Enterprise Architecture from Practice Issues to Research Innovation

Abstract—A number of EA frameworks, methods and tools are available on the market, and already at use in administrations, companies, and proposed by consultants. Organisations are able to solve a number of issues using them, but these approaches generate new risks too, and some issues remain open. What are the next evolutions to cope with these risks and issues? We believe that research has already anticipated these risks and solved some of these issues that organisations dealing with - or will have to face in a near future. The purpose of this paper is to draw from these lessons learned in research a few guidelines to face the next generation of challenges of Enterprise Architecture.

Index Terms—Enterprise Architecture, Innovation, Industry

I. INTRODUCTION

Enterprise Architecture (EA) is widely used in practice as a way to deal with a number of practical organisational issues and Information System (IS) issues such as enterprise agility, IS flexibility, interoperability, alignment, governance, etc.

EA entered the enterprise world in the 80's when J. Zachman created the IS Architecture framework [1], then left IBM to fund the ZIFA institute and disseminate his well-known Zachman framework [2]. The Zachman EA framework stands in a 6x6 table which cells identify the various models that can be developed when documenting an organisation (enterprise as well as government agency) and its information system.

The Zachman framework was seminal in its way to establish a common vocabulary and a set of perspectives for building a holistic description of complex enterprise systems. The fundamental message behind Zachman Framework is inherited from the lessons learned in research works achieved in the 70's about IS engineering and software engineering methodologies: various modelling techniques are needed to deal efficiently with various subjects, and they are complementary to understand complex systems such as IS ecosystems [3].

Both industry and government agencies all over the world have recognized the value of EA. In the 90's, the Clinger-Cohen Act (also called IT Management Reform Act, 1996) was created to improve the way the US federal government acquires and manages information technology. It required to use performance based management principles for acquiring IT, which generated a number of changes. In particular, the Clinger-Cohen Act mandated the use of a formal EA process for all federal agencies.

In Europe, several governmental EA initiatives have been also been undertaken, such as the InfoCitizen project (to establish a common EA approach among European countries), Eu-Publi.com (to facilitate collaboration across employees of European public administrations), SAGA (to develop service-oriented e-administration in Germany), e-GIF (to enable the seamless flow of information from back-end systems to citizens and businesses and between government organisations in UK), F3 (to provide effective enterprise modelling methods) or INTEROP (to innovate and disseminate knowledge in the domain of interoperability for enterprise applications and software).

Industry has also been motivated by the simple reality that they need EA to remain competitive and support business continuity. Consultancy, system integrators and research organisations such as CapGemini, IBM, Accenture, Deloitte & Touch, Forrester, the Meta Group or Gartner have largely contributed to the dissemination of EA in enterprises.

As all state of the art and state of the practice resources show it (see [4] to [20]), EA has greatly evolved since Zachman's seminal Framework. On the industry side, hot topics for using EA are delivering road maps for change, managing IT portfolio, managing complexity, or better support system development [21]. On the research side, new lessons have been learned on these issues in many different fields such as Enterprise Modelling, Requirements Engineering, Alignment Engineering, Ontologies, Interoperability, as well as Ubiquitous Computing or Web Services. Some of them are already entering into daily practice, others are still theoretical but will impact practice very soon.

However, very few of the aforementioned the state of the art papers, books and reports really gives an idea of how current research might impact future practice in the domain of EA.

This paper proposes to contribute to this transition by a contrasted analysis of EA in current research and practice. The purpose is neither to propose yet another state of the art, nor to look into a crystal ball.

Our approach is original in that it compares research and practice by looking at (i) similarities and differences of EA in these two worlds, (ii) comparing hot topics in EA practice with risks already identified in EA-related research. Based on this analysis, the draws a few research issued hints on how to face the next generation of EA challenges.

The next section starts the paper with a few definition of what is meant by EA. Section 3 presents EA practice and looks...
at hot topics in EA practice. Section 3 focuses on 3 particular EA research approaches and looks at how they could contribute to solve the issues raised by practice. A collection of six challenges for research grounded on practical issues is raised from this analysis. Section 4 discusses these issues in-depth, looks at how other research could further contribute to solve these issues and provides practical guidelines for practitioners. The concluding section discusses threats to validity of this analysis and proposes a number of research directions: (a) to complement the piece of research reported in this paper, and (b) to further deal with research challenges that would contribute to better EA practice.

II. SOME DEFINITIONS

Before entering into a definition of EA itself, one might want to discuss what is meant by “architecture” in general.

The ANSI/IEEE Std 1471-2000, Recommended Practice for Architectural Description of Software-Intensive Systems defines architecture as “the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution”. This definition is intended to encompass a variety of uses of the term architecture by recognizing their underlying common elements, such as the need to capture, understand, control the system’s utility, cost, and risk represented by various elements such as physical components of the system and their relationships.

In the Rational Unified Process an architecture is “the set of significant decisions about the organization of a software system, the selection of the structural elements and their interfaces by which the system is composed, together with their behavior as specified in the collaborations among those elements, the composition of these structural and behavioral elements into progressively larger subsystems, and the architectural style that guides this organization—these elements and their interfaces, their collaborations, and their composition”.

As these two definitions show it, the term architecture can have different meanings depending on its contextual usage [11]. In the context of this paper, this term will be used to deal with Enterprise Architecture (EA) and EA frameworks.

