

# AN OVERVIEW OF THE DIGITAL TRANSFORMATION AND INDUSTRY 4.0 TECHNOLOGIES IMPLEMENTATION FRAMEWORKS

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**Abstract:** Digital transformation is vital for improving overall enterprise performance. Many companies are already engaging in such activities, but they often overlook the importance of a structured approach to these projects, considering their complexity and readiness. With technology advancing rapidly, manufacturing companies, which face unique challenges related to standardization, change management, and culture, must adopt a structured approach to digital transformation projects. This paper provides an overview of existing frameworks for implementing digital transformation and digital technologies, aiming to draw conclusions for future research in this area.

**Keywords:** digital transformation, industry 4.0, governance, framework, lean management

## 1. INTRODUCTION

The impact of technology development disrupts organizations in different sectors, posing challenges in implementing new technology. Meanwhile, the popularity of the Digital Transformation (DT) and Industry 4.0 (I4.0) is still increasing in both scientific and business communities (Kraus, et al., 2021), but also with the general public (in a number of searches) as shown in Figure 1, generated with Google Trends tool in June 2023.

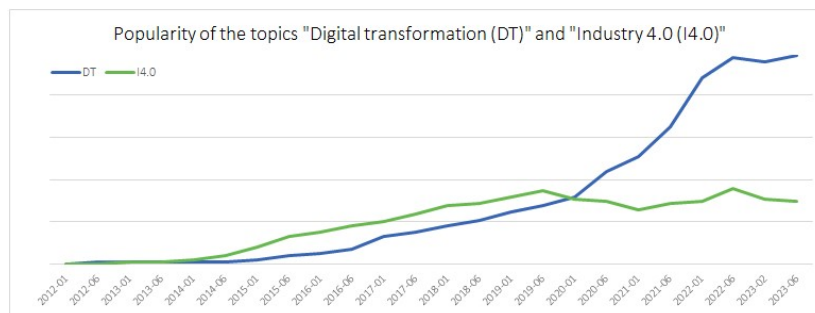


Figure 1: Popularity of the topics "Digital transformation" and "Industry 4.0" according to Google Trends

While the "buzz" around these words is getting louder, surveys reveal high failure rates (70-80%) in digital transformation and Industry 4.0 implementation projects (Carr, 2023; Uchihiro & Eimura, 2021). As discussed further in the paper, many authors have emphasized the fact that the success of DT and implementation of I4.0 technologies is not purely based on the introduction of technology, but rather on structured organizational change and governance. Therefore, this paper aims to:

- explore the need for a comprehensive DT and I4.0 implementation framework, and
- review the current frameworks for implementation of DT and I4.0 technologies.

The next chapter provides a brief introduction to the relationship between DT and I4.0. The third chapter focuses on the need for a new comprehensive framework that will address the contemporary challenges, and finally the fourth chapter is presenting a literature review of the existing frameworks for DT and I4.0.

## 2. RELATION BETWEEN DIGITAL TRANSFORMATION AND INDUSTRY 4.0

DT and I4.0 are often used interchangeably. According to their high-level goal, they seem to be very similar – they both help companies become more efficient and productive through utilization of digital technologies; however, they are two different concepts (Koh, 2022). To understand the relationship between DT and I4.0, first, a distinction between digitization, digitalization, and digital transformation will be made. **Digitization** is the process of making information available and accessible in digital format. **Digitalization** is the activity of making processes more automated by means of digital technologies (the

ones that are part of the I4.0 concept). Finally, digitization and digitalization are the processes that precede **digital transformation** activities to create new business values. Based on (Connamix, 2021; Abdallah, Shehab, & Al-Ashaab, 2021; Bumann & Peter, 2019) the relationship between these three concepts is illustrated in Figure 2.

