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THE ROLE OF DIGITAL INFORMATION MODELS FOR HORIZONTAL AND VERTICAL INTERACTION IN INTELLIGENT PRODUCTION

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Abstract. *Intelligent production is the future of industrial production. It is the leading way to a new industrial era and it best defines the concept of the Fourth Industrial Revolution. Getting the real-time data on quality, resources and costs it provides significant advantages over classical production systems. Intelligent production must be built on sustainable and service-oriented technological and business practices. They are characterized by flexibility, adaptability and self-learning, resilience to failures, and risk management. The high levels of automation, on the other hand, become a mandatory standard for them, which is possible thanks to a flexible network of production-based systems that automatically monitor the production processes. Flexible systems and models that are capable of responding in real time allow internal processes to be radically optimized. Production benefits are not limited to one-off production conditions, and the capabilities include optimization through a global network of adaptive and self-regulating manufacturing components belonging to more than one operator.*

Key Words: *Fourth Industrial Revolution, Industrial Information Models, Automation, Production Based Systems*

1. INTRODUCTION

The introduction of intelligent production is a production revolution in terms of cost and time savings. Intelligent production brings many advantages over conventional production, or it is the transition to future smart production. The interaction between embedded systems based on highly specialized software and dedicated user interfaces that are integrated into digital networks create a whole new world of system functions.

A well-established production and engineering system is one of the prerequisites for the normal operation of intelligent production systems. This system shall fully satisfy, under the existing conditions, the requirements of operation ability and functionality of industrial

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processes in an industrial plant. This part includes services and features for operational activity that are executed as web-based software components and can be used continuously in contact with both internal and external objects. AT&T's Bell Laboratories stands as an exemplar of this model, with many notable research achievements but a notoriously inwardly focused culture. Other celebrated twentieth-century examples of this model include IBM's TJ Watson Research Center, Xerox PARC, GE's Schenectady laboratories, Merck, and Microsoft Research. In other countries, such as Japan, the closed model remains quite popular to this day [1, 2].

This traditional innovation process is closed because projects can only enter it in one way, at the beginning from the company's internal base, and can only exit in one way, by going into the market. Traditionally, new business development processes and the marketing of new products took place within the firm boundaries. In future, intelligent embedded systems will contribute to more efficient manufacturing and more manageable technological processes, with the principles of network econometrics undergoing full communicative change [3]. This is also related to the impact of Web technologies on production technologies, which is shown in Fig. 1.

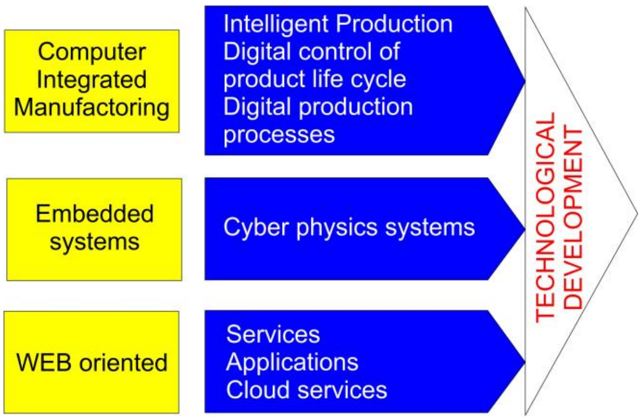

Fig. 1 Web Impact of Web Technologies on Production Technologies

The connections of information technologies with people, machines and products have been rapidly realized thanks to the rapid development of technology transfer standards and a comprehensive information infrastructure. The current development and future development as a change in the requirements in information and communication technologies on the way to the Fourth Industrial Revolution is given in Fig. 2.

2. Horizontal and Vertical Integration

There are conditions and opportunities, based on models and trends in the generated data, to make decisions in real time. It is also possible to build digital information integration models for horizontal and vertical action. Horizontal integration means the integration of various information technology systems in the production and automation equipment at different stages of the production and planning process in order to find a constantly optimal solution [4]. Vertical integration means the integration of information technology in IT systems at different hierarchical levels in the production and automation equipment in order to find a consistently optimal solution.

The vertical and horizontal machine-internet, machine-human and machine-machine collaboration along the value chain, in real time, is the basis of the intelligent production system.

