DIGITAL TRANSFORMATION OF INDUSTRIAL COMPANIES IN THE CONTEXT OF INDUSTRY 4.0

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Rezumat. *Piaţa bunurilor de larg consum se apropie de punctul în care doar inovaţiile aduse produselor nu mai sunt suficiente pentru menţinerea în faţa concurenţei; extinderea numărului de produse personalizate şi Industry 4.0 creează o piaţă volatilă care le impune producătorilor să se adapteze şi să răspundă prompt prin digitalizarea întregului lanţ de valori.*

Abstract. *The consumer goods market is quickly approaching the point where innovation in products alone will no longer be enough to keep companies ahead of their competitors; increased product personalization and Industry 4.0 are creating a volatile market that will require manufacturers to adapt and respond quickly to keep a competitive edge by adopting the digitalization of the whole production value chain.*

Keywords: Industry 4.0, Industrial Internet of Things, Digital Manufacturing, Smart Factories.

1. Industry 4.0 - introduction

Industry 4.0 (the fourth Industrial Revolution), the Internet of Things and the Internet of Services are among the most commonly used terms to describe the accelerating intelligent connections among people, products, equipment, services, things and the data generated during production and throughout the entire lifecycle of the product.

The term of "Industry 4.0" continues to be changed and completed with new technologies developed in the last few years. Beginning with the German government's involvement, this public-private partnership (BASF, Bosch, Daimler, Deutsche Telekom, Klöckner & Co., and Trumpf) supports the next revolution in manufacturing – creating decentralized, autonomous real-time production.

The core of Industry 4.0 deals with creating adaptive, agile manufacturing networks. Industry 4.0 envisions the ability to harness intelligence from production while using connections from the objects being built to the people and machines building them – in order to accelerate innovation, quality and efficiency.

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The virtual design and simulation of products must be connected to the intelligence gathered during manufacturing, but it goes beyond that.

The Internet of Things, or the IoT, is an abstract concept about the interconnection of physical things that have their own intelligence. The connectivity of the IoT has become a driving force of Industry 4.0. The realization that a machine or system can catch and prevent human errors on a daily basis has led to greater scrutiny of how to rethink supply chain complexity, and to create the infrastructure that supports the intelligence of the things in those networks. As the technology evolved during the last 10 years, implementing Industry 4.0 in a company in order to transform it into Digital Enterprise (also called Smart Factory) is not so expensive as it was before, according to a 2015 study of Accenture (see Figure 1).

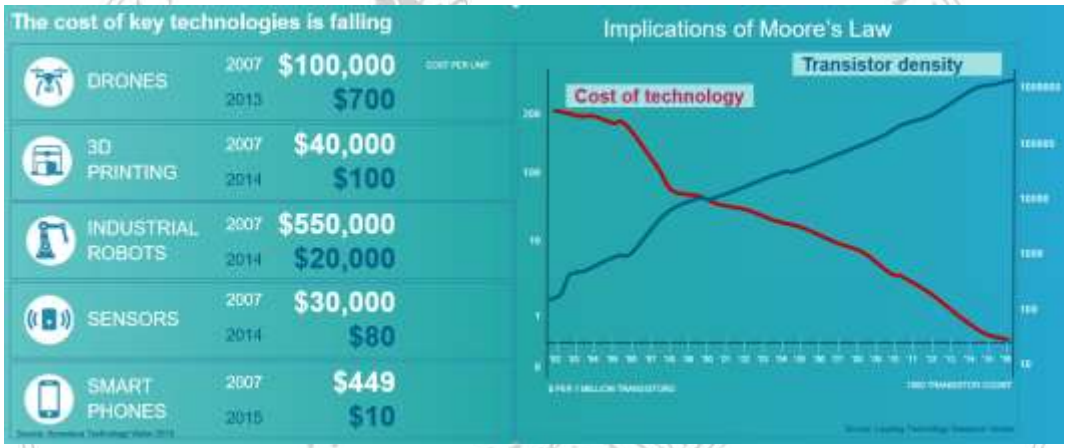

Fig. 1. Cost of key technologies used in Industry 4.0

2. Manufacturing innovation requirements in Industry 4.0

Industry 4.0 is quickly becoming the new reality in the market, and every innovative manufacturer must embrace it to stay competitive. To achieve full manufacturing innovation, businesses must be able to define what they need and the required operational changes to stay successful in the next phase of industrial production design.

