Current and Future Tool Support for EA Management

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Abstract: A company, planning to introduce tool support for enterprise architecture (EA) management, finds itself confronted with an ever changing market of tools and vendors from a variety of different backgrounds. This paper sketches the approach we have taken in a survey on these tools. The evaluation criteria used are related to tool requirements, which were developed in cooperation with EA management practitioners. Complementing these requirements, we detail on general results of the survey and outline important strengths and weaknesses of the tools, identifying distinct approaches for EA management as found in the tools. Concluding, we give indications on potential future topics in this area, interesting both for tool vendors and academia.

1 Motivation

Application landscapes of modern enterprises consist of hundreds or even thousands of business applications, which are tightly connected systems with a long lifetime. The application landscapes form a major investment of today's enterprises and are mostly historically grown structures, which provide support for the enterprises' business processes. Thereby, the dynamics of the business, which has to react to global shifts of the market as well as competing enterprises, constitutes a major challenge for the IT support, as provided by the application landscape. The misson of enterprise architecture (EA) management therein is to optimize the alignment of business and IT.

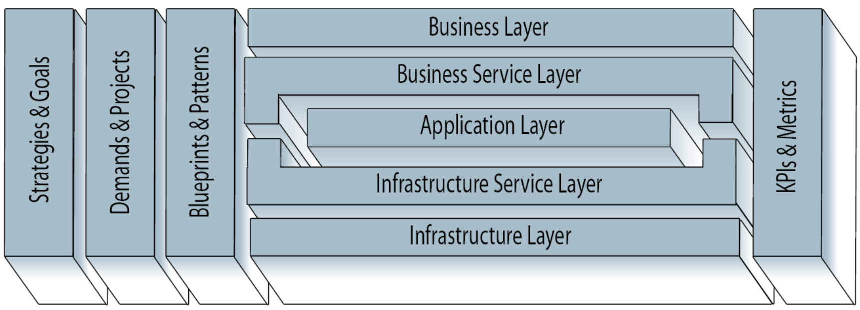

Figure 1: Layers and cross functions for EA management

EA management therefore is not only concerned with technical aspects, e. g. infrastructure components, business applications, but also with processes, organizational structures, etc. Figure 1 illustrates the different layers, which can be used to organize the relevant concepts for EA management. In addition, orthogonal cross functions are introduced, which can exert influence on any of the elements organized in the layers. The color coding in Figure 1 indicates the variability concerning the involvement of information from the specific area in a holistic and compulsory EA management approach. Some practitioners, for example, think of information on technical infrastructures, e. g. servers being important for EA management, while others abstract from this technical information [MBLS08].

In order to manage, plan, and control the EA, companies started to document the artifacts mentioned above, with a focus on their dependencies. Due to the number of objects to be documented and stakeholders involved, tool support for the collaborative process of EA management is strongly needed. An appropriate tool can be used to capture relevant information and helps to process this information, using e. g. reports or visualizations supporting the users, when performing different EA management tasks.

An overview on tools supporting EA management was given in an extensive survey in 2005 [seb05]. The increased understanding and importance of EA management as well as the enhanced demands on a tool support for EA management were our key motivators to perform an update of the survey. The *Enterprise Architecture Management Tool Survey 2008* [MBLS08] was recently conducted in cooperation with 30 sponsors and industry partners[1]. The survey analyzed the products of nine major players in the market of EA management: adaptive EAM (adaptive, Inc.), planningIT (alfabet AG), ADOit (BOC GmbH), EA/Studio (Embarcadero), ARIS IT Architect (IDS Scheer AG), MEGA Modeling Suite 2007 (MEGA International SA), Metastorm ProVision (Metastorm), System Architect (Telelogic AB), and Troux (Troux Technologies, Inc.).

In this article key findings from the survey on the current tool support are summarized and areas retaining potential for improvement are outlined, both interesting for future developments by tool vendors and research by academia. The article is structured as follows: Section 2 sketches related work concerning the topic of EA management and the currently available tool support. Section 3 illustrates the approach taken to analyze the tools and details on exemplary demands in the context of EA management. An overview of the results of the survey are provided in Section 4, which discusses the strengths and weaknesses discovered. Section 5 proposes a characterization of different EA management approaches taken by the tools. Finally, Section 6 points out future topics of EA management tool support.

2 Requirements regarding EA management tool support in literature

EA management is an emerging topic in research and practice. Nevertheless, no generally accepted definition or common understanding of the field exists. Therefore, this section refers to related work in this management area, which can be used to derive requirements for the tool support, and introduces approaches to evaluate the support available.

