

In order to explore the literature in the EA area, an initial definition should be stated. We cite Lapalme et al. [33], who build their definition upon the ISO/IEC/IEEE 42010 standard: "EA should be understood as being constituted of the essential elements of *a socio-technical organization*, their relationships to each other and to their changing environment as well as the principles of the organization's design and evolution. Enterprise architecture management is the continuous practice of describing and updating the EA in order to understand complexity and manage change".

3 Systems Approaches – A Theory for the EA Research Area?

According to Mingers and White [37], systems approaches emerged in early to mid-1900's, and were developed, among others, by von Bertalanffy [57] in the form of Systems Theory, and further, by Wiener [61] and Beer [4], who discussed with these approaches among other things cybernetics. Arnold and Wade [2] note that systems thinking was coined by Barry Richmond in the late 1980's, and define systems thinking consisting of elements, interconnections and a purpose. Probably the most applied General Systems Theory (GST) approach in the IS field of research is the nine-fold hierarchy of Boulding [8] presented initially to the management field of science (see e.g. [1]). It has found resonance in the study of IS-related semiotics through the work of Stamper [52, 53], that continues to impact as an underlying theory in foundational research on enterprise modeling [8]. Relying on Boulding, Daft and Weick [13] lay out a theoretical baseline for organizational information and the management and processing of information in organizations, well-cited within the IS field.

As a practical application, Checkland [12] developed the Soft Systems Methodology to support the systemic organizational design and change, and in order to serve these goals, to enhance the involvement of stakeholders at the implementation of technical systems. In the same vein, Senge's [50] learning organization as a further application of systems idea to organizational development take on this approach to stress the interdependencies within the organizational subsystems, and the socio-technical system perspectives. Mingers and White [37], use the generic term *systems approaches* to cover systems related lines of research ("theory" or "thinking" [23]). They discover the following common elements, reflected here for the setting of EA.

- Systems consists of wholes comprising of parts, or sub-systems.
- Systems exist in the midst of their environment and are defined by their boundaries.
- A system can be described as a static entity (system structure), or through its dynamics, i.e. the processes, or transformations in the system.
- Systems change (evolve) over time.
- Systems (and subsystems) appear as hierarchical, and there is a hierarchy of levels of complexity.
- Within the system and at its boundaries, there are feedback loops (positive and negative) between the structural elements, potentially influencing the system dynamics.
- Systems entail information processing, regarding both the system and in exchange with its environment.
- System and subsystems are normally "open", i.e. they are taking inputs from and sending outputs to the environment, and possible adjacent (sub-)systems. (This influences the analysis of a system, its components and their evolution.)
- System thinking is a holistic approach, i.e. taking into consideration the whole also in the examination of parts of the system.
- Systems approaches afford for an observer, i.e. a point of view, or a position taking a holistic perspective to the system.

For the EA-related EE research area, we find a thorough elaboration on enterprise engineering *theories* [14]. Further, some questions on the role and the nature of theories in the field of IS have been elaborated [18]. In accordance, to find a theory or theories for a research focus area, the following points or basic questions are involved:

- *Establishing the domain*. What are the characteristics of the domain of interest? What phenomena are in the focus of the study, and what problems are to solve? [18]. The outlining of the disciplinary boundaries is done by applying a standard definition of organization for enterprise. Further delineation are the problems related to the IT in the organizations in questions going *beyond one information system*. Single information systems (with their entire life cycles) are dealt with in various research areas within the IS field of study.
- The *ontological* theories [14], or the structural or *ontological* questions [18]. Although theory for EA is claimed missing, it appears that the research has indeed brought forth several suggested ontologies, the Zachman [64] Framework as the most prominent one. Suggested structures ("contributions to knowledge", or expressions of theory [18]) for the area are abundant, but none commonly accepted. Neither are patterns for research questions or the resulting claims [18].
- The *epistemological* questions relate to the nature of knowledge in the research area [18]. This raises questions of how to capture, and by which methods to validate and verify knowledge. Dietz et al. [14] thus join with epistemology also logics, mathematics and phenomenology. With the complexity of the research target, this apparently presents challenges to both the research, and to the question of the theoretical base. With different viewpoints to EA, different epistemological foundations and research methods not only apply but are fundamental.
- Gregor [18] points also to the broader environment, where the research is undertaken: The influential socio-political questions, seen by Dietz et al. [14] as a category of *ideological theories*. The related questions remind of the role of diverse stakeholders within and outside of the research area, and further, the complexity of social behaviors, and the challenges of objectivity in research.
- Further, Dietz et al. [14] see the *technological theories* as a distinct category in their theory framework. This seems to map to the theory for "design and action" [18]: to know how to accomplish something in reality.

