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Enterprise Architecture Framework Design in IT Management

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Abstract

Since the inceptions of Information Technology (IT), organizations have experienced a permanent increase in size and complexity of enterprise information systems. To manage and organize these systems, logical constructions and representations in the form of models were needed, and an architecture approach was developed in response to these challenges. Architectures are used commonly in IT domain to construct blueprints of an enterprise for organizing and optimizing system components, interfaces, processes, and business capabilities, among others.

The paper contains a perspective on some of the most important technical issues regarding the designing and selection of an architecture framework for an organization. An Enterprise Architecture Framework (EAF) sets a practical guidance for analyzing, understanding and applying technical descriptions of an architecture in a certain business area. Designing and/or adapting an adequate EAF has been one of the challenging issues of the past years for many companies. Thus, the paper contains a research accomplished by using a comparative analysis of the main Enterprise Architecture Frameworks, underlining the stronger and weaker points of each one. The findings relate mostly to what and how things should unfold in designing the Enterprise Architecture Framework in order to optimize the workflow and thus maximize the business benefits. The paper underlines the most important issues that must be taken into account in designing an Enterprise Architecture Framework or adapting the already existing ones in order to better fit the organization's objectives and optimize the ongoing processes.

Keywords: enterprise architecture framework; EAF; information technology; information system.

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1. Introduction

Information Technology (IT) has a constant growing role not only in our daily lives, but also for many organizations, as IT management becomes more and more critical in achieving their business objectives. Optimum use of IT within an organization implies making wise choices. Thus, architecture is an important tool in making the right decisions. Designing enterprise architecture only on theoretical level does not necessarily bring an organization any closer to more efficient use of IT, nor does it help in achieving the business objectives any faster. The enterprise architecture needs to become an integral part of the organization and be supported by the organization as a whole [1].

A well-designed reference architecture helps various functions within the business work with each other using a common taxonomy and accelerates the business transformation when this is desirable. When different businesses need to collaborate, they have to relate their Enterprise Architecture Frameworks (EAFs) to each other, and this means they should document their EAFs and thus, a common understanding of each other's EAFs is required. An EAF, capable to integrate existing frameworks, is useful for such a task, because it can show how the integrated EAFs relate to each other [2]. However, organizations have not been always able to fully translate EA solutions to meet organizational needs despite the vast selection of existing EAFs. From a certain perspective, EA can be seen as the process of aligning the business part of a company with information technology where there is an integration of processes, organizations and people in the company [3]. Most of the enterprises must deal with business changing, like a new development of products and services or different economic situations and they must improve their business processes in order to be able to survive. In this regards, these enterprises, should adapt themselves to these changes effectively [3]. In view of the increased business and organizational extension and dynamics, integration, agility and the ability to change, are becoming more and more important. Enterprises should thus pay considerable attention to their enterprise architecture [4]. Enterprise architecture is an instrument to articulate an enterprise's future direction, while also serving as a coordination and steering mechanism toward the actual transformation of the enterprise [5]. However, similar to the management of IT architectures, the EA structure alone is not enough to reach architectural goals on the long term. The governance principles are necessary in order to increase control on architectural evolvement and insure that implementation will continue further [13].

As modern organizations struggle with the complexity and dynamicity of their business environments, they increasingly turn to Enterprise Architecture as a means to better organize their capabilities. However, adopting Enterprise Architecture is not a straightforward matter as the practical guidance available is characterized by disparity in nomenclature as well as content [16]. Thus, the main objective of this paper is to attempt an examination on the four of the most well-known frameworks with the aim to provide more knowledge about the various dimensions of enterprise architectures.

2. Main EAFs

There are several EAFs that have been used in the past decades. Among the most well-known, the following are worth mentioning:

- Generalized Enterprise Reference Architecture & Methodology (GERAM)
- Model Driven Architecture (MDA), introduced by Object Management Group
- The IEEE Recommended Practice for Architectural Description of Software-Intensive Systems (IEEE Std 1471-2000 also known as ANSI/IEEE Std 1471-2000 and more recently as ISO/IEC 42010:2007)
- Reference Model for Open Distributed Processing (RM-ODP)
- The Open Group Architecture Framework (TOGAF)
- The Federal Enterprise Architecture Framework (FEAF)
- The Department of Defence Architecture Framework (DoDAF)
- The British Ministry of Defence Architecture Framework (MODAF)
- The NATO Architecture Framework (NAF)
- Service-Oriented Architecture (SOA)
- Zachman Enterprise Framework (ZEF)
- Extended Enterprise Architecture Framework (EEAF or E2AF)

From the aforementioned EAFs, the paper will approach in more detail four of them: FEAF, ZEF, RM-ODP and TOGAF.