As smart machines, materials and products begin to proliferate, so does the data they produce. How should innovative manufacturers prepare themselves to harness this data and these intelligent networks to be more competitive, more responsive and more agile?

In this chapter, we will present six key capabilities that will become even more critical for manufacturing business as Industry 4.0 becomes reality: speed, advanced automation, connection, insight, effective action and agility.

2.1. Speed

Speed is one of the most critical factors determining today's market leadership. Companies that get their innovations to market more quickly than the competition will capture greater market share. For manufacturers, speed must always be coupled with quality. But the increasing complexity of processes with increased data inputs and decision criteria create added barriers to speed.

New product introduction (NPI). The growing power of consumer preference is driving the proliferation of customized features. Even with the added complexity for NPI, companies will simultaneously face growing pressure to shorten time to market.

Engineering and component changes. Speed means that companies must react quickly to both after-market feedback and complex supply chain changes and interruptions as they attempt to shorten the cycle time for engineering changes.

Cost optimization. Continuing optimization to remain cost competitive requires quick detection and response to fluctuations in supply alternatives and market prices.

Quality issue resolution. Anticipating potential quality issues before they happen will require continued monitoring of the intelligence of every node on the intelligent network.

Industry 4.0 anticipates that already existing complex products, processes and supply chains will multiply in complexity with the exponential growth of intelligent data streams into the mix. With supply chains more complex than ever, getting faster at the same time requires a different paradigm – driving the urgency of agile and adaptive manufacturing networks. That requires an infrastructure with specific characteristics.

2.2. Advanced automation

To achieve manufacturing innovation in Industry 4.0, manufacturers will have to invest in smart, Industrial Internet of Things-enabled machines and controls; these machines and controls should allow equipment to provide real-time information on processes and their condition – for example, up, down, supply needs or quality problems.

If we consider that devices, materials, components and products will also be intelligent, automation will become networked across plants and the supply chain. This will generate new feedback channels, error reduction capabilities and real-time awareness of quality and upstream and downstream conditions that affect the entire production line.

This is where the Enterprise Manufacturing Execution System (MES) is still the central core, managing and controlling signals across areas of automation.

Even beyond production, intelligence from these orchestrated automation networks will feed into improvement cycles, engineering changes and the next product lifecycle. It will bridge the gap between engineering and manufacturing – closing the loop across product development and the factory floor.

What is the promise of this new intelligent automation network? With more intelligent processes orchestrated by the Enterprise MES, the leap forward in efficiency feeds production speeds with far fewer resources and at a higher quality.

2.3. Connection

Connection takes on new meaning in Industry 4.0 manufacturing. Connection is required to harness the power of the entire infrastructure's intelligent nature. Even the most brilliant innovations in automation can only deliver a local benefit if it's only operating on an island. In fact, cells of automation that focus on optimizing a local plant or an individual line can actually hurt overall performance if they aren't synchronized with the overall operation – what lies in the realm of the Manufacturing Execution System, or the MES (see in Figure 2 a sample connection).

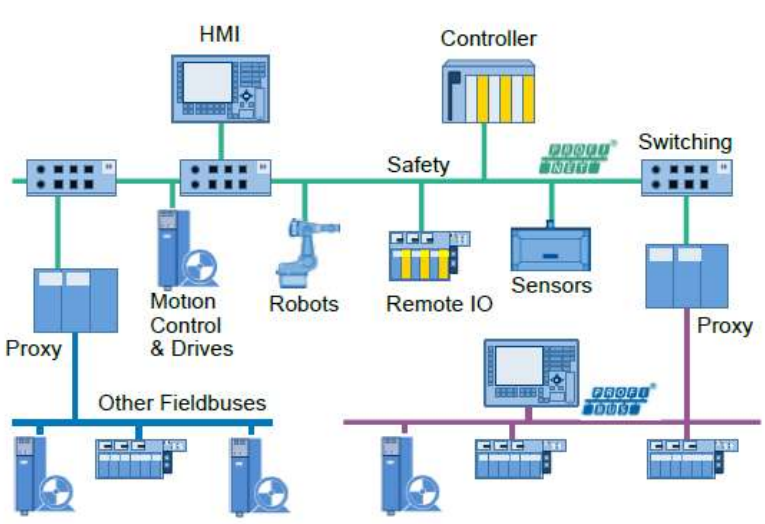

Fig. 2. Sample connection

Maximizing the throughput on a line that feeds a slower operation can generate additional work-in-process inventory. In that case, excellent automation on an island won't increase final production rates; it will actually increase the amount of

capital tied up in inventory, which affects the overall economics of a business and its ability to fund growth initiatives.