[1] Allianz Group IT, sd&m – software design & management, Siemens IT Solutions and Services, act! consulting, Detecon, Münchener Rück, O2 Germany, SYRACOM | The Business and IT Architects, BMW Group, BSH Bosch und Siemens Hausgeräte, Deutsche Bahn IT-Strategie, Deutsche Bank, Deutsche Telekom, EWE, FIDUCIA IT, Fraport, HSH Nordbank, HVB Information Services, Kuehne + Nagel, LVM Versicherungen, Nokia Siemens Networks, Postbank, Procter & Gamble, Schufa, SEB Bank, TeamBank, TUI, Wacker Chemie, ZF Friedrichshafen, Zollner Elektronik

One of the first papers on EA management dates back to the late 1980s, when Zachman developed a framework for information systems architecture [Zac87]. In order to address the growing complexity of information systems, [JZ92] propose the usage of five different perspectives, e. g. *scope description* or *business model* and six levels of abstraction, e. g. *data description (what?)* or *process description (how?)*. The Zachman framework combines these two dimensions into a matrix. Thereby, each cell of the matrix can be documented and analyzed independently in order to reduce the complexity of EA management tasks. From this, one could say, the Zachman framework introduced the requirements for a tool supported EA management approach, to provide different perspectives for various stakeholders[2] and different levels of abstraction.

Another prominent approach, presented in [HW05, WF06], refers to EA as a *cross-layer view of aggregate artifacts*. Thereby, the different hierarchical layers, e. g. business architecture, which introduce essential concepts and need to be integrated, are complemented by the respective views. Depending on the complexity of the concern, the layers can be analyzed together or separately. With a special focus on concerns, [BEL+07] and [KW07], propose a method engineering approach to create enterprise-specific information models for EA management. Thus, a tool incorporating these ways to approach EA management would provide means to start with a core information model only, which could be enhanced iteratively.

[Fra02] suggests a closely related approach, emphasizing the necessity to support different views on the enterprise on a different level of abstraction. Thereby, these views provide information on a fine-grained level of detail and use different special purpose modeling languages to meet the specific concerns of the various stakeholders. The modeling languages are defined in metamodels, which correspond to a common meta-metamodel to support integration. Leveraging the *multi-perspective enterprise modeling (MEMO)* approach in a tool for EA management would require the implementation of different special purpose modeling languages.

Whereas the Zachman framework and MEMO are mainly concerned with static aspects of an EA management, the dynamic aspects of the EA constitute the focal point of the definitions given by [Buh04, EHH+08]. According to these definitions, an EA consists of different interrelated models, describing the structure, tasks, and strategies of an enterprise. Therefore, the documentation of the EA is the foundation of the strategic evolution of an enterprise and influences the planning, execution, and monitoring of the various activities [Buh04]. The strong focus on evolutionary aspects would require an EA management tool to e. g. support different planning states of the application landscape, which result from the execution of distinct sets of tasks.

In addition to the definitions as given above, a number of frameworks trying to establish an EA management methodology have been introduced in recent years. These frameworks, among others DODAF [DOD04], TOGAF [TOG05] and the Enterprise Architecture Desk Reference [MET02] are to some extend implemented in the tools analyzed but are not further considered here.

[2] The term *stakeholder* is used here in accordance to the definition of the IEEE Std. 1471-2000: *An individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system* [IEE00].

3 Scenario based operationalization of EA management for tool evaluation

Surveys analyzing the existing tool support for EA management are regularly performed especially by consultants as the Institute for Enterprise Architecture Developments [Sch07], Gartner Research [JH06], or Forrester Research [Pey07]. These evaluations can be considered the only sources for a comparison of available tool support for EA management. Thereby, they mostly offer only a high level view on the market without explicating the analyzed requirements and evaluation criteria used. We wanted to complement such evaluations with an extensive survey more focused on the specific tool functionalities and their application to EA management. Therefore, we created a definition of EA management, which we operationalized via a set of different scenarios complemented by an online questionnaire, to incorporate the respective requirements and evaluation criteria.

An important part of the approach is the continuous involvement of the industry partners during the creation of the list of criteria and the scenarios. Since some of the partners have already introduced EA management tools, they gave great input to refine both questionnaire and scenarios. As a consequence of the scenario based evaluation, we also chosed to not give a simple ranking of the tools, which would have led to an aggregation of the scenario results, but to detail and rank each of the scenarios independently (see Section 4).

The **list of criteria** was used to gather data directly from the tool vendors and collect information, which could not completely be covered by the scenarios, e. g. support for integration with project management software. The list contained 43 questions about the functional, technical, and additional criteria and was structured into the parts: 1) vendor data, 2) tool data, 3) general tool architecture, 4) collaboration support, 5) internationalization/localization, 6) integration with related domains, 7) methodology, 8) integration with other modeling tools, and 9) administration. The answers given by the vendors were used during the evaluation of the EA management tools to complement the findings obtained during the *scenario simulation*[3].

As outlined above, evaluating the tools solely against a list of criteria seemed to us not to be the sufficient for a comprehensive analysis of the tools capabilities in supporting EA management. Therefore, we developed in cooperation with our industry partners two distinct sets of **scenarios**. The first set is used for analyzing specific functionalities, e. g. visualization techniques and metamodeling capabilities, thereby contrasting the claims made by the tool vendors in filling out the list of criteria with an actual usage of the respective functionality. The second set is used to analyze the tools' support for tasks and processes typical for EA management, e. g. landscape management.

