# A Taxonomy for Enterprise Architecture Analysis Research

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Abstract:     Enterprise Architecture (EA) practitioners and researchers have put a lot of effort into formalizing EA model representation by defining sophisticated frameworks and meta-models. Because EA modelling is a cost and time-consuming effort, it is reasonable for organizations to expect to extract value from EA models in return. Due to the plethora of models, techniques, and stakeholder concerns in literature, the task of choosing an analysis approach might be challenging when no guidance is provided. Even worse, the design of analysis efforts might be redundant if there is no systematization of the analysis techniques due to the inefficient dissemination of practices and results. This paper contributes with one important step to overcome those issues by screening existing EA analysis literature and defining a taxonomy to classify EA research according to their analysis concerns, analysis techniques, and modelling languages employed. The proposed taxonomy had a significant coverage tested with a set of 46 papers also collected from the literature. Our work thus identifies and systematizes the state of art of EA analysis and further, establishes a common language for researchers, tool designers, and EA subject matter experts.

## 1 INTRODUCTION

The continuous establishment of Enterprise Architecture (EA) techniques as a means to model a holistic representation of corporate structures, processes and Information Technology (IT) infrastructure still attracts many researchers today (Aier et al., 2008; Saint-Louis and Lapalme, 2016). While themes like EA frameworks, modelling languages, Enterprise Architecture Management (EAM) are reasonably represented, EA analysis, a fundamental practice in EAM, has received much less attention from the research community.

EA analysis is based on the data collected from models and documents. EA modelling itself is a cost and time-consuming effort and, therefore, organizations expect to extract value from those EA models in return (Välja, 2018). EA analysis enables informed decisions and plays a crucial role in projects because it manages the projects complexity and provides the possibility of comparing architecture alternatives (Manzur et al., 2015b).

To date, there are a plethora of analysis paradigms such as ontology-based (Bakhshadeh et al., 2014), probabilistic network analysis (Johnson et al., 2014) and network theory (anonymous, 201x); which use

several types of EA model based on OWL-DL, Archimate, Graphs and so on. Every analysis supports a different analysis concern and, thus, for a sound evaluation of the architecture different kinds of analyses are required (Rauscher et al., 2017).

Despite the importance of EA analysis, EA practitioners and researchers do not have an overall shared and acknowledged comprehension about EA analysis techniques. Little research about mechanisms to classify, compare, or organize the existing EA analysis research can be found. As a consequence, the task of choosing an analysis approach might be challenging when little guidance is provided. Even worse,the design of analysis efforts might be redundant if there is no systematization of the analysis techniques due to the inefficient socialization of practices and results.

We contribute with one important step in that direction deriving a taxonomy to classify analysis research according to its layers, analysis concerns, analysis techniques, and modelling languages. We also evaluate the proposed taxonomy against recent EA analysis research. Doing so, we create foundational elements aiming to foster the development of this research field and also establishing alignment among researchers, tool designers, and EA subject matter experts. Therefore, in this paper, we answer the follow-

ing question:

RQ *How is the EA analysis research classified according to its analysis concerns, techniques, and modelling languages?*

The next section presents the key concepts involved in this research and gives insights about the correlated literature. Section 3 elaborates in detail the approach to answer the research question. The taxonomy is presented in Section 4. The discussion is made in Section 5. In closing, Section 6 gives our final considerations and directions for further work.

## 2 KEY CONCEPTS

### 2.1 Enterprise Architecture, Layers and Models

According to Kotusev, Singh, and Storey (Kotusev et al., 2015): "EA is a description of an enterprise from an integrated business and IT perspective". However, EA is more inclusive if it is presented from different perspectives at different layers of abstraction (Ahlemann et al., 2012). According to TOGAF (Haren, 2011): "EA is a system formed by four subsystems, namely Business, Data/Information, Application, and Infrastructure (or Technology) Architecture". Archimate 2.1 (Group, 2013) defines a motivational extension to include concerns regarding strategy and governance aspects (e.g., goals, principles, requirements, stakeholders, intentions). This particular layer, Value, aims to understand the factors that influence the architecture as a whole. Therefore, we consider those five layers (value, business, information, application, technology).

Considering the previous layers, EA models are used as an abstraction of the structure of the enterprise in its current state (AS-IS models). They show possible alignment issues, ease communication and can aid in decision-making, by being used to predict the behavior of future states (TO-BE state models) rather than modifying the systems in the current architecture (Buschle et al., 2010). EA models are tools for planning, communicating, and of course, also for documenting (remembering) (Johnson, P., Lagerström, R., Ekstedt, M., & Österlind, 2012).