2.4. Insight

Speed, advanced automation and connection all have an impact on a manufacturer's ability to compete in Industry 4.0 manufacturing. But companies also need insight to ensure these capabilities will work well together.

We know that data is a huge element of Industry 4.0 manufacturing. We have intelligent machines and automation systems giving us not only their own up/down status, but also information about materials, processes, the throughput performance and maintenance requirements.

We have intelligent products giving us information not only about the working/not working status, but also about how and how much it's being used. We also have nodes of the supply chain that can signal to us whether we should make alternative sourcing decisions. And, we have consumer networks giving us data on their preferences.

2.5. Effective action

Companies must be able to use the intelligence from the networks (from sensors and other hardware equipment) to make the best decision at the earliest possible moment. But also must go beyond using the information to choose the best action: the companies must use this intelligent network to monitor and verify how effective that action is.

It's a responsive feedback loop across many nodes on the network. Is the action producing the desired correction or prevention? What evidence do the company has that the action taken will solve the problem completely? Are there additional actions that need to follow?

The manufacturers that can leverage their new intelligent networks to take the swiftest, most appropriate actions and to verify effectiveness will protect and build their brand in Industry 4.0.

2.6. Agility

Agility anchors every other capability described before. Agility means having the ability to quickly respond to rapid change. Many companies now strive to design, build and deliver products anywhere to enable faster local response with standardized and effective processes. Some companies are moving to local production. Others are closing smaller plants to create highly flexible mega-plants that can build a wider array of products with economies of scale.

Effective action requires not only analytics, but the delivery of information to plant-wide and enterprise-level decision makers, an infrastructure for rapid collaboration and the communication of the action to elicit an immediate network-wide response.

The communication is a networked feedback loop. Information is delivered to the required decision-makers to collaborate on the decision, and the resulting action is expedited back to the entire intelligent network where its effectiveness is confirmed. The agile manufacturer can absorb the action and rapidly reconfigure for the required action.

Operational agility goes hand-in-hand with innovation delivery. Both must occur to achieve market leadership. The ability for an enterprise to make better decisions more rapidly, and control the rapid response of its operations more swiftly than the competition will be a critical capability in Industry 4.0.

3. Software technologies used to digitize the complete manufacturing chain

There are many software companies which produce software applications for different stages of a product development, but the main issue is how to integrate all the information into one system. Data transfer between systems usually generates lots of errors. Out of the most important companies, like Siemens PLM, Dassault Systems and PTC, only Siemens PLM offers a complete automation solution covering all major Industry 4.0 requirements: the Digital Enterprise Software Suite (see Figure 3).

Fig. 3. Digital Enterprise Software Suite

3.1 Product Lifecycle Management (PLM) applications

In general, for any product development there are software to digitize the product, production planning and simulation, robots off-line programming. This software is part of Product Lifecycle Management, as we will see described below:

Design: Siemens NX, Solid Edge used for mechanical design. Fibersim for unique and complex design and manufacturing methodologies of advanced composite materials. Syncrofit is a family of specialized engineering products for designing and manufacturing complex assemblies and large aerostructures.

Programme: Polarion is an application lifecycle management (ALM) enterprise solution. Software is an integrated part of the product development across all industries and ALM enables manufacturers to continuously integrate, verify and validate the growing software content they build into their products. Together with Teamcenter, Polarion is an integral part of the product development process and systems driven product development.

Simulate: NX Nastran, Simcenter, Femap

Build: Tecnomatix (Robcad, Process Simulate, Plant Simulation), Line Designer, Intosite used to create an virtual environment of a digital factory (see Figure 4).

Fig. 4. Digital Factory using all PLM components

The main advantage of using software application to digitize the development and manufacturing planning from Siemens is that all the information is connected by Teamcenter. Also it is possible, using Teamcenter for data management, to exchange data between multiple systems (for example the 3D models designed in

NX CAD can be accessed in real time by manufacturing simulation engineers using Process Simulate).

