

Assessing the Need to Implement Industry

4.0 Technologies with TOGAF

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Abstract

AI, cybersecurity, cloud computing, and robotics are becoming ubiquitous technologies in the industry sector, which has witnessed several successive industrial revolutions: mechanization, electrification, digitalization, and now Industry 4.0. Industry 4.0 refers to the technologies reinventing manufacturing practices, leading to smart factories where systems, machines, and products communicate constantly. To implement I4.0 successfully, companies must manage, control, and contain many changes and risks. As a result, organizations must ensure that introducing these new technologies is valuable, determine what challenges they face and what opportunities they can take advantage of, and anticipate their future needs and the conditions to implement to optimize their resources. In addition, the enterprise architecture can contribute to the good governance of I4.0 technologies within an enterprise. Using an enterprise architecture, a company can better understand its current situation, capabilities, and how it interacts with its environment. This enables it to align IT with business needs and assess the need to adopt new technologies for any organization with strategic goals. Specifically, this study aims to determine how TOGAF (The Open Group Architecture Framework) could assist companies in assessing the necessity of implementing Industry 4.0 technologies. Specifically, the study explores the factors influencing the company's transformation, the potential benefits of I4.0 technologies, and the phases and artifacts stakeholders should consider when adopting I4.0.

Keywords: Industry 4.0, Industrial Revolution, TOGAF, Enterprise Architecture

1. Introduction

Technologies are characterized by rapid growth and impact a variety of fields. The industry sector has been particularly affected since 2010 as it has experienced rapid technological advancement and acceleration [1]. Technology continues to enhance the way it is conducted. With the advent of the Internet of Things (IoT), robotics, 3D printing, and much more, the industry has entered a new era. Following the first industrial revolution of mechanization, the second with electrification, and the third with digitalization, we now witness the fourth industrial revolution, Industry 4.0 (I4.0). This revolution requires manufacturing companies to change their business models, organizational structure, and work processes. The transformation to I4.0 can give the organization a colossal advantage by dominating the market, outperforming competitors, and generating significant revenue for its benefit and expansion. However, business management practices and methods must be standardized to achieve this transformation. Thus, enterprise architecture can ensure the proper implementation of I4.0 technologies within a company. Enterprise architecture is crucial in determining the need for I4.0 adoption by companies seeking to achieve their strategic goals. The purpose of enterprise architecture is to manage meaningful organizational changes, which includes following I4.0 changes. The Open Group's standard for enterprise architecture, TOGAF¹ (The Open Group Architecture Framework), helps organizations better understand their current situation and more easily align their strategic objectives with their capabilities and technologies while maintaining the flexibility they need to remain responsive to changing conditions. Implementing I4.0 technologies is an important strategic decision because of the implications they generate [2]. Despite the apparent necessity of implementing novel technologies to endure in a fiercely competitive marketplace, the substantial expenses associated with this choice may be disheartening. For entrepreneurs hesitant to leap, saving money on implementing pricey technologies becomes alluring. Businesses must answer the following queries to implement I4.0: What is the company's context and adaptability to these new technologies? What effects would this change have on the organization and its design? Does achieving strategic objectives require an I4.0 transformation? By providing a straightforward method for reaching the desired target architecture, guaranteeing to sound IT governance, and foreseeing the consequences and adjustments such an endeavor will bring, we assume that TOGAF enables the organization to be supported in this transition. The impact of

I4.0 solutions on businesses has been the subject of several studies, including [3] and [4]. The authors of these studies divide the impact into various categories and use relevant performance metrics to evaluate the effect. However, a question still needs to be answered: how can the multiple viewpoints be combined for a holistic evaluation? This topic raises additional questions on using TOGAF for assessing the need for I4.0 technologies:

- What aspects of TOGAF contribute to determining the impact of such a transformation on the company and evaluating the contribution that I4.0 technologies could make toward the company's goals and development?
- Which phases and artifacts should stakeholders consider when deciding whether or not to adopt I4.0 in their organization?

This paper is organized as follows: The first section introduces the main concepts, namely enterprise architecture and the TOGAF Framework on the one hand and industry 4.0 technologies and implementation dimensions and challenges on the other. We then discuss some related works in the next section. Finally, we discuss how the TOGAF underpins the need for I4.0 technologies throughout the ADM phases. The conclusion of this work hints at its main findings and highlights its perspectives.

