

DIGITAL FACTORY – A PREREQUISITE FOR REVITALIZING THE PRODUCTION SECTOR

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ABSTRACT

The high demand in certain industrial sectors requires a steadily rhythm of production. In addition, although in many cases mass production is being used, a particular emphasis has to be placed on individualized production. Connecting many products to the Internet, presence of sensors, wireless communications expansion, robot and intelligent machine development, real-time data analysis have the potential to turn the way in which production is made in what is considered to be the fourth revolution, called "Industry 4.0". The digital plant makes it possible to implement manufacturing processes, plant concepts and new technologies that, without simulation-based solutions, could not be put into practice or could be put into practice, as the case may be, but only by incurring considerable costs. The aim of this article is to study the benefits of digital factories in Romania as a prerequisite for revitalizing the production sector. The research methodology of the paper is focused on literature review and on the analysis of various studies and relevant findings in the field. From an economic point of view, digital factories represent a chance for relaunching, re-engineering production and evolving business models for services and products. To achieve the true Industry 4.0 potential, companies need to plan digital transformation. Manufacturers need to start searching for the best talent with digital skills and develop a clear plan on the manner digital factories will evolve.

KEYWORDS: *digital factory, digitalization, enhancement of productivity, industry 4.0, manufacturing industry.*

1. INTRODUCTION

Connecting many products to the Internet, wireless communications expansion, robot and intelligent machine development, real-time data analysis have the potential to turn the way in which production is made in what is considered to be the fourth revolution, named "Industry 4.0" (Caggiano & Teti, 2018). Industry 4.0 represents the current concern of manufacturing companies to set up as clearly and precisely as possible with the help of the Internet and software, manufacturing processes and technologies. Flexible automation technology, the Industry 4.0 or Internet of Things initiative, constitutes a fundamental change in the production process (Chen et al., 2018; Jeschke et al., 2017). An essential condition for this change is the intelligent interconnection of production systems and autonomous manufacturing units with self-handling and self-configuration, depending on the situation. Industry 4.0 is thus a new paradigm for structuring, designing and executing production processes using modern IT and communication methods. Connecting the physical world to the virtual world in cyber-physical systems will have a disruptive impact on technologies, manufacturing processes and people (Mueller et al., 2017).

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The digital factory represents a step forward from more traditional automation to a fully connected and flexible system that industry 4.0 offers (Burke et al., 2017). Digital factory is defined as a generic term for a wide network of digital models and methods, including simulation and 3D visualization. Its objective is integrated planning, application, control and continuous improvement in all material factory processes and resources associated with the product (Urbinati et al., 2018). The aim of the digital factory is to make a virtual replica of the real factory in order to visualize the processes that intervene in it to simulate them and understand them better. On the other hand, the digital factory is defined as the totality of personnel, software tools and processes that are necessary for the execution of real production in a virtual environment. In addition, between the tools and the digital factory methods, the vision of virtual production or virtual logistics are separated.

Virtual production refers to the coherent capacity of experimentation with the planning, evaluation and control of production processes and devices using digital models. The concept of virtual logistics describes the design software for logistics processes and structures. The scope of application of the Digital Factory is the production phase within the product life cycle: Product Life-Cycle Management (Sjödín et al., 2018). During this phase, the main operating units are established. Its objective is the integrated planning, application, control and continuous improvement of all manufacturing processes and resources associated with the product, for example, automobiles, airplanes.

Over the past 15 years, the variety of products has doubled while the life cycle has been reduced by 25%, resulting in the development and manufacturing process growing and requiring new models and technological solutions to meet customer needs. It can be said that digital factories have emerged as a necessity for streamlining production processes. The exponential technological advance, manifested by processing power, storage capacity and the multitude of developed applications have made industry evolve to this level (Richter, 2017).

In Europe, the concept of Industry 4.0 was launched and supported by Germany through government programs and top companies such as Siemens or Bosch. In America, the move is called "Smart Manufacturing," China is talking about "Made in China 2025", and Japan calls it "Innovation 25" (Li, 2018). They all want to develop an industry that launches products faster, increase flexibility and increase resource efficiency through digitization.

