A Conceptual Blueprint for Enterprise Architecture Model-Driven Business Process Optimization

Dóra Őri and Zoltán Szabó(✉)

Department of Information Systems, Corvinus University of Budapest,
Fővám tér 8, Budapest 1093, Hungary
{dora.ori, zoltan.szabo}@uni-corvinus.hu

Abstract. Business process management (BPM) is a traditional approach to achieve process excellence, and a key success factor of digitization initiatives. It facilitates strategic alignment by streamlining business processes, and harmonizing business and IT domains. The main goal of this research is to map BPM and enterprise architecture management (EAM), to provide a systematic review of EAM-supported process optimization methods. BPM is focusing on the business architecture layer of EAM frameworks, so EAM can be a major facilitator of BPM lifecycle activities, especially the optimization phase. Our proposed analytical framework can contribute to the evaluation of process architecture, considering the context and dependencies of the process-related models to the components of an information architecture.

Keywords: Business process management · Enterprise architecture management · Modelling · Optimization

1 Introduction

Success in digitalization, implementation of disruptive innovations, integrating digital technologies (social media, mobile applications, business analytics and cloud-based services), and effective and fast integration of emerging new business models require a solid base in technology governance and business process management too. Maturity in business process management (BPM) is a key success factor to implement digital strategies and transform the business.

Business process management is a traditional approach that focuses on business operations, seeking for process excellence. BPM integrates several methods and techniques for modelling, analysing, reorganizing, operating and monitoring the processes of an organization. It is an efficient management method that facilitates strategic alignment by streamlining business processes, and harmonizing business and IT domains. BPM ensures flexibility and dynamic fit between external and internal domains. It is a key enabler of harmonization focusing on product/market, strategy, administrative structures, business processes and IT [1]. Although BPM is recognized as a strategic instrument of business revitalization, it is still interpreted simply as modelling business activities and implementing workflows.

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As a result of growing complexity in technology and organizational configurations, process innovation is a real challenge; the harmonization of processes, organizational structure and underpinning technology needs considering several factors in a dynamic environment. Enterprise architecture management (EAM) enables technology-related planning, management of implementation, but also maintains a comprehensive model of the organization. This EA model of the organization provides a solid base for the management of complexity and integrates technology and business domain-related details. The goal of this paper is to prepare a conceptual framework that facilitates process improvement and optimization through enterprise architecture model-based analytical opportunities and methods.

The rest of the study is organised as follows: Section 2 describes the most relevant aspects of business process management, focusing on optimization and innovation. Section 3 provides an overview of enterprise architecture management, maps BPM concepts with EAM, and finally presents an EA-based analysis method that can be utilized in business process optimization.

2 Business Process Management Overview

Business process management is a key factor of surviving in the turbulent economic environment. Since the seminal work of Hammer [2, 3], business process reengineering (BPR) has become one of the most popular and successful business movements. As it is widely accepted, reengineering is a radical, IT-driven approach to improve business efficiency. Reengineering has two main approaches: Business Process Redesign is concentrating on streamlining individual processes, while Business Reengineering has a wider focus, its purpose is to rethink and redesign the business as a whole. A less radical, incremental approach is Continual Process Improvement.

Business Process Redesign is considered as "the analysis and design of workflows and processes within and between organisations" [4]. The main features of reengineering are [5]: the creation of customer orientation, the examination of existing value-adding processes (process- and cross-functional orientation), the questioning of outdated organisational principles, the elimination of unnecessary activities, the minimisation of delays between process stages, the reduction of effort-duplications, the improvement in internal communication, the empowerment of the staff, benchmarking, outsourcing and the use of IT as an enabler. Based on a holistic view, Rosemann and Brocke [6] suggest six core elements of BPM: strategic alignment, governance, methods, information technology, people, and culture.