2. Background

2.1 Enterprise Architecture

Given the complexity of the system that the organization forms, it is modeling an organization faithfully to cover all its areas (people, business processes, information system, and infrastructure) and its knowledge capital. Nevertheless, this representation is necessary for the company to adapt, evolve, and change. The lack of a consistent model for the enterprise, including all its components, can result in the emergence of diverse perspectives on the organization. This can impede the identification of weaknesses and areas for enhancement and hinder the capacity to evaluate its current status. “The development of an enterprise architecture is the outcome of an ongoing procedure involving the modeling, integration, and maintenance of consistent alignment among the various components necessary for the management and comprehension of a company. Enterprise architecture thus allows companies or institutions to manage their activities according to market dynamics. This needs to design a dynamic and

flexible architecture capable of reacting quickly to the continuous changes it faces requires frameworks and methodologies. The article [5] highlights enterprise architecture's indirect, far-reaching benefits, including improved alignment between business and IT, increased responsiveness, reduced IT costs, improved risk management, improved integration, better strategic business results, improved business processes, and reduced IT complexity.

2.2 TOGAF (The Open Group Architecture Framework)

TOGAF is an enterprise architecture standard developed by The Open Group Architecture Framework (TOGAF) to establish a common framework for communicating and capitalizing on enterprise architecture practices within the architect community. Based on the Architecture Development Method (ADM), the framework describes steps and prescribed tools to migrate to the target architecture. TOGAF was first released in 1995 and has been consolidated, corrected, and enriched by the Open Group, a consortium of over 800 organizations worldwide. The latest version, TOGAF 9.2, was released in April 2018, offering structural updates and allowing architecture development in different sectors. Despite having multiple similar EA methodologies, TOGAF is considered the most common and trusted enterprise architecture standard globally, with 80% of Global 50 companies and 60% of Fortune 500 companies using it. With over 75,000 certified individuals worldwide, TOGAF is a universal EA (Enterprise Architecture) framework applicable to various industries. The TOGAF Standard, Version 9.2, is a reference document on the Open Group's official website. It comprises six parts: Introduction, ADM (Architecture Development Method), ADM guidelines and techniques, constituents of architecture (Architecture Content), enterprise continuum and tools, and architecture capability framework. The ADM wheel represents the heart of the repository, and the framework is structured into ten phases, including eight sequential phases and two preliminary and requirements management phases. The TOGAF standard provides a structured approach to architectural projects, focusing on the organization, skills, roles, and responsibilities necessary for successful implementation. The Architecture Design Management (ADM) cycle is a systematic process that involves several phases. The preliminary phase involves preparing for an architecture project, defining the principles, and forming a "Request for Architecture Work" document. The next phase, Phase A vision, consolidates the previous phases by adding and enriching elements. Phase B business architecture involves modeling the initial business architecture and developing the target architecture. Phase C architecture of the information system describes the application

architecture and architecture, focusing on data and applications for process automation. Phase D technical architecture focuses on the technical aspects of the architecture, focusing on technologies, hardware, and infrastructure. Phase E, opportunities and solutions, consolidates phases B, C, and D, examining the feasibility of migrating to the target architecture.

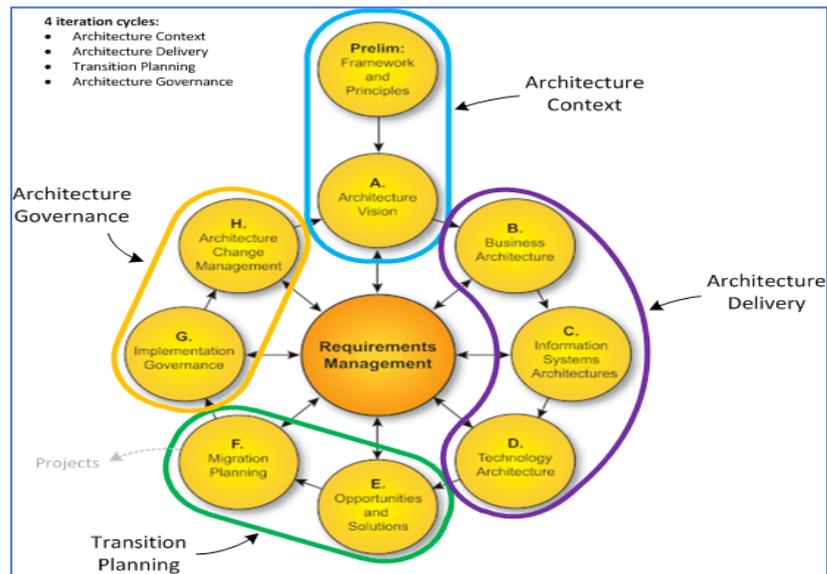


Figure 1. Cycle ADM (The TOGAF® Standard, Version 9.2)

Phase F migration planning establishes a migration plan, while Phase G implementation governance ensures projects comply with the targeted architecture and meet specifications. Phase H management of maintenance and evolutions manages new change requests that could impact the architecture and maintain alignment between IT and the business. The ADM cycle illustrated in Figure 1 can be adapted according to the situation and application case.

2.3 Industry 4.0

The term “industry 4.0” was first introduced publicly in 2011 during the Hannover Industrial Technology Fair by a German working group as part of a project that is part of the strategy initiated by the federal government of Germany concerning high technologies (high-tech) and aimed at encouraging the digital revolution of industries [1,6]. The term then spread outside German-speaking countries and has grown in popularity and prominence. From a historical point of view, “Since the beginning of industrialization, technological leaps have led to paradigm shifts now called industrial revolutions” [6]. Figure 2 illustrates the evolution of industrialization over time.