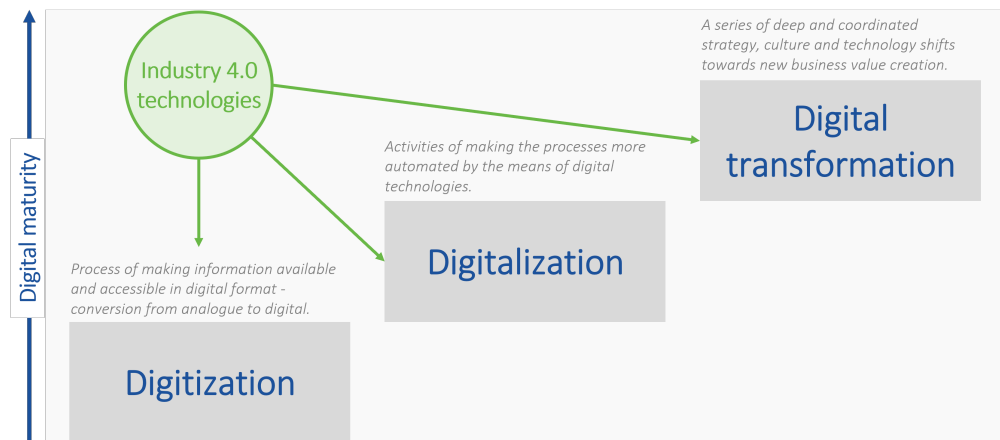


Figure 2: Relation between digital transformation and Industry 4.0 technologies

**Industry 4.0 technologies**, which is a set of digital technologies, come as an aid to the organizations to reach certain digitization and digitalization that will lead to the overall digital transformation of the organization. It is crucial to make a difference between these concepts considering that they are at entirely different levels in the maturity of the organizations when it comes to their digital goals (Katuu, 2022).

### 3. THE NEED FOR NEW COMPREHENSIVE FRAMEWORKS

There is not a definitive list of reasons why DT projects fail, but many authors have stated their perspectives or presented lessons learned regarding what can influence these failures. These insights serve as valuable guidance for future strategies, frameworks, and projects related to digital transformation and Industry 4.0.

According to (Carr, 2023), improving the existing processes towards digital transformation won't be successful unless the organization is focused on strategic objectives and includes measurable (where possible) demonstration of performance impact. This author emphasizes that digital transformation requires careful planning as many other projects. (Uchihira & Eimura, 2021) defined six impeding factors that could bring the digitalization projects in jeopardy. They accent the information and knowledge gap, but also the incomplete assessment of the current situation and the inconsistencies with the perspective of the future. In more general research, (Budagov, 2020), it is stated that there are three key groups of reasons for failure of these projects: strategic management, organizational management, and corporate culture development. These three factors along with people roles, responsibilities and organizational structure, top management engagement, current infrastructure and others are referred as identified issues and challenges when it comes to digitalization projects according to another comprehensive research by (Mahmood, Khan, & Khan, 2019). In more recent extensive research by (O'Brien, et al., 2023), the main reasons and risks to failure are stakeholders, culture, organization and strategy, processes, and technology. (George & Fernando, 2019) refer to the culture and management leadership as a main factor for success of the digital transformation and once again stress the fact that technology is not the first thing that companies should care about when it comes to digital transformation.

On a more practical level, the local SMEs also struggle when it comes to implementing DT and I4.0 technologies due to strategy and organization related factors. In previous research during the DigiTS-ME project (DigiTS-ME, 2022-2023) where the maturity of the local SMEs was assessed through three different maturity models, it can be observed that none of the included companies is at the top level of maturity when it comes to Industry 4.0 technologies implementation. If we take an example from the IMPULS maturity model (VDMA, 2016) that was applied in more than 20 Macedonian manufacturing companies, in the dimension "Strategy and organization", we can observe that 31% of the surveyed companies are in Level 0 in this field; meaning they still haven't integrated the digital technologies in their business strategies nor have any set rules for the governance of such activities. Half of the companies

(50%) are in Level 2, which means they have pilot initiatives in the departments, but strategic relevance is still lacking. No companies are in Level 4 (the highest level of maturity).

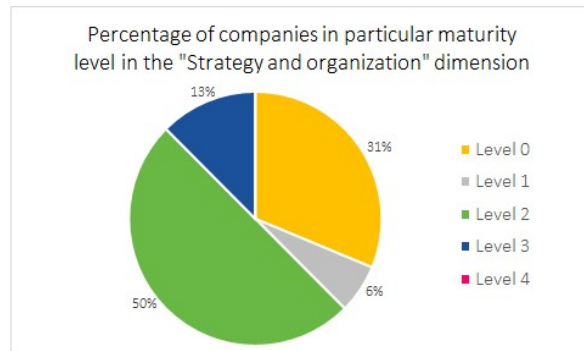


Figure 3: Maturity of the Macedonian SMEs in the dimension "Strategy and organization" according to IMPULS

To succeed, a well-defined and comprehensive framework that will not only focus on technology, is essential to guide the process. Butt (2020) highlights the need for such a framework and points out that organizations often lack a standardized implementation protocol, especially when introducing new technologies. A comprehensive framework is crucial to manage the digital transformation project effectively.