### 2.2 EA Analysis and Concerns

EA analysis is one of the most relevant functions in EAM as it enables informed decision making and plays a crucial role in projects (Matthes et al., 2008). This paper will use the definition suggested by (anonymous, 201x), that defines EA analysis as "the property assessment, based on models or other EA related data, to inform or bring rationality to decision support of stakeholders."

The property is related to an analysis concern (e.g., risk, business-IT alignment, cost, etc.). Our definition of concern agrees with the Oxford Dictionary of English definition, which is "A matter of interest or importance to someone". We consider as an analysis concern the main objective of an analysis approach such as cost, risks, performance and so on.

### 2.3 Related Work

Past works also tried to discuss and categorize analysis approaches. While (Lankhorst, 2004) shows the variety present in techniques and methods and analyses them according to the type of the employed technique (analytical x simulation) and type of produced result (quantitative x functional). (Buckl et al., 2009) perform their classification representing different contexts of EA: academic research, practitioners, standardization bodies, and tool vendors (Manzur et al., 2015a). Their classification covers the following dimensions: the body of analysis, time reference, analysis technique, analysis concern and self-referentiality. Both classifications proposals evaluate their framework by classifying published works.

Niemann (Niemann, 2006), in contrast, describes different types of analysis according to the object under investigation (dependency, coverage, interface, heterogeneity, complexity, compliance, cost and benefit) and discusses each one separately, although Niemann does not base it in a broad sample of studies. Andersen and Carugati (Andersen and Carugati, 2014) shed light on findings regarding the main focus of the papers analyzed (business, technical or financial), their approaches' outcomes (model, measurement, method) and which elements their techniques are evaluating (architecture, IT projects, and IT initiatives; services and applications; business elements). However, this classification is still superficial in light of the plurality of methods, techniques, and concerns related to EA Analysis. (anonymous, 201x) designed a meta-model to characterize network analysis initiatives, based on 74 works found through a systematic literature review (SLR), and classified the initiatives according to their analysis concern of interest and other information requirements. This current work, though, is not limited to network analysis techniques.

Hanschke provides "analysis patterns" and defines two dimensions for the classification of analysis approaches: analysis function and architecture sub-model (Hanschke, 2009). Regarding the anal-

ysis functions, the following possibilities are proposed: discovery of potential, redundancies, discovery of potential inconsistencies, needs for organizational changes, implementation of business goals, optimization, and required changes on technical and infrastructure layer. Similarly to our research, that work identifies Business, Information Systems, Technical, and Infrastructure Layer as targets for the analysis approaches.

Abdallah et al. (Abdallah et al., 2016) mapped the concepts measured in EA measurement research. Based on previous works, (Lantow et al., 2016) propose a more detailed so-called EA classification framework and evaluate it by using papers from published research, similarly to our research design.

(Rauscher et al., 2017) define requirements for an EA analysis and utilize them to classify of the various approaches in two categories: technical (according to their utilized techniques and requirements for execution) and functional (according to their goals and their provided result). The authors also propose a domain specific language for EA analysis.

Similarly to (Lankhorst, 2004), (Buckl et al., 2009), (Lantow et al., 2016), and (Rauscher et al., 2017), we use the analysis technique and analysis concern dimensions in our taxonomy. Although, our approach differs from previous works because we expand the classification of EA analysis research including also modelling languages and EA layers categories in our process. A differential to (Lantow et al., 2016) is that our search scope is broader than all previous ones regarding the query string and also in terms of time interval (the last EA analysis literature review was published in 2016). This was reflected in the numbers of categories we found for taxonomy's dimension, for instance.

## 3 RESEARCH DESIGN

This is a qualitative and descriptive research split up into four steps. First, we apply the SLR method according to Kitchenham (Kitchenham, 2004) to gather a set of papers related to EA analysis research (Step 1 in figure 1). Second, we perform a data categorization (Cruzes and Dyba, 2011) to end up with a taxonomy answering the question: "How to classify EA analysis research according to its analysis concerns and modelling languages?" (Step 2 in Figure 1). We obtained a second dataset with papers published between 2016 and September 2018 (Step 3 in Figure 1). Finally, we apply the taxonomy created in Step 2 in the evaluation dataset (from Step 3) to evaluate and improve the taxonomy. Our research design is depicted in Figure 1.
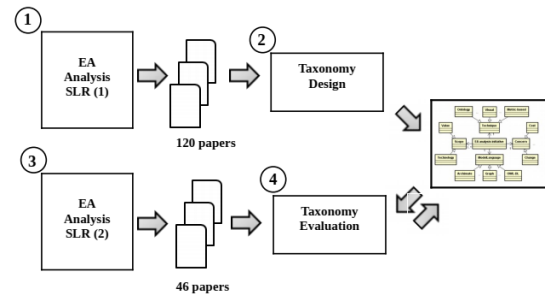
The SLR steps are detailed in the next sections.



