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PARTICULARITIES OF THE DIGITAL TRANSFORMATION OF THE MANUFACTURING INDUSTRIES

BY

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Abstract. Digital transformation is a global process that has an impact on all economic, administrative, and social domains. In industrial sectors, particularly in manufacturing industries, the widespread implementation of concepts and principles of Industry 4.0 is underway. Digital transformation involves operationalizing the principles of Industry 4.0, and companies are determined to formulate implementation strategies for the digitization process. A preliminary step in this endeavor is evaluating the level of digital maturity or preparedness for digitization, for which various tools are utilized. This paper discusses some evaluation tools, how they are structured, and the information they provide.

Keywords: digital transformation, manufacturing industry, assessment tool.

1. Introduction

Nowadays, all specialists refer to the fourth industrial revolution (Industry 4.0) as a merging of physical environments and digital technologies,

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such as the internet of things (IoT), artificial intelligence (AI), robots, drones, autonomous vehicles, 3D printing, cloud technology, and others, which are interconnected and capable of communicating, analyzing, and intelligently acting. Companies that adopt the concept of Industry 4.0 are more flexible, responsive, and intelligent, and therefore better prepared to make data-driven decisions.

The initial objective of Industry 4.0 was to automate and optimize production systems. Currently, as a result of achieving the initial objectives, Industry 4.0 involves focusing efforts on innovation and creating new business models.

The elements that define the concept of Industry 4.0 are:

1. Automation - through the use of autonomous robots that interact with each other and complement the work performed by humans;
2. Big data and analytics - by collecting and analyzing data from various sources (equipment, management, and manufacturing systems) that can contribute to real-time decision-making;
3. Virtual reality - by transposing physical environments (machines, products, people) into virtual models for testing designed products/systems and reducing risks;
4. System integration - by ensuring the connection of all systems within the company, both horizontally and vertically;
5. Internet of Things (IoT) - by interconnecting equipment and devices, ensuring "communication" between them to decentralize production decision-making processes;
6. Cybersecurity - to protect industrial systems that are increasingly targeted by cyber attacks;
7. Cloud services - enabling the exchange and storage of increasingly complex data;
8. 3D printing - for creating prototypes or small quantities of customized products;
9. Augmented reality - to allow real-time tracking of relevant information, by overlaying virtual reality with real life.

In the context of manufacturing industries, which specifically involve a significant number of operators who directly influence the conduct of processes, the adoption of digital processes presents certain particularities. At the level of company management processes, there is discussion about digital transformation (DT) as the means of adapting companies and their new business model to the Industry 4.0 context.

What is Digital Transformation (DT)? One definition states that DT "... can be understood as the change produced by digital technologies in all aspects of people's lives" (Stolterman and Croon Forst, 2006). Another definition states that DT represents "the use of technology to radically improve the performance that an enterprise can achieve" (Westerman *et al*., 2011). Both definitions indicate that DT involves a radical change in all processes within an organization, later defined as "transformative change" (Lucas *et al*., 2013). To evaluate a change as transformative, Lucas *et al*. proposed a set of seven criteria that allow an organization to be classified as undergoing transformation, namely:

Process change - a significant number (at least half) of the partial and global processes of an organization are changed;

Creation of new organizations;

Change in customer relationships - a significant increase in the number of customer contacts;

Change in markets - significant change in the number of markets (leaving existing markets, entering new markets, or creating new ones);

Change in user behavior - recording a minimum of two hours per day of changed behavior by employees;

Significant modification of the number of customers - an increase of at least 50% in the number of customers;

Disruptive impact - the level of impact on competing organizations, market influence, significant cost reduction.

Expanding the process of transforming an organization into the realm of digital transformation, Dehning *et al*. (2003) emphasize that adopting digital technologies means:

1. A fundamental modification of traditional ways of doing business by redefining capacity, processes, and internal or external business relationships;
2. Making strategic investments in technology to gain new capabilities or access new markets;
3. Using IT tools for a radical change in the way employees perform tasks.

These approaches have been contested by some researchers (Remane *et al.*, 2017) who consider them oversimplifying and unsuited to the context of each industry.

Digital technologies integrate informational, computer, communication, and connectivity technologies (Bharadwaj *et al*., 2013). The application of these technologies is often what is considered digitalization. Furthermore, the stage at which the digitalization process is at any given time, for a particular organization, characterizes the level of digital readiness (DRL) (Westerman *et al*., 2011).

