

# Bottom-up EA Management Governance using Recommender Systems

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**Abstract:** Enterprise Architecture (EA) Management is an activity that seeks to foster the alignment of business and IT, and pursues various goals further operationalizing this alignment. Key to effective EA Management is a framework that defines the roles, activities, and viewpoints used for EA Management in accordance to the concerns that the stakeholders aim to address. Consensus holds that such frameworks are organization-specific and hence they are designed in governance activities for EA Management. As of today, top-down approaches for governance are used to derive organization-specific frameworks. These usually lack systematic mechanisms for improving the framework based on the feedback of the responsible stakeholders. We outline a bottom-up approach for EA Management governance that systematically observes the behavior of the actors to learn user concerns and recommend appropriate viewpoints. With this approach, we complement traditional top-down governance activities.

**Keywords:** Enterprise Architecture, Enterprise Architecture Management, Viewpoints

## 1 Motivation

The management of the IT of an enterprise is a collaborative endeavor, involving a large number of different *stakeholders* taking distinct roles. These stakeholders have diverse concerns that all pertain to the one architecture of the enterprise, the so-called Enterprise Architecture (EA). Crucial to the successful utilization of the EA is the establishment of appropriate EA management (EAM) governance and EAM processes. Different approaches, as for example [Hal3] and [Bu11], provide a methodology describing how this can be achieved. Both authors identify a number of steps required for the deployment and evolution of an EAM framework within an organization (see Figure 1). For the initial deployment, the organization's vision – its long-term objectives – as well as the stakeholders participating in this vision are identified. Once this is achieved, the goals and concerns of each particular stakeholder can be formulated. These concerns then serve as a foundation for the specification of the two artefacts building the EAM framework within the organization. The first of those is the definition of an appropriate *knowledge base* describing manifold aspects of the EA as a set of typed elements, their properties, and relationships to each other, as well as the viewpoints which address the concerns identified. This artefact of the EAM governance process is denoted as an EA framework and is usually implemented through an EAM tool. The second constituent element of the EAM framework is the specification of the EAM method – an abstract

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knowledge-intensive process involving organizational aspects specific for the stakeholders involved. Once this third step of the EAM governance process is complete, the EAM framework can be utilized productively within the organization.

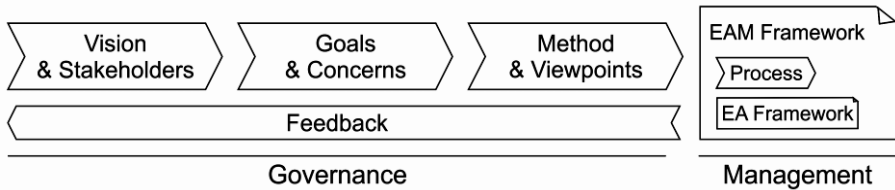


Fig. 1: The EAM Governance and Management Processes

For their collaborative management activities, the stakeholders use the *knowledge base* that describes manifold aspects of the EA. As a means to tackle the inherent complexity of the knowledge base, the stakeholders apply **viewpoints** to derive concern-specific views. Each viewpoint defines both an aggregation of information and an information representation; the former describes the relevant part of the knowledge base, and the latter specifies how the elements, properties and relationships are visualized. Both domain experts and experienced stakeholders design viewpoints to address both **recurring** and **ad-hoc concerns**.

With continuous use of the knowledge base, three effects prevail:

- Further information is added to the knowledge base
- Viewpoints are defined and stored as meta-data for the knowledge base
- Additional and less experienced stakeholders gain access to the knowledge base.

Together, these effects result in a rapidly increasing number of viewpoints and an even wider configuration space for viewpoints. Consequently, stakeholders find themselves confronted with an increasingly rich structure, making it hard

- to identify and select a viewpoint for a current concern from a list of hundreds of predefined viewpoints (**viewpoint selection**) and
- to configure a new viewpoint for an ad-hoc concern based on a multitude of element types, properties and relationships (**viewpoint configuration**).

EAM methodologies recognize this phenomenon and address it through an additional phase in the EAM governance process, the “learning” or “feedback” phase, both on the level of the EA framework and on the level of the EAM process, so that the EAM framework can evolve with the requirements it has to fulfill. While this learning process is suggested by different methodologies, to the best of our knowledge no particular procedure is provided. In this sense, current methodologies lack support for the systematic

usage of feedback from the utilization of an EAM framework for its continuous improvement, which results in a de-facto Waterfall governance model, but also, as suggested above, impedes with the usefulness and usability of the EAM framework.