Within the survey every scenario of both sets is described in detail, starting with the relevant concerns for the functional requirement or task addressed, detailing the questions arising from the concern and the associated tasks for simulating the scenario. Finally, exemplary deliverables of the scenario are described, showing what the results of the scenario could look like.

[3] In this context *simulation* refers to the actual execution of a scenario with a specific tool.

Scenarios for analyzing specific functionality

The survey used nine scenarios for *analyzing specific functionality*, these were: 1) importing, editing, and validating model data, 2) creating visualizations of the application landscape, 3) interacting with and editing of visualizations of the application landscape, 4) annotating visualizations with certain aspects, 5) supporting lightweight access, 6) editing model data using an external editor, 7) adapting the information model, 8) handling large scale application landscapes, and 9) supporting multiple users and collaborative work.

Exemplarily, the scenarios *interacting with and editing of visualizations of the application landscape* as well as *annotating visualizations with certain aspects* are further detailed below, to explain the structure of a scenario. These scenarios are concerned with functionalities for editing existing visualizations, both with and without changing their semantics. The semantic preserving changes thereby include but are not limited to basic interactions, e. g. zooming as well as rerouting lines without changing their endpoints. The semantic updating changes include e. g. creating and deleting symbols, as well as moving a symbol from one logical domain to another. Further, the scenarios cover ways to annotate an existing visualization with additional aspects, e. g. operating costs of application systems. This can be achieved in several ways, e. g. via color-coding or adding a symbol (see for example Fig. 2). Aspects to be used in this context can be attributes as well as indicators (e. g. metrics) derived from attributes and relationships. The concerns of the scenario *annotating visualizations with certain aspects* are:

≪An enterprise wants to get an overview of the business applications that raise high maintenance costs. This information should be visualized on already existing visualizations of the application landscape, e. g. cluster or process support maps. As an additional property of the business applications, availability should be visualized on a similar map. Finally, the process support of the enterprise should be analyzed regarding to the usage of standard business applications. ≫

During the simulation of questions, as the following ones, should be answered:

≪Does the tool support the visualization of the maintenance costs of the business applications, e. g. by changing the background color of the symbolic representations of the business applications? Does the tool provide the capability to visualize the availability of each business application using a threshold, e. g. by adding a red/amber/green traffic light to the symbolic representation of the application? ≫

Scenarios for EA Management support

The second set of scenarios evaluates the tool's capabilities for specific EA management tasks. Therein the following nine scenarios were employed: 1) landscape management, 2) demand management, 3) project portfolio management, 4) synchronization management, 5) strategies and goals management, 6) business object management, 7) SOA transformation, 8) IT architecture management, and 9) infrastructure management. As an example for a scenario of this set the scenario *SOA transformation* is explained in detail, of which the concerns are subsequently described:

≪An enterprise wants to transform its architecture into a service oriented one, with a top-down and bottom-up approach to identify the possible candidates for reusable services.

The top-down approach starts identifying services from the business objects perspective within the conduction of different business processes. The bottom-up approach starts with technical functionalities currently provided by business applications. The services should not only be identified but also the effects of the transformation should be modeled. ≫

Exemplary questions arising in the context of the scenario are:

≪Is support a differentiating or a standardized business process considered? Does the supporting business application change frequently? Which business applications will be affected by a change in the near future? Which business functions supported by the current landscape are used within numerous domains? What would a service oriented target architecture aligned to business needs look like? ≫

These questions can be addressed among others employing a visualization called time interval map [Wit07], which shows the relocation of functionalities from business applications to business services (see Fig. 3).

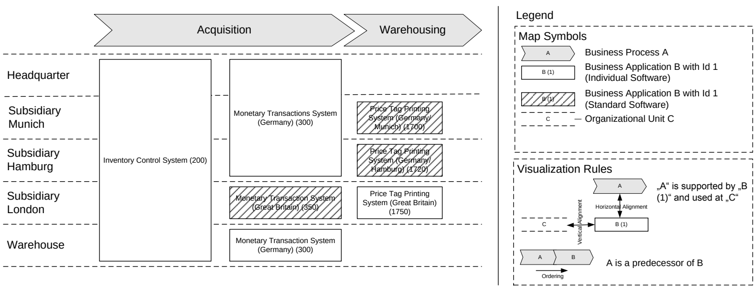

Figure 2: Example for annotations within a Process Support Map

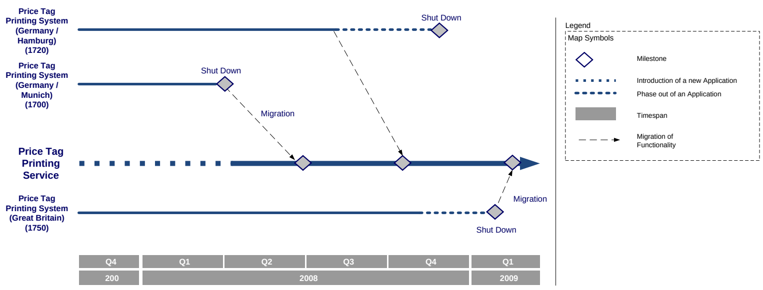

Figure 3: Example for a visualization supporting SOA Transformation

Simulating scenarios as the ones outlined above requires certain information about the EA being available to the tool. In order to ensure this, an information model built around a fictitious department store has been developed for the survey, on which a set of suitable demo data is based. This data was subsequently mapped to the underlying models of the tools and imported into them. From that, the scenarios were simulated by a two-people team separately for every tool. For each set of scenarios, specific information gathered