2.1 BPM Life Cycle

Business Process Excellence is the traditional and generally accepted major goal of process management [7]. Key dimensions of a process – time, cost and quality – are always on the focal point of business initiatives; matured process management can be a strategic asset for the organization. BPM is also an appropriate tool to efficiently support the day-to-day operations in an organization, as regulations, roles and responsibilities are clearly defined in process models, that can be interpreted in an easy-

to-use form for the relevant staff. Process-oriented measurement – monitoring of process performance and reporting of process KPIs – is a common practice that enables the smooth operation of many huge organizations. BPM is a complex and comprehensive approach, its scope covers strategy, organizational structure, supporting technology, skills and knowledge. The lifecycle of BPM has several phases [8], covering all aspects of process-related tasks necessary for achieving process excellence [7]:

- Business process strategy, that defines the strategic goals and prepare a process portfolio
- Process documentation, that prepares the process models and collect relevant information
- Process analysis and design, that investigates process-related problems (cycle time, cost, quality, etc.), and optimises the process, defining an integrated system of the process, organization and technology
- Implementation and change management, that ensure the realization of plans, IT projects and organizational changes
- Process operation, that maintains an appropriate organizational environment for the utilization of processes
- Process controlling/monitoring, that collects process-related KPIs and provides a feedback mechanism for further development.

BPM is a radical change program, integrating radical top-down initiatives with a set of continuous efforts towards process excellence. Within the overall framework of BPM lifecycle model, process analysis and design is the most challenging phase, that should aim at optimizing processes according to business needs and strategy.

2.2 Knowledge and Semantic Aspects of BPM

Maddern et al. [9] discusses the importance of a holistic approach, the end-to-end process management, and presents BPM-related symptoms of fragmentation in modelling, optimization. They reported that the ongoing maintenance of a process infrastructure is a very challenging task for organizations. End-to-end process management raises the question of complexity, especially in the case of inter-organizational processes.

The necessity of the fusion between knowledge and process management is a recognized issue and challenge in the literature [10]. Semantic Business Process Management (SBPM) is a new approach that can increases the level of automation in the translation between business and IT domains [11]. A major challenge in BPM is the management of the knowledge, related to the process portfolio. The distributed nature of knowledge represented in numerous information systems makes integration even more challenging. Lin and Krogstie [12] presents a framework for semantic annotation of processes to avoid the problem of the heterogeneity of distributed process models to facilitate the management of process knowledge.

BPM is a well-established method and technology for many companies, but the extension of modelling towards automated application generation, extended functionality, and integration with other technologies (interoperability) are still major trends in R&D. Recently, the focus of BPM activities is on the implementation phase: process

modelling is a tool that has to support (semi-) automatic IT development [13]. The extension towards performance measurement, knowledge-based applications, and compliance check [14, 15], etc. are also promising directions.

Semantic technologies have been integrated to BPM in the last decades to facilitate automated utilization of process models for the development of applications. Semantic description (machine processable representation) of processes can bridge the gap between the business logic and the IT perspective [11]. Semantic annotation of the models also enhances the services built on process models. SBPM integrates BPM methodologies and tools with Semantic Web Services frameworks and ontology representation [16]. Management of the knowledge dimension of business processes is a recognized problem, many initiatives purpose ontology-based semantics, even fuzzy ontology to manage organizational knowledge [17].

2.3 Optimization in BPM

In Business Process Management, we consider optimization as the fundamental rethinking of business processes to achieve substantial improvements, which are then reflected in the critical performance variables of time (speed), costs, quality, service/customer satisfaction. Business process optimization initiatives reduce lead (cycle) time, decrease cost, improve quality of products/services, and enhance customer satisfaction, to sustain the competitive advantage of the company. Optimization of processes in the above-presented dimensions is based on several methods. Some of them are based on experiences and management techniques, like brainstorming, others use formal methods, like simulation. In this context we have to distinguish between business-oriented optimization (in the sense of innovation) and formal (mathematical) optimization.

There are several process modelling techniques that capture and address different aspects of a business process, emphasizing that only a limited number of these process modelling approaches allow extensive quantitative analysis, and only a few are appropriate for more complex, structured process improvements [18].

Traditionally, process improvement is based on relatively simple techniques, like observation, workshops and high-level KPI-based evaluation methods (performance analysis) to identify nonvalue-added activities, redundancy, rework, and bottlenecks. To eliminate these problems, the typical approaches are the simplification or combination of activities, and the parallel/concurrent execution of synchronized tasks. Process models and process controlling-based data are major facilitator of the optimization, but it is still a trial and error-based approach. There are opinions that the analysis and improvement of the process is not transparent, there is no formal underpinning methodology to ensure the logical consistency [18].