Assuming the usage of an EA tool as an EA framework, two use-cases are critical for collaborative work on the complex knowledge base describing the EA: viewpoint selection and viewpoint configuration. We expect the stakeholders to have specific, yet evolving, **preferences** regarding the viewpoints, and the element types, properties and relationships, they are most interested in. This expectation is supported by the fact that stakeholders assume specific roles in the organization and **responsibility** for particular concerns with a clear focus on an aspect of the knowledge base.

Consequently, by observing user behavior, we expect to identify user preferences which reflect the actual utilization of the EAM framework. These observations can be seen as systematic and automatic feedback, and can be used to “learn” how the EAM framework evolves. For the automatic improvement of the EA framework, the user preferences have to be observed and used to aid the users in their future interactions with the system. Similar challenges prevail in fields like e-commerce or social networking and have been addressed by so-called Recommender Systems. This yields the objective of our research:

Study the potential for harvesting feedback in an EAM framework, as well as improving the usefulness and usability of the underlying EA framework by applying Recommender Systems for user-specific viewpoint selection and viewpoint configuration.

The remainder of the article is structured as follows. Section 2 introduces the terminology of the ISO Standard 42010 [ISO11] and gives a brief overview of the different approaches to Recommender Systems. In Section 3 we describe use-cases as well as requirements for an EAM Recommender System based on the beforehand established terminology. We further elaborate a formal perspective on the subject and identify the relevant concepts of EAM with the constituents of Recommender Systems. Based thereon, Section 4 describes the solution idea. With our research currently in progress, we do not supply a fully-fledged validation of our solution, but share current experiences and manifest challenges in Section 5, and give an outlook on future work in the research project.

## 2 Fundamental concepts and related work

EAM involves different stakeholders that seek to address different concerns pertaining to the enterprise in general and the IT support of its operations in particular. One group of stakeholders, for example, might want to improve the IT-support for sales processes in the enterprise, while another group may seek to reduce the number of currently used IT-systems. The former example also outlines, that the different concerns are not completely independent from each other, as they influence the overall organization of the enter-

prise and its IT support. To understand the interplay between the stakeholders, the concerns and their intended effect on the enterprise, we introduce the ISO standard~42010 [ISO11] in Section 2.1. This standard provides a terminology for reasoning and discussing management of software-intensive systems. Based on prevalent EAM literature, Section 2.2 identifies different kinds of stakeholders involved in EAM. In final Section 2.3, we briefly reflect on the field of Recommender Systems outlining general application alternatives in the field.

## 2.1 Designing Software-intensive Systems: ISO 42010

The International Standards Organization (ISO) Standard 42010 **Systems and Software Engineering – Architecture Description** [ISO11] is a slightly modified adoption of the IEEE 1471-2000 standard **Recommended Practice for Architecture Description of Software-Intensive Systems** [IE00]. The ISO 42010 provides a meta-model for the description of architectures, revolving around the central notion of architecture:

**(software) architecture:** “the fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution”

Since this definition is abstract many of its aspects have a semantic nature and cannot be captured explicitly. Thus, architecture is expressed through its architecture description:

**architecture description:** “a work product used to express an architecture”

In this sense, the architecture description is the actual artifact which is produced through the effort to capture an architecture. Inherently, an architecture description can have many facets, corresponding to different aspects of the architecture. Consider, for example, the architecture of a building. The description contains different plans, for example one considering the locations of the pillars and another containing the electrical wiring. The two plans are realizations of two different perspectives, through which the architecture description is considered. These perspectives are called *architecture viewpoints*, and defined by the ISO 42010 as follows:

**architecture viewpoint:** “a work product establishing the conventions for the construction, interpretation and use of architecture views to frame specific system concerns”

The two plans concerning the architecture of the specific building are *instances* of those two perspectives and are called *architecture views*:

**architecture view:** “work product expressing the architecture of a system from the perspective of specific system concerns”

Consequently, each architecture viewpoint is a way of seeing the architecture description which addresses specific concerns, i.e. has the purpose of providing the conventions for describing certain features of the architecture. The architecture views are manifestations of those concerns in a specific architecture. The ISO 42010 defines a concern as

**concern:** “interest in a system relevant to one or more of its stakeholders”

Note that a concern is relevant for a stakeholder, i.e. an

**stakeholder:** “individual, team, organization, or classes thereof, having an interest in a system”

In the example above, the plan of the building structure might concern the civil engineer, while the plan of the electrical network might concern the technicians responsible for the wiring. In this sense, the civil engineer and the technician are stakeholders having different viewpoints – the structural work and the wiring, respectively.

