








Systematic Literature Review: The Role of Enterprise Architecture in Digital Transformation in the Era of the Fourth Industrial Revolution

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Abstract. This research aims to conduct a systematic literature review (SLR) on the role of Enterprise Architecture (EA) in supporting digital transformation in the era of Industry 4.0, with a specific focus on the industrial sector. Utilizing the Google Scholar database, the methodology employed in this research includes the examination of journal articles, conference proceedings, and literature reviews or systematic literature reviews (SLRs) published between 2018 and 2022. The synthesis analysis of the research model is based on the Preferred Reporting Items for Systematic Review and Meta Analyses (PRISMA) guidelines, resulting in 16 articles that meet the key issue criteria. The study's findings reveal that four digital transformation technologies and nine EA frameworks have been developed in Industry 4.0. This research demonstrates the pivotal role of EA in supporting digital transformation in the industrial sector, particularly in the design and management of information technology infrastructure to minimize risks and complexity, while promoting efficient and effective transformation. The results of this study underscore the importance of EA in facilitating the successful implementation of digital transformation initiatives in the era of Industry 4.0.

Keywords: Digital Transformation, Enterprise Architecture, Industry 4.0.

1 Introduction

The Fourth Industrial Revolution (4IR) is a profound transformation that is underway, brought about by the integration of digital technologies into various industries. This revolution is marked by the emergence of innovative technologies, such as the Internet of Things (IoT), big data, artificial intelligence (AI), robotics, and cloud computing, among others¹. These advancements are driving improvements in efficiency and productivity across a range of sectors. The Fourth Industrial Revolution facilitates the immediate and comprehensive analysis of data, thereby empowering organizations to make more informed and rapid decisions [1].

Digital transformation is an organizational change which entails the utilization of technology and business models to modify people, processes, strategies, and structures, with the objective of improving performance and enhancing efficiency [2]. Digital transformation is a process of evolution that utilizes the capabilities and technologies of the digital realm to enhance, modify or create business processes, operational processes and customer experiences in order to achieve new levels of value [3]. Digital transformation is a formal process that entails utilizing available resources, including harnessing current digital technologies, to produce outputs that provide novel experiences [4].

The enterprise architecture is a strategic blueprint that binds the business operations with information technology. The enterprise architecture offers a comprehensive depiction that encompasses the organizational objectives, business processes, roles, organizational structure, organizational culture, business information, and information technology [5]. Enterprise architecture is a critical component for digital transformation that can provide numerous benefits, including increased efficiency, enhanced quality, and heightened security. However, the successful implementation of digital transformation requires a comprehensive and integrated approach from the enterprise architecture that encompasses the technology, business processes, and corporate policies of the organization [6].

In the future, the organization aims to implement enterprise architecture practices that are geared towards addressing the requirements of digital services related to customer journeys and experiences, architectural diversity and evolution, architectural modularity, as well as social and cultural alignment within the company. This approach highlights the growing significance of enterprise architecture in supporting digital transformation within organizations and managing the complexities brought about by advancing technologies and evolving customer needs [7]. Enterprise architecture is an indispensable tool for the development of infrastructure and the creation of a digital enterprise architecture that can be applied across industries. The integration of seven architecture perspectives, including business, application, data, technology, security, user, and environment, enables the modeling of a framework that facilitates the creation of a comprehensive and effective enterprise architecture [8].

Enterprise architecture plays a crucial role in integrating various digital transformation initiatives and aligning these initiatives with the organization's vision and business strategy. This can ensure that the digital transformation initiatives are executed in a manner that supports the long-term goals of the organization [5]. Enterprise Architecture has been demonstrated to play a critical role in the successful digital transformation of organizations, and has been shown to create considerable business value. Despite the numerous studies conducted on various Enterprise Architecture frameworks, there is a lack of systematic review of the literature on the subject of Enterprise Architecture frameworks and digital transformation in the industrial sector. This review aims to address this gap by examining the role of Enterprise Architecture frameworks in the digital transformation of the Fourth Industrial Revolution, drawing from research articles published between 2018 and 2022.