2.1. FEAF

The Federal Enterprise Architecture Framework (FEAF) was built and implemented by the United States Federal Chief Information Officers Council, in order to facilitate interoperability, the shared development of common federal processes, and information exchange between different agencies and entities of the federal government. FEAF was developed on the enterprise architecture model of the National Institute of Standards and Technology. This model permits better planning and organizing processes, while in the same time contributing to form an integrated and robust pack of information and IT architectures. It consists of five layers which are defined separately, but are interconnected: the business architecture, the information architecture, the information systems architecture, the data architecture, and the delivery systems architecture [15].

FEAF is partially based on Zachman framework (presented in the following paragraph), but refers only to the first three columns there (using slightly different column names) and focuses on the top three rows. FEAF consists of six reference models:

- Performance Reference Model (PRM) – is used for measuring the performance of initial IT investments and estimating how they contribute in future based on performance
- Business Reference Model (BRM) – is used for organizing, building in a hierarchical approach and depicting daily business activities undertaken by the federal government without a connection to the entities that execute these processes
- Data Reference Model (DRM) – is a generic model that provides the required information needed to keep track of the details on operation level
- Technical Reference Model (TRM) – checks and confirms the ability of the components in relation to the described specification and agreed level of performance according to predefined standards
- Infrastructure Reference Model (IRM) – is used for supporting the hardware that provides functionality
- Security Reference Model (SRM) – is used as a common language, as well as a methodology, for describing security and privacy regarding business goals in various organizations.

The main objective of FEAF is to enhance interoperability level within government entities by using a one enterprise architecture for the whole federal government. The purpose of this framework is to allow the business activities alignment and use a predefined pack of models in order to provide support for IT systems.

2.2. ZEF

Zachman Enterprise Framework (ZEF) was published by John Zachman in 1987 and is seen as one of the pioneers in this domain [6] [9]. The Zachman Enterprise Framework (ZEF) is constructed upon the principles of classical architecture that set a common language and the foundation for depicting complex enterprise systems further. ZEF has six perspectives: Planner, Owner, Designer, Builder, Subcontractor and User.

This framework is a structure for helping the management to organize and classify the detailed representation of an enterprise, which represents in a visual way the interaction between the roles in the process. Moreover, it defines owner, designer and builder of the process, as well as setting the component, the way it works, the location where it is situated, the person who is responsible, the team which does the work and why it matters [10]. ZEF, on the one hand, is shown as a planning tool, which can be helpful for enterprises in making better choices, finding the issues in the context of the business and seeing the alternative options and solutions. The second dimension of ZEF approaches the six main questions: what, how, where, who, when and why [6]. It does not offer advice on process, on the right order of activities, or their execution, but rather on making sure that all views are clear and firmly set, thus ensuring a complete system, without taking into account the sequence in which they were set. As it is not a standard written by or for a professional organization, it also worth mentioning that ZEF does not have any precise compliance rules [8].

Columns give the answers to six questions:

- What? – data that needs to be understood and worked with.
- How? – function or how the process of changing the aim of the enterprise into a more detailed description of its operations.

- Where? – network or where the business activities are taking place or will be distributed in the future.
- Who? – people who are involved in the business processes and into implementing the new architecture.
- When? – time and effects of time on the organization.
- Why? – motivation and formulating the business goals and strategies [9].

This framework was designed to provide an architecture that embraces all of the descriptions used by a large organization. It makes more sense for business managers to maintain those aspects of the architecture that they create and for information system managers to focus on the documentation that they create [11]. ZEF is used on a large scale and is seen as a way for expanding or documenting an architecture for the entire organization, as it shares the basis with Information System Architecture [15]. It is viewed as being the starting point, the foundation for other EAs and is usually used in an environment which can handle organization structures and sets of applicable methodologies.