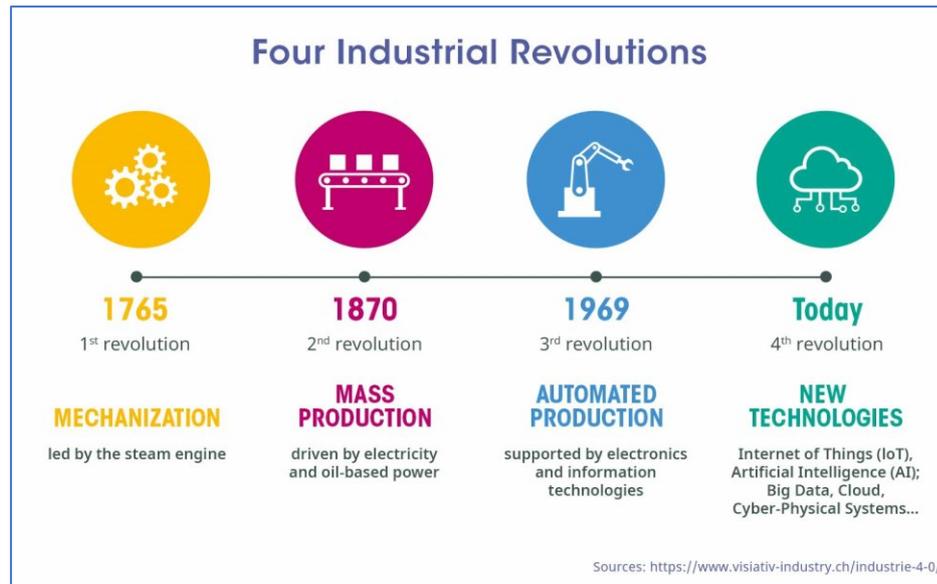


Figure 2. The Four Industrial Revolutions

(https://www.linkedin.com/posts/muqrinalamri_industry-revolution-industry40-activity-7122551781527576576-pdeP)

The ecosystem making up the I4.0 is rich in technologies and concepts, each providing added value. Even if the definitions of I4.0 may differ according to the authors, certain key technologies and concepts are considered pillars of I4.0 [7, 8]. These so-called pillars include eight technologies: the Industrial Internet of Things, cloud computing, autonomous robots, simulation, augmented reality, additive manufacturing, extensive data analysis, and, finally, cybersecurity. Technologies are listed in Table 1, along with their definition and their usefulness in the context of the industry:

Table 1. I4.0 Technologies

Technology	Definition	Role
Internet of Things (IoT)	The Internet of Things (IoT) is an infrastructure for interconnecting intelligent objects that can interact with each other and the environment by sharing information and data.	The gain in agility, scalability, reliability, and productivity of operations. Better decision-making thanks to real-time data collection

<p>Cloud Computing</p>	<p>It is a change in computing geography, with applications and documents hosted in “a cloud,” composed of servers and networked computers accessible from the Internet.</p>	<p>Facilitate management and administration.</p> <p>Facilitate communication with partners and between the different sites of the organization.</p>
<p>Autonomous Robots</p>	<p>Autonomous robots are brilliant machines that independently execute real-world tasks without explicit human intervention.</p>	<p>Improve safety (e.g., robots can access dangerous or inaccessible areas for humans). Achieve a greater degree of precision in performing and solving complex tasks.</p>
<p>Simulation</p>	<p>Simulation is the approach that makes it possible to model a real-world system or process and then perform experiments on the model to better understand its operation or to evaluate strategies by considering a set of criteria and reflecting real-world conditions.</p>	<p>We reduced production times. Reduction of failures and improvement of quality. Decision support.</p>
<p>Augmented Reality</p>	<p>Augmented reality is the system that allows the virtual world to be combined with the physical world in real-time by recording objects in 3D representation, thus enriching reality.</p>	<p>It helps with decision-making and allows remote task control. Improves human-machine interaction.</p>
<p>Additive manufacturing</p>	<p>Also famous under the name of 3D printing, additive manufacturing is a formalization of the term “Rapid prototyping” that describes a succession of processes aimed at manufacturing parts by adding layers, unlike subtractive manufacturing, which subtracts material from a block of raw material. The objective is to quickly obtain a prototype or a</p>	<p>Ability to support customer customization needs. Reduced costs and production times. Facilitates the manufacture of light but complex products.</p>

	basic model from which the product to be marketed will later be derived.	
Big Data Analytics	Big Data is the collection, processing, analysis, and visualization of information characterized by very high volume, velocity, and variety. These specificities require the use of analytical methods to extract valuable information.	Real-time decision support allows predicting potential production failures or identifying customer preferences and trends.
Cyber Security	Cybersecurity includes policies, technologies, actions, procedures, or tools to protect the cyber-environment and an organization's material and immaterial, informational, and non-informational assets. Vulnerable to being reached via cyberspace.	Prevent cyber-attacks and protect company assets.