2 Method

The methodology employed in this article adheres to the rigorous standards of a Systematic Literature Review, utilizing the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) approach. The following steps were meticulously followed in the execution of this review [9]: Identification was conducted through the utilization of numerous databases, encompassing the stages of screening, selection of relevant papers, and subsequent execution of a qualitative synthesis study, during which data items were carefully selected for synthesis.

The aim of this research is to determine the function and frameworks of enterprise architecture in digital transformation during the era of the Fourth Industrial Revolution. The research question (RQ) for this study is as follows:

1. RQ 1: What is the function of enterprise architecture in relation to digital transformation amidst the Fourth Industrial Revolution?
2. RQ 2: What enterprise architecture frameworks are currently being utilized within the industrial sector for the purpose of digital transformation?

A comprehensive review of the literature was carried out to pinpoint relevant material on digital transformation, focusing on crucial enterprise architecture viewpoints such as "digital transformation," "enterprise architecture," "industry sector enterprise architecture," "Industry 4.0," and "digital transformation." The search was confined to articles published between 2018 and 2022, and only English-language articles were included. Prisma flowchart shown by Fig 1 as follow:

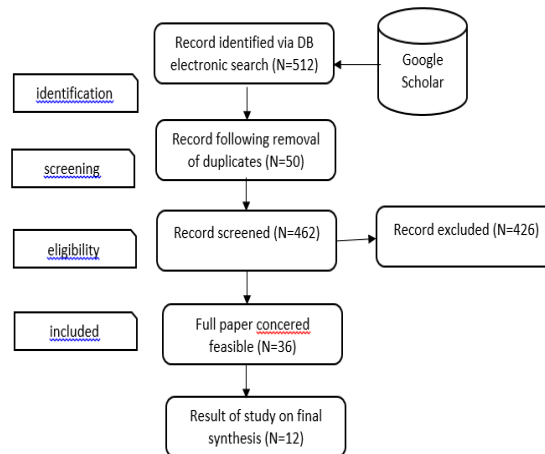


Fig. 1. PRISMA Flowchart

The selection process employed for this study utilized inclusion criteria of articles that examine enterprise architecture in the industrial sector and were published as full-text articles in the English language between the years 2018 to 2022. The exclusion criteria consisted of duplicate articles, non-English language usage, and articles lack-

ing full-text content. The inclusion and exclusion criteria were employed to select the primary studies for this research.

The article selection process consists of several steps, namely:

1. Step 1: A search for relevant articles is executed through the utilization of Google Scholar and the Publish or Perish tool, with the aim of identifying suitable articles related to enterprise architecture, enterprise architecture in the industry, and Industry 4.0 digital transformation. The search operation employs the "OR" operator as an alternative to the "AND" operator in order to expand the search results. A total of 512 articles are discovered through this process.
2. Step 2: Elimination of duplicate content and irrelevant articles is an essential part of the selection process. A total of 50 articles were rejected owing to duplication, while 426 articles did not meet the criteria, which included relevance to the industrial sector, digital transformation, and being in the English language.
3. Step 3: Through the process of reviewing the abstracts, extraneous articles that are not pertinent to the research question are discerned and excluded, resulting in a total of 36 remaining articles. Out of these, 20 articles are deemed irrelevant and therefore eliminated from further consideration.
4. Step 4: A comprehensive examination of the complete texts of the qualified articles is executed to discern critical issues. This process results in the selection of 12 articles that are considered appropriate.

A systematic literature review is utilized to undertake the process of data extraction and synthesis. This involves a rigorous examination of the full text of each article, after which the relevant information is organized into Table 1. The items that are to be extracted include ID, references, evaluated research contexts, and frameworks. Following the extraction of data, it is then synthesized for the purpose of analysis.

Table 1. Data Extraction.