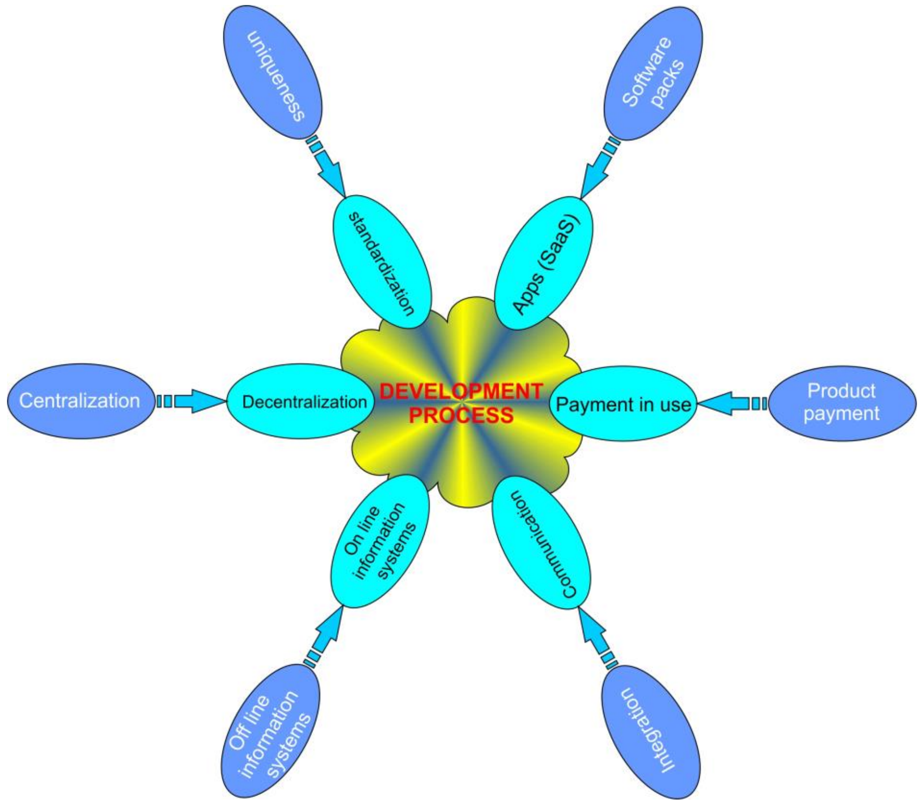

Fig. 2 Change in the requirements to information and communication technologies

Horizontal compatibility means integration of different technology and information systems into different stages of production and product planning. Therefore, the automated system is formed by a single material, energy and information flow that makes connections both inside the company and with external companies. In doing so, it maintains optimal and continuous horizontal compatibility at the level of intelligent solutions.

Vertical compatibility means the trouble-free integration of different information technologies into information systems at different hierarchical levels in the vertical production structure. The goal is to maintain an optimal management solution.

The interaction between embedded systems based on highly specialized software and dedicated user interfaces that are integrated into digital networks create a whole new world of system functions. Thus, in intelligent production, the ability to communicate and decentralize data processing, as well as optimization, is done through embedded systems equipped with dedicated software and hardware. These embedded systems are connected wirelessly (partially) to the information net-works of other systems of stakeholders, companies, and others with a view to exchanging data and accessing web-based services. All this requires interoperable communication interfaces and standardized protocols, continuously integrated IT systems, control and fast, real-time communication. Fig. 3 shows the development of the IT architecture of intelligent systems [5, 6].

ERP is a software architecture that facilitates the flow of information among the different functions within an enterprise. Similarly, ERP facilitates information sharing across organizational units and geographical locations. It enables decision-makers to have an enterprise-wide view of the information they need in a timely, reliable and consistent fashion. ERP provides the backbone for an enterprise-wide information system. At the core of this enterprise software is a central database which draws data from and feeds data into modular applications that operate on a common computing platform, thus standardizing business processes and data definitions into a unified environment. With an ERP system, data needs to be entered only once. The system provides consistency and visibility or transparency across the entire enterprise. A primary benefit of ERP is easier access to reliable, integrated information. A related benefit is the elimination of redundant data and the rationalization of processes, which result in substantial cost savings.

