Artificial Intelligence and Digital Transformation: Analyzing Future Trends

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Artificial Intelligence and Digital Transformation: Analyzing Future Trends

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***Abstract*—In recent decades, technological advances have exponentially accelerated the search for digital transformation. The use of technologies based on Artificial Intelligence (AI) is essential to achieve these goals. In this work, we investigate the future trends in the field. We conducted a systematic review and analyzed their content with a methodology based on Future-Oriented Technology Analysis (FTA) techniques. We have identified 30 future events related to digital transformation and AI and their respective feasible years. Our findings are categorized into industry fields: business process management, construction industry, digital economy, human resources, healthcare, industry, social innovation, tourism, and education. Our work allows decision-makers to draw up strategies, map the paths to be taken, and better prepare for their future needs, using AI as a tool for value aggregation.**

***Index Terms*—Artificial intelligence, Digital Transformation, digital innovation, Future-oriented Technology Analysis**

I. Introduction

Digital Transformation is a series of technology-based changes, including Automation, Digitalization, Robotization, and the use of data-based systems [1]. Increasingly, Digital Transformation permeates every aspect of businesses that adopt state-of-the-art and often converging technologies. Digital Transformation strategies are not only relevant to policy and practice in the industries, but it is also an approach to understanding the role of industries in fomenting innovation and entrepreneurship in high-tech and other sectors of the economy. Moreover, Digital Transformation is expected to help with environmental sustainability [2].

Industry transformation requires the integration of various facilitating technologies such as cloud computing, IoT, and cyber security, among others [3]. Artificial Intelligence (AI) is widely used for this purpose and has been studied in different types of industries before [4]. Computational processing capacity and AI, especially, have been evolving exponentially and in recent years are considered the greatest value aggregators in several industries. Adding AI techniques to processes is seen as the next industrial revolution [5]. Knowing the role of AI in the industry today, we can outline expectations and future perspectives for the field.

In this work, considering the importance of Digital Transformation and AI for the future of the economy, we present trends and points of attention regarding the future changes that are taking place in various industries. Therefore, we expect to answer the following research questions:

RQ1. *What are the main future events in terms of Digital Transformation and AI application by the Business Sector?*

RQ2. *What is the future scenario for Industry 4.0 in the coming decades?*

To answer these research questions, we combined five Future-Oriented Technology Analysis (FTA) methods – such as literature review, brainstorming, and futures wheel. FTA is a broad concept that includes any systematic methodology for measuring impacts and supporting technology decisions. It is a consensus in the academic environment that better results are achieved with the combination of different and complementary FTA methods, creating a workflow of methodologies like the one used in this research [6]. FTA not only brings benefits but is practically a necessity for companies to remain competitive. In addition, it allows for better management and raising of financial resources for the implementation of necessary changes, which is one of the main factors for the digital stagnation of industries [3].

The remainder of this paper is organized as follows. Section II presents the methodology used in the research by explaining each of the five FTA methodologies that were applied. Section III presents the scenario for Industry 4.0 which includes the 29 future events organized by decade, from 2020 to 2040. Section IV presents some final remarks, including contributions and limitations of the research, and future work.

II. Methodology

The study is structured according to the following five sequential steps, as presented in Fig. 1. Initially, we carried out a Systematic Literature Review (SLR) to capture future events described in the state-of-the-art literature. Next, we performed a Brainstorming to discuss the events collected in the SLR and propose new ones. In the third step, we use the Futures Wheel technique to find cause-consequence relations that are hints about how such events develop. In the fourth step, we organized the events into a Roadmap by estimating when each future event is expected to occur. In the fifth step, we describe the developed roadmap using a Scenario to check the consistency of the results.