From the perspective of experts at the Innovation Value Institute (www.ivi.ie), TD refers to the profound and accelerated transformation of activities, processes, competencies, and business models through the full exploitation of changes and opportunities offered by digital technologies in order to maximize their impact on society, strategically and prioritized, in accordance with present and future changes. Digital readiness is an organization's ability to anticipate and respond to these transformations.

2. Romanian manufacturing industries in the digital transformation context

A research conducted on the websites of consulting firms or digital solution providers for manufacturing companies (Digital Twin, GreenSoft, Senior Software, TUV Sud, Deloitte, etc.) has allowed the identification of some markers that govern the attitude of companies in Romania towards Industry 4.0.

Several advantages of implementing Industry 4.0-specific technologies for productive fields in Romania have been identified, such as:

- Increased market competitiveness;
- Real-time transactions;
- Easy addition of new procedures and processes to existing technology;
- Improved resource management through the implementation and monitoring of new communication methods;
- Provision of microservices;
- Improved work-life balance for employees;
- Maintaining attractiveness for foreign investors;
- Continuous development of the IT sector.
- The challenges facing the implementation of Industry 4.0 are:
- Concerns about data security;
- The need to improve employees' digital skills;
- The need for investment in IT infrastructure and maintenance, which involves high costs;
- The need for companies to invest more to become competitive;
- Decreased resistance to digitalization;
- The significant proportion of rural areas with generally low development may represent a disadvantage;
- Relatively low IT skills of the population;
- The accentuation of the "brain drain" phenomenon;
- Relatively high resistance to change of Romanian companies.

Starting in 2011, the interest of production companies has turned towards incorporating the newest technologies in their created products and including Industry 4.0-specific technologies in their own production systems. This is possible due to the unprecedented evolution of digital technologies that are becoming easy to adopt and integrate, with an effect on reducing the time for creating and launching new products. The COVID-19 pandemic has been a turning point in accelerating the process of digitization in all fields of activity, including manufacturing industries. Reports show that they have been more strongly affected and will experience slower growth than other leading economies (https://www.europarl.europa.eu/RegData; https://www.consilium.europa.eu/media). Although the effect of government support initiatives cannot be underestimated, the resilience of production is what made the difference and helped many companies thrive in these difficult times. It also highlighted the ability of many companies to address adaptability and development flexibility. Significant disruptions similar to those (such as regulations regarding climate change, raw material shortages, etc.) are expected in the near future, and the response to addressing these challenges is the increased resilience of production companies.

When considering medium or large volume manufacturing industries, resilience can only be achieved through the ability to quickly reconfigure and digitize. Rapid reconfigurability must be addressed at all levels of production, from manufacturing level (section logistics, layout planning, etc.) to job sites (equipment, devices, positioning and handling of the workpiece, etc.) and to each individual stage of the process (process parameters, quality assurance, etc.), as well as interaction with the supply chain as a whole.

Digital tools are key factors for rapid reconfigurability. Production digitalization can encourage process control on the production line and allow for autonomous decision-making for production equipment, thus aiding in rapid reconfigurability. Digital twin-based tools can support the virtual commissioning of systems before physical reconfiguration, reducing the downtime imposed by the reconfiguration process.

3. Tools for digital transformation assessment

In recent years, numerous assessment tools have been created by research groups from universities, consulting firms, or government institutions (Axmann and Hamoko, 2020) to evaluate the level of digital transformation maturity of a company. These tools can help companies measure their readiness for implementing digital transformation.

The simplest type of tool comes in the form of digital transformation self-assessments or surveys that analyze digital transformation readiness. These can take various forms. Some are marketing tools to obtain general information about a company. The details they cover vary widely, but they are all valuable for the

information they provide about the current stage of readiness. A self-assessment is a necessary starting point for any transformation process.

In principle, a maturity level assessment tool (including digital maturity) is structured into a variable number of analysis dimensions, each dimension being structured into sub-dimensions or categories depending on the research objective. Each category is assigned a scale or an index that will ultimately allow for the expression of an overall level of maturity.

After extensive internet research, four available tools have been selected for presentation.