Enterprise Architecture is defined by J. Zachman [23] as “the set of primitive, descriptive artifacts that constitute the knowledge infrastructure of the Enterprise”.

Another lightening definition is the one proposed by Infocitizen [12] “an EA represents a body of structured knowledge for the engineering and the integration of the enterprise, knowledge that includes the analysis and the detailed description of the enterprise, the design and the development of the engineering project and the operation of the enterprise”. As Lillehagen [11] shows it, EA should also be compared to enterprise modelling: “an enterprise model will have an EA, and Enterprise Modelling languages have meta models that are components of the EA at the knowledge layer”.

This paper deals with EA Frameworks and Enterprise Modelling Methods, techniques and tools as defined earlier. For the sake of space, technical principles of architecting and architecture technologies (such as service oriented architecture) were voluntarily left out of the scope of the paper.

III. EA IN PRACTICE

In its 2005 survey [21], the Institute For EA Development (IFEAD) shows that enterprise EA is felt as particularly important to: support decision making (16%) deliver road maps for change (14%), manage IT portfolio (14%), support systems development (12%), manage complexity (12%), support business & IT budget prioritization (11%), and deliver insights and overview of business and IT (11%).

The survey shows that EA is especially present in very large multinational organisations and governmental agencies, which have adopted EA as strategic governance tools, but in smaller enterprises too. According to the survey the top two issues that justify undertaking EA are Business-It alignment (20%), building a transformation roadmap (15%).

Numerous EA frameworks and methods are available on the market: Zachman, E2AF, EAP, FEA, TEAF, TOGAF, IAF, JTA, DodAF, TAFIM, CIMOSA, PERA, or SAGA, just to name a few (see [16]). The most used EA approaches are [21]: the Zachman Framework (25%), the TOGAF (11%), DoDAF (11%), FEA (9%, declining), E2AF (9%), Cap Gemini’s IAF (3%), and home-made frameworks (22%, declining).

The rest of this section focuses on the two EA Frameworks that are mostly used internationally, namely the Zachman Framework, and TOGAF. An additional section on the French EA approach, namely Information System Urbanisation (USI) was also added. Each approach is described very briefly with a cost benefit analysis. The focus is put on practical issues and risks identified with the use of these approaches to facilitate correlation with lessons learned in research.

Interested readers can find detailed information on the Zachman Framework in [1][2], on the TOGAF in [24], [25]. A mapping between the two is also proposed in [26]. Information about the “urbanisation” paradigm of EA is available in [27] and [16] (in French).

A. Zachman Enterprise Architecture Framework

Zachman published for the first time his Framework (initially named ISA) in 1987. The philosophy of the Zachman EA framework is based on a principle of classical architecture according to which a complex system such as a building or a plane can be effectively described using a common vocabulary and according to a collection of predefined perspectives.

Many EA Frameworks such as FEA, TEAF, IAF, DoDAF, or AFEAF [16] are directly inspired by the Zachman Framework. Sometimes they are a subset of it, other times they

---

1This choice is not only justified by the fact that the author is French but also and mainly by the fact that USI has an original approach to EA and that most French enterprises who have an EA practice recognize themselves in USI.
The Zachman Framework is a documentation heavy-approach. It indicates what to model to produce a rich picture of the IS and its ecosystem, but does not propose any methodological guideline or management advice to think these documents out and manage them efficiently.

The issue is raised when an enterprise that adopts this Framework expect guidance, e.g. to audit its current EA, to improve methodological consistency throughout the enterprise, to analyze the impacts of change, or to develop change scenarios and analyse them. Besides, there is no way to evaluate compliance with the Zachman Framework when it is achieved by a consultant, or to evaluate the degree of maturity of an enterprise in terms of methodological processes. Even further, the lack of well documented methodological process is aggravated by the absence of specific tool and guidance to adapt the Framework to the specific context of an enterprise.

Several well-documented methodological processes , such as the the Enterprise Unified Process [33], or EKD-CMM [34], or even simple tools such as the IFEAD EA scorecard [35] are publicly available. These could be used together with the Zachman EA framework. Unfortunately, they weren usually not defined to comply with the Zachman framework, and they usually do not say how to perform adaptation to the specific context of an enterprise.

3) Lack of formal definition
Zachman's approach is taxonomic in the sense that his framework identifies and classifies a collection of concepts to describe EA but it does not precise definitions, meta model or formal ontology to define the underlying semantics of these concepts. On the good side, this approach raises the barrier of complexity by offering a degree of liberty in the way the concepts can be used. However, on the other side, it does not say which concept to use and how to use it. Research has been undertaken in this area [36][31][37] but effort are still needed to integrate the result of this research in the daily practice.

4) Static vision
In the Zachman Framework, time is only one particular dimension and it is the subject of a specific modeling. This does not match with current practice in which a distinction is made between the current situation (As-Is) and the future situation (To-Be). From a practical point of view, this means that the global consistency of IS evolution and enterprise change is not controlled, and its improvement is not guided.

B. TOGAF
The Open Group Architecture Framework (TOGAF) was proposed by the Open Group in 1995 to allow users implementing open solutions at reduced costs, simplifying the processes associated to design, planning, acquisition and integration of open systems, and helping CIOs better communicate their goals and strategies to decisions makers.

The TOGAF is based on two main components: the “Foundation Architecture” and the “Architecture Development Method” (AMD).