throughout the simulation process was taken into account. For the *scenarios for analyzing specific functionality* this was:
ACHIEVEMENT OF OBJECTIVES: Was it possible to create the deliverables, the scenario was aiming at (or comparable deliverables)?
TOOL HANDLING: How many pitfalls and shortcomings led to a high effort in producing the deliverables? For the *Scenarios for EA Management Support* the following criteria were further used:
PROCEDURE CONSISTENCY: Does the procedure for creating the deliverables correspond to the methodology the tool is relying on or have parts of the tools model be misused to simulate a scenario?
PROCEDURE INTEGRATION: Does the tool provide an integration of the activities and objectives in respect to other relevant activities and objectives of EA management and other simulated scenarios, etc.?

In order to ensure consistency of the simulation results provided by the different evaluation teams, inter-team workshops were held during the course of the simulation.

4 Results of the Survey

This Section sketches how, based on the simulation performed according to the scenarios as presented in Section 3, the results of the survey were compiled. Then, strengths and weaknesses generally applying to the tools are outlined, abstracting from the results in respect to specific tools. The general results for the first set of requirement are shown in a kiviat diagram, displaying *minimum*, *maximum*, and *median* values achieved by the tools.

The kiviat diagram in Figure 4, refering to specific functionalities, consists of eight axes[4]:

IMPORTING, EDITING AND VALIDATING reflects the capabilities to import and export data in various formats. In addition, the capabilities to validate the imported data against the information model are considered. Finally, the editing functionalities are evaluated – especially concerning the support for multiple edits, pick lists, or external editors.

CREATING VISUALIZATIONS assesses the automation provided for generating visualizations, which show parts of the EA. The tools are evaluated according to the different kinds of built-in visualization techniques. Furthermore, the options to customize the built-in and define new visualization techiques are evaluated.

INTERACTING WITH, EDITING OF, AND ANNOTATING VISUALIZATIONS evaluates the functionalities for adapting the generated visualizations. An important object of investigation in this context is, whether a mechanism to automatically add graphical annotations, which are used to display attributes of the visualized objects, is provided.

COMMUNICATION AND COLLABORATION SUPPORT reflects, if and to which extent collaborative editing of the maintained data is supported. In this way, mechanisms and functions are evaluated, which are provided to synchronize the data edited by different users.

[4]The result on an axis therein reflects the aggregate result from different scenarios as well as from information drawn from the online questionnaire.

Furthermore, lightweight facilities to provide easy access to the data (e.g. webfrontends) are taken into consideration.

FLEXIBILITY OF THE INFORMATION MODEL assesses to which degree the information model can be adapted to the requirements of the enterprise. Here also possibilities to export and re(-import) the information model are taken into consideration.

SUPPORT OF LARGE SCALE DATA examines the ability to handle large scale application landscapes with a plethora of objects and relationships inbetween. Here, e. g. the achieved performance is considered as well as mechanisms to automatically organize such large scale datasets.

IMPACT ANALYSIS AND REPORTING reflects the capabilities to traverse relationships between model elements and display the results graphically or textually. Further, functions for performing calculations on the model and deriving metric values are considered.

USABILITY mirrors the ergonomics and the handling. Aspects of the analysis are e. g. the user support with a well structured menu, navigation, and a context sensitive help-system.

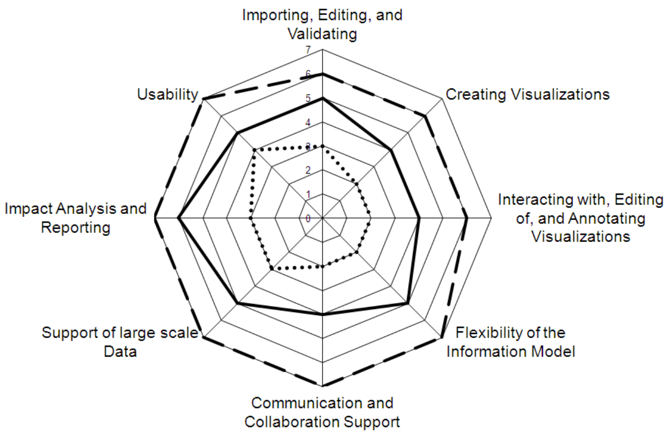

Figure 4: Minimum, maximum, and median scores in specific functionalities

The overeall results of the tools in supporting ten typical EA management tasks can be shorthanded as follows:

LANDSCAPE MANAGEMENT reviews the support for creating, maintaining, and comparing versions and planning states for the application landscape, also in respect to planned and scheduled projects.