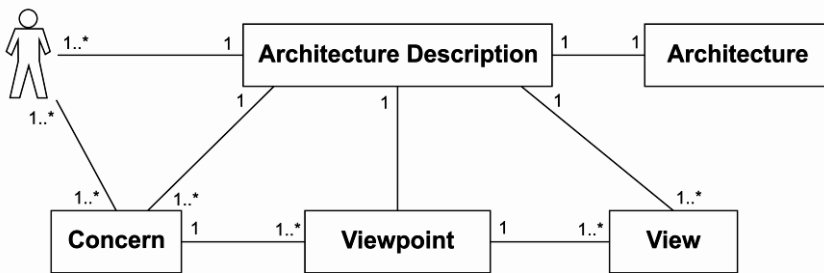


Fig. 2: The ISO 42010 Meta-model

Figure 2 depicts a reduced version of the ISO 42010 containing only the elements of the architecture description meta-model relevant for this article.

A further important aspect of the description of the architecture is the maintenance of consistency between the artifacts stakeholders use to perceive the architecture -- the views. Since the views themselves are instances of certain viewpoints, the task of assuring consistent depictions of the architecture description can be embedded in the viewpoints. Such an approach, based on the ISO 42010, is proposed by Dijkman et al. in [DQvS08]. The authors extend the base ISO standard with a number of additional concepts, in particular re-usable consistency rules, which serve the purpose of assuring correspondence between different perspectives (viewpoints).

In the scope of this paper, consistency is provided by the EA modeling tool, which is assumed to supply a unified meta-model as the basis for the architecture description.

## 2.2 Stakeholders of EA Management

In a qualitatively and quantitatively complex environment, such as an EA modeling tool, numerous different stakeholders collaborate in the effort to create and retrieve data in accordance with their respective viewpoints. Hanschke [Ha13] identifies a number of roles, which can be assumed in the scope of the enterprise IT management, all of which associated with respective responsibilities. A high-level perspective of the stakeholder landscape yields a differentiation between two major stakeholder categories, defined by their respective responsibilities: casual users and expert users (see Figure 3).



Fig. 3: Categorization of Users

Experts are users, which are responsible for several entities of the EA landscape and are responsible for the definition of strategic goals, as well as for the definition of viewpoints, which enable them and others to evaluate the current state of the architecture. In this sense, expert users are usually interested in an ad-hoc analysis of the EA and the mining of knowledge from the EA can be seen as a creative process. Such users are confronted with the full complexity of the architecture description. Expert users usually are people with a lot of experience in the field of EAM and are a comparatively small group in an enterprise.

Casual users do not define new viewpoints, but rather evaluate and analyze existing ones. This means that their tasks with regard to the EA can be classified as more formal. Casual users can be found on different levels in the structure of the organization, from single departments, where their responsibility is the management of a few applications, to the senior leadership level, where such users may extract information from the architecture description for the purpose of analysis only.

## 2.3 Recommender Systems

Recommender Systems are a comparatively recent yet rich field of study in computer science and are concerned with the task to improve the usefulness (e.g. by countering lacking user experience) and usability (e.g. by reducing an overwhelming amount of information to a manageable one) of a software service by providing users with suggestions, called **recommendations**, pertaining to entities handled by the service, called **items**, respecting the users' interests, and further considering additional information available through past user behavior, context information, inference or otherwise. Ac-

According to [Ri11], Recommender Systems can roughly be separated in a number of categories, called Recommendation Techniques, discriminating on the basis of how information is gained and processed to provide the **user** of a software service with recommendations:

- **Collaborative Filtering:** Items are recommended to users on the basis of the preferences of similar users, whereby similarity is measured on the basis of past user feedback, provided, for example, through explicit rating of items.
- **Content-Base:** Items are recommended on the basis of past user preferences with regard to properties of the items, called *features*.
- **Knowledge-Based:** Knowledge-based techniques recommend items on the basis of specific domain knowledge, by inferring the significance of a particular item through its features. Here, the notion of similarity is based on a matching between the user and the items.
- **Demographic:** Items are recommended respecting demographic features of the user profile, such as country, language or age.
- **Community-Based:** Items are recommended in accordance with rankings provided on the basis of a social graph of the users, i.e. items liked by “friends” are more likely to be useful to a particular user.
- **Hybrid:** Recommendation techniques in which several other recommendation techniques are combined.