2.3. RM-ODP

The Reference Model of Open Distributed Processing (ISO-RM-ODP) offers a framework for the evolvement of systems that can handle processing between different platforms. RM-ODP uses object-modeling approach in order to model distributed systems. RM-ODP is the result of a collaboration between three major actors: the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the Telecommunication Standardization Sector (ITUT). The connection between "problem" and "solution" can be achieved by the "viewpoints" which offer an approach for the system to be represented. The ISO Reference Model of Open Distributed Processing provides five viewpoints, where a viewpoint is "a subdivision of the specification of a complete system, established to bring together those particular pieces of information relevant to some particular area of concern during the design of the system".

RM-ODP was designed to handle the distributed systems. It contains five viewpoints, each having the required model:

- The *enterprise* viewpoint - shows the enterprise requirements and policies on high level and it targets the needs of the information system users.
- The *information* viewpoint - puts the accent on the structure and flow of information, logical and physical organization of information with information modification tracing.
- The *computational* viewpoint - handles the definition of application components, their interfaces and the connections established between them.
- The *engineering* viewpoint - indicates overall organization of the objects recognized and their contribution in different interaction patterns in order for a service to be fulfilled.
- The *technology* model - recognizes artefacts from technical perspective for the previously defined structures: engineering mechanisms, computational, information and enterprise structures.

Also, each viewpoint is needed to represent the system from a certain number of perspectives.

2.4. TOGAF

The Open Group Architectural Framework (TOGAF) was initially designed in 1995 and had its foundation on the Department of Defence's Technical Architecture Framework for Information Management. TOGAF is a comprehensive methodology, including a set of tools to develop an EA. It is based on an iterative process model supported by best practices and a reusable set of existing architecture assets TOGAF contains regulations for unfolding proper principles, rather than offering a number of architecture principles. The three levels of principles help taking decisions throughout the whole organization. It offers guidance of IT resources and sustains architecture principles for growth and practical execution [8].

TOGAF has the following views and viewpoints for development of enterprise:

- Business Architecture Views - deals with the problems of the system users and depicts the transfer of information between people and business processes.
- Data Architecture Views - depicts the data management capacities arranged to logical and physical assets helping application accomplishment.

- Applications Architecture Views - shows the base architecture, it contains architectural segments along with their interrelationships that suits the organization's business processes.
- Technology Architecture Views - deals with the preoccupations of buying the commercial off-the-shelf parts that could diminish the cost for development the software further.

TOGAF is an architectural framework, which in comparison to The Zachman Framework, gives an approach to designing, planning and implementing of EA and is provided by The Open Group free of charge. While TOGAF consists of three main elements: Architecture Development Method (ADM), Enterprise Continuum and Resource Base, ADM is considered as the key component of this framework.

3. Architecture as a link from objective and strategy to design and implementation

The Open Group states that "Enterprise Architecture is about understanding all of the different elements that do the business and how those factors are related to each other" [18]. Enterprise Architecture (EA) is a complete expression of the modern organization, a holistic plan which acts as a collaboration force between objective, vision, strategy and governance principles. It connects also aspects of business operations like business terms, organization structure, processes and data; and aspects of automation such as information systems and databases; and the enabling technological business infrastructure: computers, operating systems and networks [6]. Therefore, in a medium or large modern company, a thoroughly defined framework is mandatory to be able to create the entire organization in all its dimensions and complexity, with the aim to coordinate the many facets in a holistic manner (Fig. 1).

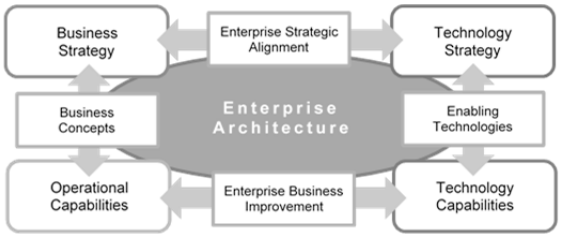

Fig. 1. Holistic view of an Enterprise Architecture framework.

