Guo, H., & Gao, S. (2024). AI Application in enterprise architecture: From the perspective of tools. In Li, E.Y. et al. (Eds.) Proceedings of The International Conference on Electronic Business, Volume 24 (pp. 615-621). ICEB'24, Zhuhai, China, October 24-28, 2024

AI Application in Enterprise Architecture: From the Perspective of Tools

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ABSTRACT

In the wave of global Digital Transformation (DT), enterprises need to be more proactive in embracing changes. Enterprise Architecture (EA) is a useful tool to help organizations establish a common and complete understanding of essential elements and operational rules and align them in response to changes. However, EA also faces challenges which have limited its widespread and successful application. In recent years, with the rapid development of Artificial Intelligence (AI), related technologies have been applied to the field of EA which might potentially help alleviate such challenges. However, the degree of AI application, the areas of AI application, and the impact on the EA domain have not been reported yet. This study analyzes public information about a leading EA consulting company and 15 EA tool vendors, pointing out that over two-thirds of 15 leading EA tool vendors have plans about AI application, and one-third have already developed their strengths with AI. The overall application is in its early stage, and the application areas are somewhat scattered, mainly including the automatic generation or completion of EA models, information analysis, and EA repository data management. EA challenges like deficiency in modeling, management and maintenance might have been alleviated to some extent.

Keywords: Digital transformation, enterprise architecture, EA, artificial intelligence, AI, EA tools.

INTRODUCTION

Artificial Intelligence (AI) has developed rapidly in the last few years. It has been applied in many different fields, including education (Zhang & Aslan, 2021), engineering and manufacturing (Nti et al., 2022), finance (Cao, 2022), and entertainment (Anantrasirichai & Bull, 2022). AI technologies have been used to facilitate Digital Transformation (DT) in various organizations (Vial, 2021). For instance, AI has been employed to enhance decision-making processes. Despite the extensive application of AI in different organizations, there remains a notable gap in the literature concerning its application within the Enterprise Architecture (EA) domain, specifically in how AI can be leveraged to address the unique challenges faced by this field.

To our knowledge, there is a lack of studies regarding the application of AI within the EA domain. The absence of comprehensive reports and studies on the application of AI within the EA domain motivates us to conduct the present study. The objective of this study is to explore the status of AI application in EA, identify specific areas where AI can be applied to EA, and examine challenges in EA that AI can help address. The following three research questions have been proposed:

RQ1: What is the general application status of AI in EA?
RQ2: What are the application areas of AI in EA?
RQ3: What EA challenges may AI application help to alleviate and how?

The rest of this article is organized as follows. Section 2 introduces background information about DT, EA, AI as well as how AI is applied to the EA domain. In Section 3, we introduce how to conduct the present research, including data collection methods and data analysis methods. Then, in Section 4, we present the research results, and lastly, we answer the RQs, discussing the implications of the present research, research limitations, as well as future work in Section 5.

BACKGROUND

Digital Transformation

Digital Transformation (DT) as a global trend (Vial, 2021) brings significant **changes** and requires organizations to better understand and coordinate various elements to respond effectively. To manage (plan, design, implement, and oversee) changes brought by DT, organizations must align their elements with appropriate approaches.

Various organizational elements may need to be aligned. **Alignment** often refers to, but is not limited to, Strategic Alignment (implementing strategies), Stakeholder Alignment (collaborating among different stakeholders), Digital Projects Alignment (ensuring digital projects support business goals), and Business and Information Technology Alignment (BITA). In summary,

alignment encompasses key elements such as strategy, institutions, members, and IT assets across various domains and levels related to enterprise composition and operation.

Alignment, as a series of mechanisms, encompasses organizational processes including not only thinking and expression but also subsequent communication, decision-making, actions, and maintenance.

Enterprise Architecture (EA)

EA is often referred to as a blueprint for enterprise composition and enterprise operating systems. Despite many kinds of benefits EA might bring (Winter et al., 2010), one main role of EA is to provide the service of understanding and communicating enterprise interaction patterns through abstract and graphical expressions, and to facilitate the **alignment** of business and information systems (Korhonen et al., 2016).

EA tools are software applications designed to support enterprise architects and other business and IT stakeholders with strategically driven planning, analysis, design, and execution. EA tools should be selected to keep compatible with enterprises' approaches to transformation, modernization, and innovation to avoid failure of such efforts. EA tools store, structure, analyze, and present EA information to aid in the investment, development, and delivery of IT solutions that enable business success. EA tool represents the most frontier EA practices (Guo et al., 2021a).