The *Foundation Architecture* is a repository of open industrial standards that can be used to define the specific services and architecture components to be used in an organisation. It is a generic architecture model that can be
adapted.

The Architecture Development Method (ADM) is a collection of methodological processes guiding the documentation of architecture in an enterprise based on the Foundation Architecture. A “Resource Base” provides guidelines, models, and fundamental information to put the ADM into practice.

The TOGAF does not impose any specific modelling language to describe EA models. However, TOGAF insists on the necessity to manage the alignment between the various models that can be developed.

Based on a number of well-documented experience reports (such as Dairy Farm, UK National Health Services, NATO, Statkonsult Norway, Litton PRC, and UK Ministry of Defense), one can see a number of advantages in TOGAF:

- guidance of a methodological process documented in depth,
- ability to adapt this methodological process,
- central position of requirements as a glue that makes the link between all the other models and phases of the methodological process,
- ability to select adequate tools (the TOGAF defines selection criteria) rather than to impose specific tools.

However, a number of issues can also be raised: lack of integration, of formalisation, and lack of support to guide strategic alignment.

1) Lack of integration.

This issue is raised by TOGAF itself : “At the present time the state of the art is such that architecture integration can be accomplished only at the lower end of the integrability spectrum [that is the “look and feel” is sufficiently similar to enable critical relationships between the descriptions to be identified]. Key factors to consider are the granularity and level of detail in each artefact .... As organizations address common themes (such as service oriented architecture, and integrated information infrastructure), and universal data models and standard data structures emerge, integration toward the high end of the spectrum will be facilitated [that is different descriptions should be capable of being combined into a single logical and physical representation].” (cf [24] p10 of introduction to ADM). Situating requirements at the center of the TOGAF is a clue to integration, but in the absence of guidelines, practitioners will have difficulty to explore this thread. Requirements-driven alignment is however a possible approach as demonstrate recent works on goal-based BP-IS alignment [38].

2) Lack of formalisation

The Open Group clearly displays its intention to avoid influencing the choice of any consultant, tool, or modelling technique, hence the lack of formalisation in the first versions of TOGAF. However, TOGAF provides minimal information on these concepts to ensure the compliance of actual practice in enterprises with the TOGAF recommendations. The TOGAF manual mentions in its introduction that meta modelling could be useful to avoid the issues raised by a lack of formality. Recent researches shows that ontologies would be useful to ensure interoperability at the methodological level between the various stakeholders and tools of an EA activity [20][39].

3) No support to improve strategic alignment:

In TOGAF, the enterprise's strategy is considered as an input in the first phase. It is therefore identified, but not modelled as the other concepts of EA. Therefore, the enterprise strategy is de facto excluded from the EA documentation, and no systematic guidance is provided to deal with the issue of strategic alignment. As a result, although strategic alignment is systematically presented in TOGAF as essential, and considered a top-priority issue by enterprises it is neither documented, nor guided by an appropriate methodological process such as [40][41][42] or [43].

C. USI (Urbanisation des Systèmes d'Information)

In the last decade, many French enterprises have undertaken to “urbanise” their Information Systems with the intention to integrate IS projects in a more evolutionary perspective. Gathered in a reflection group, the “club des Urbanistes de Systèmes d’Information”, several CIOs of major French companies and governmental agencies have developed a “French approach” to deal with practical EA issues based on their common experience.

This approach uses the metaphor of city planning (urbanisation) to deal with EA and develop an original repository of EA methodologies. As Zachman did, these methodologies exploit the idea that multiple modelling perspectives are necessary to produce a rich picture of the enterprise and its IS.

All USI methods have 8 main goals in common: (i) model Business Processes, (ii) document As-Is EA, (iii) define a target EA, (iv) define a migration plan, (v) use a modelling tool to document EA, (vi) define rules, (vii) support projects, (viii) manage projects.

One of the USI methods is documented in English and provides guidelines on how to deal with these issues [27]. The approach is organised in 7 phases:

- planning,
- review of strategic axes,
- As-Is analysis,
- strategy definition,
- convergence plan,
- publication of the strategy, and
- update of the strategy.

The approach proposes to use Ishikawa’s fish bone diagrams to model enterprise strategy by decomposing it into strategic goals and impact analysis matrices to articulate business processes evolution requirements and the goals of the enterprise strategy.

Besides, the method relies heavily on IS cartography (similar to IS-centered EA models) for documentation based on the principle of modularity. The underlying idea is that if the IS cartography is designed as individual components that interact with each other, then it is easier to manage the evolution of each individual component. To ensure this, the IS
decomposition is a facet of enterprise decomposition. In the USI approach, these facets are organised into levels: enterprise strategy, business processes, function, application, and technical architecture (while for instance in Zachman’s enterprise architecture Framework they are cells of a 6x6 table in which rows and column have no particular ordering relationships). Besides French cartography assumes that the components of a cartography may be defined in three predefined granularity levels (zone, district, and block). The underlying assumption is that when an element of the enterprise (strategy or business) evolves, it is likely that the corresponding elements in the IS in the application and technical systems will symmetrically evolve with little impact on other elements that are not directly related.