#### 4. DT AND I4.0 FRAMEWORKS LITERATURE REVIEW

In the most general sense of the word, a framework is a structured set of guidelines, tools and deliverables that provide a foundation for developing or implementing projects, organizations, products, strategies or similar (Jabareen, 2008). It is very hard to narrow the final list of areas in which a framework can be applicable considering that they vary from project management frameworks to product development frameworks, testing frameworks, research frameworks etc. Frameworks can be **theoretical** (combining concepts and existing theory) or **conceptual** (unity of concepts for a particular study), (Ahrens et al., 2017). Frameworks can also be of **strategic type** – the ones that are related to designing or pursuing a certain organizational strategy, or **procedural type** – the ones that are related to the governance of certain activities. Some authors include the maturity models in the group of frameworks for the implementation of DT and I4.0 (Denning & Liyanage, 2022). This question was previously extensively researched in (Argilovski et al., 2022). In this paper, the accent is on the procedural type of frameworks, however some of them also include a strategic aspect.

In Table 1 the literature analysis regarding the existing procedural frameworks for implementation of DT and I4.0 is presented. They are analyzed according to the following criteria: phases/steps (which phases are part of the implementation procedure of a certain framework), topic (which concept is emphasized in the framework), type (strategic or procedural), SDLC (which System Development Lifecycle was used to design the framework), maturity models (are the maturity models considered within the framework), Lean aspects (are the Lean aspects considered within the framework). Authors often use different terminology and include varying aspects in describing the phases and procedures, but they generally share similar objectives. Some authors (Stojkovic & Butt, 2022; Mayer, Romina & Pessl, 2017; Gajdzik, Grabowska & Saniuk, 2021) refer to the frameworks as "Industry 4.0 implementation frameworks" but at the core of it, they consider strategy, people, processes and technology, meaning that these frameworks also fit the broader digital transformation definition rather than Industry 4.0 technologies. Only one of the reviewed frameworks, (Butt, 2020), is focused on transforming a process; all others refer to an organization-wide transformation.

One of the main similarities, in almost all shown examples in Table 1, is the inclusion of the maturity models or generally the awareness of assessing the current level of maturity for DT or I4.0 technologies implementation. Considering the importance of Lean management for the future research, the frameworks were reviewed from a Lean perspective too. Few frameworks mind the fact that the processes should be optimized prior to the transformation (Mayer, Romina, & Pessl, 2017; Sameer, et al., 2020) and one of the frameworks, (Butt, 2020), is entirely based on the DMAIC framework associated with Lean Six Sigma methodology. Regarding the System Development Lifecycle (SDLC) model used to design the frameworks, it can be noticed that the traditional waterfall model (typical for project management) is widely used. Many of them also use hybrid models (waterfall in combination with iterative or incremental model), and only one of the reviewed frameworks used the V-model, which is more often used for smaller projects in software testing.