Many organizations have been using EA approaches to facilitate the transformation of their business models and services (Anthony Jnr, 2021). This digital transformation aims to enhance efficiency and agility. However, it also presents significant challenges for EA, including managing complexity, ensuring alignment with business goals, and maintaining compliance.

EA is managed, developed, and maintained throughout the EA implementation (Rouhani et al., 2015). In (Ansyori et al., 2018), it was indicated that most organizations still face problems in EA implementation. According to the analysis of 16 primary studies, "Technical support and development", "Methodology, framework and tools", and "operational excellence" are the top three Critical Success Factors to implement EA. In (Rouhani et al., 2015), there are still problems in EA implementation, including "lack of tool support", "deficiency in addressing the EAIM's practices especially in modeling, management, and maintenance". In (Ahmad et al., 2019), "top management support", "governance", "communication" as well as "EA knowledge and skill" are thought to be factors that mostly influenced the EA adoption in organizations.

Artificial Intelligence

AI is a technology that enables machines to imitate various complex human skills (Sheikh et al., 2023). AI encompasses a variety of relevant concepts, each with distinct functionalities and applications. Some of the key concepts that we applied in this study include Machine Learning (ML), Generative AI (GenAI), natural language interfaces, and language models.

1. Machine Learning (ML): ML is a branch of AI that systematically applies algorithms to synthesize the underlying relationships among data and information (Awad & Khanna, 2015).
2. Generative AI (GenAI): Generative AI is a form of AI that can autonomously generate new content, such as text, images, audio, and video (Lv, 2023).
3. Natural Language Interfaces: Natural Language Interfaces allow human-computer interaction through the translation of human intention into devices' control commands, analyzing the user's speech or gestures(de Barcelos Silva et al., 2020). This includes voice recognition systems, chatbots, and virtual assistants like Siri, Alexa, and Google Assistant.
4. Language Models: Language models and other natural language processing (NLP) approaches involve developing algorithms and models that can process, analyze and generate natural language text or speech trained on vast amounts of data using techniques ranging from rule-based approaches to statistical models and deep learning (OECD, 2023). Language models are specialized AI systems designed to understand and generate human language. These models, such as GPT (Generative Pre-trained Transformer) and BERT (Bidirectional Encoder Representations from Transformers), are trained on vast amounts of text data to understand context, syntax, and semantics. They can perform tasks like translation, summarization, and content generation.

Each of these concepts contributes uniquely to the field of AI, pushing the boundaries of what machines can achieve and opening new possibilities for technological innovation and application. For instance, GenAI is broader in scope, focusing on creating various types of content, whereas language models are specialized in understanding and generating human language.

AI Application in EA

As we discussed above, many EA application and adoption challenges are related to complex human skills**.** Such challenges include lack of EA knowledge and skill, lack of technical support, lack of tool support, and deficiency in modeling, management and maintenance. We assume AI technologies might offer some help as they enable machines to imitate complex human skills. However, to our knowledge, there is a lack of studies on how AI technologies have been applied in the EA domain. In (Hakimi, 2024), the research investigated the integration of AI and EA into digital governance. It was indicated that the EA framework significantly enhanced interoperability and efficiency while AI enhanced service delivery by automating procedures and improving decision-making skills. Integrating such technologies presents unparalleled possibilities for revolutionizing digital governance, and their scalability should be prioritized. And in (Denni-Fiberesima, 2024), the paper

discussed the transformative potential and strategic importance of Generative AI (GenAI) in Enterprise Architecture (EA). GenAI promises to improve efficiency, productivity, and decision-making, but it also requires a shift in the skills of EA professionals and leaders, ushering in a new era of capabilities and challenges. However, in these papers, how to apply AI in EA was not discussed yet.

Furthermore, according to the conducted literature review by (Rittelmeyer & Sandkuhl, 2021), the authors also found that there were very few existing studies regarding effects of AI on EA and highlighted the need for further research in this field. Therefore, this study aims to explore the potential application of AI in EA.

METHOD

In this study, we primarily used the grey literature review approach (Garousi et al., 2016) to collect and analyze the data. Grey literature reviews have been acknowledged as a valid alternative to academic literature reviews where the state of the practice is concerned, as they can give substantial benefits.