DEMAND MANAGEMENT assesses the support for collection and consolidation of demands as well as for deducing projects from the demands.

PROJECT PORTFOLIO MANAGEMENT evaluates the functionalities for managing a project portfolio. The projects are compared to the demands, they arise from, and also the elements of the EA, they affect. The creation of portfolio matrices is further considered here.

SYNCHRONIZATION MANAGEMENT reflects the functionalities for managing and handling EA related inter-project dependencies. Here, e. g. capabilities to derive possible project conflicts caused by elements of the EA are considered.

STRATEGIES AND GOALS MANAGEMENT mirrors the capabilities to support strategic alignment of projects and demands. Therein, also the support for operationalizing strategies into goals is evaluated.

BUSINESS OBJECT MANAGEMENT targets the support for modeling information flows within the application landscape. Further, the types of business objects exchanged should be modeled, as should the operations performed on them by the business appplications.

SOA TRANSFORMATION reflects the functionalities to support the transformation of the application landscape into a service oriented one. For this the evaluation, functions for identifying applications as service candidates are considered.

IT ARCHITECTURE MANAGEMENT mirrors the support for managing blueprint architectures to realize a standardized application landscape. Additionally, means to evaluate application conformance and landscape homogeneity are considered here.

INFRASTRUCTURE MANAGEMENT evaluates the support for managing infrastructure components and services, especially considering life-cycle information. Furthermore, issues of infrastructure homogenization are assessed here.

For compiling the results, the following procedure was applied. At first, a textual description of the steps necessary to achieve the objectives and create the deliverables of the scenario with each tool was created by the team executing the scenario simulation. This description was then discussed with the vendor of the tool to ensure, that no alternative way to perform the scenarios had been overlooked. Having thus ensured, that the description reflects the actual capabilities provided by the tool, the evaluation documentation was presented to all members in the survey team. The subsequent group discussion led to an ordering of the tools in respect to their fulfillment of the scenarios' objectives. In this ordering also an *imaginary super-tool* was included, reflecting full support for the scenario's objectives. Therefore, it is possible, that this tool was solely ranked best – thereby indicating, that none of the tools in the survey was capable of achieving all objectives. The created ordering was finally reflected by ordinal valued scores for each of the tools.

Subsequently, we detail on selected axes and explain the conclusions, which can be drawn from the overall results of the tool evaluation. Concerning the axis *flexibility of the information model*, it has to be noted, that the capabilities of the tools vary widely – especially regarding the underlying metamodeling facility. Some tools are fully compliant to the OMG's Meta Object Facility (MOF) version 2.0, in contrast to others, which do not support any adaptations to the information model. The predefined information models are as diverse as these modeling facilities – both in size and complexity. Some tools come shipped with a core information model, which only contains a few classes and associations, merely providing a starting point for creating an organization specific EA management model. Other information models contain more than 300 classes complemented with a number of attributes and associations. These models are commonly regarded by the vendors as reflecting a superset of the information demands related to EA management. In using these models, the level of documentation for the classes and associations becomes an important issue. Compared to the results of the 2005, an increase in the coverage of the different aspects of a holistic information model (cf. Figure 1) can be noted, although no convergence concerning the used models is at sight.

A maximum score of 7 has not been reached on the axis *interacting with, editing of, and annotating visualizations*, reflecting that the demands as rised by the sponsors and partners of the survey could not be fully satisfied by any of the analyzed tools. Further, the results achieved vary widely. While visualizations can commonly be created and edited manually, the editing capabilities differ concerning their semantic implications. Some tools offer the possibility to perform arbitrary changes to the visualization – especially, e. g. neither the relative positioning nor the color-coding of the symbols have a strictly defined semantics. In these tools, the visualizations cannot be considered visual models of the underlying information but mere drawings. Other tools offer more sophisticated support creating and editing visualizations via specific types of visualizations, in which certain associations from the information model are represented by relative positioning, e. g. *nesting* of symbols. These diagrams can therefore be utilized by the user to perform changes in the underlying data. Nevertheless, the types are mostly predefined ones and provide only minor support for adaptations. Contrasting this apparent potential for improvement, non-editing interaction mechanisms, e. g. *zooming*, are widely supported. Further, concerning the capabilities to annotate an existing visualization with additional information, e. g. of *costs* or *availabilities*, via color-coding is not directly supported by all the tools in the survey, although a few provide convenient support in this area. In comparison to the results from the 2005 survey, an increase in the interaction capabilities can be perceived. This is especially true, when concerning mechanisms for deriving the semantics of a visual change in a diagram and propagate the information to the underlying model. Nevertheless, for flexible visualizations beyond pure drawings the capabilities to annotate are still limited, with the exception of one tool providing a powerful mechanism to define annotations for arbitrary visualizations.