Figure 1: Research Design

### Research Query

The keyword design was intentionally generic as it aimed for wide coverage of publications in the EA analysis field. The final string combined the terms related to EA and its subsets, as used in the work of (Simon et al., 2013b); and terms related to "analysis" such as goals, metrics, and evaluation, as listed by (Andersen and Carugati, 2014). Thus, our final string was:

*("Enterprise architecture" OR "business architecture" OR "process architecture" OR "information systems architecture" OR "IT architecture" OR "IT landscape" OR "information architecture" OR "data architecture" OR "application architecture" OR "application landscape" OR "integration architecture" OR "technology architecture" OR "infrastructure architecture") AND (Goals OR concerns OR methods OR procedures OR approaches OR analysis OR evaluate\* OR assess\* OR indicator OR method OR measur\* OR metric)*

### Inclusion and Exclusion Criteria

The inclusion criteria consisted of papers containing techniques, methods or any initiative to evaluate EA, e.g., papers which use EA as input for taking decision or papers that analyze EA itself, its changes and evolution. Papers in any language but English, related to product architecture analysis or internal architecture of software, containing only modelling approaches or that do not analyze EA itself but instead they describe the EA as a whole organizational function to an organizational variable (e.g., organizational performance) were not included. Literature reviews about EA (secondary studies) and papers dealing with the discussion of analysis approaches, but not performing any, were also excluded from the study.

### Used Engines

We selected the main engines/databases accessed in the information system community as our data-

sources for primary studies: Scopus, IEEE, ScienceDirect, ISI Web of knowledge and AIS electronic library. Duplicates were removed. Table 1 presents the results returned by each engine.

Table 1: Results by engine for the two time intervals of our SLR

| Engine | Time interval 1 | Time interval 2 |
|---|---|---|
| IEEE | 1,762 | 358 |
| ScienceDirect | 832 | 623 |
| Scopus | 3439 | 949 |
| AISEL | 25 | 0 |
| ISI | 1,162 | no access |
| Total (duplicates removed) | 5174 | 1076 |

**Screening Phases**

The SLR was performed considering two intervals. The first one (Step 1 of our research design) covers papers published until 2015. Then, using the data extracted from those papers, we applied the data categorization to derive our taxonomy's constructs. The second interval (related to Step 3 of our research design) encompass papers published from 2015 to September 2018.

Considering the previous inclusion and exclusion criteria, our screening process was divided into three rounds for each one of the two-time intervals. For the first interval, during our first round, we read 7220 abstracts and titles of primary studies returned by the engines. In the next round, the reading focus was on the introduction and conclusion sections of 803 remaining papers. Finally, the 183 resulted papers were completely read, forming a set of 120 final papers. For the second interval (2016 to September 2018), we performed the same previous screening strategy: the first round had 1076 titles and abstracts to be read, the second had 168 introductions and conclusions, 65 full paper readings in the third and 46 final papers as final dataset, under the same process of the first interval. The papers were selected according careful inclusions and exclusion criteria, and according their availability to the authors. We took the papers from this second set to validate the produced taxonomy.

**Data Categorization**

We screened the 120 papers from the first data-set for the identification of common dimensions related to the EA analysis. Considering our research goals, this

ended up in the four dimensions: EA Scope, Analysis Technique, Analysis Concern, and modelling Language.

To bring the *coding* into practice, we follow an inductive approach of Cruzes and Dyba (Cruzes and Dyba, 2011). We reviewed the data line by line in detail and as a value becomes apparent, a code is assigned. To ascertain whether a code is appropriately assigned, we compare text segments to segments that have been previously assigned the same code and decide whether they reflect the same value. This leads to continuous refinement of the dimensions of existing codes and identification of new ones (Cruzes and Dyba, 2011). This process does not necessarily take a linear order rather an iterative and dynamic one. In the next section, we present the proposed taxonomy.