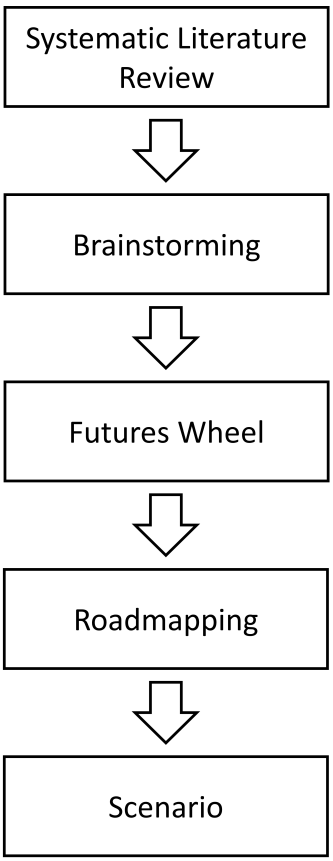

Fig. 1. Methodology of this work. Note that the steps form a linear workflow.

Ferreira et al. [7] presented cases where communication, cooperation, and coordination were important for solving the problems plus that is possible to promote collaboration along an FTA workflow, using results from one methodology as an input to the next planned one. To support this workflow of methodologies we use the software developed by the Future Lab of COPPE/UFRJ called Tiamat [8] and used in several studies [9]–[12].

Next, we present the details of each step of the Methodology.

A. Systematic Literature Review

The Systematic Literature Review presented in this paper is based on the methodology proposed by Kitchenham et. al [13]. Kitchenham's methodology is structured according to the following three steps:

1) **Planning**: In the first step, we lay the objectives and needs for this review. We have defined the set of research questions and the review protocol.
2) **Conducting the review:** In this second step, we have defined a search strategy to select a set of relevant research studies. The search was done according to the protocol established. Finally, for each selected research work, the data extraction is performed and classified according to its relevant characteristics.
3) **Reporting:** In this last step, we present the results and answers to the defined research questions.

We defined research questions to discover references in the state-of-the-art that could include relevant works in Artificial Intelligence and Digital transformation. The research questions are:

TABLE I
SEARCH STRING USED IN THE SLR.

("Artificial Intelligence" OR "AI")
AND ("Digita* Transfor*" OR "Digital business" OR "digitization" OR "digitalization" OR "Industry4.0" OR "Industry 4.0" OR "Industrial Revolution 4.0")
AND ("roadmap" OR "research avenue" OR "research agenda" OR "trend")
AND (NOT "review")
AND (PUBYEAR $\geq$ 2015)
AND (LIMIT-TO (PUBSTAGE, "final"))
AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar"))
AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI"))
AND (LIMIT-TO (LANGUAGE, "English")

TABLE II
SELECTION CRITERIA FOR THE SLR.

ID	Inclusion Criteria
I.1	Included studies must have been published in the last 7 years (included).
I.2	The work is a primary study.
ID	Exclusion Criteria
E.1	Works outside the computing area.
E.2	The work does not relate to the context of Artificial Intelligence.
E.3	The paper is not written in the English Language.

RQ1. *What are the main future events in terms of Digital Transformation and AI application by the Business Sector?*

RQ2. *What is the future scenario for Industry 4.0 in the coming decades?*

To retrieve relevant research papers, we performed a search on Scopus Library in January 2022. The search string is defined in Table I.

As part of the protocol implementation, a set of inclusion/exclusion criteria was specified and is reported in Table II. These criteria secure that only relevant papers are included in the study.

The following steps were performed to select the set of relevant studies: first, the search string was used in the selected database returning an initial set of papers; second, we evaluated the papers according to the contents of their title and abstract using both the inclusion and exclusion criteria; third, we selected 36 of the 148 papers for the last step of data extraction and synthesis. These studies constituted the new selection for the next step of the study.