More than 40 enterprises such as AXA, Aéroports de Paris, Réseau de Transport d’Électricité, or Renault practice USI and share regularly their experiences. For example [19] reports several benefits of USI:

- it provides CEOs with a better understanding of the IS and of the organisation,
- it ensures a better continuity between the business and the IS,
- it provides project participants with a bigger picture of the enterprise and of the IS than the ones they usually have within their projects,
- it helps uncover alternative solutions to IS evolution,
- it provides project participants with complementary knowledge to manage projects and increases the methodological consistency across projects by defining common rules and principles of IS construction
- it helps quality progress across the enterprise,
- it helps control and improve strategic alignment, and
- it improves the enterprise's and IS’s ability to evolve.

We believe that introducing the principle of modularity and systematising IS cartography into companies are good things. However, a number of issues can also be raised about the USI approach:

1) Inconsistency across various methods

The USI approach is particular with respect to other EA approaches in the sense that it is itself a repository of particular methodologies used in practice whereas other approaches are either individual (e.g. Zachman EA framework), or integrated from scratch (e.g. TOGAF). On the positive side of USI, there is the richness of the methodological repository: more than 40 companies contribute regularly to capitalising knowledge around EA. All these experiences participate in a kind of empirical validation of USI. On the negative side, each method uses a different terminology, relies on different concepts, uses different tools and different ways of working. Inconsistency is an issue not only because it obliterates knowledge capitalisation and sharing experience, but also because it makes it difficult to collaborate across enterprises (e.g. between a consultant and an enterprise that has already undertaken an USI step). These inconsistencies could be solved by using an ontological approach, and by integrating method systematically with a method engineering approach, as is done for instance in the Systems Engineering domain [45].

2) Lack of guidance of co-evolution

USI provides guidance to deal with strategic alignment, to define IS targets, and to evaluate the impact of individual projects on the EA. However, they neither say how to ensure a consistent evolution of the enterprise strategy, of its business processes and of its IS, nor how to measure and improve alignment between these different items. As defined in [44] this issue has been handled in the RE community under the angle of co-evolution: several entities (the enterprise, the information system, business processes, strategies, IT infrastructures, etc) must evolve and remain consistent through time.

3) Adaptation processes not documented

USI is grounded in practice. This is of course an advantage because it demonstrates the scalability of the approach, but also an issue, because very little effort has been made to tell how to adapt the USI methods in specific enterprises. Experience shows however that non-French enterprises would be interested in the French experience and would be willing to adopt some of the USI methodological guidelines if they were more adaptable and less ad hoc [46].

D. Summary on the issues and risks found in EA practice

Many other EA frameworks, methods and tools such as EAP (Spewak), agile enterprise architecture (HP), ARIS Toolset (IDS Scheer AG), MEGA (MEGA International SA), System Architect (Telelogic), or Metis (Troux Technologies), just to name a few are available on the market. The purpose of this section was not to make an extensive review or a benchmark, but to analyse a sample and identify some issues and risks identified in method documentation and in experience reports:

- Lack of integration: EA approaches provide very little support to ensure the consistency of the various models to be documented. The integration issue is due to the holistic approach combined with the tendency to put modelling techniques next to each other without showing how they relate to each other, or even how to document models with each other to document their alignment. Several other issues are directly related to the lack of integration, from the difficulty to demonstrate the IS fitness for use, to monitor and improve the IS strategic alignment, and to the difficulty to maintain IS-BP alignment through time.
- Lack of formal definition: the main reason invoked for avoiding a formal definition of the concepts proposed by EA approaches is the need for language-

---

[2] An extensive and up to date list can be found at http://www.enterprise-architecture.info/EA_Tools.htm
independence and adaptability. However, the effects are negative too: difficulty to deploy approaches in enterprises lack of guidance, misinterpretation and misuse of the concepts. Overall, experience shows quality decrease and miscommunication, which is the exact opposite of what is looked for.

- **Lack of process documentation**: strangely, although most EA approach seem to agree about the importance of documenting processes to understand businesses, very few document the business of dealing with EA (in other words the methodological processes). Of course the consequence for practitioners is a lack of guidance which results in quality decrease, difficulty to deal with specific issues such as co-evolution or strategic alignment, and difficulty to adapt the methods to the specific methodological environments of enterprises. This of course has an impact on the evaluation of EA approaches when benchmarking them to make a selection, it also raises the barrier of adoption in the sense that it leaves complexity of adapting these approaches on the shoulder of practitioners.

IV. EA IN RESEARCH

The origin of EA research lies in the numerous research programs on IS engineering, which produced most of the underlying concept, techniques and principles of the methods used today in practice to deal with IS architecture.

The terminology used in the research community shows difference with industry. Indeed, researchers talk about enterprise modelling rather than EA (which is ambiguous and source of misunderstandings), methods, rather than frameworks, As-Is and To-Be rather than legacy and target.

Of the numerous research works achieved in this domain, three have been chosen: GERAM, EKD-CMM, and ACEM. This choice has been made because:

- these are complete methods that embrace the whole EA life cycle and not just techniques to be used to deal with local issues;
- each of them reuses former research results and adds new original features;
- they are validated by other research EA methods, which, taking similar approaches have provided similar results;
- they are well documented;
- they are scalable.

Each of the following three sub-sections gives an overview of the chosen methods, and analyses some of the lessons learned that could have some use to deal with EA in practice. More information on GERAM can be found in [47], on EKD CMM in [48] and on ACEM in [38].