For EE, Dietz et al. [14] propose eight specific kinds of theory for the different aspects of enterprise and the diverse systems belonging to enterprises. Systems approaches, or their applications [e.g. 10, 12, 57] are pointed at as the basis of several of these theory classes, emphasizing the relevance to the enterprise systems area. In our exploration on theories in the area of study, it is of interest what the theory offers for the research, and to what extent it is indeed applied. The five functions of theory listed in [18] give a starting point:

1. *Analysis:* 'what is', i.e. the ontology and structure of the focus area. At this level, the theory remains descriptive, showing elements and relationships, but not making inferences to causality, or making predictions.

2. *Explanation* – extends analysis with explanations, also attempting to answer the questions how, why, when, and where. However, this does not imply prediction or hypotheses.
3. *Prediction* – the theory allows for developing predictions and hypothetical propositions but does not explain causalities.
4. *Explanation and prediction* – the theory answers the questions what is, how, why, when, where, what will be. It allows for developing testable hypotheses, predicts the future states, and provides causal explanations.
5. *Design and Action* – an applicable theory, that *prescribes* how to do or achieve something, meaning the development of articulate instructions (as e.g., methods, techniques, principles of form and function) for constructing an artifact.

We seek to find out, how the systems approaches are reflected in the EA research and in the use of theories in it presently, and discuss if a potential could be detected for a common theoretical foundation.

4 Method of Study: Literature Review Protocol

According to Templier and Paré [56], leading researchers, e.g. Webster and Watson [58], have noted the relevance of publishing quality standalone literature reviews. In an attempt to strengthen the theoretical foundations of EA, we conducted a comprehensive systematic literature review. We followed the guidelines proposed by [56], hence our work included the following phases: (1) formulating the problem, (2) searching the literature, (3) screening for inclusion, (4) assessing quality, (5) extracting data, and (6) analyzing and synthesizing data.

To ensure a comprehensive look into the contributions of systems paradigms on EA we chose to look for relevant literature from three databases: Google Scholar, Scopus and IEEE Xplore Digital Library. We used the following search phrases appearing anywhere in either the title of the article, in abstracts or in keywords: “enterprise architecture” AND (“system thinking” OR “systems thinking” OR “system theory” OR “systems theory”). The search was conducted in February 2018.

Initially, a total of 3457 results was found, 3380 of these from Google Scholar, 71 from Scopus and 6 from IEEE Xplore Digital Library. The amount of initial results was extensive, mainly due to Google Scholar’s search algorithms and limited options in filtering the search results. Google Scholar’s “Advanced search” allows search terms to appear either in the title of the article, or anywhere in the article. To find all the relevant articles, the search terms were allowed to appear anywhere in the article. In terms of literature coverage, we aimed to conclude the search and selection process when the research material was saturated [56, 58]. In order to gather all relevant literature, the first 960 papers from Google Scholar and all papers from Scopus and IEEE were screened. At this stage, we read the titles, abstracts and keywords of the articles, and included those that mentioned EA and referenced “systems thinking” or some systems theory. We included journal and conference articles as well as books. We excluded articles that were not written in English as well obviously those that were inaccessible. 156 articles and books were chosen for a more thorough inspection. Also, 18 articles

found with forward search were included. After crossing out the doubles and excluding articles that did not contribute to the research question, we ended up with a total of 47 publications (see Appendix A).

5 Results and Analysis

The included studies were published in various journals and conferences, although the systems nature of enterprises has been mostly discussed at the Hawaii International Conference on System Science (7 items), IEEE International Conference on Systems, Man and Cybernetics, International IEEE EDOC Conference, and the Journal of Enterprise Architecture (5 each). In retrospective, a broad search covering also less well-known journals and conference proceedings was needed. Our sample shows varying quantity per annum. Eight articles were published 2012 (most publications), while only one article was published in 2008 and 2015, none in 2004. Although we did not have preconceived inclusion or exclusion criteria concerning the year of publication, all the included articles were published 2000 onwards.

Several systems theories, e.g. General Systems Theory [e.g. 21], Living Systems Theory [e.g. 60] and Complex Adaptive Systems [e.g. 24] are taken as underlying theory. Further, Viable System Model [e.g. 64], simply System of Systems [e.g. 54], and own coinages such as "complex adaptive living system" [#27], appear in EA studies. Most studies did not name a particular theory, but refer to Systems Thinking [e.g. 40], (which however has been theorized as well [11]), or merely to "systems theory" [e.g. 36], without specifying which approach the study relies on. Notably, not only several different approaches came up, but multiple studies mention more than one systems approach.

According to the analysis of the articles included, *enterprises* are perceived as a type of *system*. There are mentions of *a system of systems,* some kind of a *complex system*, such as a [*complex*] *socio-technical system,* or *complex network,* if not a *Complex Adaptive System*. GST, Systems Thinking and an unspecified "systems theory" are the most frequent theoretical starting points. Enterprise architecture is defined in a number of ways, most often as a comprehensive view of an interconnected and networked whole of an organization with multiple information systems, possibly in two different states: as-is and to-be.