Digital transformation is a fundamental change facilitated by innovative digital technologies, aiming to improve an entity and redefine its value proposition for stakeholders. Implementing Industry 4.0 (I4.0) technology in a company leads to profound changes in resource management and business models. Companies must carefully measure the pros and cons of this strategy, understanding how it impacts their processes, business model, and organization. The I4.0 transformation can be likened to a specific digital transformation case where the innovative digital technologies used are those of Industry 4.0.

2.4 I4.0 Technologies Implementation Dimensions

To exploit the opportunities offered by Industry 4.0 and take full advantage of them, companies must take specific and concrete measures to implement Industry 4.0 technologies in a targeted and adequate manner. Companies need to undertake appropriate implementation strategies tailored to the individual design of their institutional organization structure, given the complex nature of Industry 4.0 [9]. Then, they propose several aspects regarding the

implementation of Industry 4.0 technologies. Finally, they have consolidated and aggregated them into seven dimensions that must be considered during implementation. Industry 4.0 technologies require changes in corporate culture, staff, company organization, safety and security, and financial feasibility. Managers and leaders must set an example for change and encourage employees to learn, accept new things, and be creative. Workplaces must be flexible and equipped with specific skills and competencies, such as ICT know-how and interdisciplinary skills. Companies should review their organizational structure to establish an agile foundation for Industry 4.0, ensuring flat hierarchies, flexible structures, and decentralized executives. Security measures should be implemented to protect against external interference and data security issues. Employees should be involved in implementing solutions, learning from mistakes, and testing new approaches flexibly. Technical integration of Industry 4.0 solutions is crucial, and financial feasibility should be considered for financing R&D activities. Cost-benefit analyses, profitability, efficiency, and time indicators are essential for evaluating projects and ensuring success. The first two dimensions of implementing I4.0 technologies that concern the management of change at the company and employee levels represent the objective of the last phase of TOGAF ADM, which implements all the techniques necessary to deal with resistance. Communication, training, and stakeholders' involvement (the matrix management of stakeholders) play a central role in the success of implementing new technologies and in the failure of those projects (the matrix management of stakeholders). For dimensions 5 and 7, which involve the managerial and financial preparation of implementation projects, the role of phase F Migration and Planning is to prioritize and organize technology implementation projects with an economic study of the costs incurred. A significant component of phase E is dimension 6: opportunities and solutions that will fill the functional gaps between the current and target configurations at business, IT, and infrastructure levels. Therefore, integration success necessarily involves these levels.

2.5 Challenges of Implementing Industry 4.0 Technologies

[10] Define Industry 4.0 implementation challenges as barriers, issues, obstacles, or questions that arise (or are expected to arise) in the implementation process of Industry 4.0. Table 2 presents the challenges by category:

Table 2. I4.0 Implementation Challenges

Technological challenges	<p>Lack of technological maturity</p> <p>Lack of integration of manufacturing systems</p> <p>The company's lack of knowledge of existing Industry 4.0 technologies</p> <p>Lack of production system reconfiguration capability</p>
Data challenges	<p>Inability to extract knowledge from data</p> <p>The unstructured format of the data collected</p> <p>Massive data to manage, store, and process</p> <p>Insufficient quality of the data collected</p> <p>Insufficient data processing power</p>
Human Resources Challenges	<p>Lack of skilled workers for Industry 4.0</p> <p>Lack of workers with a clear vision and commitment to implementing Industry 4.0</p> <p>Worker resistance to upgrading knowledge</p>
Security Challenges	<p>Low level of trust of manufacturing companies towards third parties.</p> <p>Insecure connectivity protocols</p> <p>The need to protect data</p>
Financial Resources Challenges	<p>Need to invest massively in new technologies</p> <p>Uncertainty about return on investment</p>
Manufacturing Systems Challenges	<p>Insufficiently developed manufacturing system infrastructures</p> <p>The high complexity of manufacturing systems</p>
The challenges of standardization	Difficulties in establishing uniform standards for the exchange of information
Communication issues	Lack of Internet connectivity
Strategy Challenges	Lack of strategy
Environmental challenges	We must prevent the potentially severe side effects of implementing Industry 4.0 on the environment.