This paper presents the initial results of a more comprehensive study aiming to emphasize the advantages related to production processes and to production costs – actions that could significantly improve if manufacturers adopted the concept of digital factory. Thus, the methodology of this paper is focused on documentary analysis that included articles, studies, reports dedicated to digital factory, Industry 4.0, smart factories, digital technologies. The paper provides a theoretical framework regarding the implementation of digital factories to the manufacturing industry, as well as a detailed analysis of benefits of Industry 4.0 and digital factories. Furthermore, it provides some insight into the competitive advantages of Romania in the perspective of implementing digital factories.

2. LITERATURE REVIEW

In the context of globalization, organizations that want to seize new opportunities must have the competence to establish and refocus on new objectives using new capabilities is vital for the survival and profitability of the company (Girneata, 2014). In the context of globalization, manufacturing companies with high financial strength focus on research and development of new technologies that allow the automation of production (Girneata & Dobrin, 2015). One of the main advantages is that human errors generated from the manual operations are considerably reduced, eliminating costs related to defective products or the waste of raw materials (Dima, 2018).

All companies, no matter their expertise field, aim to improve their production process along with decreasing their production cost. A useful method for achieving this action is by using the *digital factory* concept. Basically, the digital factory represents a significant method issued from a set of software tools and methodologies, proposing the design, simulation and optimization of production systems (Bracht, 2005).

Moreover, this approach of digital factory is defined as an integrated way of improving the product as well as its production engineering processes, all these actions being accomplished by the use of simulation (Chen, 2009). In this way, we can consider the simulation as a key technology which can be applied in virtual models on different information levels and stages in order to improve the factory planning.

The digital factory could present a vision systematized as following: a central database creates a network connection between all computer-aided tools necessary for the planning of new products and production plants as well as for the operation of the factories. For ensuring that the need for simultaneous engineering is accomplished, new structures in the product development and manufacturing processes are needed. In this way, the whole factory becomes a simulation on the computer like a continuous virtual reality model, which has the ability to be applied, with 0 interruptions, all the way starting from the product idea until reaching the final disassemble of the production plants and buildings.

Digital factories represent a new step for structuring, designing and executing production processes using modern IT and communication methods (Cheng et al., 2018). This results in completely new ideas and concepts, for which IT solutions are decisive precursors, especially from **two perspectives**:

- First of all, a 3D-based simulation software makes it possible to visualize and validate processes and production tasks. This is important because the production facilities are seldom built from scratch, but often redesigned in parallel with the production in progress. This is not something new in itself, and the corresponding solutions for the digital factory have been used for a long time. In order to achieve the ideas and concepts of Industry 4.0, factories and virtual plant models must be an accurate picture of actual production systems, not only geometric and cinematic, but also logical behavior and command of manufacturing units, a so-called digital twin, or shadow factory. In this manner, companies can the step from the rigid, pre-established processes to the agile production units with their own organization.

- Secondly, the digital factory makes it possible to implement manufacturing processes, plant concepts and new technologies that, without simulation-based solutions, could not be put into practice or, as the case may be, could be put into practice, but only by incurring considerable expense. The more robot-based applications are used not only for simple handling tasks but also for more complex production steps, the more programming and simulation tools are needed. IT solutions meet these complex applications by providing the operator with the programming and simulation environment necessary for the realization of applications, which by means of a Teach-In manual can no longer be efficiently represented or of the quality required by the process.

The high demand in certain industrial sectors requires a steadily rhythm of production. In addition, although in many cases we are talking about mass production, a particular emphasis has to be placed on individualized production. Digitizing these processes creates a number of very important benefits for a producer (Richter et al., 2017):

- Increasing speed, efficiency and flexibility in the product development and manufacturing process;
- Organization of processes from the first variant to the finished product through parallel operations;
- Avoid prototypes and costly tests by exposing a mature product from the very first test by using modern simulation processes on a computer - either for the design of a vehicle or for a plant that produces it.

From an economic point of view, digital factories represent a chance to relaunch, re-technologize production and evolve business models for services and products (Burke et al., 2017). From a political and social point of view, it is intended to reindustrialize Europe for sustainable development, after two decades in which production has been shifted to Asia and only one in 10 EU-level manufacturing companies is actually producing by itself. The European Commission has developed a "European Industrial Renaissance" plan. In 2014, value added in production accounted for only 14.5% at EU level and the growth target was 20% by 2020.