Data Collection

The evidence primarily comes from Gartner's annual **report** titled "Gartner Magic Quadrant for Enterprise Architecture Tools" (Gartner, 2023), which introduces and evaluates 15 leading EA tools. We also referred to the **website content** of these 15 leading EA tools to complement our understanding about important information. According to our observation, 6 vendors have published specific AI related sections, videos, or web pages (Ardoq, 2024; Avolution, 2024; BOC-Group, 2024; LeanIX, 2024; MEGA-International, 2024; Qualiware, 2024). There are three reasons for us to review such EA tools. *First*, tools are both instrumental and very important in the EA discipline. *Second*, tools in general make it easier for users to accept one technology. For EA, user acceptance has been perceived as one of the critical challenges. We assume that tool support could facilitate EA application. *Third*, we believe that how these leading vendors apply EA represents the current trend of frontline EA application.

In the report, EA tools are defined as software applications that allow organizations to examine both the need for, and the impact of, change. Fifteen leading vendors which were selected according to a few pre-defined criteria, are grouped to 4 Quadrants: 10 *Leaders*, 1 *Challengers*, 1 *Visionary* and 3 *Niche Players*. Standard capabilities for this market include 11 Features: *Repository*, *Modeling*, *Presentation*, *Analysis*, *Configuration and management*, *Publication*, *Integration*, *Extensibility*, *Innovation management*, *Intelligent automation*, and *Frameworks*. For each vendor/EA tool, information about its *Future work or roadmap*, *Strength* and *Cautions* are introduced.

Data Analysis

We first went through the report and got a general idea about how the application of AI is discussed in the overall report, especially about which AI relevant terms/ keywords are used. We identified five AI-related terms used in the report: AI, ML, Generative AI/ GenAI, "natural language interfaces", and "language model". Then we searched for all these terms, highlighting related sentences for further analysis. There were no specified descriptions on how natural language interfaces and language models were applied. We assume that they are related to user interfaces and indirectly related to all the modules we are concerned about. As what LeanIX introduces on its website (LeanIX, 2024), "Inventory AI prompt leverages generative AI to provide a natural language interface for querying data, generating documentation, and obtaining insights in the inventory." Similarly, we do not cover other base AI capabilities, such as simplifying and standardizing text creation, to aid users in understanding tasks better by providing details and explanations, and to translate labels. Therefore, our subsequent analysis mainly focuses on the other three terms: AI, ML, Generative AI/ GenAI.

For all the occurrences of AI terms, we highlighted key information including the *vendor*, *future work* or *strength*, and cautions. Then we answer the questions by classifying such information according to different criteria and frameworks as below.

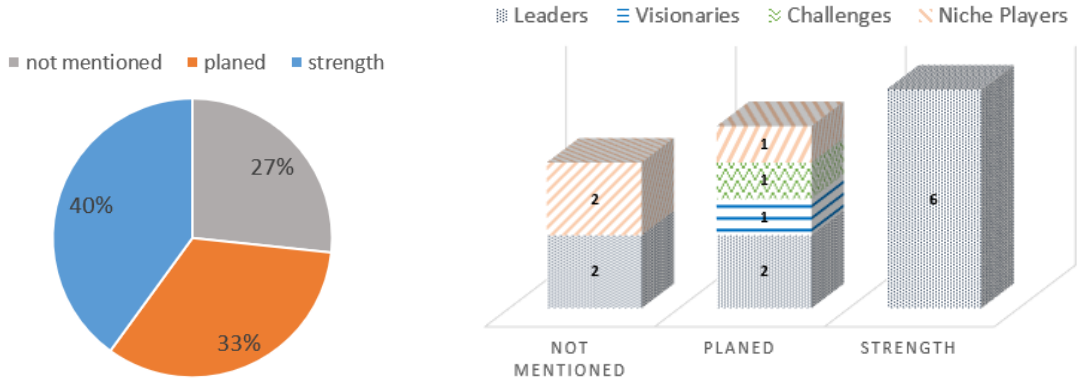
For EA tool features, we chose eight features defined in the report, namely, *Repository*, *Modeling*, *Presentation*, *Analysis*, *Publication*, *Integration*, *Extensibility*, and *Frameworks*. The other three, namely Innovation management, Configuration and management, and Intelligent automation, are excluded as they are relevant to overall performance instead of specific EA management activities.

In addition, we grouped such features in five areas raised in our previous research (Guo et al., 2021b). By doing so, it is easier for us to group findings according to different EA areas in a common framework. These five areas are EA Conceptualization (*EACon*), EA Externalization (*EAExt*), EA Computation (*EACom*), EA Activation (*EAAct*), and EA Evolution (*EAEvo*). EACon includes activities to scope and define EA models such as deciding meta-models, EAExt then externalize such models physically. By leveraging modern computation techniques, EACom provides further information based on EA models. Further, EAAct could trigger human activities or transfer data to other applications to realize the expectation within EA models. Lastly, EAEvo means management and maintenance of the EA data, which enables continuous improvement of model development and realization.