We fully read the 36 relevant studies (from 2016 to 2022) to extract data relevant to the research questions. The selected papers are recent and the subject popularity appears to be on the rise, as shown in Fig. 2. Finally, we have analyzed the results, focusing on producing the desired answers for current trends in AI. Our analysis selected 8 papers that indicated possible future events – the SLR process is shown in Fig. 3. We were able to identify 20 events for future studies in the area of AI and digital transformation from the papers found in the literature review [14]–[22], as shown in Table III. We highlight that some papers produced more events than others: for example, Turner et al. [14] produced 6 events about Construction Industry, Singh & Shaurya [19] produced 3 events about Human Resources, and Majeed [20] produced 3 events about Healthcare.

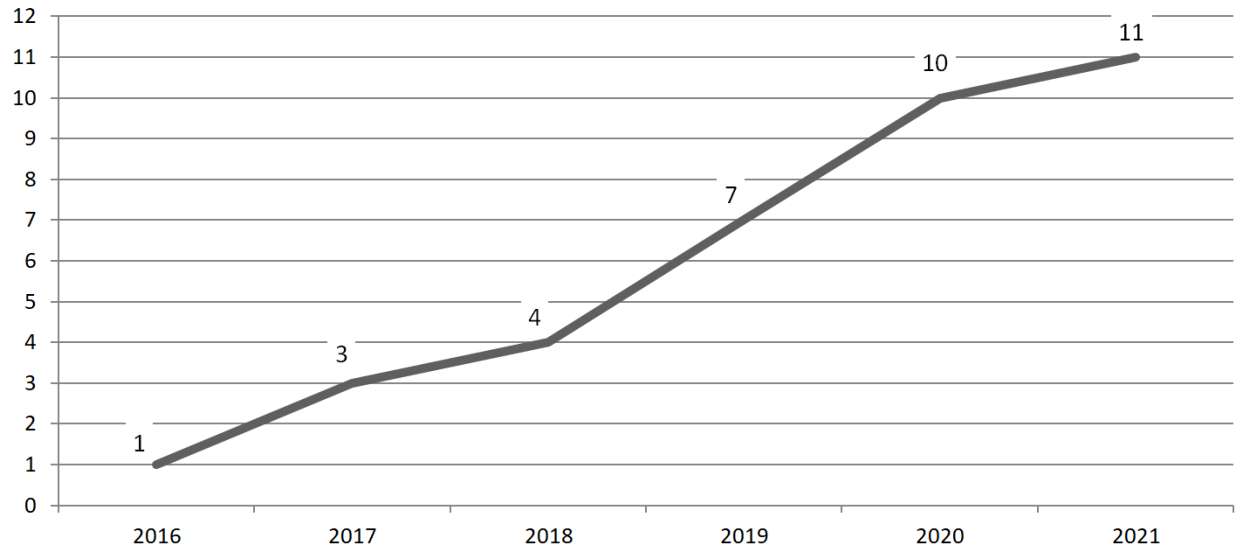

Fig. 2. Papers publication year analysis. Note the rise in the subject popularity.

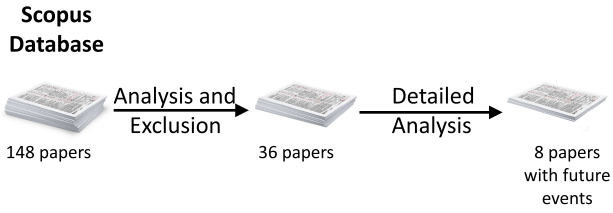

Fig. 3. SLR from 148 papers in search results to 8 papers with future events.

B. Brainstorming

Based on the events identified in the SLR in Table III, we held two brainstorming sessions as discussed in Barbosa et al. [8]. The first brainstorming session evaluated the events identified in the SLR. The second brainstorming session was focused on identifying new events not mentioned by the selected papers. Therefore, Brainstorming sessions helped us to validate the events identified in the SLR and new events were included in the research in Table IV.