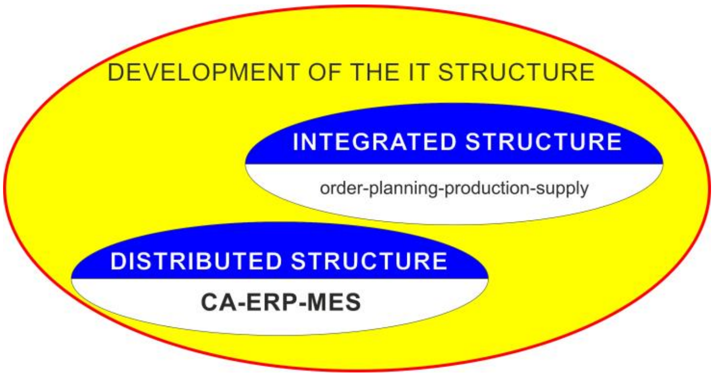

Fig. 3 Development of the IT architecture of intelligent system

As a result, data and services can be used in real time, creating great flexibility and ability to meet customer requirements. It is also important to follow the development of the information technology architecture shown in Fig. 4.

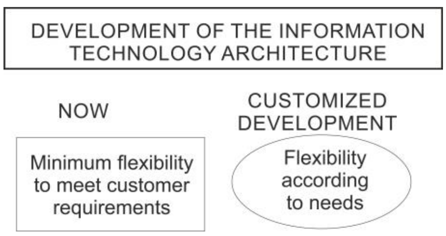

Fig. 4 Development of the information technology architecture

3. Turning Innovation into Product Concept

The concept formation aims at further development of the innovation idea and its transformation into a real innovative product designated for the market, as well as at turning consumer wishes into a manufacturing-wise feasible product. Usually the company has at least several innovative ideas about a product [7].

We are aware of different approaches towards the formation of product concept, but those that got established in practice are less. Fig. 5 shows the concepts that got established as approaches for solving the problem.

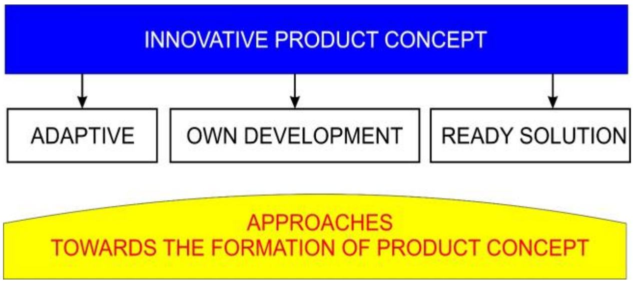

Fig. 5 Approaches towards the product concept formation

In the case of the adaptable approach the most important thing is to satisfy consumer requirements and the market requirements. The own development provides greater capacities, as well as better freedom of usage and creates competitive advantage for the company but is related to the maintenance of higher innovative potential.

The acceptance of ready solution (open innovation) is related to the need of particular prerequisites to realize it and the need of preliminary research about its purposefulness. Nevertheless, in all the cases the concept should be directly related to market and it should define certain market positions [8].

After the formation of the product concept we proceed to the next phases, design and production. In view of the smooth running of these processes they should be planned in advance and we should choose the instrumentation for time and resources management.

4. Design and Implementation of Innovative Products

When it comes to designing innovative products and processes we take the technical-economic indicators as input data that include: production order, including the necessary number of items to be produced, technical economic product indicators (type, mass, size etc.), requirements towards the construction and technology of the product manufacturing, accounting value with stages and performance terms, economic and social effectiveness, ecological requirements, specific requirements towards the production, storage and realization of the product [9].

The design and implementation of innovative products pass through several stages to be reviewed in short. The process of designing innovative products is graphically shown in Fig. 6.

In most cases the suggestion for the most effective technological concept for product manufacturing includes [10]:

- Basic information about the technical terms and conditions of manufacturing the product,
- Managerial information about the types of technological processes, standards and work organization,
- Inquiry information that includes description of progressive methods of processing, catalogues, reports, technical norms and operational production regimes.

The design takes place during a single stage that combines draft and working project. The draft solution includes the selection of version of the innovative product. Usually it is being developed in several versions thus resulting in certain complexity because of the versatility of the factors impacting the choice of the optimal version. In principle, one of the indicators is perceived as the basic optimization criterion (objective function) [11]. Hence the draft project should be perceived as a systematic solution in order to clarify the cause and effect of the basic parameters and distribute their impact onto the end result, including producing the item.