3.2 Manufacturing Operation Management (MOM)

Usually when production starts the design and manufacturing departments do not have any feedback from what is happening in production with the equipment. Also control engineers have issues to connect PLC (Programmable Logic Controls) to the sensors and signals of mechanical devices. This gap between PLM and MOM can be eliminated by connecting them through the same source of information (Teamcenter). The manufacturing operation management software applications are described below:

Analysis: Mindsphere, Omneo. These two are cloud based applications used to collect data from production through PLC and other hardware equipment and to monitor the production.

Automate: Total Integrated Automation (TIA) Portal (see Figure 5) which can manage all the PLCs from a factory, the postprocessors Sinumerik for CNC machines.

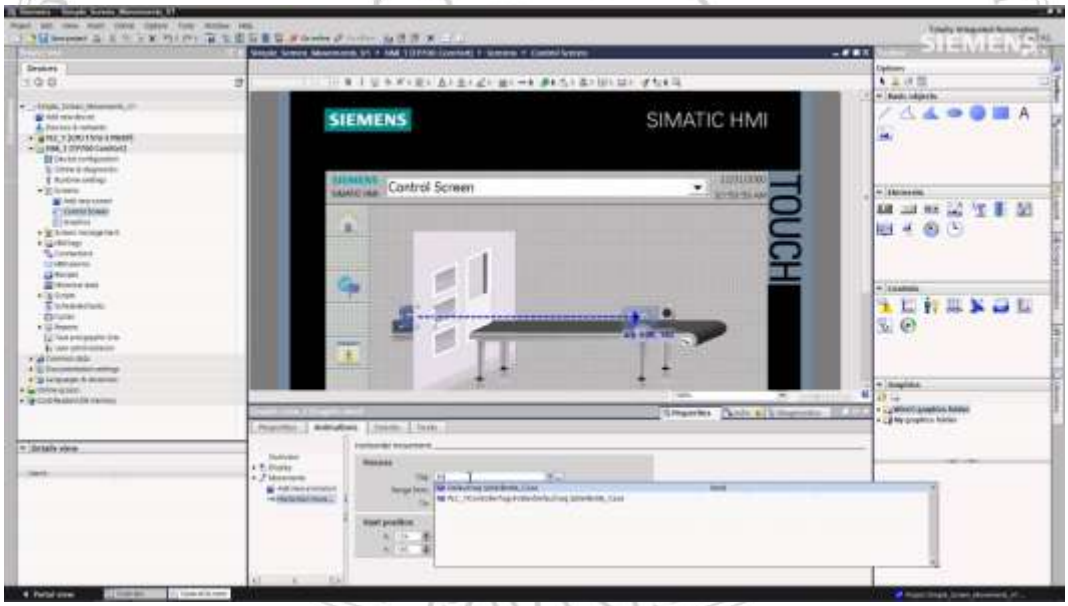

Fig. 5. Integrated system

Execution: Simatic IT, IBS QMS, WinCC, Camstar, Preactor are manufacturing execution system (MES) software applications used to monitor production, increase productivity and, in the case of Preactor, to have a predictive maintenance based on BigData collected from production in MindSphere cloud.

If we put together all the software applications from Siemens, from product lifecycle management to manufacturing operation management, we can see how important it is to have all the information in digital form. Without an integrated system of the complete manufacturing value chain digitized, the companies from industry will struggle to develop new personalized products mass produced. Only by changing the way products are made in the context of Industry 4.0 (see Figure 6) the companies will survive.

Fig. 6. Integrated system

To get the most out of Industry 4.0 technologies, and to get past square one with a digital business model, companies will have to take a third step: prepare for a digital transformation. Manufacturers should begin today to join the hunt for the best digital talent, and think about how to structure their digital organization. Data management and cybersecurity will be critical problems to solve. Many companies will find that a "two speed" data architecture can help them deploy new technologies at the speed required, while also preserving mission-critical applications.

Conclusions

Digital systems and the steady increase of connectivity among them are transforming the entire industrial production chain. Every machine, every system, and every step of the production process generates vast amounts of data. In order to consolidate, understand, and purposefully use this data, we need intelligent cloud-based systems, open operating system for the Internet of Things. This is how big data is transformed into smart data. As a result, downtimes are reduced, production is boosted, and efficiency is enhanced.

Abbreviations

PLM - Product Lifecycle Management

MOM – Manufacturing Operation Management

IoT – Internet of Things

PLC – Programmable Logic Controller

MES – Manufacturing Execution System

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