Among some of the numerous aspects of an enterprise can be mentioned its organizational structure, business processes, information systems and infrastructure. All these take part on making an enterprise architecture. When it comes to models representing these areas, the quality and completeness of information often decreases when going from top to bottom. For lower levels information such as concrete IT services and applications is often difficult to gather and maintain updated [7]. An enterprise architecture should provide an elaboration of an enterprise's strategy such that it enables the steering and coordination of the programs and projects. It is quite natural to identify different granularity levels of essential requirements addressed by an EA. For example, in TOGAF a distinction is made between a strategic architecture, segment architecture and capability architecture. These architectures become increasingly more specific in terms of their scope, while reducing their intended time-horizon to the horizon relevant to the program or project. More specifically:

- Strategic Architectures shows a long-term summary view of the entire enterprise.
- Segment Architectures provides more detailed operating models for areas within an enterprise.
- Capability Architectures shows in more detail how the enterprise can support a particular unit of capability.

As a synthesis, Fig. 2 summarizes how architecture forms a link between strategy and design, and ultimately the implementation of the future company.

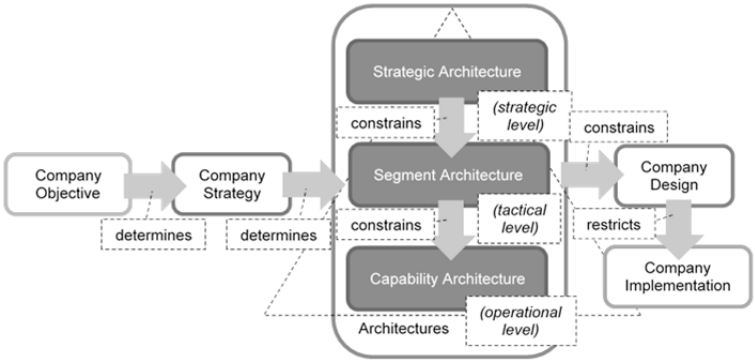

Fig. 2. Architecture as a link from company objective and strategy to design and implementation.

Based on the distinction between a strategic architecture, segment architecture and capability architecture, as suggested by TOGAF, three levels of architecture can be identified. These levels correspond to the three levels of transformation granularity. The company objective determines the company strategy, that determines the enterprise transformation, and therefore also the formulation and use of the architecture. The strategic architecture constrains the design space for the segment architecture, while the segment architecture restricts the design space of the capability architecture. Finally, the architectures limit the design space of designers, while the design on its term can be regarded as limiting the space for valid implementations [5]. Taking things a step further, Fig. 3 also underlines that architecture principles are funded on all kinds of issues, among which are worth mentioning the business strategy and business drivers, the existing environment and external developments. It shows the sequence from company strategy through architectures, to the design of some specific system within the system of systems that forms the enterprise, to that system's implementation. Also, it highlights the way scientific principles help in the designing of architectures.

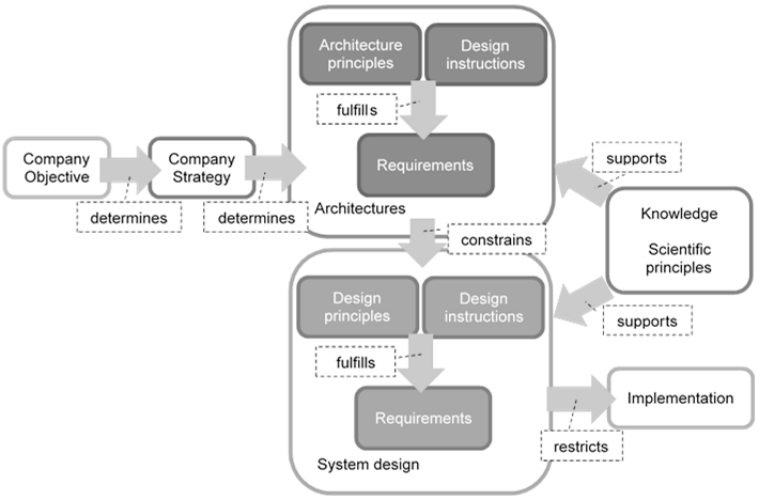

Fig. 3. Architecture principles as an alignment instrument between objective, strategy and operations.

They also affect many kinds of other things, among which can be enumerated guidelines, architecture instructions, design requirements and instructions and implementations. Architecture principles truly make the connection between strategy and operations; they are mainly an alignment tool (Fig. 3). Gathered experience, knowledge and opinions of all types of people involved in doing the work the organizations lead to their formulation. This team of varied people also forms the target audience of normative principles. In this regard, the definitions of normative principles also offer a common lexicon for that enterprise.