- This reflects to the first fundamental question to develop theory: Establishing the research domain, in this case EA. We can conclude that the systems nature of the target domain is widely recognized.

For the question on ontology, systems elements have been suggested. E.g. Wegmann [#1] notes that "an enterprise is a system in which the components are the enterprise's resources". Schuetz et al. [#32] see that "Following a system theoretical perspective we consider EA as a system, consisting of components (or 'things') and relations", also making a very clear relation between the two and reflecting the basic concepts of systems approaches. Santana et al. [#44], reflecting the ideas of the theory of Complex Adaptive Systems, define EA as a "complex network" and elaborate it as an "interwoven system of

strategic goals, business processes, applications and infrastructure components", which "is subject to a variety of relationships and dependencies among its several components".

Table 1 classifies the 47 articles based on the dominant systems approach referenced in each study. We classify the studies according to the purpose of the theory (first column) following roughly the aristotelian classification [18], see above. We also distinguish, whether the article presents only conceptual or theoretical ideas, or if the study is based on, or supported by, evidence from empirical work (second column).

Table 1. Classification based on systems approach and type of article

For the advancement of	Argumentation	Systems approach (n): Paper ID #	Total	
1. Theory or discipline	Conceptual or theoretical	STH (9): #14; #20; #23; #24; #31; #37; #41; #42; #43 CYB (3): #11; #29; #36 GST (2): #39; #47 VSM (1): #21 CAS (1): #44 ORT (1): #38	17	19
	Based on or supported by empirical evidence	STH (1): #34 MHS (1): #28	2	
2. Ontologies and frameworks	Conceptual or theoretical	STH (3): #3; #15; #16	3	6
	Based on or supported by empirical evidence	GST (1): #10 SM (1): #13 MHS (1): #8	3	
3. Methods and modelling	Conceptual or theoretical	STH (8): #1; #17; #25; #30; #33; #35; #45; #46 VSM (2): #26; #27 GST (1): #19 CYB (1): #22 LST (1): #2	13	20
	Based on or supported by empirical evidence	STH (2): #9; #32 GST (2): #12; #18 VSM (1): #40 CAS (1): #5 LST (1): #7	7	
4. Software tools	Conceptual or theoretical	LST (2): #4; #6	2	2
	Based on or supported by empirical evidence		0	

Legend: CAS = Complex Adaptive Systems (2), CYB = Cybernetics (4), GST = General Systems Theory (6), LST = Living Systems Theory (4), MHS = Theory of Multilevel Hierarchical Systems (2), ORT = Orientor Theory (1), STH = 'Systems Theory', 'Systems Thinking' etc. (23), VSM = Viable Systems Model (5)

Comparing to the theory functions (p. 6), the results show that to a good portion, 'systems' idea is seen as an analytical expedient of the research domain, i.e. analytical tool for managing enterprises and their IT. Missing the theories for explanation and prediction is likely due to the research methodologies used, and further, the complicated nature of the research target. To pinpoint causalities and develop predictions would require simplified views, loosing from sight the holistic systemic nature of the research target. However, with a more established theoretical outline, the reduction needed to study causal relationships could become possible.

Most often, systems approaches appear in the studies of methods and modeling, i.e. the practicable knowledge "for design and action", for which, empirically founded studies are more frequent. Even if frameworks used to be often on the fore in discussions on EA, the systems approaches appear less often as a basis for explicit ontological structuring for EA study, and only half of the studies for this purpose rely on empirics.

- A commonly acknowledged, consistent systems theoretical ontology for EA remains to be established.

To summarize, despite of keen interest on the systems approaches, they seem still more rarely contribute to empirical efforts. Different systems approaches, and some specific models are used in the studies. In the following, we present and discuss the individual systems approaches found in this study.

6 Discussion

It appears plausible to anchor EA in the field of system sciences, a discipline providing the necessary theoretical foundations to design, model and manage socio-technical systems. The literature review results show maybe a more fragmented theory base than could be expected. The specified systems approaches that appear in the included papers have, however, each contributed to an understanding of the problem field of EA. We attempt to summarize with a brief characterization of each theory or model in the following paragraphs.