Having detailed on specific functionalities above, we subsequently give an overview on the support for typical EA management tasks as provided by the tools. The 2005 version of the survey (cf. [seb05]) elaborated on some weaknesses concerning the support for *synchronization management*. Here only a minor improvement has occurred, as the concept of *time* is nowadays more widely supported by the EA management tools. Nevertheless, the notion of projects as the drivers of the organizational change, which actually execute the transformation from a current to a future EA, is not present in all tools. Some tools support this concept to a certain extent, by e. g. deriving future state application landscapes from the project plan and the landscape transformations as planned for the projects. Nevertheless, this support has its limitations when concerning project delays, which cannot directly be represented in any of the analyzed tools. Furthermore, the integration to *classic* project management tasks and topics is in most tools only partially realized, e. g. managing project dependencies, which do not result from the artifacts of the EA, is mostly not supported. These dependencies might notwithstanding be influential in synchronization management, as they e. g. explicate resource restrictions. In the context of this topic, further issues are likely to arise, especially concerning the exchange of information between different tools, namely the EA management tool and a project management tool. From there, challenges of distributed data sovereignty and management are of further interest.

A scenario, newly introduced in 2008, is concerned with the introduction of a service oriented architecture (SOA). In this scenario *SOA transformation*, we have decided not to rank a tool at score seven, as none of the tools was capable of completely supporting the transformation process. As alluded to in Section 3, the sponsors and partners of the survey did not want the tool to support *service orientation* via a simple replacement of the concept `application` by a `service` concept. They expected the tools to help a user in determining the service candidates for introducing a SOA. Contrasting this, the majority of tools actually supports managing services (similar to managing applications), but does not provide mechanisms for identifying service candidates. One might speculate, why this is the case – we see the following potential reason: Although a multitude of approaches on how to determine the services and introduce service orientation in the EA exists, none of these approaches has yet proven to be the most successful one. Therefore, tool vendors could have abstained from implementing a vast variety of approaches, in order to not bewilder the user. In addition, implementing one of these approaches might result in an overcommitment of the tool to a SOA transformation strategy no yet being completely mature. Nevertheless, as reflected by the sponsors and partners demanding a support for this task, future tools are expected to provide improvements in this field, which might also be justified by further research in this area.

5 Approaches of EA Management Tools

Complementing the scenario specific findings, the subsequent section elaborates on the variety of ways the current tools choose for approaching EA management. These approaches have already been mentioned in [seb05]. As of 2008, the approaches have become even more prominent, providing a set of *dimensions of distinction*, which span the solution space of the current market for EA management tools.

Every EA management tool analyzed in this survey is based on its individual approach to EA management. These approaches differ widely and cannot be compared in a simple one-dimensional manner. However, some approach may be suited better for a specific user with a specific usage scenario. We have identified three prominent dimensions, a tool supported approach to EA management can be classified in. These dimensions are characterized by the three choices subsequently detailled:

The first dimension, **flexibility vs. guidance**, gives three different options *metamodel driven*, *methodology driven*, and *process driven*. These options actually can be used to describe the tools evaluated in this survey. Subsequently, we sketch the main properties for each option.

The *metamodel driven* approach gives the user maximum flexibility concerning the adaptation of the information model of the tool. Therefore, strong metamodeling capabilities are incorporated in the underlying repository. These capabilities may nevertheless vary from tool to tool; some tools adhere to standardized metamodeling facilities, e. g. MOF, while others bring their individually developed facilities, possibly resulting in limitations to the adaptability of the information model. The tools pursuing a metamodel driven approach commonly provide facilities for adapting the visualization techniques in accordance to changes in the information model. A tool adhering to a metamodel driven approach may be especially beneficiary for companies, which already have developed their own method for EA management, potentially complemented by an individual information model tailored for their specific demands. Companies, which – in contrast – are on the way of introducing EA management *from scratch* may need additional guidance for developing and implementing an information model.

In contrast, some tools evaluated pursue the *methodology driven* approach, commonly providing a comprehensive predefined information model together with a set of predefined visualization, reporting, and analysis techniques. In these tools, minor adaptations to the underlying model are possible, e. g. the introduction of new attributes. This is due to the fact that the core concepts of EA management should be covered by the predefined information model. The tools differ concerning the provision of a semantics for the concepts defined in the information model – ranging from the usage of descriptive names for the concepts to a comprehensive textual documentation of the method and its constituents. This definition of the semantics is often complemented by a description of the usage context for each of the predefined visualizations and analysis techniques. Sometimes, these techniques are realized in an adaptable way, such that the user can extend them to also make use of the information model adaptations. A tool adhering to a methodology driven approach may be useful for enterprises, which would like to execute EA management based on a well-founded methodology, instead of developing a fully individual approach. Nevertheless, when establishing a EA management process in the organization, a company has the flexibility to choose the best suited organizational implementation for the process, based on the user roles, which have been introduced by the tool's methodology.