3. RESEARCH METHODOLOGY

The study aimed to present the manufacturers the main advantages for transforming a factory into a digital one. It is known that every change attracts a certain reluctance after it. So based on this assumption, the manufacturers need to know the main advantages that could be obtain by passing from a normal factory to a digital one (improvements in production flow, decreasing production costs etc.).

Therefore, the research methodology focuses on analyzing the factories from Romania as well as presenting the main improvements that could be brought once these factories transform to digital ones. As we have already mentioned, this represents an ongoing research, since at the moment the paper analysis only the theoretical aspects of the situation.

3.1 Implementing the digital factory to the manufacturing industry

The use of Virtual Reality by the design and optimization of systems and production processes is often entitled as Digital Factory.

Digital factory represents a virtual picture of a real production sequence. Basically, by the digital factory we can entitle the environment integrated by computer and information technologies, in which the reality is replaced by virtual computer models. The main actions of the digital factory are:

- Planning support;
- Analysis;
- Optimizing complex products production;
- Creating proper conditions for products production;
- Requires team work.

With the Digital Factory methods, the field of action between product development and production control will be closed. Digital Factory in the general context of the company can be divided into four levels:

1. Databases / data center.
2. Integration platform.
3. CAD tools.
4. Organization and planning of the workflow.

The objective of the digital factory is to obtain the best practices, processes and standardized resources so that they can be used in another product or planning model as reusable building blocks. The process redesign should be based on the four digital factory guidelines:

1. A common database to reduce redundant data.
2. The standardization of processes, resources and equipment.
3. The logical clarification of activities, competencies and responsibilities regarding the process of integration of work processes.
4. The potential for automation.

The activities in the Digital Factory include (Hovanec, 2017; Chen et al., 2018):

- Acquisition of product design data.
- Programming of process times.
- Planning of production processes.

- Resource Planning (design proposal, identification number).
- Planning of the use factor.
- Planning the layout of processes and workplaces.
- Systematization of costs.
- Ensure the results of planning.
- Data transfer to plan operations.

For manufacturers the obstacles to digitization scare them away from modernizing their factories, making them to ignore the potential long term benefits that could derive from this action. Still, for easing their vision about digital factory, we presented a six step plan:

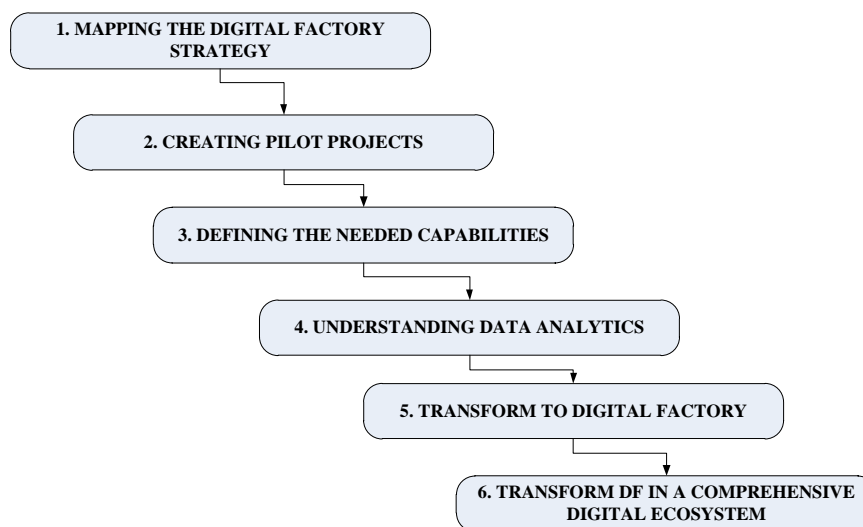


Figure 1. Roadmap for transforming normal factories into digital factories

Source: Authors

Following this plan, we consider that manufacturers could develop it in order to apply it to their factories. This represents a possible scenario for transforming a normal factory into a digital one.