TOGAF can provide solutions to some of the implementation challenges listed above. The Opportunities and solutions phase (phase E of TOGAF), for instance, can address at least in part the lack of knowledge of I4.0 technologies, especially since it is during this phase that a study is conducted to determine what possibilities exist in terms of technologies, as well as to decide between the options. Data challenges can be addressed at the enterprise architecture level of information systems. Going through intermediate stages, such as a data cleaning phase, conceptual structuring, and physical storage, gaps observed between existing unstructured data and the structured target data can be gradually filled. The top management at the strategic level is the trigger for an enterprise architecture project, so an absence of strategy has no place in a project whose main objective is to align the business needs with investments and technology implementations. When top management is sensitive to ecological issues, the ecological dimension and financial or human resources (missing qualifications) concerns will be considered during the project implementation.

3. Related Works

Although the need to adopt new technologies to survive in a highly competitive market may seem evident at first glance, the enormous costs generated by such a decision can be discouraging [11]. Saving on implementing expensive technologies becomes tempting for entrepreneurs who are reluctant to take the plunge. Companies face several questions regarding implementing I4.0: How do we define the company's context and ability to accommodate these new technologies? What implications does such a transformation have on the company and its architecture? Is an I4.0 transformation necessary to achieve strategic objectives? With this in mind, we discuss how TOGAF intervenes to clarify the need to adopt the new technologies of I4.0 and dare to embark on this transformation by considering the resulting implications. Our bibliographical research has been oriented in two directions. The first direction consisted of defining potential indicators or measures that would make it possible to assess the impact of I4.0 on business and allow stakeholders to take a position on the adoption of Industry 4.0 [4, 12, 13]. The second direction of the research consisted of finding works dealing with enterprise architecture and, in particular, the TOGAF Framework in supporting an I4.0 transformation in a company. In addition, these articles sought to understand how enterprise architecture could complement an I4.0 transformation and the elements of enterprise architecture that an I4.0 implementation would most Impact [3, 14, 15]. The article [12] highlights the importance of

enterprise architecture in the success of Industry 4.0 transformation. They argue that Industry 4.0 results from technology acquisition over time and individual needs, leading to heterogeneous applications. Organizations must constantly re-examine their services holistically to address this, focusing on customer concerns and implementing precise strategies. Architecture building blocks (ABBs) can be developed based on industry and business requirements, avoiding vendor or product specificity. EA (TOGAF) separates technology stacks and physical implementation to manage technological change, allowing easy replacement without impacting the industry. In their work [4], the authors want to determine the components of the enterprise architecture model that an I4.0 transformation could impact based on the TOGAF and RAMI4.0 Frameworks, Architectural Reference Model of Industry 4.0. They hope to support stakeholders when integrating I4.0 technologies into their future target architectures. By comparing the two frameworks, the authors indicate that the latter is designed from two different perspectives: on the one hand, TOGAF is inclined towards a managerial perspective aimed at "analyzing the possibilities of change before implementing them" [4] and understanding how IT capabilities can serve strategic business objectives; on the other RAMI4.0 is taken towards an IT operational perspective where the main concern is how to integrate the I4.0 component into the company as much as an intelligent object. In other words, the TOGAF model considers IT to be an element among the elements of architecture, allowing it to achieve business objectives. In contrast, RAMI4.0 considers the I4.0 component (the company's connected objects) as the model's core and is interested in integrating it into the company to improve performance. They crossed between the components of the TOGAF model (architecture principles, vision, and requirements, business architecture, IS architecture, and architecture technology) impacted by the introduction of the elements of the I4.0 axes of the RAMI4.0 framework (hierarchy, architecture, and product lifecycle). The authors found that the IS architecture and infrastructure are most affected. Therefore, stakeholders must meticulously study the shortcomings, flaws, and opportunities for change in the current architecture and distinguish the elements of the EA to be readjusted or supplemented before deciding on introducing an I4.0 component. In addition, the current architecture's principles, vision, and requirements must also be adjusted according to the principles of I4.0 and the needs of business transformation. This work has had continuity in the paper presented in what follows. The article [13] identifies the direct and indirect impacts of I4.0 components with the corresponding enterprise architecture elements. They used the TOGAF metamodel to detail the direct impact of an I4.0 transformation and how it can be propagated to identify all elements