Grant [19] investigates the available business analysis techniques (problem analysis, root cause analysis, duration analysis, activity-based costing, outcome analysis, technology analysis, business process analysis and activity elimination), and concluded that complexity of process innovation requires a variation of multiple techniques to diagnose problems. Tsakalidis and Vergidis [20] argue that Evolutionary Computing (EC) techniques can effectively support multi-criteria optimization (optimization based on multiple evaluation criteria). Multi-criteria optimization is necessary to avoid

discrepancies between the key dimensions and requires holistic frameworks, and potentially evolutionary approaches.

There are new, more formal emerging methods, that concentrate on the performance (behaviour) of the processes. Process mining is an analytical approach to discover, monitor, and improve processes. It is based on data mining techniques (classification, clustering, regression, association rule learning, etc.) using event data [21]. Process mining can also be used for the automatic discovery of process-related information [22]. Process simulation facilitates process diagnosis and optimization too. Simulation is an effective approach when scenarios of proposed changes should be evaluated to determine the optimal set of changes, using sensitivity analysis of modifications in process activities, resource usage, schedules, etc., to achieve performance improvements in throughput, costs, cycle times, and resource utilization [23].

3 Enterprise Architecture Management and BPM

3.1 Overview of EAM

Architecture is regarded as the fundamental structure of a system, including its components and their relationships. It is a formal description which also shows the main architectural principles and guidelines that facilitate the construction and operation of the system. In this respect, enterprise architecture (EA) is the construction of an enterprise, described by its entities and their relationships. EA is an organising logic for business processes and IT infrastructure in order to review, maintain and control the whole operation of an enterprise. This organising logic acts as an integrating force between business planning, business operations and enabling technological infrastructure. Enterprise architecture integrates information systems and business processes into a coherent map. Enterprise architecture supports IT strategy, IT governance and business-IT alignment [24]. It also helps to capture a vision of the entire system in all its dimensions and complexity [25]. Enterprise architecture is a structure which helps, (1) coordinate the many facets that make up the fundamental essence of an enterprise and (2) provide a structure for business processes and supportive information systems [25].

Enterprise architecture management provides instruments to build and maintain enterprise architectures. The management of enterprise architecture results in increased transparency, documented architecture vision and clear architecture principles and guidelines. These factors contribute to efficient resource allocation, the creation of synergies, better alignment, and reduced complexity. In the end, better business performance can be achieved by using the EAM concept. EAM promotes the vertical integration between strategic directions and tactical concepts, design decisions, and operations. Additionally, it provides horizontal alignment between business change and technology. In addition, EAM improves the capability of an enterprise for perceiving, analysing and responding to organisational changes. It helps (1) to align the organisation with strategic goals, (2) to coordinate interdependencies in business and IT, (3) to prepare an organisation for an agile reaction. EAM plays a role in strategy formulation as well. Strategic EAM helps (1) to analyse the current situation, (2) assess

strategic options, (3) formulate strategic initiatives, (4) develop an architectural vision, (5) roadmap migration activities, (6) assess and prioritise project portfolio and (7) monitor architecture evolution [26, 27].