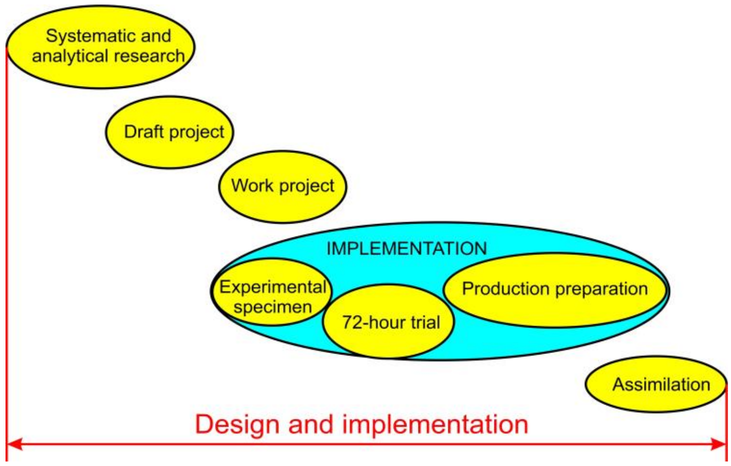

Fig. 6 Process of innovative products' design

The draft solution of the innovative product usually includes: draft constructive-technological documentation of the product (draft drawings and documentation), description of the main technical-economic product indicators, bill of quantities that contains the costs under the individual stages, design, aesthetics, market requirements, effectiveness or expected profit from the production and realization of the product, other specific requirements, ecology etc.

5. Software Packages

In terms of horizontal integration, companies shall be able to use next-generation ERP systems that are suitable for use in an integration (hybrid) environment. These are intelligent ERP systems using Service Oriented Architecture (SOA). This allows the use of functions and services by other software providers through standardized interfaces [12].

These ERP systems are integrated with technological processes that are compatible with intelligent production systems. The Internet of Things allows direct communication of an ERP system with CPS (cyber physical systems) and intelligent products at the production level. By using in-memory databases and large amounts of data, CPS sensors can process the information in real-time. Thus, in the case of production changes, simulation is performed using in-memory technology in real time. Direct access to production data from the ERP system ensures transparency of technological and business processes for all individual orders. These solutions are easier to perform because the simulations and forecasts (created by the ERP system) are presented in a handy way on mobile devices such as tablets or smartphones. The new ERP system uses Cloud Computing for Services Access to Internet (IOS) capabilities. This part of the Internet includes services and features that are executed as web-based software components and can also be used in contact with external companies and users.

In building Cyber Physical Systems (CPS), depending on their intended complexity and type, different types of software are used. Firstly, these are the most used software tools included in: product development (CAD/CAE), process planning (CAP, CAM), order management (CRM, ERP, /PPS, SCM), operational management (MES, BDE, QM) and service (IPS) [13]. Secondly, these are the software packages built in recent years by industrial companies, which enable them to track their entire value chain, bringing them closer to the requirements of the (CPS). Thirdly, the trend of software development towards web services and platform connectivity is outlined. Many companies, technology centers and research institutes work in this direction. This may also be the case for digital business software. A portfolio of software based systems is developed, which is based on a Backbone Data Platform and includes the modules;

Product Lifecycle Management (PLM) module. It allows you to virtually completely create and optimize new, unproduced products. It enables you to effectively manage the product lifecycle from the idea and its design to its production, maintenance and recycling [14, 15].

Manufacturing Execution System/ Manufacturing Operations Management (MES/MOM) module. This module is highly saleable, offers a variety of functions and allows production to be combined with quality and transparency as well as to speed up the production process. This complete solution maintains the entire value chain of product development, planning, production, growth and operation.

Totally Integrated Automation (TIA) module. It is an open system architecture that covers the entire production process and provides effective interaction of all automation components. This comprehensive approach to totally integrated automation includes:

- Industrial Communication
- Industrial Security
- Integrated Engineering
- Industrial Data Management
- Integrated Security.

Technological building blocks of the Digital Single Market

The most important technological building blocks of the Digital Single Market defined by the European Union are:

- New Generation Networks (5G)
- Computer Cloud Services.
- Internet of Things.
- Technologies for processing large information arrays.
- Cybersecurity.

These are areas of extreme priority in terms of rapid development of the necessary directions for the Fourth Industrial Revolution.

6. CONCLUSIONS

On the basis of the above, the following conclusions can be drawn:

The connections of information technologies with people, machines and products have been rapidly realized thanks to the rapid development of technology transfer standards and a comprehensive information infrastructure.

The vertical and horizontal machine-internet, machine-human and machine-machine collaboration along the value chain, in real time, is the basis of the intelligent production system.

A portfolio of software based systems, based on a Backbone Data Platform, is proposed and includes the modules;

- Product Lifecycle Management (PLM).
- Manufacturing Execution System/Manufacturing Operations Management (MES/ MOM).
- Totally Integrated Automation (TIA)

Flexible systems and models that are capable of responding in real time allow internal processes to be radically optimized.

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