C. Futures Wheel

After Brainstorming was completed, we started the Futures Wheel to identify the consequences of the events. In a Futures Wheel, each event is analyzed, producing a set of primary consequences – i.e. events which depend on other events. To discover the consequences, we asked to each other three questions: "*If this event occurs, then what happens next?*","*What necessarily goes with this event?*", and "*What are the impacts or consequences?*". The Futures Wheel analysis is recursive. The primary consequences are recursively analyzed to generate a set of secondary consequences, and so on. The Futures Wheel analysis usually goes until the tertiary consequences, but there is no rigid limit. Contradictory consequences may also occur. In this step, we mapped the events to their consequences, producing a concentric graph as shown in Fig. 4.

Fig. 4. Futures Wheel produced.

D. Roadmap

Roadmaps are used in the context of FTA to provide a better understanding of future events by chronologically organizing

TABLE III
EVENTS FROM THE SLR.

#	Event	Ref
1	[BPM] Machine learning and artificial intelligence advance in the BPM field.	[23]
2	[BPM] Artificial Intelligence to explore another communication tech in control and management tasks.	[18]
3	[Construction Industry] Sensors may be built into passive equipment associated with construction	[14]
4	[Construction Industry] Smart fabrics that when worn can be used to detect presence of workers in risky areas.	[14]
5	[Construction Industry] Increases in power-density of batteries, and higher computational power in IoT edge devices and AI.	[14]
6	[Construction Industry] Real-time connected models of construction sites to provide full life-cycle.	[14]
7	[Construction Industry] Using AI to enable communication and learning from each other machines/devices.	[14]
8	[Construction Industry] Intelligent assets could provide a new real-time and context-aware stream.	[14]
9	[Digital economy] Development of the field of artificial intelligence in open systems.	[17]
10	[HR] AI is assumed to replace administrative tasks in both the recruitment process.	[19]
11	[HR] Use AI systems to connect employees to HR in large companies.	[19]
12	[HR] Use AI to automate HRM tasks in recruiting activities.	[19]
13	[Healthcare] Applications of machine learning and high-performance computing in the era of COVID-19.	[20]
14	[Healthcare] Use AI to identify COVID-19 risky areas based on patients' frequented addresses.	[20]
15	[Healthcare] Use AI systems to identify risk places based on patients' locations.	[20]
16	[Industry] AI enhance collaboration between robots and human by supporting communications interfaces.	[21]
17	[Industry] Machines may interpret and predict the human behavior.	[22]
18	[Industry] Using machine learning, data analytics, big data analytics, artificial intelligence, data engineering, data management, supply chain management with data-driven approaches, smart manufacturing, supply chain.	[15]
19	[Social Innovation] Using blockchain, artificial intelligence and connected objects.	[16]
20	[Tourism] Increases the quality of the experience at the destination.	[24]

them using a timeline [25]. Roadmaps can be used to facilitate the development of scenarios [26], [27]. Roadmaps are more focused on the time relationship between events than the cause-consequence relationships, for example.

The roadmap can be found in Table V, where we synthesize the results from previous steps. The year in the first column is the result we arrived from the event, based on the journals observed, our discussions on the subject, and research on the progress of the development of this technology at the time we conducted the research.

E. Scenario

Scenarios are used in the context of FTA to develop cohesive narratives about the future. Several methods implement scenarios, varying if their goal is to produce normative (aspirational) or exploratory scenarios. The main use of the scenario is to facilitate the understanding of relevant decision-makers, or even laymen if the goal is to increase the society's awareness of

TABLE IV
EVENTS FROM THE BRAINSTORMING.

#	Event
21	[BPM] Facilitate job learning due to disruptive technologies such as AI and IoT.
22	[BPM] Utilize AI to look for digital process performance and mastery improving business intelligence.
23	[BPM] Finding a balance between strategic transformations and the incremental side of lean paths.
24	[BPM] Use AI for diagnostic/predictive/prescriptive process analytics to improve customer experience.
25	[Education] AI can be used to design a study plan for elementary school for each student.
26	[Education] Seize the opportunity to use AI like Alexa to motivate kids in the classroom.
27	[Industry] Analysis to the examination of graph structures and AI to reveal technical trends.
28	[Industry] AI + human knowledge to enhance Industry efficiency.
29	[Industry] AI for non-AI practitioners: IDEs can help practitioners without skills to build models.

possible future events. In this work, we use scenarios to enrich the described events of the roadmap produced previously.