As main advantages of becoming a digital factory we can present the following:

- ✓ Reducing risks like entrepreneurship risk by introducing a new production type;
- ✓ Verifying processes before the production starts;
- ✓ "Virtual" visits of the production hall;
- ✓ Optimizing the allocation of production equipment;
- ✓ Reducing bottlenecks and collisions analysis in different areas;
- ✓ Good resource utilization;
- ✓ Decrease the number of prototypes;
- ✓ Designing ergonomics analysis, etc.

One of the main advantages of the digital factory is represented by the fact that by working with digital factory managers are able to test and reveal all possible production issues and shortages before production starts. In addition, there are several physical and immaterial planning objects considered by the digital factory, namely:

- ✓ Plant, logistics and machinery – facilities' and equipment's efficient planning in close relation to material and information flows;
- ✓ Layout and floor space – proper arrangement of rooms, spaces, objects, etc;
- ✓ Complementary operations – integrating the auxiliary functions linked with factory's main processes;
- ✓ Organization – structures' planning and sequences;
- ✓ Design, building and infrastructure – defining an appropriate design of the working environment along with the efficient supply of required media (VDI, 2008).

3.2 Integrating the simulation information in digital factory

The production processes of the future are based on new systems, structures and processes. The software of the digital factory makes an essential contribution to this transformation through:

- Enhanced interconnection of IT facilities and systems (IoT)
- Enhanced Data and Information Transparency (Production Monitoring, Predictive Maintenance)
- Decentralized, self-contained decisions with cyber-physical systems
- Secure and, at the same time, technically improved working conditions, such as the use of cooperative robots.

If the robot-based applications include more complex production steps, it will increase the need for programming and simulation tools. Therefore, IT solutions become the roadmaps of these complex applications, providing the operator with the programming and simulation environment necessary to make possible applications that by means of a Teach-In manual cannot be efficiently represented or at the quality required by the process.

By developing a system that supports the action of simulation information, the main focus should be on the capacity of integrating the information linked to the product and process using the resource data, all of these being in different formats.

In this way, the agents of digital factory simulations have to analyze three main information models in order to support the global coordination decisions:

- a) The *product* information model;
- b) *Manufacturing* information model;
- c) *Order* information model.

In order to better express the relationship between these three factors, we propose the figure below:

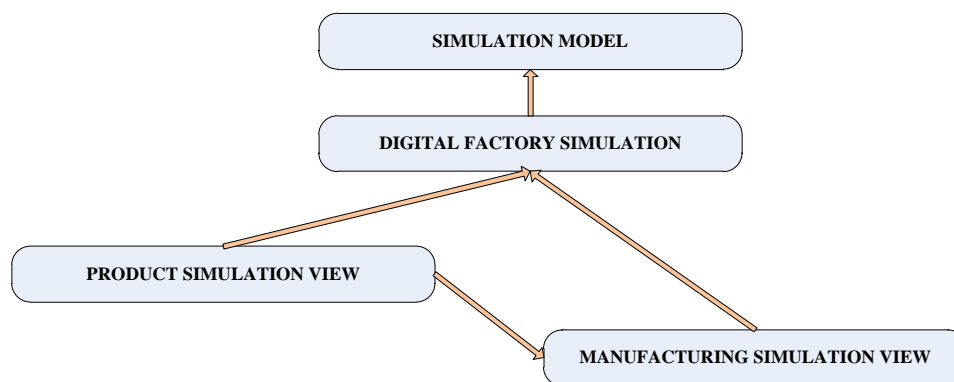


Figure 2. The link between product, manufacturing and simulation model information

Source: Sliskovic (2011)

What is it important at this step of the process is that the manufacturing model keeps all manufacturing process information for every products while the product model demands, in order to accomplish the product fulfillment, only some specific manufacturing process data.

These factories should allow the products to be customized on the production line: an incomplete product line would "transmit directly to the machine what services it needs" and the final product would be assembled immediately.

Germany has opened the new battlefield in the digital revolution in a Siemens factory where the products communicate with the machines via the Internet and the human contribution is minimal. The Siemens plant in Amberg is part of a concerted effort by Germany's government, companies, universities and research institutions to develop "smart", fully automated, Internet-based factories.