A. GERAM (CIMOSA, GRAI-GIM, PERA)

A task force on Architectures for Enterprise Integration was formed by IFAC (International Federation of Automatic Control) and IFIP (International Federation for Information Processing) in August 1990 to review the field of EA and make recommendations for the future development of EA.

The Task Force early recognized that a single, universally accepted architecture, framework, or model would be a major contribution to the field of enterprise integration. The group first tried the path of finding an acceptable candidate within existing approaches. The group failed in this goal for political rather than technical reasons. However, it developed a new approach from the best characteristics from:

1. CIMOSA — As developed by the AMICE Consortium under the ESPRIT Program of the European Community, which was used to produce models of the engineering processes.
2. GRAI-GIM — As developed by the GRAI Laboratory of the University of Bordeaux, France, under its own research program for production management systems.
3. PERA — The Purdue Enterprise Reference Architecture and its associated Purdue Methodology.

One salient aspect of the resulting GERAM (Generalised Enterprise Reference Architecture Method) is that it distinguishes between the methodological process for enterprise engineering and the modelling languages that are used in these processes to describe and model the structure, content and behaviour of various enterprise entities.

The methodological processes and the languages used for enterprise modelling are supported by tools. The semantics of the modelling languages may be defined by ontologies, meta models and glossaries which are collectively called generic enterprise modelling concepts. The modelling process is enhanced by using partial models which are reusable models of human roles, processes and technologies.

The operational use of enterprise models is supported by specific modules which provide prefabricated products like human skill profiles for specific professions, common business procedures (e.g. banking and tax rules) or IT infrastructure services, or any other product which can be used as a component in the implementation of the operational system.

The lessons learned from GERAM are the following:

- two aspects of an EA method should always be documented: the methodological process and the language used for modelling;
- guidance can be provided by unfolding the process as well as by providing reusable models, tools, and generic sources of organisational and technological knowledge;
- correct modelling is only ensured if modelling languages are formally defined, at least with a meta model, the semantics of the modelling concepts can be made more precise using ontologies and glossaries. These last three are also useful to support better communication.

B. EKD-CMM

EKD-CMM (Enterprise Knowledge Development-Change Management Method) is an outcome of the European research
project ELEKTRA (ESPRIT V, no 22927). The ELEKTRA project mainly aimed at dealing with the change management issue in two European utility companies, namely Public Power Corporation (Greece) and Vattenfall AB (Sweden), and to generalise best business practices for dissemination and application to other companies.

EKD-CMM use enterprise modelling to represent various views of an enterprise. Different kinds of models are recommended. These models are inter-connected and organised in three levels according to their concern: the first level deals with enterprise goals, the second level deals with enterprise business processes, and the third level is the one of the Information System. Models belonging to this last level are used in EKD-CMM to define the requirements for an Information System to support the goals, processes and actors of the enterprise as defined in the models of the previous levels.

The EKD way of working is documented by methodological process models organised into a road map\(^3\). The EKD CMM road map proposes numerous guidelines to elicit enterprise goals, to conceptualise enterprise process models, and to conceptualise the Information System. Its originality is that it is built with numerous variants so to be usable in different contexts and for different purposes, as for instance:

- forward engineering (from business goals to business processes and from business processes to information systems development),
- reverse engineering (from legacy information systems to the information system level which may be then used to model the business processes level),
- business process re-engineering (from business processes level to the business goals for change).

One particular aspect of the EKD-CMM road map is the guidance provided to deploy goals. EKD-CMM organises goal deployment by studying the impact of the contextual forces on the current goals, eliciting and introducing the change goals, reflecting the impact, and envisioning alternative solutions. Change goals are elicited based on the type of impact of contextual forces on current goals and on the goals being impacted. A change goal can be achieved in several alternative ways with respect to different factors (quality requirements, market opportunity, technology availability, etc.). EKD-CMM proposes to envision alternative goals so as to describe all possible alternative ways for fulfilling the change goal, and thereafter to make the right choice concerning the target organisation and Information System design.

A number of the lessons learned from EKD-CMM result directly from their use at PPC and Vattenfall:

- A methodological process model should be described as a multi-purpose roadmap so that the methodology is adapted from the beginning to the various contexts in which it shall be used.
- Organising enterprise models into levels is not enough. Models should be related to each other to ensure alignment of the enterprise strategy, the business, and the IS. Goals provide the right level of abstraction to relate the other models efficiently.
- EA should provide modelling languages for documenting As-IS, as well as change goals, To-Be, and alternative change scenarios.

C. ACEM

The purpose of the Alignment and Co-Evolution Method (ACEM) is to guide the joint evolution of enterprise business processes and of the information system.

ACEM builds upon EKD-CMM in several ways. For instance, ACEM provides guidance through a rich process model described as a multi-purpose roadmap. Besides, as in EKD-CMM, ACEM provides modelling techniques to document the As-Is, as well as the To-Be and change goals.

Additionally, ACEM offers a number of specific and original features including modelling operational change requirements, tighter integration of the multiple EA models, and in-depth guidance to adapt the method.

**Modelling change**: in EKD-CMM change is modelled under the form of abstract change goals that relate to contextual forces. In ACEM early change requirements are high level change goals further refined as precise change requirements specified as gaps expected between As-Is models and the envisioned To-Be models.