of EA models that would need to be adapted due to the introduction of an I4.0 component in an organization. The approach followed includes several steps. Firstly, it is necessary to identify the direct impacts caused by the I4.0 components on the entities of the TOGAF metamodel; then, determine the entities that may be impacted due to their relationships and dependencies with the entities already identified as directly impacted entities. The results obtained will provide AE leaders and practitioners with practical guidelines. The main limitation is that feasibility depends on the solid knowledge of evaluation concepts and related technology that evaluation managers and practitioners must possess to apply it correctly in real evaluation projects. In the article [3], the authors consolidate the impacts of technological applications and define adequate performance measures to evaluate each of them in the small and medium enterprise context. Furthermore, they combine traditional metrics for process evaluation and extend them with additional performance metrics relevant to evaluating I4.0 solutions. The authors categorize the impact of I4.0 solutions on businesses into four categories: procedural, ecological, social, and technological. The procedural impact measures the performance of business processes and expenses, while the ecological impact focuses on the environmental impact, such as energy consumption and greenhouse gas emissions. The social impact measures the impact on the human component of companies, such as resistance to change and the cost of recruiting and developing new skills. The technological impact focuses on targeted objectives like process monitoring and cybersecurity. However, it needs to be clear how the different perspectives will be used together for the overall assessment. The article [14] seeks to establish an indicator system to adopt Industry 4.0. They believe that such work helps in the development of specific strategies at each phase of the implementation of I4.0, in the orientation of decision-makers, practitioners, stakeholders in planning or even strategists, in the allocation of resource efficiency and evaluation of the innovative idea and concepts related to the implementation of I4.0. Adopting I4.0 technologies involves pre-adoption, adoption decisions, and post-adoption. The pre-adoption phase evaluates the technology's compatibility, ease of use, perceived usefulness, and risks. The adoption decision evaluates the technology's alignment with the company's needs, risks, and system readiness. The post-adoption phase confirms the initial assessments and assesses the technologies' validation, acceptance, and use. Indicators for this phase include financial leverage, operational risk, and work simplification. [14] Claim that these indicators allow better decision-making for stakeholders and the resolution of problems and questions the company may face during the

different phases of implementing I4.0. However, the evaluation of the proposed indicators has been carried out on a small group of decision-makers (in the case studies, only middle managers participated in this evaluation). The evaluation should be achieved holistically with a well-represented group of decision-makers at several organizational levels. The article [15] presents a global readiness assessment model for Industry 4.0 titled GRAMI4.0 (Global Readiness Assessment Model for Industry 4.0) using globally comparable standard metrics to determine I4.0 readiness for a country. The authors have brought together the metrics and measures collected in the literature to assess the overall state of readiness for Industry 4.0; among the most recurrent, we can cite the level of digitization of the organization, adaptability of employees with I4.0, senior management involvement, and commitment, horizontal and vertical integration of processes and organization, legal considerations, considerable data maturity, intelligent business processes, real-time integration, organizational alignment, data-driven services, agile IT infrastructure. The article defines GRAMI4.0 as a holistic approach taken to measure I4.0 readiness. To help understand a nation's capacity for innovation and the more general factors necessary for the economic development of a society. The authors have structured the I4.0 readiness index into seven dimensions (enabling environment, human resources, infrastructure, ecological sustainability, innovation capacity, cybersecurity, and consumers), 17 pillars (including digital awareness, active intellectual property, digital and physical infrastructure), and 63 indicators (including environmental performance index, cloud computing scorecard, ICT service experts and political and operational stability). This study was carried out at the scale of a country (126 economies); however, the proposed indicators can be reused at the company's scale.

4. Discussion

The works presented show that adopting I4.0 brings changes at several levels of the company and its architecture. TOGAF makes it possible to support the company in this transformation by describing a precise approach to achieving the coveted target architecture, ensuring good IT governance, and anticipating the implications and changes that such an initiative will generate. The works also indicate the potential that TOGAF can bring in measuring indicators and thus increase stakeholders' awareness about the need to implement I4.0 technologies in their companies. Through similar work, we've discovered that evaluation must occur at each implementation phase because each presents unique issues and requires different kinds of assessment. As a result, TOGAF can provide valuable information for

assessing the need for I4.0 adoption through ADM phases through its specific artifacts. Figure 3 illustrates the artifacts influencing implementing I4.0 technologies during the ADM phases.