GST – As an early systems approach, especially in the studies of organization and management, the General Systems Theory suggests hierarchically layered systems at nine distinct levels, with growing autonomy and increasing complexity towards the top levels [9]. Human deliberation enters at level 7, leading to less predictable actions and introducing complexity. Enterprises as such at level 8 of the GST hierarchy, as social (or rather socio-technical) systems, consist of several, both more and less complicated and complex (sub)systems. EA elements, such as the technical systems on one, and the human activity systems on the other hand, can be described, and their behaviors to an extent also explained through GST. Openness (cf. Open Systems, [57]) is assumed, meaning interactions with the environment and across system boundaries, as no enterprise exists in isolation, but within an environment with which it is in multiple relationships. The purpose of GST is to be "a body of systematic theoretical constructs which will discuss the general relationships of the empirical world" [9], and it has

found application in empirical EA work both on ontologies or frameworks [#10], and methods or modelling [#12] [#18].

LST – In addition to an eight-level hierarchy, building on the GST, the Living Systems Theory [38] purports a division of labor between the system components. In LST, processing and transmission of information is in focus, making it apt to the study of IS and IT in organizations. The parts of a living system are classified to those processing either matter and energy, or information, or both [30]. In addition to this division, more refined roles are specified, e.g. for enabling managed interactions with the system environment at its boundaries. Openness is naturally also an attribute of an LST. System states and event cycles, as well as the 'in-, out- and throughput' concepts are a root for the current understanding of enterprises as a set of (business) processes, transforming inputs to outputs. The LST has been seminal in early EA research, especially in the extensive, well known work on the SEAM methodology [#1], [#2], [#4], [#6], [#10], leaning on the LST, but also supported by GST. Following SEAM, with LST as a theoretical base, a process meta-model for EA management has been presented in an empirical study investigating the partitioning of the complex whole to manageable parts in EA ("EA domains") [#7]. In alignment with the systems approach, feedback loops in this model ensure informed decisions by the upper levels in the systems hierarchy. The LST is conceptually rich, and has found application both in organization and management, and e.g. in industry automation, where it is the basis for Multilevel Hierarchical Systems **MHS**, [35]. MHS has been tapped on also directly in an EA study [#28] included in our SLR.

VSM – The Viable Systems Model proposes a simplified view for formal modelling to a system "capable of independent existence". A viable system, however, in also exchange with its environment (which may be another viable system, as implied by the recursion principle). The challenge of a VS is to cope with 'variety', and it is deploying 'intrinsic control' as means to sustain its viability. Cybernetics (CYB) as such complements the theory, rather than being an independent systems theoretical approach. Cybernetics is presented as an aspect of information processing and diffusion within the VSM.

From a Viable System Model perspective, [#13] analyzes EA management functions, proposes a method framework for EAM, and describes the results from a case study. Here, VSM provides a framework through which complex management systems can be described from a systemic perspective, and with five subsystems – operation, coordination, control, planning and identity. In the context of EA, operation is formed via EA projects, by the enterprise-level management functions, whereas the communication function of EAM forms systems two – coordination [#13]. Control systems forms the reactive function of EAM, establishing higher level control over the coordination system function, i.e. ensuring stability in the enterprise-level management process interaction. Furthermore, the authors argue that EAM encompasses a proactive function (planning), which anticipates and addresses environmental changes. Lastly, identity system concerns EAM governance – the scope and reach of EAM. [#11] is another paper deploying the VSM. Similarities between EA and the Viable System Model, as well as with Cybernetics have been found in other studies as well [#26, #27].

An adaptation of **Cybernetics** is applied in [#21] that the authors call Enterprise Architecture Cybernetics as the research framework for their study, to formulate methods to calculate and reduce the structural complexity of collaborative networks. Furthermore, they use the extension of Axiomatic Design Theory as an approach to treat complex systems whose operation cannot be fully predicted. The decisions regarding such systems are based on incomplete information, and therefore the ability to estimate and control their complexity can yield better guided decisions. The paper provides an interesting example of the use of systems approaches to propose an applicable method as a solution to a problem that stems from a high structural complexity of the domain.

CAS – Complex Adaptive Systems has raised interest more recently, likely following the technological developments with non-human agents interacting alongside of humans within networks [20]. The main emphasis is in the system adaptive behavior conditional to the signals received from the environment and explained through the common characteristics of evolution, aggregate behavior (parts or subsystems contributing to the overall system behavior), and anticipation, where the system aims at adapting in anticipation to the changes of the environment [#5].

The Orientor Theory (**ORT**) complements the views to system with the orientors defining the overall desired system outcomes (or system states). As pointed out by [#38], in the case of EA, the orientors can be seen the desired EA principles to follow in design and development activities.

The highest number of studies fall into the category Systems Thinking that may, or may not be explained in the individual studies in more detail. The high occurrence of the Systems Thinking or unspecified systems theory may indicate that the field of research does rely on some generic system related truths, as maybe a common 'mental model' [50] that potentially supports the research community in learning on the subject. As pointed out for organization and management [3], maybe in the EA field of research there are also "missed opportunities", for not more consistently relying on the systems approach. Rather than mere metaphorical use, a systems paradigm tuned for EA could support the description, explanation and even prediction of the enterprise and its information systems phenomena. We assume that this is a call for unifying the view of this paradigm in the EA field of research. The common features presented in this paper (based on [37], cf. Sect. 3) is an attempt in this vein. As a summary (Table 2), where the EA research stands, with examples we suggest how the common systems features reflect to well-known EA concepts in use in the EA studies. Further, we consider with these concepts, what challenges could be ahead for the systems related EA research.