3.1. The Emerson Digital Maturity Assessment Tool
(https://dmmindex.emerson.com/)

The Emerson Digital Maturity Assessment Tool (https://dmmindex.emerson.com/) is an evaluation instrument developed by Emerson Electric to assess the level of digital maturity. The objective of this tool is to determine which operational areas are capable of producing the fastest return on investment (ROI) and to identify digital transformation projects that will significantly impact the company's key performance indicators (KPIs). Originally developed by EE as a marketing tool, the instrument also proposes solutions that the evaluated company can implement.

The tool is structured into 9 dimensions, each with a predetermined number of sub-dimensions/categories/items that can receive scores on a scale from 1 (conventional/classic) to 9 (digitalized), as follows:

D1. Production Management
- Sd1.1. Control and optimization
- Sd1.2. Management and operations
- Sd1.3. Quality management
- Sd1.4. Fiscal reporting and regulation
- Sd1.5. Production planning and scheduling
- Sd1.6. Storage, transportation, and logistics

D2. Maintenance Management
- Sd2.1. Maintenance strategies
- Sd2.2. Work management
- Sd2.3. Spare parts management
- Sd2.4. Maintenance planning

D3. Energy and Environmental Sustainability
- Sd3.1. Energy management
- Sd3.2. Resource efficiency
- Sd3.3. Emissions monitoring and compliance

D4. Risk Management
- Sd4.1. Personnel safety
- Sd4.2. Operational risk

Sd4.3. Process safety
D5. Supply Chain Management
Sd5.1. Supply chain adaptability
Sd5.2. Product customization
Sd5.3. New product development
Sd5.4. Value chain integration
D6. Staff Culture
Sd6.1. Staff productivity
Sd6.2. Training and competency management
Sd6.3. Change management
Sd6.4. Continuous improvement
Sd6.5. Knowledge management
D7. Statistics and Analysis
Sd7.1. Analytics, reporting, and KPIs
Sd7.2. Control and optimization
Sd7.3. Critical point management
D8. Interoperability and System Management
Sd8.1. Data architecture and governance
Sd8.2. Business process automation
Sd8.3. IT-OT alignment
D9. Security and Operations
Sd9.1. Cybersecurity
Sd9.2. Infrastructure enablement

The result of the assessment consists of representing the level of digital maturity in a radar chart (Fig. 1), which shows the evaluated company's results in relation to the industry average it belongs to. Additionally, the tool provides percentage values that indicate the relevance of the digital transformation project for the speed of recovering the investments made for digitization. The result of the assessment consists of representing the level of digital maturity in a radar chart (Fig. 1), which shows the evaluated company's results in relation to the industry average it belongs to. Additionally, the tool provides percentage values that indicate the relevance of the digital transformation project for the speed of recovering the investments made for digitization.

Fig. 1 – The result of assessing the level of digital maturity using the Emerson tool (https://dmmindex.emerson.com/, accessed at 24.05.2023).

3.2. The Smart Industry Readiness Assessment Tool
(https://siri.incit.org/assessment)

The Smart Industry Readiness Index (SIRI) was created by the Singapore Economic Development Board (EDB) in partnership with a network of top technology companies, consulting firms, industry experts, and representatives from academia. SIRI includes a suite of recommendations and tools to support manufacturers - regardless of size and industry - to initiate, accelerate, and sustain their digital transformation efforts in production. SIRI covers the three essential dimensions of Industry 4.0: process, technology, and organization.

This tool has a structure based on 3 general dimensions, each with 2 or 3 sub-dimensions, with a variable number of items and a scale from 1 to 5 for the assessment of the current implementation level.

D1. Processes
Sd1.1. Operations (vertical integration)
Sd1.2. Supply chain (horizontal integration)
Sd1.3. Product lifecycle (integrated lifecycle)
D2. Technology
Sd2.1. Automation
I1. sales automation
I2. administration automation
I3. production automation
Sd2.2. Connectivity
I1. sales connectivity
I2. administration connectivity

I3. production connectivity
Sd2.3. Information
I1. sales information
I2. administration information
I3. production information
D3. Organization
Sd3.1. Human resource development
I1. workforce training and development
I2. leadership competency
Sd3.2. Structure and management
I1. inter-company and intra-company collaboration
I2. strategy and leadership