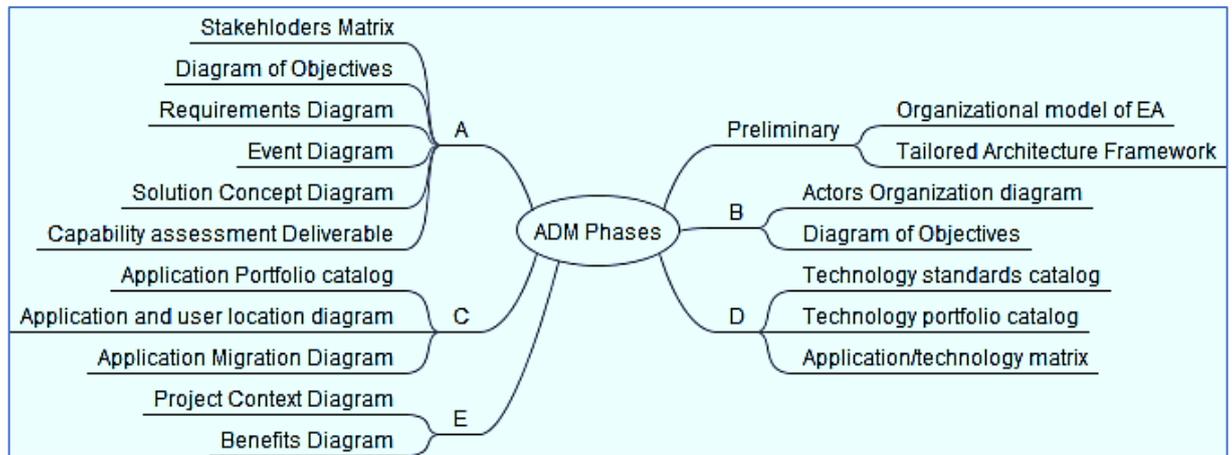


Figure 3. ADM Phases Deliverables for Implementation Decision-Making

The preliminary phase of the ADM cycle involves adapting TOGAF to the company's context and specificities. It provides stakeholders and architects with an organizational model for enterprise architecture, outlining the scope of the enterprise impacted by I4.0 transformation, roles and responsibilities, constraints, maturity assessment, resolution approach, governance strategy, and financial needs. The output is a tailored architecture framework, defining relevant points of view and selecting necessary artifacts. This deliverable also presents architectural principles for implementing architectural governance. The phase allows for a global appreciation of the extent, complexity, and implications of the I4.0 transformation project and helps the company understand the issues, implications, and necessity of implementing I4.0. Phase A (Architectural Vision) is crucial in the I4.0 transformation process, providing a comprehensive current and target architecture model. This phase includes the stakeholder matrix, value chain diagram, objectives diagram, requirements diagram, event diagram, and solution concepts diagram. The stakeholder matrix identifies all actors contributing to the I4.0 transformation, while the value chain diagram helps identify the sources of value provided by the company to customers. The objectives diagram defines the scope of the system's capabilities, which can be prioritized and allocated to system actors. The requirements diagram outlines the system's requirements for implementation, allowing for flexibility in decision-making. The event diagram identifies the company's processes and provides a detailed map indicating triggering events and actors involved. The solution concept

diagram simplifies sharing the solution's vision and changes to be implemented, facilitating easier communication with stakeholders after implementing I4.0. The "Architecture Vision" deliverable addresses questions about a company's I4.0 adoption capabilities, including business capacity, IT capacity, architecture maturity, and transformation capability. This phase gives stakeholders a clearer vision of the target architecture, responsibilities, and measures to be adopted, enabling them to project themselves into a potential future I4.0 and understand the changes, measures to put their organization in capacity, and how this initiative aligns with their strategic objectives. Phases B, C, and D of TOGAF describe the architectural perspectives of a company, which the I4.0 transformation will significantly impact. To assess the need to implement I4.0 technologies, stakeholders must assess the changes resulting from this transformation and be reassured about the future target architecture. Decision-makers can simulate the result of adopting I4.0 even before its actual implementation in the field through the deliverable "Architecture Definition Document," which includes the scope of the transformation project, objectives, constraints, current architecture (baseline architecture), data and applications, and infrastructure, and target architecture (target architecture). Gap analysis is possible by comparing the initial architecture to the target architecture and establishing a gap analysis. Transitional architectures are defined and documented in the architecture definition document when the gap is too large to be conducted in a single ADM iteration. Artifacts used in phase B include the organization diagram, the diagram of objectives, and the business process diagram. The organization diagram establishes the list of actors and roles, while the objectives diagram consolidates the vision of the target architecture. The business process diagram describes the sequence of activities of a business process and better understands how it works. In phase C, the application portfolio catalog, application, user location diagram, and application migration diagram help identify and maintain the list of company applications, map the application portfolio and govern changes caused by implementing I4.0. The technology standards catalog documents the agreed standards for technology in the enterprise helps select the most suitable and recommended technologies, and the application/technology matrix makes communication between applications and technological platforms possible. In summary, phases B, C, and D enable decision-makers to describe the target architecture's current architecture, measure gaps, evaluate impacts, and set up a roadmap. Phase E Opportunities and Solutions: in this phase, the focus is on integrating the needs of the business impacted by the I4.0 transformation, the integration of legal and regulatory requirements, risk assessment, and the results of the analysis of the business impact to prioritize projects. Architects should work

with existing transformation, IT infrastructure operations, and application management teams to define and prioritize projects. At the end of this phase, project definitions with technical priorities are identified. The technology deployment and process improvement roadmap will result from this phase. We can cite the project context diagram and benefits diagram among the diagrams created during Phase E. *Project Context Diagram*: A project context diagram shows the scope of a set of works to be implemented as part of a more extensive IT transformation roadmap. 4.0. This diagram links work to the organizations, functions, services, processes, applications, data, and technologies that are added, removed, or affected by the project. It is also a valuable tool for project portfolio management and project mobilization. *Benefits diagram*: The benefits diagram shows the opportunities identified in an architecture definition, categorized by size, benefit, and complexity. Stakeholders can use this diagram to select, prioritize, and sequence identified opportunities. Phase F Migration planning, a project management office, should be set up as part of this phase. The team of architects must also identify the impact of deploying the technological components of I4.0. The prerequisites are identified and communicated to the respective stakeholders of the organization. Changes to be made for integration with service, availability, and performance management tools will be discussed and communicated to the respective stakeholders in the organization. Processes and other operational requirements should also be identified. The plan to make these elements available to the operations team will be defined. The technology tools deployment project plan will be developed in this phase. Finally, the resources required for the deployment must be identified. Phase G Implementation governance: the identified project team must complete the deployment. The team of architects provides governance support for these I4.0 technology deployment projects. It validates the tools' implementation methods and procedures to ensure they are deployed and configured according to the architecture artifacts. It also confirms that the service delivery and maintenance details are captured and deposited into the architecture repository. Phase H Management of maintenance and upgrades in this phase, regulatory requirements for data protection and privacy are increasingly stringent with Industry 4.0 technologies. To keep up with this evolution, the architecture must assess the coverage of the new environment from a security perspective and the effectiveness of existing tools and technologies in complying with organizational policies and applicable regulatory requirements. A summary of this section is presented in Table 3.