Table 1: Reviewed digital transformation and Industry 4.0 frameworks

Article	Phases/Steps	Area	Type	SDLC	Maturity models	Lean aspects
(Stojkovic & Butt, 2022)	Business requirements, Operational requirements, Systems architecture integration and business case, Subsystems definition and subsystems design. Components design and test, Subsystems tests, Systems integration test, Concept of operations test, Technology transfer to Business as Usual (BAU).	Industry 4.0	Procedural	V-model	<i>Not included.</i>	<i>Not included.</i>
(Butt, 2020)	Process identification, discovery and process analysis, Process redesign and process reengineering, Streamlining business processes, Risk management & contingency planning, Skills gap analysis, Change management, Cost-benefit analysis, Process validation, process implementation, Process monitoring and controlling	Digital transformation	Procedural	Hybrid	<i>The paper emphasises that the frameworks could be based on maturity but this one is not based on it.</i>	<i>Lean Six Sigma as an approach in the Process Monitoring and Controlling phase</i>
(Korachi & Bounabat, 2019)	Business strategic planning, Organizational structure, Steering committee, Prioritization process, Investment decisions, Strategic planning, Budgeting, Reporting, Reaction capacity, Management strategy	Digital transformation	Procedural and strategic	Not specified.	<i>Includes recommendation for maturity assessment prior to the formation of the strategy.</i>	<i>Not included.</i>
(Majdalawieh & Khan, 2022)	Problem identification, Defining the objective of the solution, Design and development, Demonstration and evaluation, Communication	Digital transformation	Procedural	Hybrid (Waterfall and iterative)	<i>Mentioned in the theoretical background, not included in the following case study.</i>	<i>Not included.</i>
(Mayer, Romina, & Pessl, 2017)	Analysis, Industry 4.0 Maturity, Define target state, Define, and evaluate measures, Realisation, Define projects	Industry 4.0	Procedural	Waterfall	<i>Entire 2nd phase "Industry 4.0 maturity" is the assessment, and following phases are based on it.</i>	<i>Lean is set as a norm strategy for companies that have not yet defined their I4.0 targets</i>
(Gajdzik, Grabowska, & Saniuk, 2021)	Analysis of enterprise's capabilities, Strategy leading to Industry 4.0, Initial pilot projects, Project implementation evaluations, Transform to digital enterprise/ smart factory, Plan ecosystem approach	Industry 4.0	Procedural and strategic	Hybrid	<i>Considered in the first phase "Analysis of enterprise's capabilities"</i>	<i>In a context that Lean supports Industry 4.0 technologies.</i>
(Sameer, et al., 2020)	Identify manufacturing data present in the SME, Smart Manufacturing readiness assessment. Develop smart manufacturing-tailored vision for SME, Identify tools and practices to realize SM-tailored vision	Smart Manufacturing	Procedural and strategic	Waterfall	<i>Included as an entire second phase of the framework.</i>	<i>Mentioned several times as an enabler of smart manufacturing, not in the context of the framework.</i>
(Butt, 2020)	Define, Measure, Evaluate, Optimize, Develop, Validate, Implement	Industry 4.0	Procedural	Waterfall	<i>Not included explicitly in any phase, however by definition it should be done in the "Measure" phase where the current situation is evaluated.</i>	<i>Heavily based on Lean Six Sigma framework, includes LSS tools in the procedure.</i>

Additionally, Deloitte (Deloitte, 2020) have developed a roadmap framework that includes four steps to digital transformation including assessing the external and internal situation, developing strategy, and assessing business impacts, architect business solution and deploy solutions. Each phase has six sub-phases. This framework is different than the others due to the level of details in each of the main four steps as well as the assessment of the external situation, a step that was not observed in any other framework during this literature review. Another simpler framework is offered by (AIMultiple, 2023). This framework is a procedural waterfall framework and consists of six steps: Identify, Formulate, Tech Selection, Leadership and Digital Culture.

Project management (PM) frameworks are also a powerful tool for managing such activities, but the fact that the digital transformation by itself is more than a project, it challenges these frameworks. It all starts from the fact that DT is not a process nor a project. The traditional design methodology (waterfall model) is not entirely satisfactory for dynamic and uncertain organizational endeavors such as DT. Existing PM frameworks are considered insufficient to support transformational projects (Kimberling, 2021; Third Stage Consulting, 2021). For successfully managing and executing DT, it is needed to incorporate additional competencies like innovation management, organizational change, organizational learning, digital strategy implementation, Lean management, change management, process mapping and improvement etc. (Verhoef, et al. 2020), therefore besides PM skills, the organizations will need wider Industrial Engineering and Management set of skills to manage the transformation.

## 5. CONCLUSION

Many authors have researched the reasons for the failure of DT and I4.0 projects and according to the literature, success relies on more complex organizational change and governance, not just technology. Despite the negative trends when it comes to digital transformation projects' success, a comprehensive framework for implementation of DT and I4.0 can help organizations avoid failure by demonstrating a roadmap to success - a standardized approach can mitigate risks and enhance digital transformation's success. Several relevant frameworks for implementation of DT and I4.0 were reviewed according to several criteria including phases, area, type, maturity models inclusion and Lean manufacturing aspects. Future research should include the design of a comprehensive framework that addresses the failure reasons as well as a universal maturity model which seems to be missing in the literature even though many of the frameworks acknowledge the fact that maturity assessment is essential in the early phase of the transformation. Lean philosophy should also be a part of the development process of the framework from the very base. Future research should also identify which type of SDLC is most suitable for DT frameworks considering that the traditional project management methodology is challenged by the authors. In a more practical sense, future research should also include testing and verifying such comprehensive framework in a scaled-down environment, such as the Smart Learning Factory – Skopje.

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