RESULTS

General Status of AI Application in EA

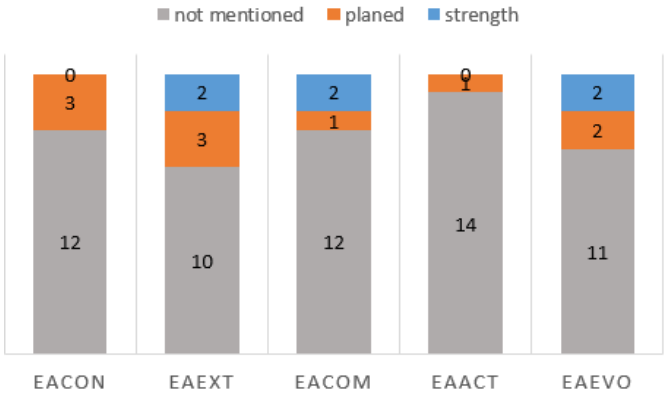
In general, as shown in the left part of Figure 1, six vendors (40% among all vendors) have developed AI application as their strengths, and five vendors (33% of all vendors) have planned AI application as their "future work" or "roadmap". Only four vendors have no explicit action or plan on AI application. Besides, as shown in the right part of Figure 1, among all ten *Leaders*, only two have not mentioned their AI application efforts. While all six vendors that have developed AI application as their strength are *Leaders*.



Source: This study.

Figure 1: General AI application status in EA (Vendors' view).

As we further look at the application of AI in different areas of EA (as shown in Figure 2), we find that AI application is in the early stage and scattered across various areas. In Figure 2, among the five areas, vendors have developed AI application as their strengths in *EAExt*, *EACom*, and *EAEvo*. As Gartner summarized, these strengths include "intelligent automation", "to generate recommendations and artifacts", and "to ease the management of data in the repository". However, in *EACon* and *EAAct*, vendors have only planned the application of EA.



Source: This study.

Figure 2: General AI application status in EA (EA areas' view).

AI Application in EA Conceptualization

How AI is applied in EA conceptualization is shown in Table 1. In the table, we use *F* to indicate that a feature is a "future work" or "roadmap", and *S* to indicate that a feature has been developed as a strength, according to the annual report. Some information is complemented according to vendors' websites, we use *Fea* indicating that it is a "feature" introduced in this way. We use these same abbreviations in Table 1-5.

In EA Conceptualization area, two vendors planned AI application as their future work. *Enterprise Architecture Solutions*, its essential product roadmap would include support for "GenAI use cases". *ValueBlue* had the plan to "include AI-powered metadata enrichment".

Table 2: AI application in EA Conceptualization.

Vendors	Features	
	Frameworks	**Extensibility**
Enterprise Architecture Solutions	F: "GenAI use cases"	
ValueBlue		F: "AI-powered metadata enrichment"

Source: This study.

AI Application in EA Externalization

As shown in Table 2, for Modeling, *BizzDesign* has developed its strength of "the use of ML in model creation" according to Gartner's report. *Ardoq*'s roadmap included "inference functionality to autogenerate architectures and synthetic data for training ML. Similarly, *QualiWare* planned to use AI to support model creation, providing "a text-to-model feature that creates a model from a text description." As introduced on its website (under the feature name of "smart capture"), user can take a text document, spreadsheet, or picture of whiteboard models and upload it to the tool, useful models will be created as they emerge. According to the website of *BOC Group*, if model name, starting object, or a process description is provided, its AI assistant can generate a process proposal which is graphically presented in the model editor, based on the best practices and the general AI knowledge. Depending on the level of detail the user chooses, more simple or more complex processes can be created including detailed tasks with detailed descriptions. Therefore, with a few clicks, the user can have a process ready for optimization and further documentation. On the website of *MEGA International*, it is said that the tool could use generative AI/ML to automatically detect software products and data in use and leverage embedded content such as frameworks and industry capability maps.

For Integration, *MEGA International* planned to support "AI-based importing from third-party diagramming tools". *Avolution*, according to its website, when uploading a spreadsheet, the EA tool can predict values in empty cells, based on patterns and relationships in existing data, and guide users to accept or clear proposed values using confidence scores.