Extracted Data	Description
ID	Unique identifier/key in the paper.
Reference	Author, year of publication, source of publication, title.
The evaluated context	The domain object evaluated in the study is the organizational sector of the industry. The role of Enterprise Architecture (EA) in the digital transformation of the Industry 4.0 revolution
Framework	Enterprise Architecture in the industrial sector in the era of the fourth industrial revolution.

Based on Table 1, it can be inferred that the evaluated context of this paper is the industrial sector organization. The data extraction from each study encompasses the Enterprise Architecture framework in the digital transformation of Industry 4.0.

3 Result and Discussion

Based on an exhaustive search, the author procured 512 articles from the Google Scholar database utilizing the Publish or Perish tool. A rigorous screening process

was then executed to determine whether the articles met the following criteria: 1) availability in online format, 2) relevance to enterprise architecture, 3) discussion of the enterprise architecture framework in the context of Industry 4.0 in the industrial sector, and 4) publication in the English language. Following the evaluation of the articles, 36 articles were found to meet these criteria. These articles were subjected to further scrutiny to assess their relevance to the research questions, resulting in 16 articles that were deemed suitable for the study.

The process of data extraction was undertaken in order to respond to the research queries. This procedure is intended to generate research results through a systematic literature review, utilizing the research questions as a basis.

RQ 1: What is the function of enterprise architecture in relation to digital transformation amidst the Fourth Industrial Revolution?

In light of the research question, the author will provide an answer by examining the findings of the past 12 relevant articles. The role of enterprise architecture in digital transformation shown in Table 2 as follow:

Table 2. The Role of Enterprise Architecture in Digital Transformation.

No	Sector	Description
1	Transportation Industry Sector	The digital transformation in the Railway Supply Chain (RSC) in Malaysia has resulted in significant changes in asset management, security, and transportation efficiency. The implementation of a high-performance Enterprise Architecture enables RSC to effectively manage indicators and adopt analytics in decision-making, leading to a reduction in procurement cycle time and allowing the Malaysian transportation industry to adapt to the modern era with an emphasis on environmentally friendly and paperless decision-making.
2	Culinary Industry Sector	There is a marked trend of digital transformation evident within the culinary SMEs sector in DKI Jakarta Province. By utilizing Value Chain analysis and the Zachman EA framework, culinary SMEs can more effectively map and understand their work processes. This digital transformation enables them to increase the overall value of their value chain, encompassing improvements in product quality, operational efficiency, and marketing through digital channels. Additionally, digitalization also aids in addressing challenges such as fluctuating raw material availability and inadequate communication, leading to optimized resource management, enhanced product quality, increased market access, and overall business process improvement.
3	Manufacturing Industry Sector, Pharmaceutical Industry Sector	Enterprise Architecture (EA) holds a pivotal position in the integration and comprehension of Industry 4.0 (I4.0) concepts such as RAMI4.0 and the digital transformation of the supply chain with Virtual Enterprise Architecture Supply Chain (VEASC). EA is accountable for devising, executing, and overseeing the architecture that supports these changes, leading to improved connectivity, effective collaboration, and prompt responses to business alterations. Moreover, EA contributes to the optimization of business processes, enhancing efficiency, reducing costs, and improving overall supply chain performance. By working with EA, organizations can address the challenges of digital transformation, manage risks, ensure data security, and maximize the utilization of technology.