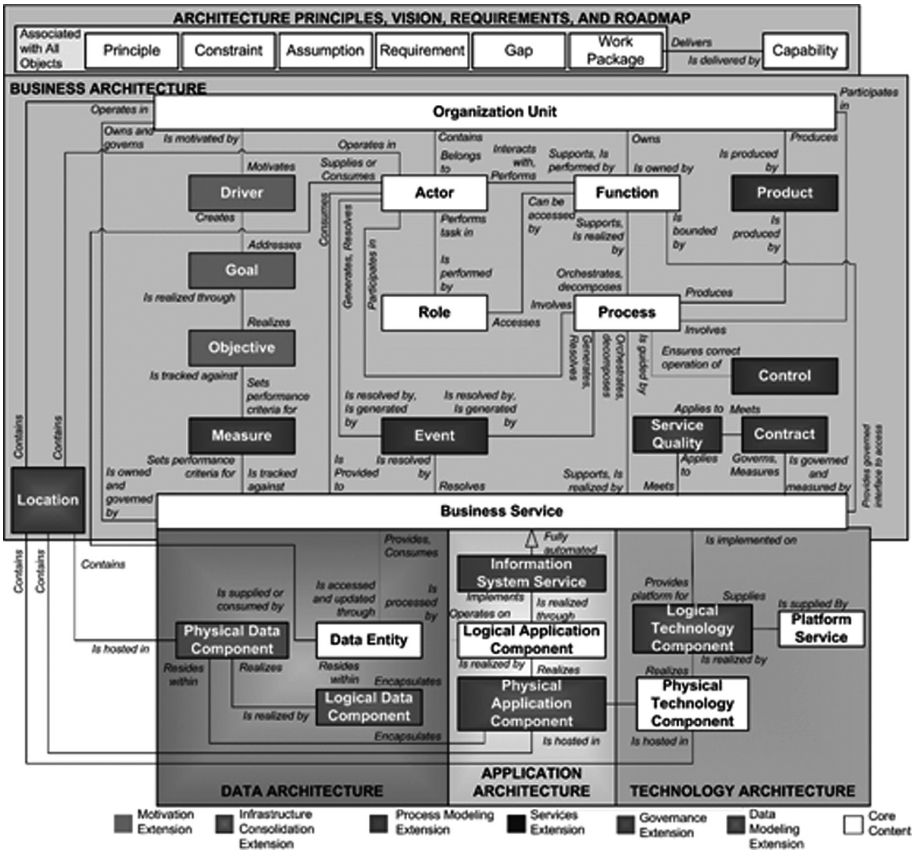

Fig. 1. TOGAF metamodel [23]

In order to cope with architecture complexity, different frameworks, methods, and tools have been developed. An enterprise architecture framework is a collection of descriptions and methods to create and manage enterprise architecture. The most recognised frameworks are the Zachman Framework [24], for rather theoretical purposes, and the TOGAF framework [25], for rather practical usage. While the Zachman Framework is defined as a taxonomy for organising architectural elements, TOGAF is a process-oriented EA framework which breaks an EA into different EA layers.

TOGAF (The Open Group Architecture Framework) is a commonly used architecture framework. It is a holistic approach which describes a metamodel for enterprise architecture and proposes different methods for building and maintaining enterprise architectures. The framework has four main components, (1) Architecture Capability

Framework, (2) Architecture Development Method (ADM), (3) Architecture Domains and (4) Enterprise Continuum. The latter consists of different reference models (e.g. Technical Reference Model, Standards Information Base, The Building Blocks Information Base). The core of the TOGAF approach is the Architecture Development Method (ADM), which proposes an iterative method for developing and managing enterprise architecture. It consists of 10 phases. Phase B-D cover the four architecture domains (1–4), respectively. Architecture domains are considered different conceptualisations of an enterprise. TOGAF provides 4 architecture domains: (1) Business Architecture, (2) Data Architecture, (3) Application Architecture and (4) Technology Architecture. In their approach, Business Architecture is served by Data, Application and Technology Architectures.

TOGAF metamodel (Fig. 1) is a reference model which sets up the formal structure of an EA model as well as provides implementation guidance on core building blocks and their relationships. The metamodel depicts the core entities of the 4 architecture domains. Entities are connected to each other within and between architecture domains. Business Architecture is primarily connected with the other 3 architecture domains via Business Service. Business Service is, therefore, a bridge between several entities, refracting the direct routes between the different items [25].

3.2 Process Optimization Based on EAM Concepts

EA analysis types provide feasible techniques for model analysis. There are different types of EA analyses, e.g. dependency analysis, network analysis, coverage analysis, interface analysis, complexity analysis, heterogeneity analysis, enterprise interoperability assessment, enterprise coherence assessment, inconsistency checking [28–30]. Frameworks for EA analysis include some TOGAF-based techniques, e.g. architecture compliance review, architecture governance assessment, architecture maturity assessment or performance analysis [25, 27]. Sources for EA analysis may also include some TOGAF-based approaches, e.g. consolidated gaps, solutions and dependencies matrix, EA state evolution table, business interaction matrix, information systems interoperability matrix, business footprint diagram, governance log, architecture compliance review log and maturity assessment log [25].