### 3 Requirements

The different types of stakeholder (cf. Section 2.2) have different use-cases with respect to the systems, yielding two sets of requirements for EAM support.

#### 3.1 Use-cases of EA Management Support

The different kinds of stakeholders (expert users and casual users) have different tasks with regard to EAM. Consequently, they use the EAM tool differently to address their respective concerns. Casual users rely on the EA modeling tool to obtain data relevant for the completion of their tasks. They obtain this data by selecting a previously configured viewpoint and retrieving the corresponding view. Thus, casual users can be associated with different use-cases for viewpoint selection:

- **Direct Viewpoint Selection:** In this use-case the system presents the user with a list of all previously configured viewpoints, encompassing all kinds of aggregations within the knowledge base, as well as representations. The user picks

the relevant viewpoint from the provided list and the system evaluates it to produce the corresponding view of the EA.

- **Representation-Driven Viewpoint Configuration:** If an expert user is already aware of the cohesions of interest within the EA, he or she can begin the configuration by selecting one of a number of possible representations, which captures the desired relationships in the knowledge base. The representation provides a number of degrees of freedom, each of which can be bound to an aggregation in accordance with the consistency rules implied by the viewpoint representation. Once a representation is selected, and its degrees of freedom configured, the viewpoint can be stored and used for the generation of views.
- **Aggregation-Driven Viewpoint Configuration:** An expert user might begin by analyzing the knowledge base through a particular aggregation of data. Once an aggregation is defined, which captures the user's current concern; he/she may decide to embed this aggregation in a number of possible representations, whose degrees of freedom fit the pattern of the current aggregation. After a representation is selected and configured, the viewpoint can be stored and used for the generation of views.

### 3.2 Requirements for EA Management Support

The established distinction between expert and casual users leads to two separate sets of requirements, each covering the use-cases of the corresponding user group. Furthermore, as each of the user categories also corresponds to one of the coarse-grained use-cases, we use these use-cases for the systematization of the requirements to the EA modeling tool. The following are required for the **viewpoint selection (VS)** use-cases:

- **(VS1) Recommendation of Stored Viewpoints:** Stored viewpoints should be recommended in accordance with their relevance for the user's concerns.
- **(VS2) Relevance Criteria for Stored Viewpoints:** Prioritization of stored viewpoints for a given user should be based on past user behavior with respect to the selection of viewpoints and regarding users with similar concerns.

Expert users have concerns which result in an advanced usage of the EA modeling tool and, to some extent, explore the enterprise architecture, for example through the ad-hoc configuration of viewpoints. Thus, requirements for the **viewpoint configuration (VC)** use-case are more deeply anchored in the underlying structure of the EA.

- **(VC1) Recommendation of Aggregations:** During the configuration of a viewpoint, the system should order elements of the EA in accordance with their stakeholder-specific relevance, as determined by past behavior of stakeholders with similar concerns.



- **(VC2) Recommendation of Representations:** During the configuration of a viewpoint, the system should offer representations and representation configurations in accordance with their stakeholder-specific relevance, as determined by past behavior of stakeholders with similar concerns.
- **(VC3) Exploration of Adjacent Configurations:** During the configuration of a viewpoint, the system should offer likely aggregation or representation configurations based on correlations with past stakeholder behavior, not necessarily constrained to stakeholders with similar concerns.

## 4 Solution Idea

Stakeholders utilize viewpoints to address their concerns and perform the management tasks. The assignment of stakeholders and viewpoints and the entailing responsibilities constitute a key determinant of the management's corresponding governance model. Traditionally, these governance models are defined top-down. The subsequently presented approach targets to develop and evolve the governance model bottom-up, i.e., by observing and analyzing the behavior of the stakeholders.

Key to our approach is the assumption, that any distinct stakeholder has concerns that cover related **areas-of-interest** in the overall EA. This means, that any stakeholder is interested in only a small set of characteristics of the enterprise, while he/she considers these characteristics in different combinations and different perspectives. This assumption is backed by the observations in [NKF94]. They describe, that concerned with a management task, stakeholders rely on viewpoints that relate to each other:

- Two viewpoints **overlap** with respect to the covered concerns, i.e., display one or more shared characteristics.
- One viewpoint **refines** another one with respect to the covered concerns, i.e., provides additional details when it comes to the relevant characteristics.