# 4 EA ANALYSIS TAXONOMY

The taxonomy has four main dimensions: EA Scope, Analysis Concern, Analysis Technique, and modelling Language, depicted in Figure 2. The dots between the entities represent additional categories hidden due to space reasons although described in the following paragraphs.
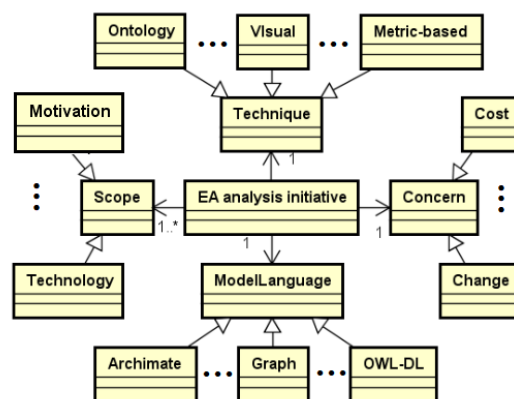


Figure 2: Proposed Taxonomy

## 4.1 EA Scope Dimension

By investigating the architecture models, we observed that plenty of papers operate their evaluation on rather specific components instead of looking at a whole model. Even if the authors introduce a case study with a comprehensive EA model, the evaluation considered very specific parts of it for example only the technical layer or process layer (Veneberg et al., 2014; authors, 201x). In (Sousa et al., 2013) the authors used

an EA model's visions and goals hierarchy for their evaluation although the exemplary data-set consists of much more information. In this case, the relevant components of the EA model were the dependencies between visions and goals. In (Xavier et al., 2017; Antunes et al., 2015; Oussena and Essien, 2013) even larger components were used spreading along multiple layers of the EA model.

Our analysis shows that the EA model related work sticks to the well-known layered structure, e.g. defined in TOGAF (The Open Group, 2011) or by Winter and Fischer (Winter and Fischer, 2006). Accordingly, our EA Model Scope dimension is composed by following well-known layers:

- **Motivation** - Since the publication of (Winter and Fischer, 2006), recent frameworks offer the opportunity to model elements modelling the motivation or the purpose of the organization (cf. ArchiMate 3.0.1 (The Open Group, 2017)). Additionally, recent research stresses the need for modelling the business motivation (Sousa et al., 2013; Timm et al., 2017). Therefore, we opt for a motivational scope, even if it is maximally implicitly included in the business layer of Winter and Fischer (Winter and Fischer, 2006).

- **Business** - This represents the fundamental corporate structure as well as any relationships between actors or processes of the business architecture (Winter and Fischer, 2006).

- **Process** - This layer represents "the fundamental organization of service development, service creation, and service distribution in the relevant enterprise context" (Winter and Fischer, 2006).

- **Application** - Since there was no observation of requirements for a deeper differentiation of business integration and software architecture, we merge the layer "Integration Architecture" and "Software Architecture" of Winter and Fischer (Winter and Fischer, 2006). Consequently, it represents an organization's enterprise services, application clusters, and software services.

- **Technology** - This layer represents the underlying IT infrastructure (Winter and Fischer, 2006).

## 4.2 Analysis Concern Dimension

We define concerns as relevant interests that pertain to system development, its operation or other important aspects to stakeholders (ISO et al., 2011). Since an approach may suit more than one concern at a time, several papers are classified with more than one concern (e.g., (Simon et al., 2013a; Vasconcelos et al.,

2004)). According to our research results, the dimension Analysis Concern consists of 55 concerns, grouped in fifteen categories:

- **Actor Aspects** - This category covers papers dealing with actor's relations to business process, goals, and the impact on them of EA changes, e.g. the organizations impact on the motivation and learning of employees (Närman et al., 2016).

- **Application Portfolio Analysis** - It means to analyze why certain applications are well-liked and widely used than others and what it means to the EA (Närman et al., 2012).

- **Best Practice** - Papers elaborating on the value of best practice analysis establish EA patterns or evaluate real-world EAs with respect to EA patterns (Ernst, 2008; Langermeier et al., 2014; Österlind et al., 2012).

- **Cost Analysis** - Papers related to the value of cost analysis are manifold. For example, they estimate or assess the cost of the current IT architecture (Francalanci and Piuri, 1999), or determine the ROI (Return on Investment) of EA (Rico, 2006). Another facet is related to the costs of changing components of the EA (Lagerström et al., 2010, p. 440),(Simon et al., 2013a, p. 25).

- **EA Alignment** - For instance, EA redundancy is contained within papers related to EA alignment. Those paper identify redundancies and eliminate unplanned redundancies (Castellanos et al., 2011, p. 118). Additionally, there are papers promoting alignment between layers (Boucher et al., 2011).

- **EA Change** - This value covers concerns related to modifications of the current EA. Scientific research related to this value elaborates, for example, the consequences of changes, scenarios' choices, or performs gap analysis.

- **EA Decisions** - This value covers approaches related to the decision-making process itself. Exemplary, it is related to the rationale behind decisions, stakeholders' influence on the decision-making process, or methods to evaluate alternatives (Plataniotis et al., 2013; Plataniotis et al., 2014).