EA assessment includes an overview of organisational models. This process can be approached in two influential ways. On the one hand, architecture domains can be reviewed using, e.g. the architecture landscape technique or other architecture overview methods. On the other hand, alignment of business and technology domains can be reviewed on an EA basis.

The approach of architecture domain overview includes (1) perspectives of the architecture landscapes (e.g. views, viewpoints and different reference models, TOGAF artefact-based overview, artefact chains, in-layer and between-layer artefact groups, architecture domain building blocks), (2) different architecture overview methods (e.g. portfolio analysis, domain analysis, change impact analysis, landscape management, blueprint management) [26, 27, 31–33] and (3) supportive concepts for architecture overview (e.g. EA model entity relationships, EA measurement items, architecture principles or architecture patterns) [27, 34, 35].

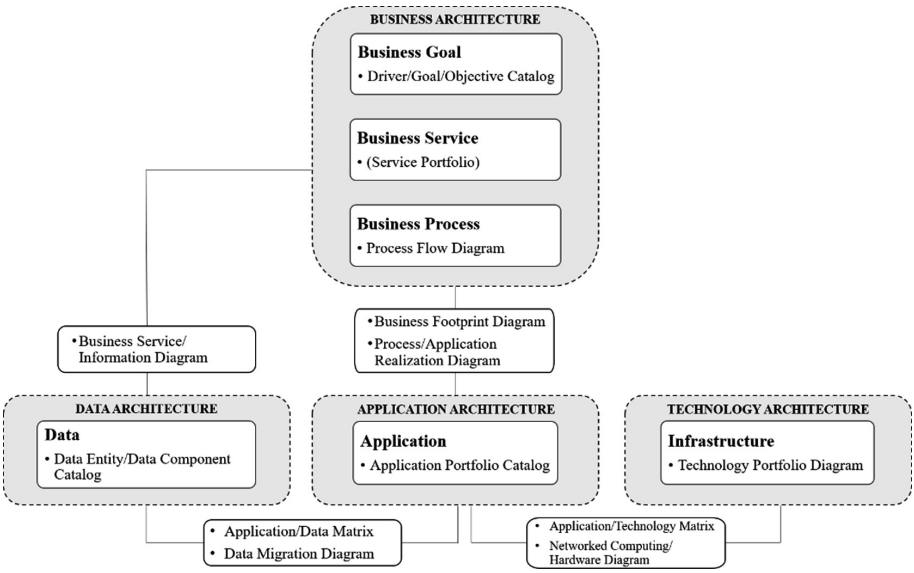

Fig. 2. A collection of EA models for inter-domain architecture comparison

A feasible approach for an EA-based process optimization overview is to connect the process management concepts with TOGAF artefacts [25]. In this approach, TOGAF artefacts are attached to corresponding BPM domains. In the proposed framework this kind of EA-based description of BPM domain will be used. Figure 2 presents specific artefacts feasible for detecting process-related issues in enterprise architecture context.

To translate the above introduced methodology into a BPM-based approach, we need the following concepts:

- BPM optimization dimension: this list contains the corresponding optimization categories for opportunity detection.
- Process-related problem catalog: this list comprises the perceived/potential process-related issues, under-utilized opportunities or actual errors.
- Artifact catalog: this list encompasses the possible containing EA models for process related problems.
- EA analysis catalog: This list includes the possible EA analysis types to recommend for opportunity detection.
- Presence in the artefact: This concept describes the sign of the process-related issue in the EA models.
- Occurrence on model entity level: This concept defines how the process-related issue is manifested on model entity level.
- Occurrence in XML model export: This item describes how the process-related issue is manifested in the XML export of the EA model.