At the intelligent "pilot" factory in Kaiserlautern, BASF's chemical manufacturer has produced a personalized liquid shampoo and soap. Here's how the experiment took place: When placing an

online test order, the identification plates on the empty shampoo bottles on the production line simultaneously communicated to the production equipment the type of soap desired, the perfume, the color of the cover, and the type of label. There is the possibility that each bottle that comes out of a production line is completely different from the others. The experiment was based on a wireless network where machines and products were the only ones to communicate with each other, and people contributed only by placing orders.

The Siemens plant in Amberg shows what is currently possible in an operational plant. At this time, the factory operates approximately 75% on an automated pilot, with 1150 employees primarily operating computers and monitoring the production process.

3.3 Benefits of Industry 4.0 and digital factories

The grand industrial revolution depends on small technological breakthroughs in various areas:

- Applying information and communications technology to digitize information and integrate systems into conception, development, manufacturing and use of products.
- New software technologies for modelling, simulation, virtualization and digital manufacturing.
- Development of cyber-physical systems to monitor and control physical processes.
- The evolution of 3D printers and additive manufacturing to simplify manufacturing.
- Decision support for human operators, the emergence of intelligent tools and assistance using augmented reality.

The main identified benefits of digital factories in the context of Industry 4.0 are illustrated in Figure 3. These refer to time, cost, flexibility and integration.

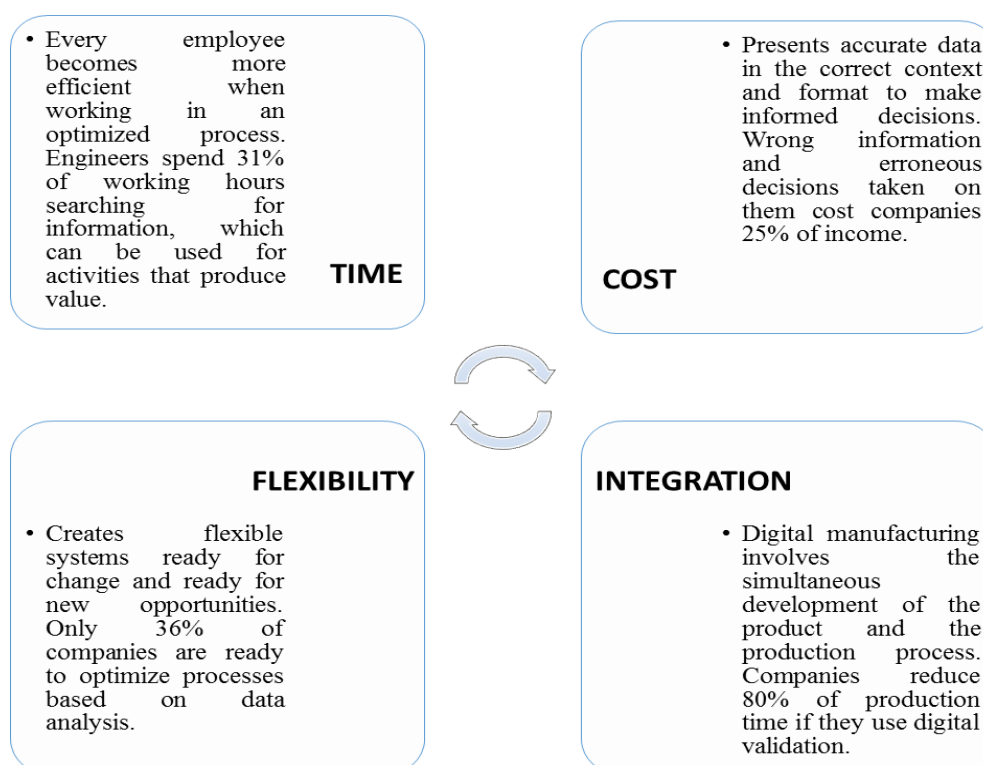


Figure 3. The benefits of digital factories in the context of Industry 4.0

Source: Designed by authors, based on literature review

It is considered that the digital factory will allow optimization of all phases in the product life cycle. Virtual design and functionality simulations developed in parallel with manufacturing planning lead to a much faster market launch, significant cost reduction and superior quality. Everything will be

driven by data analysis. The Digital Factory integrates Product Lifecycle Management, Digital Manufacturing, Manufacturing Execution System, and IoT components that communicate feedback from on-going manufacturing processes or from in-service products.