- **EA Governance** - Research related to EA Governance evaluates EA from a strategic viewpoint, comprehending the analysis of EA's overall quality and its function. This value includes works dealing with EA effectiveness, EA data quality, EA documentation, or metrics monitoring (Davoudi and Aliee, 2009; Capirossi and Rabier, 2013).

- **Information dependence of an application** - This category aims to evaluate dependent applications on EA, helping CIOs to manage their application landscape and to eliminate redundancies (Addicks, 2009).

- **Model Consistency** - This value aims to evaluate the integrity of EA models and its consistency through time and organizations' evolution (Bakhshadeh et al., 2014; Florez et al., 2014b).

- **Performance** - This value is concerned with specific measures of performance, e.g., EA component performance, business performance, or system quality (Garg et al., 2006; Närman et al., 2008).

- **Risk** - Papers related to the value of risk elaborate on different aspects: risk of component's failure and its consequences, information security as a whole, EA project risks, or EA implementation risks (Garg et al., 2006; Grandry et al., 2013).

- **Strategy Compliance** - Research on Strategy Compliance analyses if EA decisions, EA projects, models, and its structure are compliant with the organization's strategy (Plataniotis et al., 2015a; Subramanian et al., 2006).

- **Structural Aspects** - This value covers analysis of how components are organized, the relations among the components and their emergent complexity, possible ripple effects, clustering issues, and positional values in the structure (Aier, 2006b; Lee et al., 2014).

- **Traceability** It represents the need of querying or tracking components that are connected/linked to a particular component and/or have specific attributes values.

## 4.3 Modelling Language Dimension

In some papers, the proposed method relies on certain properties introduced by specific frameworks (Xavier et al., 2017; Oussena and Essien, 2013). Others require EA models where the actual meta-model was of less importance or they require models that follow either less formalized or more general meta-models (authors, 201x). Researchers, therefore, may require model data to follow a specific conceptual format which is captured by the third dimension *modelling Language*. In this case, conceptual format serves as a generic term for meta-model or framework.

We identified several modelling approaches, some already existing, others created by the authors to suit their specific analysis approach. We categorized the modelling techniques into nine values of the dimension. Due to space limitations, we will present the full

description for the four main categories, which represent 80% percent of all papers classified. The other five categories are DoDAF models, Probabilistic networks based, Intentional modelling, Formal Specification Based, and UML based.

- **ArchiMate-based** - Obviously all research modeled with ArchiMate is classified within this value. Mainly, there can three subcategories be distinguished: Firstly, papers applying ArchiMate (Plataniotis et al., 2015a; Davoudi and Aliee, 2009). Secondly, papers extending ArchiMate (Grandry et al., 2013; Capirossi and Rabier, 2013). Finally, papers that explicitly used the Archimate adapted or merged with other entities and attributes (Plataniotis et al., 2015b).

- **Combined models** - This category comprises papers that use more than one model to perform their analysis, e.g. (Sunkle et al., 2014) which uses Business Motivation Model (BMM) and Intentional modelling together with Archimate to evaluate if and how business rules and goals are compliant with the organization's directives.

- **Graphs** - In this value, the EAs are modeled as graphs, with their components and relations being represented by nodes and edges, respectively. In addition, design structure matrix is included because they are structurally equivalent to graphs. Examples can be found in (Garg et al., 2006; Aier, 2006a). A special sub-case of EA graph models are probabilistic relational models, influence diagrams, Bayesian networks, and fault tree analysis models. All those models work with uncertainty and probability principles in their modelling approaches (Österlind et al., 2012; Johnson et al., 2014).

- **Own** - In this value, we included papers that present their own EA modelling framework and it is not classifiable in none of the other categories (Langermeier et al., 2014; Holschke et al., 2008).

## 4.4 Analysis Technique Dimension

This dimension covers techniques and methods used to perform EA analysis. We identified a plurality of different approaches, as a large portion of the approaches was proprietary, and many were poorly detailed, focusing on the results rather than the analysis process. The results were classified in 22 categories according to their main characteristics: (Semi) Formalism based, Analytic Hierarchy Process (AHP), Architecture Theory Diagram (ATD) based, Axiomatic Design, Best practice conformance, BI,

BITAM, Compliance analysis, Design Structured Matrix, EA Anamnesis, EA executable models, EA misalignment catalogue, Fuzzy based, Machine learning techniques, Mathematical functions, Metrics based, Multi-criteria analysis, Prescriptive models, Probabilistic based, Proprietary techniques, Structural analysis, and Visual analysis. About 70% of the studies corresponded to the following five values:

- **(Semi) Formalism Based** - It includes description languages, ontologies, set theory, and other formalisms. All those techniques try to take advantage of reasoning mechanisms to perform (semi) automated analysis of the EA, through queries, model consistency, and restrictions checks, for example (Florez et al., 2014a; Langermeier et al., 2014).