Table 2. Common systems features vs. EA concepts, and EA research challenges

Common features of systems approaches	EA concepts and challenges
Systems consists of wholes comprising of parts, or sub-systems	View of 'organizations' or 'enterprises', the unit of analysis in EA studies, as systems/systems of systems (with different characterizations)
Systems exist in the midst of their environment and are defined by their boundaries	EA as a tool for managing enterprise IT and information resources, a tool corporate and business strategy within these limits *Challenge:* EAM for the extended, federated enterprises, networks and ecosystems
A system can be described as a static entity (system structure), or through its dynamics, i.e. the processes, or transformations in the system	EA modelling, EA descriptions; Business architecture descriptions; E.g. business processes as an element ("layer") *Challenge:* Modelling of the evolving/constantly changing enterprise
Systems change (evolve) over time	EA current and future stage ("as-is", "to-be") *Challenge:* The synchronized evolution of related enterprise subsystems and sub-subsystems
Systems (and subsystems) appear as hierarchical, and there is a hierarchy of levels of complexity	Enterprise and enterprise segments ("domains"), EA describing systems-of-systems *Challenge:* EA Management for systems consisting of complex systems, where also the sub-systems change independently
Within the system and at its boundaries, there are feedback loops (positive and negative) between the structural elements, potentially influencing the system dynamics	The EA Process/The EAM Process *Challenge:* Understanding and supporting the nature of feedback as signals from (sub) system to system within the enterprise
Systems entail information processing, regarding both the system and in exchange with its environment	Information Architecture Dimension of EA *Challenge:* Inclusion of Information and Data Architectures and their management as an integral part of EA and EAM
System and subsystems are normally "open", i.e. they are taking inputs from and sending outputs to the environment, and possible adjacent (sub-)systems	EA acknowledges the enterprise environment as source of diverse influences for enterprise behavior *Challenge:* EAM for the open systems-of-systems emerging with the evolution of technologies (e.g. Industrial Internet of Things) and digitalization; with federated, loosely-coupled and independently managed systems collaboration

(*continued*)

Table 2. (*continued*)

Common features of systems approaches	EA concepts and challenges
System thinking is a holistic approach, i.e. taking into consideration the whole also in the examination of parts of the system	The essence of EA, the strength of EA methodology *Challenge:* With the above mentioned challenges, how well are the current EA methods equipped for this, especially with the new technology developments?
Systems approaches afford for an observer, i.e. a point of view, or a position taking a holistic perspective to the system	The 'Enterprise Architect' *Challenge:* In large enterprise and networked settings, the task is too broad for any one role; but requires coordinated, collaborative activity, presenting a challenge to methodology

7 Conclusions

The purpose of this study was to discuss firstly, to what extent the systems approaches are already in use in EA research (RQ1). Secondly, we wanted to examine the specific aspects of theory in this regard. This means, we look into the basic theory types or basic questions on theory, and further, the functions of theory (analytical, predictive, causal or "technological", i.e. for design and action), and aimed to find out if the EA research already deploys the systems approaches for these purposes (RQ2). In order to account for the contribution of the systems approaches in the field of EA, we look into the use of the theories in the studies we examine, and take account where empirical work supports the theory development in these studies. Further, we count the occurrence of the different systems theories and models, and discuss their contribution to this field of inquiry.

The common elements of systems theories that are discussed with reflections to existing concepts in the EA studies could be seen as signifying a systems theoretical starting point for EA, with the various theories and models providing further support for specific cases of inquiry. With this summarizing view also some further challenges are presented, that in our view are emerging for EA with the evolving technology landscapes.

More consistent use of the systems paradigm could move the research closer to being on the same page. To an extent, testing and validation of the theories in empirical efforts is taking place, but a common account of general systems ontology as the EA core is yet to develop. Beyond analysis and explanation, the use of systems paradigm for design and action seems to be taking place: There are already numerous empirical examples for methodologies and modelling, where also the strengths of EA as an approach lie for the enterprise information and systems management and development.

Systems paradigm is promising also from the point of view of the combination of formal, semi-formal and non-formal approaches. As noted in prior research [5]: "EA must encompass both soft and hard systems problems, model complex systems

behavior through self-design, and add the human interpretive behavior and cognition to organizations as living systems". Systems theories are feasible candidates for extending and enriching EA research in order to achieve exactly that effect. Systems models are used for formal modelling, and this aspect indeed is successfully made use of. However, the paradigm can also be a starting point for exploratory approaches. A comprehensive paradigm depicted already in the GST, from mechanistic, simple systems to highly complex social systems, further explicated with the diverse constant roles and sub-system relationships as the strength of the LST approach, seems to be fitting for EA.