III. A SCENARIO FOR THE INDUSTRY 4.0

Based on the roadmap designed by this research, we have created a scenario where each of these events would occur in the years expected, and we discuss the impacts of these events on each other and the world. For organization purposes, we divide the events into three decades: the years 2020 and 2030.

A. The 2020s

The nearest event refers to 2023, we will have AI able to predict places that should be avoided during an epidemic or pandemic to minimize contagion using by infected or likely infected people's GPS location history. Frequent visitors of high-risk areas can use AI to trace routes that prevent crossing with infected or likely infected persons. Still in 2023, AIs will be able to perform blockchain operations on connected objects. As a public record, blockchain can guarantee more agility and transparency in financial operations, carrying out transactions without intermediaries or validating institutions.

By 2024, AI should be able to mediate HR efforts of large companies with employees, possibly through applications that support people's work, gather suggestions, listen to problems and motivate workers, as if there were a human professional available at any time to speak with the employee.

By 2025, AI will be able to improve customer experiences by predictively analyzing their behavior. This can help predict behavior intentions. For example, a smart car can notice that a pedestrian intends to cross the street when he shouldn't, even before he starts walking, reducing accidents. This is the result with the smallest forecast variation among all respondents, including our result, implying a certain agreement with the timing of the event.

By 2026, one event seems like an evolution of the 2023 technology of AI predicting based on people's location history safer routes during epidemics and pandemics. Now, two years later, AI should be able to identify which locations will become high-risk locations, also taking into account the type of activity at the location. Finally, in 2026, we believe that AIs should be able to create individual personalized study plans

TABLE V
THE ROADMAP FOR AI AND DIGITAL TRANSFORMATION.

Year	Event
2022	[Tourism] Increases the quality of the experience at the destination.
2023	[Healthcare] Applications of machine learning and high-performance computing in the era of COVID-19.
2023	[Healthcare] Use AI to identify COVID-19 risky areas based on patients' frequented addresses.
2023	[Social Innovation] Using blockchain, artificial intelligence and connected objects.
2024	[HR] Use AI systems to connect employees to HR in large companies.
2025	[BPM] Machine learning and artificial intelligence advance in the BPM field.
2025	[BPM] Finding a balance between strategic transformations and the incremental side of lean paths.
2025	[BPM] Use AI for diagnostic/predictive/prescriptive process analytics to improve customer experience.
2026	[Education] AI can be used to design a study plan for elementary school for each student.
2026	[BPM] Artificial Intelligence to explore another communication tech in control and management tasks.
2026	[HR] Use AI to automate HRM tasks in recruiting activities.
2026	[Healthcare] Use AI systems to identify risk places based on patients' locations.
2027	[Construction Industry] Smart fabrics that when worn can be used to detect presence of workers in risky areas.
2027	[Industry] AI for non-AI practitioners: IDEs can help practitioners without skills to build models.
2027	[Industry] Machines may interpret and predict the human behavior.
2028	[Industry] Using machine learning, data analytics, big data analytics, artificial intelligence, data engineering, data management, supply chain management with data-driven approaches, smart manufacturing, supply chain.
2028	[Construction Industry] Sensors may be built into passive equipment associated with construction.
2028	[Construction Industry] Increases in power-density of batteries, and higher computational power in IoT edge devices and AI.
2028	[Education] Seize the opportunity to use AI like Alexa to motivate kids in the classroom.
2028	[Industry] Analysis to the examination of graph structures and AI to reveal technical trends.
2028	[Industry] AI + human knowledge to enhance Industry efficiency.
2029	[HR] AI is assumed to replace administrative tasks in both the recruitment process.
2029	[Construction Industry] Real-time connected models of construction sites to provide full life-cycle.
2029	[BPM] Utilize AI to look for digital process performance and mastery improving business intelligence.
2030	[Digital economy] Development of the field of artificial intelligence in open systems.
2030	[Industry] AI enhance collaboration between robots and human by supporting communications interfaces.
2031	[BPM] Facilitate job learning due to disruptive technologies such as AI and IoT.
2032	[Construction Industry] Intelligent assets could provide a new real-time and context-aware stream.
2038	[Construction Industry] Using AI to enable communication and learning from each other machines/devices.

based on the profile, abilities, and difficulties of each student, from the most basic to the most advanced levels of education.