4	Energy Industry Sector, Gas Station Industry Sector	The organization employs Enterprise Architecture (EA) to conceptualize an IoT-based gasoline distribution monitoring system as part of its digital transformation initiative. This innovative approach is intended to enhance inventory tracking and distribution efficiency by incorporating cutting-edge IoT technology. By leveraging real-time monitoring capabilities, the system can lead to improved sales productivity and customer satisfaction. The digital transformation aims to maximize the utilization of IoT technology in gasoline distribution. EA serves as a unifying framework that aligns systems and infrastructure with business requirements and strategic objectives during the adoption of Industry 4.0 technology.
5	Information Technology Industry Sector	The organization employs Enterprise Architecture (EA) to create an integrated operational information system that incorporates cloud computing technology as part of its ongoing digital transformation initiatives. The utilization of EA is expected to improve the quality of services and operational performance of PANDI by providing guidance for effective architectural changes. By implementing a cloud-based system, flexible and secure access will be available to streamline PANDI's operational management processes. Additionally, the EA framework connects to existing applications, allowing the company to plan and manage architectural changes in a structured manner towards the desired digital transformation goals.
9	Service Industry Sector	Enterprise Architecture (EA), utilizing frameworks such as TOGAF, assumes a vital function in addressing the digital transformation challenges faced by the digital services industry. By designing integrated architectures that effectively deliver customer feedback data, EA enables service providers to expand their reach to partners and suppliers. This strategic role of EA aligns business needs with technology, supports effective decision-making, value chain mapping, and governance, ultimately enhancing service quality and operational efficiency in the era of Industry 4.0. Additionally, EA's adaptability to customize architecture frameworks to the unique needs of service-oriented companies proves instrumental in navigating the evolving landscape of the digital service industry. In conclusion, EA empowers organizations to seamlessly integrate digital transformation strategies, ensuring that technology aligns with business goals while mitigating associated risks, thus playing a crucial role in shaping the future of digital business.

RQ 2: What enterprise architecture frameworks are used in the industrial sector for digital transformation?

Enterprise architecture framework in digital transformation shown in Fig. 3 as follows:

Table 3. Enterprise Architecture Framework in Digital Transformation.

No	Technology	Framework	Number of articles	Paper Identification
1	Big Data Analytics	TOGAF; Enterprise Architecture RSC; EA otomatis (AMA4EA); Zachman Framework;	5	16,17,18,8,6

2	IoT	Archimate TOGAF ADM; Enterprise Services Architecture Reference Cube (ESARC); Referensi Arsitektur Model Industri 4.0 (RAMI4.0); ARIS (Architecture of Integrated Information Systems)	4	19,11,10,13
3	Cloud computing	TOGAF; Virtual Enterprise Architecture Supply Chain/VEASC; Enterprise Architecture RSC	2	12,14
4	Blockchain	Blockchain Enterprise Architecture (BEA)	1	15

4 Conclusion

This formal literature review examines the pivotal functions and frameworks of enterprise architecture in managing digital transformation during the Fourth Industrial Revolution era in the industrial domain. A rigorous evaluation process led to the identification of 12 relevant articles, which were subsequently analyzed. The findings indicate that the Fourth Industrial Revolution era is characterized by four transformative technologies, including big data analytics, IoT, cloud computing, and blockchain. Furthermore, the study uncovered nine enterprise architecture frameworks, including TOGAF, RSC Enterprise Architecture, Automated EA (AMA4EA), Zachman Framework, Enterprise Services Architecture Reference Cube (ESARC), Reference Architecture Model Industrie 4.0 (RAMI4.0), ARIS (Architecture of Integrated Information Systems), Virtual Enterprise Architecture Supply Chain (VEASC), and Blockchain Enterprise Architecture (BEA).

The present study aims to elucidate the function of enterprise architecture frameworks within the digital transformation of the Fourth Industrial Revolution. The author obtained responses to the research questions from 12 scholarly sources. The enterprise architecture plays a pivotal role in the digital transformation of the Fourth Industrial Revolution by providing a structured approach, guidance, and support in the areas of planning, integration, risk management, coordination, and decision-making. By utilizing enterprise architecture, organizations can achieve successful digital transformation and gain a competitive advantage in the era of Industry 4.0. The framework can also assist businesses in designing, integrating, and effectively managing information technology to leverage new technologies and realize successful digital transformation in the context of the Fourth Industrial Revolution.

In the industrial sector's digital transformation, the utilization of an Enterprise Architecture (EA) framework that is widely recognized and extensively used in the industry for the purpose of designing and implementing EA is TOGAF (The Open Group Architecture Framework).

TOGAF offers a systematic approach for the thorough planning, execution, and administration of enterprise architecture. This framework includes a collection of methods, guidelines, and tools that enable architects to create harmonious architectures that are aligned with the organization's objectives.

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