**Relating views**: another important feature of ACEM is the central role taken by goal models. Whereas in EKD-CMM goal models have the same status as other models, in ACEM, they play a special role to ensure tighter integration between the business and the IS. In this approach, the goal models are ambivalent: they can be seen both as a view of the Information System and as a view of the enterprise business processes. This approach has several advantages: (i) it helps to document more easily the alignment between business processes and the information systems, (ii) it guides a systematic measurement of the degree of alignment, (iii) it allows to ensure that changes on the two sides are consistent, and (iv) it helps demonstrating the improvement of alignment in this co-evolutionary context.

**Guiding the adaptation of the method**: an important expectations towards methods is that they adapt to the situation at hand in the enterprise in which they will be used. Too often, methods are rigid and offer no support for their adaptation. An important feature of ACEM is that it is a generic and adaptable method. It is generic in the sense that the meta-models on which it relies can be instantiated into many different kinds of specific EA meta-model (e.g. those recommended by the Zachman Framework, or those recommended by a specific tool such as ARIS or MEGA, or even with UML). The ACEM way of working to achieve adaptation of the method to a specific context is documented with a process model, which is complementary to the ACEM roadmap provided to guide the alignment and co-evolution method.

**Lessons learned**:

- To be adaptable, a method should provide a

---

\(^3\) See EKD-CMM electronic guidebook at URL http://crinfo.univ-paris1.fr/EKD-CMMRoadMap/
generic view of the modelling languages to be used and instantiation mechanisms to adapt the method to the specific modelling techniques used in a given enterprise. It should also document the way of working to adapt itself with an adaptation process model.

- Change should be documented on different levels of abstraction from high level change goals down to operational change requirements.
- Co-evolution should be considered as an issue calling for specific approach. Goals are a language shared by all stakeholders. They help organising information between the other models of the EA and focus on these models concern-based. Ambivalent goal modelling helps guiding co-evolution of all EA models, and measuring and documenting alignment between these models.

D. Summary of lessons learned and other research threads to improve EA practice

There are six particular lessons that were learned from EA research and could, as we could see from experimental practice, have positive impact on the maturity of EA practice and on the quality of EA results. These are:

- Make goal modelling central and use it to provide an ambivalent view on the other EA models.
- Model change to avoid the static vision. Use several levels of abstraction to deal with complex evolutions.
- Manage co-evolution to ensure consistency of the EA.
- Define rich methodological process models with multi-purpose road maps to stimulate their adoption in different contexts.
- Formalise EA languages on a generic level and provide instantiation mechanisms to support adaptability.
- Guide the process of method adaptation to avoid methodological drifts.

These are discusses into more details in the next section.

V. Threads for innovating in EA practice

New EA practices are constantly making their ways in enterprizes and governmental agencies by the means of external consultants, and the improvement of local experts through EA books, web sites, courses, seminars, workshops, and of course meeting with more experienced architects [21].

As was the case years ago (and still today) with IS engineering methods techniques and tools, produced by research laboratories, research progresses on EA related topics are also influencing organisations’ practice, consultants methods, standardization institutes, and tool editors.

The following sections describe six fundamental issues met in EA practice that could be solved in the near future by transferring recent research innovation into industrial practice.

A. Alignment

The [49] report shows that the issue of IS alignment represents 54.2% of CIOs’ concerns and in the same study, the IS Alignment takes second place as the factor that most contributes to the IS success in organizations.

Managing and especially documenting alignment is one way to deal with organisation and IS complexity. This is a top issue for which CEOs expect more maturity from EA practice [21]. Improving alignment is one responsibility that CIOs assume daily in enterprizes. However, alignment can not be governed in the long term if it is not documented.

There are multiple benefits in documenting alignment. First of all, it helps checking the global consistency of the multiple views dealt with in EA: strategy with the IS, of the business with IS, of requirements and architecture, etc. Besides, documenting alignment allows to support a better integration of the different models at use, and therefore reduce the need for manual coordination and conflict resolution.

As [50] show it, enterprise architects have well understood that “starting anywhere else but from the top” is the first mistake to avoid when dealing with EA. The need for abstraction is particularly striking when dealing with alignment issues; not only because of the risk of conceptual mismatch [51], but also because of the combinatorial explosion of any approach focusing on details.

Several researchers have explored these tracks:

- [52] has shown that the alignment issue should be treated at the operational level as a requirements engineering issue.
- Business alignment has been explored by [53] and [54]. Measures for business alignment are proposed by [38].
- Strategic alignment is still an open research issue. [40] proposes an approach based on I* modelling language. The approaches proposed by [43] and [55] are also based on goal modelling.
- Researches in requirements engineering, business engineering, and information systems engineering, show that the most adequate abstraction mechanisms are provided by the intentional approach. In the international approach, the focus is on goals, objectives, intentions and value rather than on detailed functions, and information and process structures.
- It was also shown that goal models can be used in an ambivalent way, i.e., the same model can represent an enterprise strategy, business processes and/or the information system.

As a result, a recommendation is not only to document alignment, but also to do it in an abstract way, preferably with an intentional approach.

B. Requirements

Whereas TOGAF (the most used EA method) recommends to place requirements at the center of the EA practice, we observe that few EA tools and practice reports deal with requirements.

Requirements are too often considered in enterprises as
Co-evolution involves both impact analysis (to evaluate how evolution requirements can affect the enterprise, the IS, and the alignment between them), and change propagation (to carry out evolution requirements into the To-Be).