Table 3. Summary of ADM Phases' Roles in Implementation Decision-Making

TOGAF ADM Phases	Role(s) Played in Decision Support to Implement I4.0 Technologies
Preliminary Phase	Assess the scope, complexity, and challenges of adopting I4.0. Answer the questions: where, what, why, and how will the enterprise architecture transformation occur?
Phase A (Architecture Vision)	Outline the I4.0 transformation by roughly modeling the current and target architecture. Determine the current capabilities (business, IT, architecture, and transformation maturity) required for the organization to lead the I4.0 transformation. Get a clearer picture of the I4.0 adoption initiative and its implications.
B, C, and D Phases (Architecture Business, IS, Infrastructure)	Clearly define the initial architectures (business, data, applications, and infrastructure) to determine their flaws and opportunities for improvement by I4.0. Simulate the results of adopting I4.0 before its implementation by defining the target architectures (business, data, applications, and infrastructure). Become aware of the gap between the current architecture and the target architecture. Anticipate impacts, changes, and risks and estimate the efforts, actions, and resources to be implemented through a roadmap.
Phase E	Determine and confirm the critical attributes of the change to I4.0 technologies. Confirm the risks associated with the company's transformation to I4.0. Identify the transition architectures needed for a successful I4.0 transformation.
Phase F	Identify the Impact of deploying I4.0 technology components. Identify changes to be made for integration with service management tools. Identify business processes and requirements. Develop the project plan for the deployment of technological tools.
Phase G	Provide governance support for I4.0 technology deployment projects. Validate the methods and procedures for implementing the tools.
Phase H	Assess the coverage of the new environment from a security perspective. Evaluate the effectiveness of existing tools and technologies to comply with organizational policies and applicable regulatory requirements.

In addition, Archimate makes it possible to describe, analyze, and visualize the relationships between an organization's activity areas by unambiguously modeling this last organizational structure, business processes, information flows, and infrastructure. It covers six different layers: Strategic, business, application, technology, physical, and finally, implementation and migration. This formalization and standardization of modeling allow architects to easily communicate their vision with stakeholders and involve them in decisions and reflection during the different stages of the architectural project. In this way, decision-makers better understand the I4.0 transformation project. They can more easily assimilate the challenges, changes, and benefits of implementing I4.0, contributing to a better assessment of the need to adopt I4.0.

5. Conclusion

We have discussed enterprise architecture within the context of Industry 4.0, where we are more specifically interested in the TOGAF framework and the guidance it can provide to companies evaluating the need to implement I4.0 technologies. Therefore, we have emphasized the importance and relevance of the Open Group Framework in supporting this crucial stage of evaluation. Through the different phases of ADM, decision-makers can collect information that will enable them to decide whether or not to implement I4.0 in their companies. It is organized into phases: preliminary, A, B, C, D, E, F, and G, which produce and enrich deliverables and relevant artifacts for decision-makers. The impact can be assessed by modeling the company's current state, pinpointing its shortcomings and capabilities, and then covering the different architectures affected by I4.0 adoption. The TOGAF architecture helps to describe a company's future architecture and the means and actions to achieve it and properly govern this significant change. This way, stakeholders can envision and project what their organization will look like once I4.0 technologies are implemented and what added value this initiative would bring. Thus, they can weigh the pros and cons of such an investment and decide if I4.0 is necessary for their business context. Aside from this, TOGAF's tools and languages facilitate communication and cooperation among the different architectural actors and stakeholders, which enables the understanding and involvement of decision-makers throughout the reflection and development of the I4.0 strategy, which facilitates IT alignment with the business strategy and highlights the practical value of I4.0 technologies for the company. Finally, this study supported the need for a study and reflection phase before launching a digital

transformation in a company. It highlighted TOGAF's usefulness in evaluating and making decisions rather than implementation. Despite this, indicators are necessary to measure the predicted impact of the I4.0 technologies with precision at each stage. The directions of this work revolve around achieving this goal.

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