- **Metric-based** - Analysis approaches including several punctual quantitative metrics to evaluate operational data from the components (e.g., performance, usage, workload) or from the overall EA (e.g., entropy) (Veneberg et al., 2014; Montino et al., 2007).

- **Probabilistic-based** - Cause and effect, uncertainty and probabilistic events are concepts present in all variations of methods belonging to this category. Typical techniques are Bayesian networks, probabilistic Bayesian networks, extended influence diagrams, and fault-tree analysis. Those are frequently used to perform EA components performance analysis (Österlind et al., 2012; Holschke et al., 2008).

- **Structural analysis** - In this category, structural aspects of the overall EA or specific layers are analyzed. Methods and techniques based on network theory are employed to identify critical points, clusters or overall indexes for the EA structure (Wood et al., 2012; Dreyfus and Iyer, 2006).

- **Visual analysis** - This category covers several techniques that use the power of visualization intrinsic to the models to extract valuable information for the experts. Typical concerns analyzed are alignment between layers, the impact of changes or failures in the overall structure (Šaša and Krisper, 2011; Lee et al., 2014).

The previous dimensions were defined as a result of the SLR performed, as described in Section 3. In order to assess the taxonomy, we updated the data through a new SLR (see Figure 1, Step 3) addressing papers published after the first research's interval and applied the taxonomy to its final data-set, containing 46 articles.

The papers on the new data-set addressed 26 concerns classified in 13 categories already present on the taxonomy, which indicates its good coverage. From the 47 preexisting concerns, six were merged into three ones and eight new concerns were mapped on the update (into the categories of Actor aspects, Best practice analysis, Actor aspects, EA Alignment, EA Change, Model consistency, and Structural aspects).

Regarding modelling approaches, 89.1% of studies presented model-based analysis. Only two new values of modelling approaches were detected, one of them also resulting in one new category (DoDAF models). The papers from the dataset were classified, according to the taxonomy, into seven categories - i.e., only one paper was not covered by the taxonomy's preexisting values, which, again, indicates it's good coverage.

Our first study resulted in a considerable number of different analysis techniques and methods, classified into 23 categories. When applying the results to the new data-set, we found 19 of those, and five new categories, determined by specific approaches.

## 5 DISCUSSION

Following, we present existing research classified by our taxonomy and discuss the insights.

All the evaluated papers were covered by the five layers of the EA scope dimension. Regarding the frequency of EA targeted scopes, most of the papers approached more than one layer. Business and Application are the layers that received more focus on the analysis in general - 77% and 83% of the total, respectively.

We identified about 22 different modelling approaches, divided into nine categories (Archimate-based, Combined models, DoDAF, Formal Specification-based, Graphs-based, Intentional modelling, Own, Probabilistic networks-based, and UML-based). The distribution of the studies, from both SLRs, regarding their modelling approaches is depicted in figure 3.

Even though ArchiMate-based and graphs-based represent a large part of the studies, 34.9% of the approaches used a proprietary model or a combined model to perform their analysis. The plurality of different modelling approaches reflects the lack of standardization regarding EA models and corroborates the affirmation from (Johnson et al., 2007) that "there is no clear understanding of what information a good enterprise architectural model should contain".

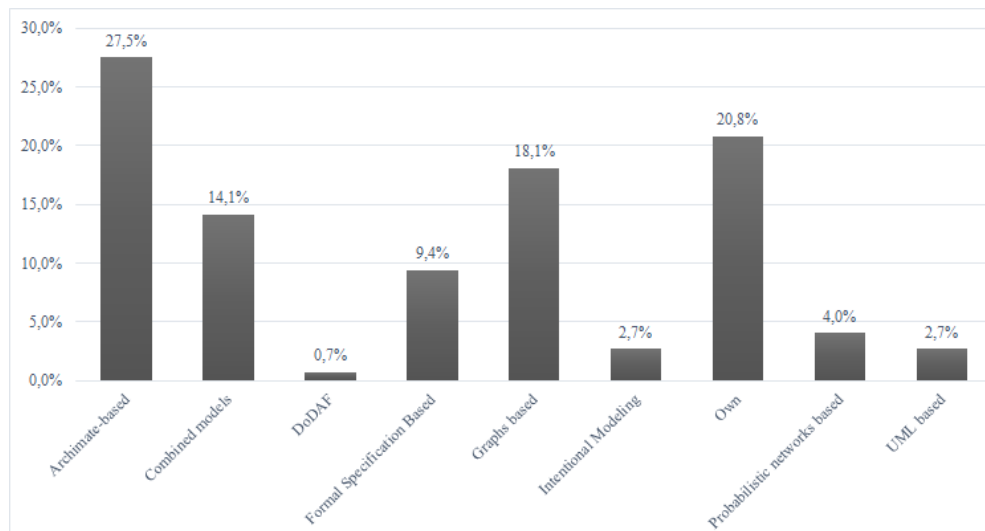Our taxonomy defined 52 concerns, classified into 15 categories: Actors aspects, Application Port-