The question is, however, not which systems approach to take, but how the specific approaches complement the overall systems approach for EA. The more recently introduced CAS paradigm that emphasizes the independent decision making within systems – and their subsystems, a facet not so much emphasized! – as well as the autonomous (re-)orientation of systems, illustrates in our view very well the challenges of EA management. In engineering, the mindset can be to manage systems, or even systems of systems, where the decision making can remain with the systems engineer, or manager. In EA, or especially EAM, relating to management and organization, the task is to manage the complexity of influences within the enterprise(s) and their segments (subsystems and sub-subsystems), that have decision making power over their own resources and strategy setting.

According to the soft systems methodology, there is a distinction between problems faced by soft systems and hard systems. While hard systems discuss types of problems that can be seen as engineering problems, soft systems deal with problems related to e.g. organizational or social problems [5] - both of which can thus be seen as dealing with problems also considered in EA. Furthermore, Bernus et al. [5] note that Cybernetics can provide a theoretical backbone for analysis of relationships between social and psychological systems – for example organizations and individuals. From the early, basic systems theories (GST and LST) emphasizing the composition of the systems and hierarchical levels of complexity, indeed the shift of focus seems to be towards the dynamic features of the systems in models like VSM and Cybernetics, as well as CAS. For EA, and its management, both the structural and the dynamical views will be needed. The diverse theories and models can be seen as complementary – for the management, also the analytical views to the structures and dynamics in EA are, however, still needed.

There is an extensive volume of prior work discussing the systems nature of enterprises, as well as the systems approaches, as a means of solving various problems also considered in the field of EA. A limitation of our study is that prior work spread out to various fields, such as cybernetics [16] and EA network analysis [46], and not covered in detail here. Further, comparisons with the work in SoSE [17] as another promising line of research, is out of the scope of this study. In terms of literature coverage, we could have used additional search phrases, concerning for example enterprise architecture and various specified systems theories, enterprise engineering, and system-of-systems related keywords. Still, as stated by [56], a developmental literature review strives to include a sample of articles covering important aspects of concerned topic. We believe that this sample enables us to answer the research questions at an adequate level. Beyond the list of all included ones (Appendix A), the

authors retain the list of papers excluded (see Sect. 4 for the exclusion criteria) at different phases of the search process for future referral.

We strive to contribute to the discussion on EA to solidify the theoretical foundations. We hope that this study elucidates the current knowledge and academic endeavors concerning Systems Thinking, Systems Theories and Enterprise Architecture. Further research is obviously necessary, as well as probing by practitioners, in order to establish EA as a field of study within the broader systems research area. It could learn from insights in related fields, e.g. Systems of Systems Engineering, Enterprise Engineering and Organization Design.

A Appendix

Included articles	ID
Wegmann, A. (2002). The systemic enterprise architecture methodology (SEAM). Business and IT alignment for competitiveness (No. LAMS-REPORT-2002-009)	#1
Wegmann, A., & Preiss, O. (2003, September). MDA in enterprise architecture? The living system theory to the rescue. In Enterprise Distributed Object Computing Conference, 2003. Proceedings. Seventh IEEE International (pp. 2–13). IEEE	#2
Harmon, K. (2005, October). The "systems" nature of enterprise architecture. In Systems, Man and Cybernetics, 2005 IEEE International Conference on (Vol. 1, pp. 78–85). IEEE	#3
Le, L. S., & Wegmann, A. (2005, January). Definition of an object-oriented modeling language for enterprise architecture. In System Sciences, 2005. HICSS'05. Proceedings of the 38th Annual Hawaii International Conference on (pp. 222a–222a). IEEE	#4
Janssen, M., & Kuk, G. (2006, January). A complex adaptive system perspective of enterprise architecture in electronic government. In System Sciences, 2006. HICSS'06. Proceedings of the 39th Annual Hawaii International Conference on(Vol. 4, pp. 71b–71b). IEEE	#5
Lê, L. S., & Wegmann, A. (2006, January). SeamCAD: object-oriented modeling tool for hierarchical systems in enterprise architecture. In System Sciences, 2006. HICSS'06. Proceedings of the 39th Annual Hawaii International Conference on (Vol. 8, pp. 179c–179c). IEEE	#6
Pulkkinen, M. (2006, January). Systemic management of architectural decisions in enterprise architecture planning. four dimensions and three abstraction levels. In System Sciences, 2006. HICSS'06. Proceedings of the 39th Annual Hawaii International Conference on (Vol. 8, pp. 179a–179a). IEEE	#7
Winter, R., & Fischer, R. (2006, October). Essential layers, artifacts, and dependencies of enterprise architecture. In Enterprise Distributed Object Computing Conference Workshops, 2006. EDOCW'06. 10th IEEE International (pp. 30–30). IEEE	#8
Wegmann, A., Regev, G., Rychkova, I., Lê, L. S., & Julia, P. (2007, October). Business and IT alignment with SEAM for enterprise architecture. In Enterprise Distributed Object Computing Conference, 2007. EDOC 2007. 11th IEEE International (pp. 111–111). IEEE	#9