Process-related problems and optimization aspects that can be explored in enterprise architecture environment include e.g. undefined organisational goals and business process goals in business process models, lack of relation between process goals and organisational goals, the signs that (1) a business process is supported by more than the minimum number of applications, (2) business activities are supported by multiple applications - unnecessarily, (3) not each application functionality supports at least one business process activity, (4) not all business processes activity create, update and/or delete at least one information entity, or (5) not all information entity attributes are read by at least one business process activity.

The list of potential issues/opportunities in process optimization (based on [7, 36]) is mapped to EA-related components and situations that can be described by EA concepts (Table 1):

All of the above-mentioned optimization aspects/potentials can be supported directly or indirectly by EAM-based analysis. Table 2 provides a short description of relevant analytical methods (artefacts).

A previous research initiative [37] can be utilized to analyse optimization opportunities based on EA models. The comprehensive model of an organization covering information and business architecture domains is an ideal base to detect organizational problems related to organizational design. The analysis method transforms process management-related concepts into formalized rules that are appropriate for testing on relevant EA models. Process-related issues, problems and opportunities are translated (mapped) to combination of EA artefacts, which potentially contain the symptoms of the non-optimized situation. The test assessment technique is suitable for detecting these symptoms by analysing EA models, discovering existing or missing relationships, linkages between the process-related objects of the EA models. The formal implementation of the analysis method is based on rule construction and testing techniques and assesses the XML export of the EA models with XML validation techniques, using the Schematron assertion query language [38].

As the above-mentioned examples illustrated, process-related issues can be detected within EA scope, as process optimization areas encompass and overarch the TOGAF architecture domains. Optimization potentials can be explored by EA artefacts and EAM-based analysis types, and the presented rule-based research initiative can be applied to business process-related issues as well (Table 3).

The analytical potential of enterprise architecture concept forms a feasible and comprehensive basis for assisting business process optimization. The mapping of potential process issues/opportunities and related EA components and situations can be extended, as well as further EA-based business process optimization areas can be translated into executable rules.

Table 1. Optimization opportunities and EAM-related components

Optimization aspects/opportunity	Related EAM models/opportunities
Optimization potential in the organisation: - Clear organizational structures - Competence & transparency - Expertise & responsibility - Integrated perception of tasks - Optimized use of resources - Decentralization vs. centralization	Analysis of business architecture components to discover: - Undefined organizational strategy and organizational goals - Undefined business process goals - Lack of relation between process goals and organizational goals - Multiple hierarchy or lines of reporting
Optimization potential in data - High data quality - Up-to-datedness & uniformity - Completeness & accuracy - No data redundancy - Integration of data records for everyone involved in process - Up to date/fast availability of information - Reduction of documents to be kept manually	Analysis of dependencies between business architecture and data architecture components to discover: - Lack of data ownership - Undefined security requirements over the information entities - Lack of data quality controls
Optimization potential in activities - Analysis of critical tasks - Analysis of standardization of tasks - Increase in IT support - Reduction of functions that create no value - Reduction of response costs	Analysis of business architecture components to discover: - Standardization problems - Non-value adding activities - Lack of IT support in process activities
Optimization potential in IT - Unification, modernization, and standardization of applications and PC tools - Integration of operational applications - Uniform user interface - Comprehensive linking of transactions - Comprehensive transfer of data due to common database - Plausibility checks for complete processing of all necessary activities - Determination of statistical key performance indicators for processes (wait times/processing times) - Improved know-how transfer to operational departments involved	Analysis of dependencies between business architecture and application architecture components to discover: - Undefined security requirements over the information entities - Users managed differently in different applications - Undefined capacity and performance requirements - Lack of application interfaces - Multiple applications managing the same information
Optimization potential in products and services - Critical product analysis - Comparison of product portfolio with core competences - Analysis of range of services - Outsourcing	Analysis of business architecture components to discover: - Potential synergies between products

(*continued*)

Table 1. (*continued*)

Optimization aspects/opportunity	Related EAM models/opportunities
Optimization potential in processes - Elimination of organizational interfaces - Elimination of media interfaces - Reduction of throughput times - Short control loops - Shorter decision-making paths - Forward shift in responsibilities - Increase in process quality - Automatic control functions - Automatic information forwarding/processing	Analysis of business architecture components combined with external data (e.g. process mining results) to discover: - Non value-adding activities - Control loops - Quality problems - Manual activities