For Presentation, *BOC Group* has developed their strength of "smart modeling assistant for ArchiMate diagrams, including automatic dual-view generation between diagrams and management dashboards".

Table 3: AI application in EA Externalization.

Vendors	**Features**		
	Modeling	**Integration**	**Presentation**
BizzDesign	S: "the use of ML in model creation"		
Ardoq	F: "inference functionality to auto-generate architectures"		
QualiWare	F: "a text-to-model feature" Fea: "smart capture"		
BOC Group	Fea: "generate processes"		S: "smart modeling assistant"
MEGA International	Fea: "detect software products and data"	F: "importing from third-party diagramming tools"	
Avolution		Fea: "predict values in empty cells"	

Source: This study.

AI Application in EA Computation

The AI application about Analysis is presented in Table 3. *Avolution* has built its strength of AI/ML-enhanced user experience, which can enable nontechnical users to build analytics for various architecture questions by using no-code algorithms. Similarly, *BOC Group* augmented its ML capabilities to support recommendations for application investment strategies.

MEGA International planned to support querying and reporting via an ML assistant. And as introduced on *Ardoq*'s website, its AI features are powered by Microsoft's Azure Open AI Service. The Generative AI Features can be used to provide "Best Practice Assistant", meaning to ask questions and get actionable advice on leveraging Ardoq's best practices and use cases, based on extensive training from the Ardoq Help Center.

Table 4: AI application in EA Computation.

Vendors	**Features**
	Analysis
Avolution	S: "analytics for architecture questions"
BOC Group	S: "recommendations for application investment strategies"
MEGA International	F: "querying and reporting"
Ardoq	Fea: "get actionable advice on leveraging Ardoq's best practices and use cases instantly with our AI-powered assistant"

Source: This study.

AI Application in EA Activation

According to the Gartner report, only one vendor, namely *QualiWare*, planned to extend its AI usage to support model sharing as it shows in Table 4. In addition, on *Ardoq*'s website, it was said that Ardoq provides AI-powered survey completion feature to save time for survey respondents and "boost completion rates with a single click".

Table 5: AI application in EA Activation.

Vendor	Features	
	Publication	**Integration**
QualiWare	F: "sharing of models"	
Ardoq	Fea: "AI-powered description in surveys"	

Source: This study.

AI Application in EA Evolution

In Table 5, we can see that in this area, *Avolution* has developed ML capabilities to help improve completeness, consistency and quality of repository data, by detecting data anomalies that may require attention for instance. *LeanIX* has also built its strength of AI application and rolled out its AI assistant to ease data management.

Similarly, *North Highland* has a roadmap which includes ML-based insights to identify repository gaps. *QualiWare* also planned to use AI to support validating models.

Table 6: AI application in EA Evolution.

Vendors	Features
	Repository
Avolution	S: "improve repository data completeness, consistency and quality"
LeanIX	S: "ease data management"
North Highland	F: "identify repository gaps"
QualiWare	F: "validation of models"

Source: This study.

CONCLUSION

According to the results, we answer the RQs. For RQ1, regarding the general AI application status, on the one hand, one-third of vendors have started working on applying AI, and more than one-third have developed AI application as their strengths, indicating that the importance of AI application might have been widely recognized and action is being taken. On the other hand, although not all *Leaders* have started to act, all vendors that have applied AI into their strengths are *Leaders*. This implies that successful application of AI may be complex, technological, or costly.

For RQ2 (about the application areas), the AI application is scattered by far. For each sub area of EA, there are few vendors that have planned or implemented AI application. Especially, Frameworks, Extensibility, and Integration, it seemed that no vendor has succeeded in leveraging AI to build their strengths. Therefore, there is still a lot of room for exploration.

And for RQ3, since Modeling, Analysis, and Repository are the most popular features that vendors have started or planned to develop, we assume by far, AI application might have successfully alleviated EA challenges such as "lack of EA knowledge and skill" and "deficiency in modeling, management and maintenance" by populating the repository with consistent and usable information, delivering business value fast, and evolving EA repositories over time. General challenges such as high thresholds and high costs might be able to be addressed to some extent.

The limitation of this study is that due to limited public information, our understanding of some information may not be sufficient. Therefore, we plan to collect information from more channels. We also plan to test such tools as well as to collect users' opinions by analyzing user forums, conducting customer interviews, etc. By doing so, we would gain insights into valuable application of AI and issues that need to be solved with AI support from users' perspective.

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