- [44] shows that co-evolution is a complex issue that can be dealt with in different ways depending on the situation. In any case, to manage co-evolution it is necessary to (i) identify evolution requirements, (ii) carry out these evolutions on the EA and (iii) check the consistency of the evolutions of co-evolving models of EA.
- Rules [61][62] can be used to ensure that the different kinds of evolution requirements are consistent.
- [63] and [38] propose metrics to evaluate and reduce the risk of alignment drift of the co-evolving entities.

In practice, co-evolution can be managed in different ways depending on the situation. The approach that ensures a minimum erosion of the IS alignment is based on an interdependent analysis of the evolution requirements combined with multi-asymmetric propagation of the evolution requirements [44]. This approach can however, be too heavy for rapid evolutions, when EA is still not mature in the enterprise. In this case, a lightweight approach can be developed based on metrics to monitor alignment when evolutions occur, and on a number of basic systematic rules to preserve/improve alignment in case of evolution.

D. Road map

EA methods differ from their IS engineering ancestors in that they usually document a methodological process in addition to traditional formal definitions of the language to be used.

There is a variety of ways to document methodological processes ranging from rigid models to modular methodological components. The lack of methodological process documentation leads to poor guidance, error-prone projects (with the resulting over-budget over-time issues), unproved and non-repeatable results, and difficulty to achieve the objectives.

Many of the methodological processes used in the industry are described as collections of activities organised in rigid sequences. The rigidity stands in the fact that these methods are prescriptive: its users are expected to achieve the recommended activities in the order predefined. When the situation is different from the one for which the method was defined, then the method becomes difficult to use and must be adapted manually.

Other methods are proposed under the form of toolkits. Instead of guiding one predefined way of working, the method user can select among a collection of pre-defined toolkits.

---

This paper provides a comprehensive overview of requirements engineering, focusing on the importance of documenting and analyzing evolution requirements. It highlights the challenges of managing co-evolution and presents various approaches and tools for dealing with evolution requirements in the enterprise architecture (EA) domain. The paper discusses the importance of EA methods in maintaining alignment with evolving business and technology needs, and the need for flexible and adaptable EA processes.

The authors present several research approaches that deal with change requirements, emphasizing the importance of documenting change requirements as high-level change goals to support the EA documentation and traceability of IS components and enterprise organization. They also discuss the need for methods to deal with change requirements, such as the EA methodological components, which are described as collections of activities organized in rigid sequences. The paper concludes with a roadmap for future research and practical considerations for managing co-evolution in the EA domain.
methodological processes depending on the situation. These processes are based on a common pool of techniques and tools but adapted to a number of predefined situations of use. The risk of not meeting the expected situation of use decreases in this kind of approach. However, each individual methodological process model is still rigid, and alternative ways of working cannot be found to deal with local issues, if these issues have not been taken into account from the beginning at the moment of method selection. The lack of flexibility is therefore still present.

Recent advances in Method Engineering research [64] have shown that highly flexible methods could be provided with a modular construction approach. In this kind of approach, the method user is provided with a flexible roadmap that can be dynamically adapted depending on the situation, and which components can be used independently and integrated into another method.

- [65] [66] have shown the importance of documenting the situation of use to take into account the contingency factors of the projects in which methods and method component shall be used.
- [67] and [68] have shown the importance of structuring method as road maps structured around the goals they are intended to achieve.
- Templates for documenting methods components so as to facilitate their selection and their reuse are provided by [69]

In practice, flexible method definition can only make sense way though an enterprise if it is supported by tool. [70] [45] show two examples of tools that could be immediately used in enterprises to deploy EA methods. One particular aspect with the REGAL tool is that in addition to supporting method adoption, it encourages maturity increase by providing special features to share experience within and between enterprises.

E. Genericity

Modelling (which is at the heart of EA) is not just just about drawing boxes and arrows. The modelling constructs must be used appropriately not only from a syntactic perspective, but also there intrinsic semantic must be respected if we want to avoid ambiguity, poor communication, lack of maintainability, irrelevant models. There are different ways to define formally the semantics of a modelling language, the most current being meta-modelling.

One difficult aspect is that while defining formally the concepts to use in a method, the method must be flexible enough to accept different adaptations or interpretations of these concepts in different enterprises with different methodological background. This calls for some genericity (in the sense of abstraction) in the definition of the concepts. Although generic, the definition of concepts must be precise enough to avoid ambiguity, misuse, and poor communication. The best response offered so far by research to deal with this issue has been to develop ontologies.

Ontologies are formal descriptions of entities and their properties, relationships, constraints and behaviours built in the intent to specify a shared body of concepts in a certain domain. Ontologies facilitate the understanding, communication and cooperation between people and organizations. They allow the key concepts and terms relevant to a given domain to be identified and defined in an unambiguous way. Therefore, the use and exchange of data, information, and knowledge among people and organizations is facilitated.

Ontologies are already at use in the industry under the form of meta data concept taxonomies, e.g XML e-commerce standards, but it has been demonstrated that ontologies could be built to achieve much more: e.g. to automate reasoning, to increase cross-application re usability, or to disambiguate data.