Table 2. Review of relevant EAM artefacts

Artefact	Brief content
Driver/Goal/Objective catalogue	A breakdown of drivers, goals, and objectives to provide a cross-organisational reference of driver fulfilment
Process flow diagram	A model to show sequential flow of tasks within a business process
Data entity/Data component catalogue	A list of all the data used across the enterprise, incl. data entities & components
Application portfolio catalogue	A catalogue to identify and maintain all the applications in the organisation
Technology portfolio catalogue	A catalogue to identify and maintain all the technology across the organisation
Business footprint diagram	A mapping of business goals, organisational units, business functions, business services, and delivering technical components
Process/Application realisation diagram	A diagram to depict the sequence of events when multiple applications are involved in executing a business process
Data migration diagram	A diagram that displays the flow of data from the source to the target applications
Application/Technology matrix	A mapping of applications to technology platform
Business service/Information diagram	Shows the information needed to support one or more business services
Data dissemination diagram	Shows the relationship between data entity, business service, and application components
Application/Data matrix	Depicts the relationship between applications (i.e., application components) and the data entities that are accessed and updated by them
Networked computing/Hardware diagram	Documents the mapping between logical applications and the technology components (e.g., server) that support the application both in the development and production environments

Table 3. Detection of a process management problem in the EA scope

Aspect	Process management related problem
Symptom Definition	*Not all data entities attributes are read at least by one process*
Suitable EA Analysis to detect the process management problem	- Dependency analysis - Coverage analysis
Occurance, Presence in EA Model	By scanning data usage in business process models, there are data entities that are not used by any business process task
Containing EA Model	- Process Flow Diagram - Data Entity/Data Component Catalogue - Data Entity/Business Function Matrix
Occurance on Model Entity Level	There are data entities from the data entity catalogue that are not present on any business process model
Occurance in XML-based EA Model Export	Comparison of business process models and data entity catalogue in terms of data entities
Occurance on Model Entity Level in XML Export	Comparison of elements between Node type: data entity in the business process model and Node type: data entity in the data entity catalogue
XML-based Query	For every node where node type = data entity: • Compare the attribute names with the data entity attribute names from process flow diagram • Alert data entity nodes if they are not present in the process flow
Query in Schematron Language	<pattern name="Not all data entities attributes are read at least by one process"> <rule context="Object Definition [@Node Type='{*data entity*}']"> <assert test="Attribute Definition [@AttributeDefinition.Type= '{*attribute name*}']// PlainText[@TextValue=document ('process flow diagram.xml')//Object Definition[@Node Type='{*data entity*}']//Attribute Definition [@AttributeDefinition.Type='{*attribute name*}']// PlainText//@TextValue]"> Alert: </assert> </rule> </pattern>

4 Conclusion

The outlined approach described in this paper provides the opportunity to make use of formal EAM-based analytical methods for discovering optimization opportunities in business architecture, analysing dependencies and relationships within process architecture models, and also between business architecture and information architecture components (existing information systems, data, and technology). EAM models cover the core aspects (dimensions) of an organization, providing solid base for comprehensive, multi-dimensional analysis. Business processes are immanent components of

an EA, and the integrity, coherence, and consistency of business architecture with the other elements of the enterprise architecture is critical. A rule-based analysis approach can be a formal diagnostic tool to discover subjects for improvement. EAM contains a formal and comprehensive representation of organizational resources, and all components should fit to the overall architecture. The proposed approach offers a formal way of checking and controlling the discrepancies in a complex enterprise architecture model base. The major limitation of the approach rooted in the quality and the coverage of the available models – in many companies there are several, domain specific, isolated models. This issue can be sorted out: the rule-based testing approach provides great flexibility by integrating heterogeneous model environments in the analysis.

There are many open questions in the application of the EAM-based analytical methods. As part of future work translation of process related problems into testable rules, integration of the approach to the other formal methods of BPM are in the focus, and the framework needs further adjustments in terms of automation and analytic potential.

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