By 2027, we believe that BPM cycles can be optimized by AI, which will make processes leaner and faster, again contributing to an acceleration of technological development. In the same year, AI should be able to assist in the decision-making process. In the same year, people who don't know how to program will be able to start building their models using AI-assisted tools capable of programming other software according to the user, such as a low-code or no-code language.

By 2028, AI can to conduct machine learning, data analysis, and big data analysis without human aid. Certainly, with the automation of the process of learning and using the data, there would be an exponential curve of AI capability starting very soon. The second event in 2028 is about monitoring passive equipment for industrial construction. A passive equipment is categorized in this way because they do not connect or interconnect the network, monitoring this type of equipment would need to be done in another way, such as visual inspection through sensors. Still in 2028, AI can be applied to increase the energy efficiency of batteries and increase the processing power of computers. Again, these gains can consequently promote an increase in the speed of growth of Artificial Intelligence itself. AI will be able to effectively read graphs, I understand the mathematical relationship between objects of the same set, capable of making predictions and analyzing trends based on the results of indicators that show up in this way. Finally, AIs should be able to assist teachers in the classroom to promote the teaching of young children, as well as motivate and engage them in the classroom.

By 2029, AI should be able to model business processes on their own. This is an important leap, assuming that in this way practically any business can be expressed, read, and discussed by two or more AIs, eliminating the human factor from this type of process.

B. The 2030s

By 2030, we expect to see the development of specific AI to be applied in open systems, such as blockchain. Blockchain offers decentralized secure transactions based on open-source algorithms. Blockchain, IoT, and AI form the backbone of a smart city's infrastructure. Still in 2030, we expect that AI also enhances the collaboration between robots and humans by supporting communications interfaces, or entire new brain-machine protocols such as Neuralink [28].

By 2031, AIs must integrate with the IoT and ensure better professional learning, promoting advantages such as efficient remote work, security, and reduced business costs.

By 2032, we expect AIs to be able to create context-sensitive flowcharts that continually change and evolve, in real-time. This implies an understanding of process change and an ability to adapt to unforeseen, and consequently unplanned, situations.

By 2038, we expect that AI becomes able to communicate and learn from each other. This means machines capable of training other machines, which is different from the current paradigm of every machine having an AI model with the same training – producing unique machines.

IV. CONCLUSION

Digital Transformation and AI are essential building blocks of the current industrial revolution through which we are going

through. As such, understanding the trends related to these phenomena helps us to prepare for the future of the economy. In this paper, we used five FTA methodologies to present a view of the future of Industry 4.0.

Our contributions include a scenario about the future of Industry 4.0 that can be used by scholars, industry professionals, and society, in general, to prepare for the trends that were outlined. We also show an example of an FTA application to explore the future of Digital Transformation and AI.

This research has some limitations. The FTA process was undertaken only by the authors, therefore, this research could benefit from a broader group of participants. Second, the SLR was focused on the Scopus Library, which is limited to academic literature. This is a methodological and justifiable decision, but including "gray literature" could be beneficial.

In future work, we propose that research focus on specific areas of Digital Transformation and AI application (i.e., Health, Education, and Law) to enable more specialized analysis. It would also be interesting to see the use of different FTA methodologies to explore the future of Industry 4.0. Finally, future research could involve different participants such as industry experts, technology providers, and policy-makers to evaluate how their views regarding the future differ.

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