Figure 3: Percentage of studies on each model category

folio Analysis, Best practice analysis, Cost analysis, EA Alignment, EA Change, EA Decisions, EA Governance, Information dependence of an application, Model consistency, Performance, Risk, Strategy Compliance, Structural aspects, and Traceability. The amount of papers on each concern category is illustrated by figure 4.

It is important to consider that some studies approached more than one concern on their analysis (e.g., (Simon and Fischbach, 2013) performs an analysis on eight different aspects of the Application scope). According to our research' results, the focus of EA analysis has been in five main categories: EA Change, EA Alignment, Strategy Compliance, Performance and Structural Aspects, as shown in figure 4. Papers covering these concerns correspond to 64.7% of the whole final set.

We identified a plurality of different analysis approaches (i.e., techniques or methods), classified in 22 categories according to their main characteristics, as shown in figure 5. A large portion of the approaches was proprietary, and some of them so specific that we gathered them resulting in a specific category. Many approaches were poorly detailed, focusing on the results rather than the analysis process.

In our present literature review about EA analysis, from both set of papers, 57.5% of the works presented empirical data, while 28.7% of them used simulated data and 13.8% only theoretical data. Although several publications present empirical cases, some of them do not present enough information about how the study was conducted and the benefits obtained from the analysis approach (e.g., (Gmati et al., 2010)). This lack of information leads, on the one hand, to

the issue of the reproducibility of methods, as some techniques require a specific set of data. This set of data is not always available, due to classification as confidential by its owning organization (Gmati et al., 2010). On the other hand, the data set might be artificially created for a special purpose, because there was no data publicly available and, therefore, the created data set might not be applicable to real-world scenarios (e.g., (Giakoumakis et al., 2012; Sundarraj and Talluri, 2003)). Despite no empirical evidence to which degree EA research faces those issues is found, many examples of a fallback to artificial evaluation by using exemplary data sets can be given (Franke, 2014; Sousa et al., 2013; Antunes et al., 2015; Xavier et al., 2017). In those cases, the developed artifact normally undertakes an evaluation at non-realistic conditions and produces results which do not hold in a realistic setting (Venable, 2006).