4. Evaluating an EAF

Designing enterprise architecture is not an easy task. Choosing among the various ideas, conceptualizations, theories, models, methods, and practices of EA is complex and demanding. This is particularly true since things are still at the beginning of a long road and have little data by which to judge and evaluate different approaches [12]. Thus, EAFs were created to simplify the process and guide an architect through all areas of architecture development. An EAF offers a set of most effective procedures, standards, instruments, processes and patterns to help in the design of the EA and architectures with different purposes. EAFs usually include: Common vocabulary, models and classifications; Processes, principles, strategies and instruments; Reference architectures and models; Prescriptive guidance: EA processes, architecture content, implementation guideline; Catalog of architecture deliverables and artifacts; Enterprise Architecture Content Metamodel; Proposed set of products and configurations.

Using an EAF facilitates the process for designing and keeping architectures at all levels (enterprise architectures, functional business segment architectures and solution architectures) and allows a company to raise the value of architecture guide lines. A number of EAFs currently exist in the industry with the goal of addressing the basic challenge for aligning and organizing business goals with strategies and technical needs [14]. Examples selected for comparison in this paper include ZEF, TOGAF, FEAF and RM-ODP. Each EAF has its own strengths and weaknesses, pluses and minuses, which makes it rather hard to find that one marvel framework that can be the perfect choice in all cases. The following table shows how some of the four most important Enterprise Architecture Frameworks compare against each other. The lowest given grade is 1 and the highest grade is 7. Table 1 indicates this comparison by taking into account the most relevant evaluation criteria.

Table 1. Evaluating four of the main EAFs.

Evaluation criterion	FEAF	ZEF	RM-ODP	TOGAF
Architecture models	7	7	7	7
Application architecture	5	5	4	5
Data architecture	4	5	3	6
Environment management	5	6	5	6
Performance management	3	3	3	6
Compatibility	4	4	5	7
Extensibility	5	6	5	6
Flexibility	4	4	6	7
Portability	4	3	6	6
Scalability	5	7	5	6
Business needs	7	7	7	7
Information system	7	4	7	7
Platform	6	7	6	6
Software configuration	0	0	4	7
Support for business model	7	7	7	7
Total score	73	75	80	96

5. Discussion, limitations and conclusions

Taking into account the most important 15 evaluation criteria, the final results show that there is no huge difference between the four EAFs considered for comparison (Fig. 4), as FEAF scored 73, ZEF 75, RM-ODP 80 while TOGAF scored 96 out of a maximum of 105 points.

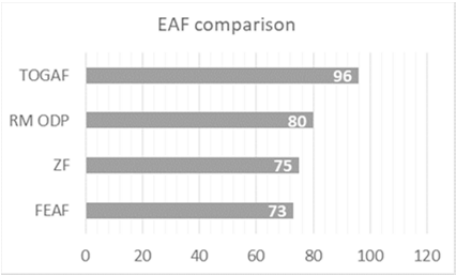

Fig. 4. EAF comparison chart.

However, there are some differences worth discussing. On “Architecture models” “Business needs” and “Support for business model” all the four frameworks scored 7 points (that is the maximum – highlighted on grey background in the table). On “Application architecture” the score is also almost equal, just RM-ODP scored a little lower. On “Performance management” TOGAF scored double in comparison with the rest of EAFs, while on “Information system all EAFs scored maximum, except ZEF where there are only 4 points.

Counting the criteria with the highest score, TOGAF has scored maximum on 7 out of 15 issues, RM ODP and FEAF on 4 out of 15, while ZEF on 5 out of 15. As a bottom line, selecting one of the four EAFs comes down to the preference of each company. Some researchers claim that the selection of an EAF is not even such an important task, but more important are other issues, like how it is being implemented and adapted according to the organization’s objectives and strategies.

There are also some limitations of the research and they relate to a certain degree of subjectivity level when setting the score for each evaluation criteria and also when selecting the 15 evaluation perspectives.

The role of an enterprise architecture is to enable the organization to be innovative and respond rapidly to changing customer behavior. The enterprise architecture has the long-term business vision of the organization and is responsible for the journey it has to take to reach this goal. They support an organization to achieve their objectives by successfully evolving across all domains; Business, Application, Technology and Data. For organizations, the design of an EA is a balancing act as time and resources are limited and circumstances always change rapidly. At least, the level of detail and the focus of the architectural efforts need to be chosen.