Our approach leverages aforementioned relationships to identify relevant viewpoints for a stakeholder, based on the viewpoints that the stakeholder already utilized. We further do not assume that relationships between the viewpoints are explicitly stated. Such assumption sensibly applies to the field of EA management, where – as discussed in Section 3.2 – EAM frameworks are organization-specific. Many of these tailored frameworks lack explicit descriptions of the viewpoints, let alone descriptions of their relationships. Consequently, we use mechanisms that observe user behavior to determine relationships between viewpoints and to make recommendations on viewpoints.

In the terminology of Recommender Systems, the first relevant use-case (viewpoint selection) can be addressed by treating **predefined viewpoints** as **items** for the Recommender System. The second use-case (viewpoint configuration) uses element **types**,

**properties** and **relationships** as **items** for a more fine-grained recommendation. Both use-cases are further related by the fact, that the items of the second use-case (element types, properties and relationships) are potential features of the items in the first use-case (viewpoints). We further identify the stakeholders with the **users**, for which the recommendations are provided. The following recommendation techniques apply with respect to the use case of viewpoint selection (cf. Section 3.1):

- **Collaborative filtering** identifies users that have utilized the same viewpoints, and provides recommendations based on this usage.
- **Feature-based recommendations** rely on characteristics of the viewpoints, so-called **features**, to identify similar viewpoints and to provide recommendations based on these characteristics.

The former recommendation technique aligns with the concept of the **role** in the governance model. The latter technique identifies relationships between the viewpoints based on these features. Consistent with the approach presented in Section 2.1, we identify these features with elements of the unifying meta-model of the architecture framework, on which the different viewpoints are based. In particular, the entity types of the meta-model (e.g. information systems or technical components) and a subset of these (e.g. only information systems that are hosted at a certain organizational unit or are not standard software) as displayed in a viewpoint, are considered relevant features for recommending viewpoints. The mapping between EAM use-cases and corresponding recommendation techniques is depicted in Figure 4.

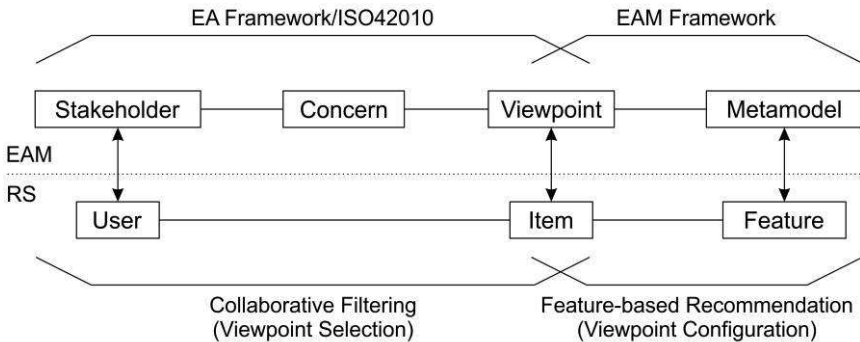


Fig. 4: Mapping of EAM to Recommender Systems

The obtained feedback can be considered from two distinct perspectives: By observing usage-patterns – which stakeholder uses which viewpoints how often – knowledge can be obtained with regard to the utilization of the EAM framework within an organization. This knowledge, in return, can be used for the analysis of the EAM framework and the improvement of the EAM process. By monitoring the usage of specific viewpoints and aspects of the knowledge base, it is possible to recognize preferences and directly and

systematically improve the EA framework itself. While analysis of both the EAM and the EA frameworks is conceivable, direct improvement of the EAM process is not feasible, since it is knowledge-intensive and not portrayed directly in the EAM tool.

## 5 Experiences, Challenges and Outlook

As a research-in-progress paper we cannot provide a full-fledged implementation nor a validation of the above described approach. Open issues and demands for current EAM tool support, however back the need for a bottom-up EAM governance using Recommender Systems. The definition of roles is a basic feature of current EA management tools [Ma08] nevertheless the concept is typically considered from the aspect of authorization and access rights. As a tooling company that provides an EAM solution, we received numerous requests regarding the support of saving and sharing filters, i.e. features or meta-model excerpt definitions.

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