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Included articles	ID
Wegmann, A., Kotsalainen, A., Matthey, L., Regev, G., & Giannattasio, A. (2008, September). Augmenting the Zachman enterprise architecture framework with a systemic conceptualization. In Enterprise Distributed Object Computing Conference, 2008. EDOC'08. 12th International IEEE (pp. 3–13). IEEE	#10
Buckl, S., Matthes, F., & Schweda, C. M. (2009, October). A viable system perspective on enterprise architecture management. In Systems, Man and Cybernetics, 2009. SMC 2009. IEEE International Conference on (pp. 1483–1488). IEEE	#11
Sousa, P., Lima, J., Sampaio, A., & Pereira, C. (2009). An approach for creating and managing enterprise blueprints: A case for IT blueprints. In Advances in enterprise engineering III (pp. 70–84). Springer, Berlin, Heidelberg	#12
Buckl, S., Matthes, F., & Schweda, C. M. (2010). Towards a method framework for enterprise architecture management–a literature analysis from a viable system perspective. In 5th International Workshop on Business/IT Alignment and Interoperability (BUSITAL 2010) (pp. 46–60)	#13
Kloeckner, S., & Birkmeier, D. (2010). Something is missing: Enterprise architecture from a systems theory perspective. In Service-Oriented Computing. ICSOC/ServiceWave 2009 Workshops (pp. 22–34). Springer, Berlin, Heidelberg	#14
Kotzé, P., & Neaga, I. (2010). Towards an enterprise interoperability framework	#15
Meschke, M., & Baumoel, U. (2010). Architecture Concepts for Value Networks in the Service Industry. In ICIS (p. 266)	#16
Bider, I., Bellinger, G., & Perjons, E. (2011, November). Modeling an agile enterprise: reconciling systems and process thinking. In IFIP Working Conference on The Practice of Enterprise Modeling (pp. 238–252). Springer, Berlin, Heidelberg	#17
Dietz, J. L., & Hoogervorst, J. A. (2011, May). A critical investigation of TOGAF-based on the enterprise engineering theory and practice. In Enterprise Engineering Working Conference (pp. 76–90). Springer, Berlin, Heidelberg	#18
Hoyland, C. A. (2011, October). An analysis of enterprise architectures using general systems theory. In Systems, Man, and Cybernetics (SMC), 2011 IEEE International Conference on (pp. 340–344). IEEE	#19
Wang, S., Xu, L., Li, L., Wang, K., & Choi, J. (2011, October). Features of enterprise information systems integration: A systemic analysis. In Systems, Man, and Cybernetics (SMC), 2011 IEEE International Conference on (pp. 333–339). IEEE	#20
Kandjani, H., & Bernus, P. (2012, June). The enterprise architecture body of knowledge as an evolving discipline. In International Conference on Enterprise Information Systems (pp. 452–470) Springer, Berlin, Heidelberg	#21
Kandjani, H., Wen, L., & Bernus, P. (2012). Enterprise Architecture Cybernetics for Collaborative Networks: Reducing the Structural Complexity and Transaction Cost via Virtual Brokerage. IFAC Proceedings Volumes, 45(6), 1233-1239	#22
Lapalme, J. (2012). Three schools of thought on enterprise architecture. IT professional, 14(6), 37–43	#23
Wan, H., & Carlsson, S. (2012, September). Towards an understanding of enterprise architecture analysis activities. In European Conference on Information Management and Evaluation (p. 334). Academic Conferences International Limited	#24