The purpose of this paper is to highlight a comprehensive measurement approach to assess the overall value contribution of some of the main Enterprise Architecture Frameworks. For this aim, a few conceptual basics and theoretical aspects have been discussed first. Also from the limitations’ perspective, current approaches are not thoroughly detailed in terms of metrics and are neither theoretically entirely based nor obtained from existing practices in an exhaustive manner.

Regarding their approach and level of detail, some of the current EAFs are quite different, as some are just offering guidelines, while others have specific methodologies and aspects to follow. Most of the frameworks are rather abstract in that as they have general terms, thus it becomes possible to question the validity or the capacity to work within that framework in a precise and efficient manner [8].

In conclusion, it can be stated that EAFs still present immense challenges and opportunities. IT practitioners and researchers have the first chance at taking advantage of the opportunity and challenge of EAs. Thus there is a unique opportunity for information system researchers to expand their knowledge and experience and to create a new existential niche that would help foster and perhaps even ensure respect of the information system academic discipline both by business practitioners and researchers [12].

References

[1] R. Wagter, M. van den Berg, J. Luijpers, M. van Steenbergen, Dynamic Enterprise Architecture, John Wiley & Sons, Inc. (2005)
[2] N. Zarvic, R. Wieringa, An Integrated Enterprise Architecture Framework for Business-IT Alignment, Business/IT Alignment and Interoperability, BUSITAL '06, (2006), pp. 262-270
[3] R. Ansyori, N. Qodarsih, B. Soewito, A systematic literature review: Critical Success Factors to Implement Enterprise Architecture, Procedia Computer Science 135 (2018) 43–51

[4] F. Behrouz, M. Fathollah, A systematic approach to enterprise architecture using axiomatic design, Procedia CIRP 53 (2016) 158 – 165
[5] D. Greefhorst, E. Proper, Architecture Principles, The Cornerstones of Enterprise Architecture, Springer-Verlag Berlin Heidelberg 2011, ISBN 978-3-642-20278-0
[6] J. Schekkerman, How to survive in the jungle of Enterprise Architecture Frameworks, Second Edition, Trafford (2004), ISBN 1-4120-1207-X
[7] Kaidalova J., Sandkuhl K., Seigerroth U., Challenges in Integrating Product-IT into Enterprise Architecture – a case study, Procedia Computer Science 121 (2017) 525–533
[8] L. Urbaczewski, S. Mrdalj, A Comparison Of Enterprise Architecture Frameworks, Issues in Information Systems, Volume VII, No. 2, (2006) 18-23
[9] J. A. Zachman, John Zachman'S Concise Definition of the Zachman Framework, p. 2008, 2008.
[10] C. L. Parmo, The use of Enterprise Architecture, IT Strategy and IT Governance at StatoilHydro, no. June, 2009
[11] P. Harmon, Developing an Enterprise Architecture, Business Process Trends, Whitepaper, January 2003
[12] L. Kappelman (editor), The SIM Guide to Enterprise Architecture, CRC Press, Taylor and Francis Group, 2010, ISBN 978-1-4398-1113-9
[13] J. Schelp, M. Stutz, A Balanced Scorecard Approach To Measure The Value Of Enterprise Architecture, Via Nova Architectura, TEAR 2007 June 6, 2007
[14] R. Covington, Hamza Jahangir, The Oracle Enterprise Architecture Framework, An Oracle White Paper in Enterprise Architecture, 2009
[15] F. Goethals, An Overview of Enterprise Architecture Framework Deliverables, SAP-leerstoel 'Extended Enterprise Infrastructures'
[16] Th. Magoulas, A. Hadzic, T. Saarikko and K. Pessi, Alignment in Enterprise Architecture: A Comparative Analysis of Four Architectural Approaches, Electronic Journal Information Systems Evaluation Volume 15, Issue 1, 2012, (pp88 -101)
[17] H. Topi (Editor) Computing Handbook, Information Systems And Information Technology, Third Edition, CRC Press, Taylor & Francis Group 2014 by Taylor & Francis Group, ISBN 13: 978-1-4398-9856-7
[18] P. Hinssen and J. Derynck, Business/IT Fusion: How to Move Beyond Alignment and Transform IT in Your Organization. Across Technology, 2009.