The *process driven* approach provides maximum guidance for EA management and can be seen as an extension to the methodology driven one. It complements the predefined information model, reports, and analyses with a defined workflow. Thereby, a whole EA management process is defined, providing procedures and defining activities, which have to be fulfilled in order to perform EA management. An activity in this context could be concerned with deriving projects from demands. To do so, a user of the appropriate role, e. g. project manager, would have to review the demands utilizing predefined visualizations and analyses, before he decides how to group them to project proposals. A tool pursuing a process driven approach may be especially interesting for companies, which are willing to adopt a best-practice process for executing EA management, e. g. as the company experiences problems with the current EA management process or has not yet established one. In adopting the process as defined by the tool, the company can leverage the maximum process guidance, without being burdened with the development of procedure and activities. In contrast, companies, which have already established their specific EA management process – potentially together with a tailored information model, may find a process driven tool too rigid and inflexible for supporting their individual demands.

Regarding the approaches presented above, a tool might not always be fixed to one of these approaches exclusively, e. g. different EA management may come with different levels of guidance. Furthermore, a tool might out-of-the-box provide no or only basic procedure guidance, but may be customizable to implement an enterprise-specific EA management process via dedicated workflow support.

The customization aspect, as alluded to above, is central to another dimension of distinction concerning EA management tools – the **preconfigured vs. customization** dichotomy. Some of the tools, especially those pursuing a methodology or process driven approach as introduced above, are designed as *EA management solutions*, which provide *preconfigured* functionalities for performing the tasks and activities connected to the management of the EA. In order to effectively execute EA management with such a tool, consulting and training is deemed advisable to foster the organizational implementation of the procedures, which are supported by the tool. In contrast, a few tools – especially ones, pursuing a metamodel driven approach – are shipped as *EA management platforms*, providing the basic capabilities necessary for realizing an organization specific EA management procedure. For these tools, consulting commonly encompasses *customization* projects, which tailor the tool to suite the individual needs of the company.

The **Integration vs. Single-point-of-truth** dimension indicates different characteristics concerning the tool's approach to information integration. On the one hand, some tools store data about the EA in their own repositories, while other information, such as project schedules or business process information is drawn from other sources via importing mechanisms. Nevertheless, when having imported this information, it can be altered in the EA management tool in order to facilitate management endeavors targeting the EA as a whole. If updates of the information from the other management tools should be taken into account, again an import can be performed, usually providing conflict resolution mechanisms. Transferring information between the tools is performed by user request via export and import mechanisms. This approach is capable of keeping data consistency high and data sovereignty issues clearly solved. Nevertheless, as EA management is commonly concerned with linking different management areas, the single-point-of-truth approach might lead to a sub-optimal information situation in the EA management endeavor.

Contrasting this, some tools exist, which pursue an *integration* approach. Therein, the EA management tool acts as a business intelligence or data warehouse platform for EA information, which is extracted, transformed, and finally loaded into the tool's repository via a multitude of connectors and mechanisms. The main focus of the EA management tool thereby lies on maintaining relationship information, connecting the data from different sources. Pursuing this approach, a tool is likely to provide comprehensive information about the EA, but also to rise additional complexity in keeping this information consistent and in resolving issues of data sovereignty, if information should be changed via the EA management tool's interface.

6 Resume and Outlook

Concluding this paper, we would like to indicate some topics, influencing future EA management tool support. The tools, as analyzed in the survey, bring along a plethora of functionalities for facilitating EA management. These functionalities are useful for documenting and planning the web of interdependencies, which is made up by the constituents of EA in general and the application landscape in particular. The capabilities are further complemented by visualization mechanisms, which are helpful for getting a holistic overview.

Nevertheless, when starting with a tool supported EA management endeavor, a company is likely to find the initial steps quite discomforting. The tool comes with a repository initially containing nothing except for an optional set of exemplary data of a fictitous company. From this the user has to get all the information needed for EA management into the tool, regardless of the fact, that some of this information could be seen as *standard* data, which a multitude of EA management tool users are likely to gather, e. g. support time information on operating systems. There we see potential for improvement, which could be realized by creating an exchange platform for such information among EA management practitioners and standard software vendors. This platform could be helpful to relief a company newly introducing an EA management tool from the necessity to gather data of that kind, providing quick access to useful content. Such a platform could be based on a common format for exchanging data between different EA management tools, which we have pointed out to be a valuable contribution in this field since 2005. In this context, standard formats for exchanging information about object oriented models, e. g. the *XML metadata interchange (XMI)* format should be considered.

Another idea, which might be addressable by EA management tools is closely connected to the complexity to the EA itself. The architecture is due to the number of constituents and dependencies of a high *static* complexity. This kind of complexity is well handled by current tools using a broad set of functionalities among other visualization facilities and collaborative maintenance techniques. Nevertheless, the EA is not a static system, but has manifold aspects of dynamics. Due to the underlying topological structure, the dynamic complexity arising is likely to be high as well, e. g. when aspects as failure propagation are regarded. These aspects are not addressed well by current EA management tools, although methodologies for this area can be found in literature, see e. g. [LS08]. For governing EA dynamics and making them transparent to the user, quantitative methods (see e. g. [AS08]) can be considered useful. Finally, simulation of the enterprise architecture (SimEA) could help to get additional insights in the complex dynamics of a *living* EA.