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Included articles	ID
Wang, S., Li, L., Wang, K., & Jones, J. D. (2012). e-Business systems integration: a systems perspective. Information Technology and Management, 13(4), 233–249	#25
Zadeh, M. E., Millar, G., & Lewis, E. (2012a). Reinterpreting the TOGAF® enterprise architecture principles using a cybernetic lens. Journal of Enterprise Architecture, 8(2), 9–17	#26
Zadeh, M. E., Millar, G., & Lewis, E. (2012b, January). Mapping the enterprise architecture principles in TOGAF to the cybernetic concepts–An exploratory study. In System Science (HICSS), 2012 45th Hawaii International Conference on (pp. 4270–4276). IEEE	#27
Abraham, R., Tribolet, J., & Winter, R. (2013, May). Transformation of multi-level systems–theoretical grounding and consequences for enterprise architecture management. In Enterprise Engineering Working Conference (pp. 73–87). Springer, Berlin, Heidelberg	#28
Kandjani, H., Bernus, P., & Nielsen, S. (2013, January). Enterprise architecture cybernetics and the edge of chaos: Sustaining enterprises as complex systems in complex business environments. In System Sciences (HICSS), 2013 46th Hawaii International Conference on (pp. 3858–3867). IEEE	#29
Kappelman, L. A., & Zachman, J. A. (2013). The enterprise and its architecture: ontology & challenges. Journal of Computer Information Systems, 53(4), 87–95	#30
Korhonen, J. J., & Poutanen, J. (2013). Tripartite approach to enterprise architecture. Journal of Enterprise Architecture, 9(1), 28–38	#31
Schuetz, A., Widjaja, T., & Kaiser, J. (2013). Complexity in enterprise architectures-conceptualization and introduction of a measure from a system theoretic perspective. In 21st European Conference on Information Systems, Utrecht (pp. 1–12)	#32
Bernus, P., Noran, O., & Molina, A. (2014). Enterprise architecture: twenty years of the GERAM framework. IFAC Proceedings Volumes, 47(3), 3300–3308	#33
du Preez, J., van der Merwe, A., & Matthee, M. (2014, September). Enterprise architecture schools of thought: An exploratory study. In Enterprise Distributed Object Computing Conference Workshops and Demonstrations (EDOCW), 2014 IEEE 18th International (pp. 3–12). IEEE	#34
Hoyland, C. A., M. Adams, K., Tolk, A., & D. Xu, L. (2014). The RQ-Tech methodology: a new paradigm for conceptualizing strategic enterprise architectures. Journal of Management Analytics, 1(1), 55–77	#35
Kandjani, H., Tavana, M., Bernus, P., & Nielsen, S. (2014). Co-Evolution Path Model (CePM): Sustaining Enterprises as Complex Systems on the Edge of Chaos. Cybernetics and Systems, 45(7), 547–567	#36
Noran, O., & Romero, D. (2014). A Pluralistic Approach towards Sustainable Eco-Industrial Networking. IFAC Proceedings Volumes, 47(3), 4292–4297	#37
Schneider, A. W., & Matthes, F. (2014). Using Orientor Theory for Coherent Decision Making for Application Landscape Design. In CSDM (Posters) (pp. 161–172)	#38
Syynimaa, N. (2013). Theoretical perspectives of enterprise architecture	#39

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Included articles	ID
Zadeh, M. E., Lewis, E., Millar, G., Yang, Y., & Thorne, C. (2014, October). The use of Viable System Model to develop guidelines for generating Enterprise Architecture Principles. In Systems, Man and Cybernetics (SMC), 2014 IEEE International Conference on (pp. 1020–1026). IEEE	#40
Bernus, P., Goranson, T., Gøtze, J., Jensen-Waud, A., Kandjani, H., Molina, A., … & Turner, P. (2016). Enterprise engineering and management at the crossroads. Computers in Industry, 79, 87–102	#41
Korhonen, J. J., Lapalme, J., McDavid, D., & Gill, A. Q. (2016, August). Adaptive enterprise architecture for the future: Towards a reconceptualization of EA. In Business Informatics (CBI), 2016 IEEE 18th Conference on (Vol. 1, pp. 272–281). IEEE	#42
Lapalme, J., Gerber, A., Van der Merwe, A., Zachman, J., De Vries, M., & Hinkelmann, K. (2016). Exploring the future of enterprise architecture: A Zachman perspective. Computers in Industry, 79, 103–113	#43
Santana, A., Fischbach, K., & Moura, H. (2016, January). Enterprise architecture analysis and network thinking: A literature review. In System Sciences (HICSS), 2016 49th Hawaii International Conference on (pp. 4566–4575). IEEE	#44
da Silva, N. M. C., & da Silva, M. L. B. M. (2017a, July). Modelling the evolution of enterprise architectures using ontologies. In Business Informatics (CBI), 2017 IEEE 19th Conference on (Vol. 1, pp. 79–88). IEEE	#45
da Silva, N. M. C., Da Silva, M. L. B. M., & De Sousa, P. M. V. A. (2017b, October). A Viewpoint for Analyzing Enterprise Architecture Evolution. In Enterprise Distributed Object Computing Conference (EDOC), 2017 IEEE 21st International (pp. 20–29). IEEE	#46
Syynimaa, N. (2017). The Quest for Underpinning Theory of Enterprise Architecture: General Systems Theory. In ICEIS 2017: Proceedings of the 19th International Conference on Enterprise Information Systems. Volume 3, ISBN 978-989-758-249-3. SCITEPRESS	#47

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