Ontologies offer a semantic – content and meaning based – approach to electronic information management and exchange. Accordingly, they promise to have a significant impact on areas that must deal with vast amounts of distributed and heterogeneous computer based information management, such as e-business, knowledge management, web portals, multimedia data, management of technical data, intelligent agents, or ubiquitous computing.

Several research projects [20] have been undertaken in the domain of EA, for example: the enterprise ontology, by University of Edinburgh, the TOVE projet at University of Toronto, IDEF5 by State University of Austin Texa, and the INTEROP European network of Excellence, which investigated the field of ontologies and their potential contribution to the synergy of enterprise architectures and to the interoperability of enterprise applications.

These projects have shown that ontologies are necessary to automate the management of the multiple models used in EA, as well as to ensure a common level of understanding of the terms used and concepts referred to in the different models of an EA.

In practice, ontologies should be developed by consultants and tool developers as standards to ensure compatibility between different EA approaches, and to ensure that local interpretations in companies are consistent with these standards. Several features could be developed in individual enterprises based on ontologies of EA concepts: to verify that recommended practice are consistent with standards, to ensure tool interoperability, and to develop rules to check that multiple models are consistent.

F. Adaptation

In its 2005 survey, the IFEAD shows that “still a lot of organizations are defining their own EA framework, often based on existing ones”. In fact 22% of the enterprises are using this strategy, which shows the importance for EA methods to be easily adaptable.

Again, method adaptation is an issue which is dealt with in method engineering research. Very few EA method actually propose a process to guide method adaptation on top of a generic approach. One can note however that [56] has proposed specific processes to guide the specialisation of her alignment measures and change requirement templates to the
specific methodological context of an enterprise.

In practice, consultants and tool developers should be able to communicate about how their methods adapt to specific situations, and systematise this process by specific and repeatable techniques. Concepts defined for IS and software engineering such as class instantiation or adaptation of design patterns can be employed with method fragments [69]. For enterprises, having defining rules for adaptation of their EA method has several advantage: it helps demonstrate that the specific use of a standard EA method is adequate to its intended semantics, and it improves the agility of the enterprise's own EA method and its ability to extend and adapt quickly to new methodological needs (e.g. in the context of specific projects, or through the intervention of new consultants), or innovation in the domain of methods.

VI. CONCLUSION

This paper has presented an analysis of EA research and practice with the goal to uncover innovative research approaches likely to help solve issues and risks met in practice. A number of issues are identified by analysing the two EA methods most used in practice, namely Zachman framework and TOGAF, and a third one, namely USI, which is specific in its way to deal with EA (and it is the most used in France).

Three EA approaches developed by research, selected for their innovativeness are considered and analysed with respect to the practical issues discovered earlier. The analysis concludes with a collection of six directions for improving EA practice using approaches developed in research. Each direction is discussed with respect to other research works with a number of practical recommendations.

Our hope is twofold:

• for research, we hope to have contributed to demonstrating the usability of their works in different domains;
• for practice, we hope to have given some hints about how to make their EA methods more mature.

The originality of this research compared to other state of the art is that it is not a simple review, comparison or classification of all existing approaches. Its intent is practical as it hopes to provide useful guidelines based on practical issues of EA methods used by companies as they are related in documented case studies, and observed in the author's experience.

There are several threats to the validity of this analysis:

• the methods chosen might not be as representative as hoped (e.g. in practice, a substantial number of enterprises claim to have their own approach);
• there might be a bias due to interaction between conclusions drawn from analysing practice and conclusions drawn from analysing research;
• conclusions have not been validated;
• many of the research approaches referenced are not so mature that they could be considered as efficient ways to solve the considered issues;
• the number of EA approaches existing in industry and the quantity of sources show the high diversity of issues that EA is supposed to help enterprises solve, the issues raised in analysing practice were more selected for the challenge they represent in terms of research more that for being representative in terms of risk, competition, or return of investment
• there are gaps between the issues and risks met in practice and the ones considered in research, but also gaps between the issues considered in this paper and the issues met in daily practice; issues that find their solutions in management (e.g. IS governance) and in technology (e.g. service oriented architecture) were not considered here or the sake of space.

Narrowing the gap between research and practice is a challenging issue. Looking at how decision-makers find their source of information (web, books, consultants, training) shows that researchers have an opportunity to influence the future of EA practice and to provide better orientations to new EA approaches.

We are currently considering several follow ups to the research reported in this paper:

• action research to test our guidelines for improving EA practice in a real setting;
• developing a method for guiding decision making in EA method selection and adaptation processes;
• undertake two surveys: one to explore the list of issues and risks in EA practice, and the second one to explore how researchers consider they can contribute to enhance EA practice;
• develop a guidebook to assist enterprises maturing their EA practice and share experience.

More generally, this work has revealed the need for more research in some areas, in particular:

• EA method development, to make them more generic and to document their adaptation processes;
• formalisation of EA concepts (in particular by the development of an ontology of EA), to facilitate a shared understanding from one method to another, from one tool to another, and from one company to another when they cant to share experience;
• original and efficient methodological processes to deal with strategic alignment and co-evolution;
• method evaluation, method comparison, and method improvement; not only because the effectiveness of most methods developed in research is not substantiated, but also to help enterprises audit their practices and look for other methodological processes with proven benefits (the benefits of industrial approaches is not formally proven either).

REFERENCES


[70] M. Saeki. CAME : The First Step to Automated Method Engineering. OOSPLA. 2003