References

[AS08] J.S. Addicks and U. Steffens. Supporting Landscape Dependent Evaluation of Enterprise Applications. In M. Bichler, T. Hess, H. Krcmar, U. Lechner, F. Matthes, A. Picot, B. Speitkamp, and P. Wolf, editors, *Multikonferenz Wirtschaftsinformatik (MKWI) 2008*, München, 2008.

[BEL+07] S. Buckl, A.M. Ernst, J. Lankes, K. Schneider, and C.M. Schweda. A Pattern based Approach for constructing Enterprise Architecture Management Information Models. In A. Oberweis, C. Weinhardt, H. Gimpel, A. Koschmider, V. Pankratius, and Schnizler, editors, *Wirtschaftsinformatik 2007*, pages 145–162, Karlsruhe, Germany, 2007. universitätsverlag karlsruhe.

[Buh04] H.U. Buhl. Unternehmensarchitekturen in der Praxis – Architekturdesign am Reißbrett vs. situationsbedingte Realisierung von Informationssystemen. *Wirtschaftsinformatik*, (4), 2004.

[DOD04] Department of Defense (DoD). *DoD Architecture Framework Version 1.0: Volume I: Definitions and Guidelines*, 2004.

[EHH+08] G. Engels, A. Hess, B. Humm, O. Juwig, M. Lohmann, J.-P. Richter, M. Voss, and J. Willkomm. *Quasar Enterprise – Anwendungslandschaften serviceorientiert gestalten*. dpunkt.verlag, Heidelberg, 2008.

[Fra02] U. Frank. Multi-Perspective Enterprise Modeling (MEMO) - Conceptual Framework and Modeling Languages. In *Proceedings of the 35th Annual Hawaii International Conference on System Sciences 35*, pages 1258–1267, Honolulu, 2002.

[HW05] M. Hafner and R. Winter. Vorgehensmodell für das Management der unternehmensweiten Applikationsarchitektur. In O.K. Ferstl and E.J. Sinz, editors, *Wirschaftsinformatik 2005: eEconomy, eGovernment, eSociety*, pages 627–646, Heidelberg, 2005. Physica.

[IEE00] IEEE. IEEE Std 1471-2000: Recommended Practice for Architectural Descriptions of Software-Intensive Systems, 2000.

[JH06] G.A. James and R.A. Handler. Magic Quadrant for Enterprise Architecture Tools, 1Q06, 2006.

[JZ92] Sowa J.F. and J.A. Zachman. Extending and Formalizing the Framework for Information Systems Architecture. *IBM Systems Journal*, 31(3), 1992.

[KW07] S. Kurpjuweit and R. Winter. Viewpoint-based Meta Model Engineering. In M. Reichert, S. Strecker, and K. Turowski, editors, *Enterprise Modelling and Information Systems Architectures Concepts and Applications*, pages 143–158, St. Goar, Germany, 2007. GI Edition, Lecture Notes in Informatics.

[LS08] J. Lankes and C.M. Schweda. Using Metrics to Evaluate Failure Propagation in Application Landscapes. In M. Bichler, T. Hess, H. Krcmar, U. Lechner, F. Matthes, A. Picot, B. Speitkamp, and P. Wolf, editors, *Multikonferenz Wirtschaftsinformatik (MKWI) 2008*, München, 2008.

[MBLS08] F. Matthes, S. Buckl, J. Leitel, and C.M. Schweda. *Enterprise Architecture Management Tool Survey 2008*. TU München, Chair for Informatics 19 (sebis), Germany, 2008.

[MET02] META Group. *Enterprise Architecture Desk Reference*, 2002.

[Pey07] H. Peyret. The Forrester Wave™: Enterprise Architecture Tools, Q2, 2007.

[Sch07] J. Schekkerman. Enterprise Architecture Tool Selection Guide Verion 4.2 July 2007, 2007.

[seb05] sebis. Enterprise Architecture Management Tool Survey 2005. Technical report, Technische Universität München, Chair for Informatics 19 (sebis), Munich, 2005.

[TOG05] The Open Group. *TOGAF "Enterprise Edition" Version 8.1.*, 2005.

[WF06] R. Winter and R. Fischer. Essential Layers, Artifacts, and Dependencies of Enterprise Architecture. In IEEE Computer Society, editor, *EDOC Workshop on Trends in Enterprise Architecture Research (TEAR 2006), Hong Kong*, Los Alamitos. CA, USA, 2006. IEEE Computer Society.

[Wit07] A. Wittenburg. *Softwarekartographie: Modelle und Methoden zur systematischen Visualisierung von Anwendungslandschaften*. Phd thesis, Fakultät für Informatik, Technische Universität München, 2007.

[Zac87] J.A. Zachman. A Framework for Information Systems Architecture. *IBM Systems Journal*, 26(3):277–293, 1987.