4. COMPETITIVE ADVANTAGES OF ROMANIA IN THE DIGITAL FACTORY PERSPECTIVE

There are many factors that place our country in a very favorable position, with the prospect of moving to Industry 4.0 and implementing digital factories. Even if there are voices claiming that Romania cannot make the leap from 2.0 to 4.0, there are several advantages that this country possess:

1. Strategy Industry 4.0 aims to bring production back to Europe, focusing on personalized production, high quality and manufacturing near the consumer market. Eastern European countries are the best destinations for investing in new production facilities.

2. The automotive industry will be the one to engage most resources and make the most investments. Fortunately in the last 10 years, this industry has grown strongly in Romania, and the number of automotive suppliers is steadily increasing. Even if there are two car manufacturers, Dacia and Ford, the supply chain is well developed. Of the top 20 global automotive suppliers, 13 are present in Romania with production facilities. According to ACAROM, the turnover of suppliers is twice as high as that of manufacturers.

3. The speed of the internet connection in Romania is one of the highest in Europe. Internet of Things will generate a huge amount of data and will require very high transfer and processing speeds.

4. IT companies will have increased involvement, Industry 4.0 will attract new cyber-physical systems (CPS) or services: IT security, Big Data analysis, M2M solutions and Artificial Intelligence. The IT sector is well developed in Romania and can support investors' efforts in digital factories.

5. The skills required for the digital factory can be found in Romania. There is a production tradition and good technical universities, as evidenced by the numerous investments in automotive R & D centers.

Many of the activities carried out today, serving production machines, precision positioning, assembly, quality inspection will be done by robots. Not only are they more effective, they also communicate perfectly with decision and control systems.

The labor market will change, but it is hard to predict if there will be more or fewer jobs overall. Robots are still in the beginning and cannot replace people in all activities. On the other hand, the rate of return on investment in a fully automated factory is not attractive now (Hovanec, 2017). All forecasts are based on historical data, but exponential technologies are completely new, so the effect of large-scale evolution and use is hard to predict. The risk is to have massive unemployment for certain categories and the lack of staff with digital skills.

The digital factory value is that it will not only reduce costs in the purchase of parts and equipment, but also offers significant advantages in terms of maintenance, flexibility and reliability (Richter et al, 2017). These routine planning activities will be transferred to the software. All participants in the planning process do their activities on the computer and create networks by workflow. Measurable progress will be made in hours during the planning process. This guarantees the availability of the required data at the right time, detail and context.

All relevant planning data (product, process, resources) will be recorded by the areas involved only once and managed by a database. These are available in the future for all planners, equipment and service providers, always in the current form. The main objective is to use the data for the new models in the early stages of planning to evaluate the costs. Not only large companies are currently dependent on new technology. However, the reasons that prevent the growth of its use are the high

cost and benefits. In addition, there are shortcomings in daily business operations in many areas required to increase acceptance by the user. Prerequisite for the success of digital factory is having full support from the managers and the management of digital factory as a business philosophy.

5. CONCLUSIONS

This paper represents an ongoing research and it had, as a main purpose, the idea of emphasizing the advantages related to production processes and to production costs – actions that could significantly improve if manufacturers would adopt the concept of digital factory.

The main role of digital factory is to adopt an integrated approach for optimizing the product, as well as its production process. By integrating soon enough the product development in production planning, we could reach some significant savings in time and cost, since a big part of the product cost is induced in the early phases of the product development cycle.

Also, it can be stated that the vision and progress for realizing the digital factory included an essential formulation and some certain potential solutions off various problems posed by future production and planning methods. Basically, each person that aims to face the global competition must diminish the time needed for products' fabrication. For this scope, the digital factory becomes a complete prerequisite.

Furthermore, there were identified significant development opportunities for Romania in the context of Industry 4.0 and the implementation of digital factories. The direction in which the industry goes is very clear. Data management and security will be key issues to solve. To achieve the true Industry 4.0 potential, companies need to plan digital transformation. Manufacturers should start searching and training the best talent with digital skills and develop a clear plan on how it will look digital factory.

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