## 6 CONCLUSIONS

In this paper, we performed a SLR of EA analysis research, its adopted models, analysis techniques and concerns analyzed. Grounded in those findings, we derived an initial taxonomy for EA analysis research to help researchers classify their work according to the analysis scope, technique, concern and modelling language. We validate the taxonomy's coverage with a second data-set of 46 papers. We consider the 46 papers in the final data-set give a good perspective regarding the coverage of our taxonomy. Therefore, we present the state of art of EA analysis research initiatives. We believe that researchers can use our
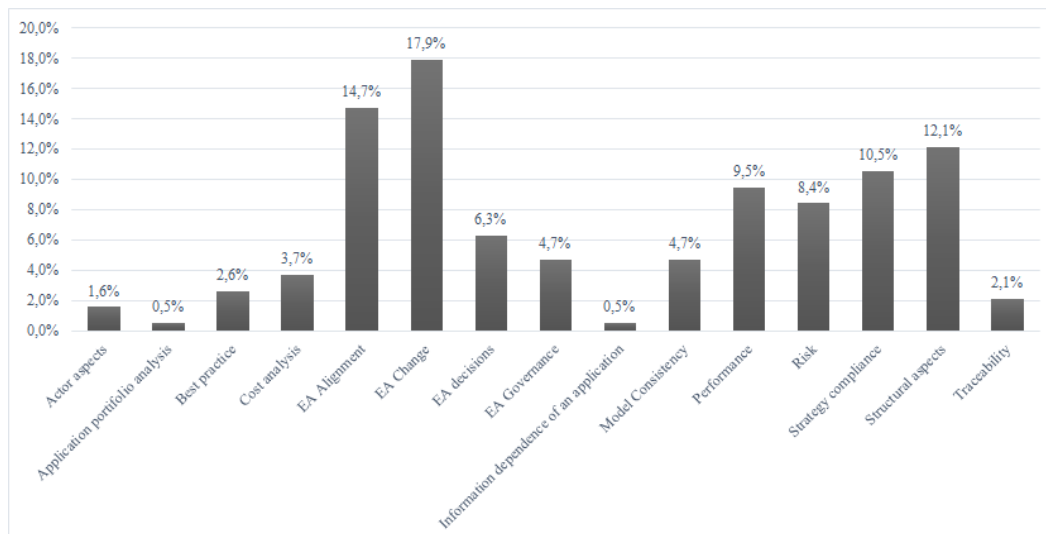
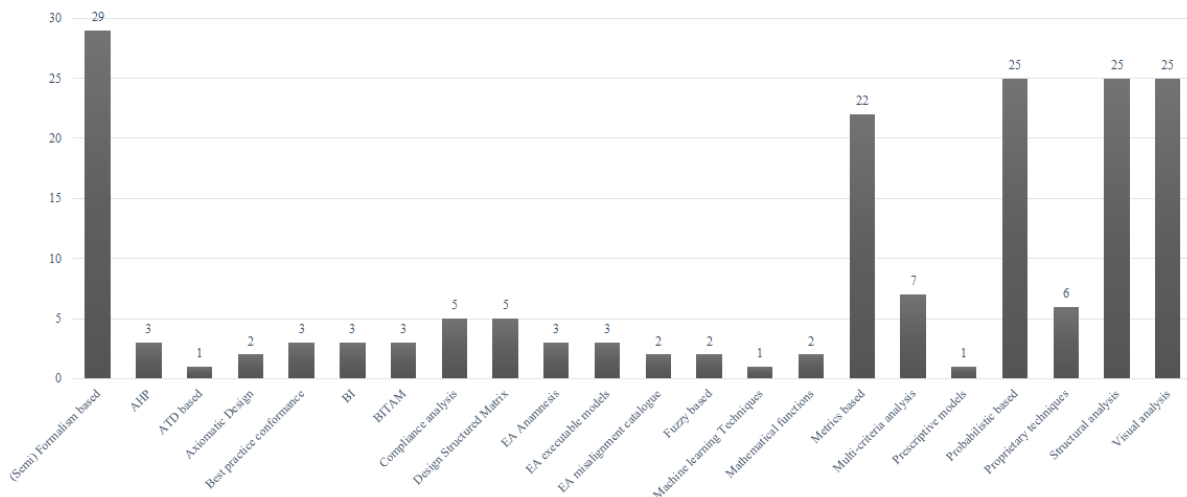Figure 4: Number of studies per Concern category



Figure 5: Number of studies per Analysis approaches category

taxonomy as a conceptual reference to classify their research and tool modelers can also take this study to design EA analysis functionalities. The findings also show that EA analysis research presents very diverse EA models and concerns. Nevertheless, cases where most EA layers were analyzed rarely appeared.

As for limitations, we did not perform backward and forward searches. However, because of the broad coverage of our search string, we are confident that the additional search would not uncover much more works. In our SLR, we did not perform a qualitative assessment of primary studies. We accepted intentionally all the works that aimed to perform EA analysis, without a very strict quality criteria, to be able to have a broad understanding of the field and the authors' purpose.

Future works may go in three main directions. First, because the taxonomy is not exhaustive, we may need to look especially to the work of (Lantow et al., 2016) to align all categories created. Then, the taxonomy's dimensions may be further validated and refined with experts (e.g., by conducting a survey to enclose more real-world examples). Second, based on our systematized set of analysis initiatives, a web catalog may be designed to share past results and to stimulate the reuse of EA models (EA data) among researchers. This could boost the EA empirical analysis research, as occurred in areas such as machine learning UC Irvine[1] which was supported by standard shared databases on which researchers ap-

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[1] https://archive.ics.uci.edu/ml/index.php

ply their analysis approaches. For example, the open models initiative[2] (Frank et al., 2007) goes on that direction, offering a collection of models and also a rough classification of them.

At the same time, further work is needed to investigate technical aspects like model anonymization or model portability to lower the barriers for EA model sharing. Since existing analysis specifications usually presuppose a specific structure of meta-models and models, it is very difficult to reuse them with organizational models that do not conform to the respective assumptions. They required a high effort to transform the actual EA model in a manner, that the analysis can be executed. Additionally, the respective meta model does not make any statements about what concepts are actually used (Langermeier et al., 2014). A generic meta-model could help in that as the one studied in (Rauscher et al., 2017). Another option would be focusing in ArchiMate-based models, the *de facto* market standard for EA modelling.

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[2]http://www.openmodels.org/

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