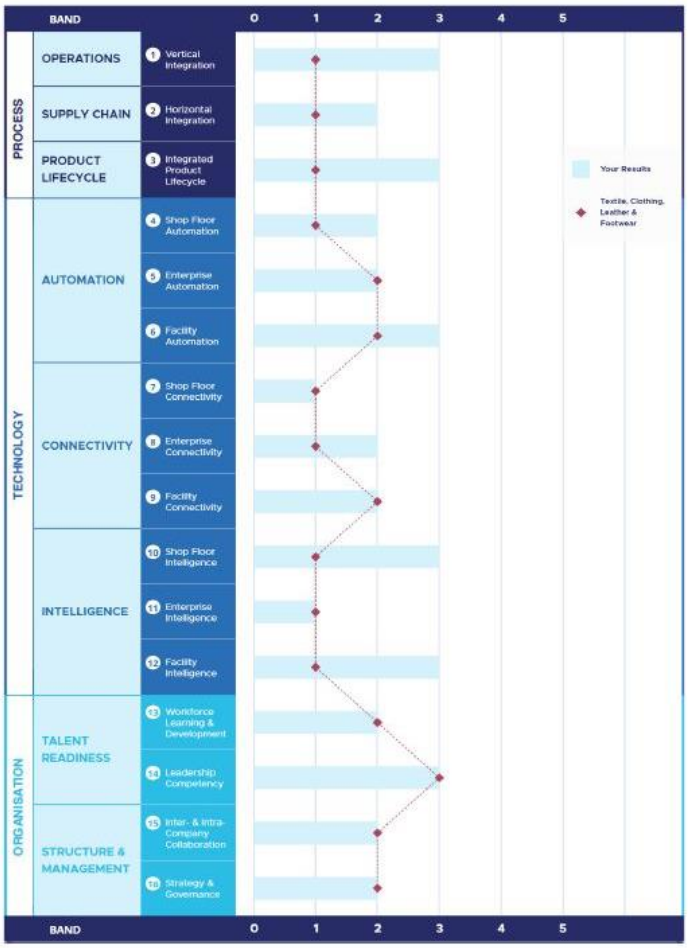

Fig. 2 – The SIRI assessment tool
(https://siri.incit.org/assessment, accessed at 23.05.2023).

Figure 2 presents an example of the result of the assessment of the level of digital maturity provided in graphical form, which allows for the comparison of the analyzed company/industry with other companies in the same industry or with other industries.

3.3. The Fraunhofer Digital Transformation Assessment Tool
(https://websites.fraunhofer.de/Digital_Transformation_Assessment/)

This tool allows for self-assessment of the level of digital transformation in a company. The output information provides insight into the operational areas where digital transformation is advanced, as well as areas that have potential for increased digitization. The questionnaire is structured into seven dimensions as follows:

D1. Corporate strategy
D2. Leadership and corporate culture
D3. Organization and processes
D4. Employees and competencies
D5. Technology
D6. Products and services
D7. Supply chain and networks.

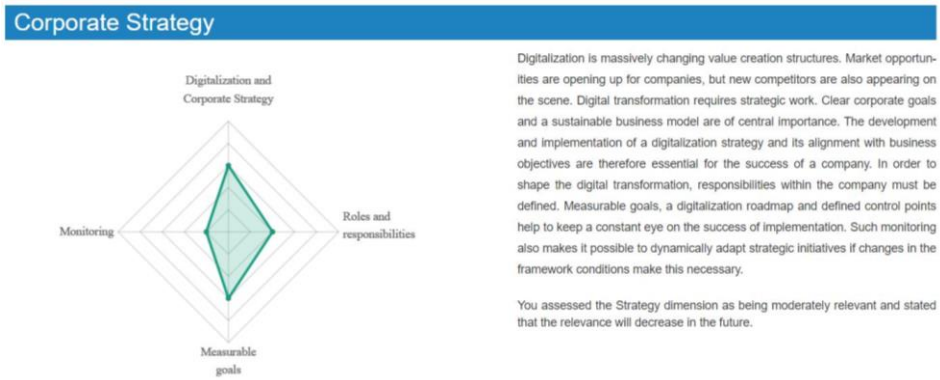

Fig. 3 - Result following the application of Fraunhofer tool (https://websites.fraunhofer.de/Digital_Transformation_Assessment/, accessed at 23.05.2023).

Figure 3 presents an example of the result of the assessment of the level of digital maturity provided in graphical form (radar chart), which allows for the investigation of the positioning of the company's operational domains in relation to the digital transformation process. Additionally, it enables a comparison of the level of digitalization with other competitors in the industry at an international level.

3.4. TUV Digital Transformation Assessment Tool
(https://www.tuvsud.com/en/i40-readiness-self-assessment)

The TUV digital transformation assessment tool allows for the analysis of companies' potential for digital transformation and to accelerate this process, with a focus on the level of implementation of specific Industry 4.0 (I4.0) techniques. I4.0 refers to agility, integration, hyperconnectivity, data, and smart manufacturing principles implemented at the corporate level and in line with the company's business objectives. The TUV tool assesses a company's readiness for digital transformation by using six dimensions, as follows:

D1. Operational management
D2. Supply chain management
D3. Process automation maturity
D4. Intelligent production systems maturity
D5. Workforce training and development
D6. Strategy and governance.

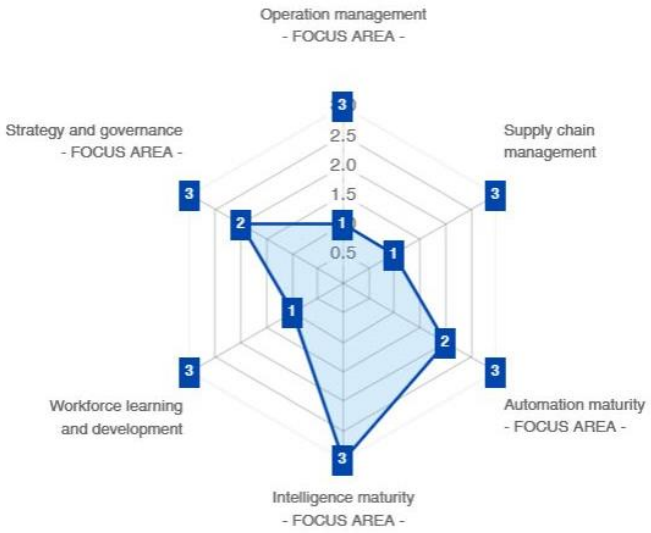

Fig. 4 – Result following the application of TUV tool
(https://www.tuvsud.com/en-us/digital-service/i40-readiness-self-assessment, accessed at 24.05.2023).

Figure 4 presents an example of the result of the assessment of the level of digital maturity provided in graphical form (radar chart), which allows for the comparison of the company's operational domains in relation to the digital transformation process. For each dimension, scores ranging from 0 to 3 are allocated, and the representation takes into account the critical designated indicator for the analyzed case.

4. Conclusions

Specialized literature that focuses on studying the process of digital transformation in general investigates the level of readiness of a system for digitization by proposing various maturity models. Maturity models are a representation of theories on how organizational capabilities evolve in a logical and predictive manner from one stage to another, in accordance with the theme studied in terms of digitalization processes. Just as there are controversies in the defining stage, the field of maturity models also presents numerous solutions proposed by researchers based on the research objective.

A digital maturity model involves defining dimensions and evaluation criteria that allow for the definition of maturity levels. Digital maturity models correlate the subsystems of an organization and enable the formulation of a digital transformation strategy.

To collect the necessary data for structuring a digital maturity model, evaluation tools are used, which can be accessed by a company for self-assessment. Four evaluation tools were analyzed and examined in terms of their adaptability to fashion industry companies. It was concluded that the development of a dedicated tool is necessary.

The results obtained from evaluating the level of digital maturity provide a clear perspective on the overall level of digitization of a company in each of the dimensions used. Radar charts highlight the strengths and weaknesses of the company, allowing it to identify areas that need improvement and develop appropriate strategies to manage the digital transformation process.

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PARTICULARITĂȚILE TRANSFORMĂRII DIGITALE ÎN INDUSTRIILE DE PRODUCȚIE / INDUSTRIA PRLUCRĂTOARE

(Rezumat)

Transformarea digitală este un proces global care generează impact în toate domeniile economice, administrative și sociale. În domeniile industriale, în special în cel al industriilor prelucrătoare, este în curs implementarea pe scară largă a conceptelor și principiilor Industriei 4.0. Tranformarea digitală reprezintă operaționalizarea principiilor Industriei 4.0, pentru acest scop companiile fiind determinate să formuleze strategii de implementare a procesului de digitalizare. O etapă premergătoare acestui demers este reprezentată de evaluarea nivelului de maturitate digitală sau a nivelului de pregătire pentru digitalizare, în acest scop fiind utilizate diferite instrumente. În prezenta lucrare sunt discutate câteva instrumente de evaluare, modul în care acestea sunt structurate și informațiile pe care le furnizează.