

Production Employees Knowledge in Digitized Production Environment

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Abstract

Skills and abilities of production employees influence radical the production processes performance, value added and efficiency of production flows. Presented paper analyse important parameters of digital literacy of employees in production processes and confronts the results with the actual requirements on production employees in digitized technology environment. Crucial conclusions of research realised in industrial companies will be presented. Orientation of production employees on standardisation of digitized knowledge and skills will be confirmed as crucial point of digitized production processes as a whole.

Keywords (12 font)

production, process, knowledge, productivity, performance

1. Introduction

In last 5 year, we have a lot of experiences from industrial companies from the area of employee's ability to learn new technologies, connected with automation a digitization of production processes. Due to the continuous automation of simple manufacturing processes, the number of workspaces with a high level of complexity will increase, which results in the need of high level of education of the staff. The challenge is to qualify employees to shift their capacities to workspaces with more complex processes and ensure the retention of jobs in changing working environments (Hecklau, 2016). Industry is currently undergoing a transformation towards full digitalization and of manufacturing processes. Although a common agreement exists on the necessity for technological advancement of production technologies and business models in the sense of Industry 4.0, a major obstacle lies in the perceived complexity and abstractness which partly hinders its quick transformation into industrial practice (Erol, 2016). Knowledge transfer is becoming increasingly important in organizations. Organizations that are able to transfer knowledge effectively from one unit to another are more productive and more likely to survive than those that are less adept at knowledge transfer. Although organizations are able to realize remarkable increases in performance through knowledge transfer, successful knowledge transfer is difficult to achieve (Argote, 2000). By focusing on the psychological processes that underlie knowledge transfer within a unit and between units within a firm, this special issue complements work in cognitive psychology on knowledge transfer at the individual level of analysis as well as work in strategy and organizational theory on knowledge transfer at the firm or industry levels of analysis. This special issue opens up the "black box" of knowledge transfer in organizations by providing new theory and empirical evidence on the psychological processes that are the foundations for knowledge transfer in organizations. Large increases in productivity are typically realized as organizations gain experience in production. These „learning curves have been found in many organizations. Organizations vary considerably in the rates at which they learn. The volume of process related data is growing rapidly: more and more business operations are being supported and monitored by information systems. Industry 4.0 and the corresponding industrial Internet of Things are about to generate new waves of process related data, next to the abundance of event data already present in enterprise systems. However, organizations often fail to convert such data into strategic and tactical intelligence. this is due to the lack of dedicated technologies that are

tailored to effectively manage the information on processes encoded in process models and process execution records. Process related information is a core organizational asset which requires dedicated analytics to unlock its full potential /Polyvyanyy, 2017). The changing business environment has influenced new innovation development, which is currently described as the upcoming 4th industrial revolution. The development of Internet of Things, Big Data concepts increased the productivity of various businesses and influenced the appearance of new business models. The appearance of cyber-physical systems and possible implementation in various other industries than production is even more stimulating the realization of the ideal Industry 4.0 concept (Navickas, 2017).

2. Theoretical background

Using of the industrial engineering methods for optimal and flexible balancing of production operations in digitized environment of INDUSTRY 4.0 concept determines the process effectiveness and secondly the process improvements and innovations (Zhou, 2017). Industrial companies implement in last year various automatized and digitized technologies and were opened an interesting point – teamwork synchronisation between employee and digitized technology. Production lines have various components, each of which can influence the productivity of the production system. Studies have been conducted on the methods to improve assembly line productivity, both from a worker’s ergonomic perspective and from a system simulation perspective (Pakdamanian, 2016). Valuable perspective of the applicability of digitized technologies as cloud computing, big data systems, 3D visualisations and projections bring in the world of process management new impulses for job standardisation, workplace organization and production process planning and management improvements. Concept INDUSTRY 4.0 opens the next industrial revolution and open new horizons of productive and innovative thinking. Firstly, there is necessary to identify the computational intelligence (CI), this involve the knowledge of computer algorithm to capture hidden knowledge from data and to use them for training “intelligent machine” to make complex decisions without human intervention (Chromjakova,2017). Cooperation of production employees requires except for CI the employee’s ability to realise the production operations with “intelligent machine” (Casalino, 2018).

As simulation is becoming more prevalent from design and planning to manufacturing and operations, material processing can also benefit from computer generating knowledge through soft computing. Secondly the vision of smart shop floor is based on the INDUSTRY 4.0 that denotes technologies and concepts to cyber-physical production systems. In smart shop floors, cyber-physical system monitors physical processes, creates a virtual copy of the physical world, and makes decentralized decisions. Cyber-physical production systems are the digitized and with relevant software support automatized technology, it allows virtual world to store data, process data, communication, cooperation with each other in real time. Every physical entity in the smart shop floor is regarded as an autonomous intelligent logical unit that performs operations guided by distributed control functions. Computing power and optimisation approaches are embedded into each logical unit to make decisions to agilely respond to frequent occurrence of unexpected disturbances at the shop floor (Tang, 2018).

With the recent introduction of ambitious industrial concepts as INDUSTRY 4.0, a massive focus has been placed on the development of and efficient robotic workplaces connected with human digital literacy. Amongst all the operations robotic systems can take care of, handling remains a preferred choice due to a combination of factors including its often-repetitive nature and low skill requirement. In industrial companies, innovation and production process improvement is considered a relevant aspect of success and long-term survival. Industrial companies should be able recognize that innovation contributes from digitized production systems create the competitive advantage in a more competitive, challenging and changing labour market (Palazzeschi, 2018). An ideal plant layout should provide the optimum relationship among output, floor area and manufacturing processes. The efficiency of production depends on how well the various machines, production facilities and employee’s amenities are located in a plant. Only the properly laid out plan can ensure the smooth and rapid movement of material, from the raw material to the end product. Plant layout encompasses new layout as well as improvement in the existing plant layout (Jain, 2014).

The fourth industrial revolution is characterised by the increased use of digital tools, allowing for the virtual representation of a real production environment at different levels, from the entire production plant to a single machine or a specific process or operation. In this framework, digital factory technologies, based on the employment of digital modelling and simulation tools, can be used for short term analysis and validation of production control strategies or for medium term production planning or production system design/redesign. To configure and verify correct layout of the upgraded manufacturing cell with the aim to increase its performance in terms of resource utilisation and throughput time, 3D motion simulation and discrete event simulation are jointly employed for the modelling and

simulation of different cell settings for proper layout configuration, safe motion planning and resource utilisation improvement (Caggiano, 2018).

INDUSTRY 4.0 is an epoch-making revolution which brought the manufacturing market much faster changes and severer competitions. As an important part of the manufacturing system, facility layout has direct impact on business benefit, at the same time, despite the intelligent factory, intelligent production has its own characteristics. However, there is one point on which industry that have basically formed a consensus: it is not true that INDUSTRY 4.0 does not need human beings, on the contrary, human initiative plays and unabated role in the development of INDUSTRY 4.0. Based on the digitized production system and the traditional optimization model, the mathematical models built the best solution for combining safety, sustainability, high efficiency, and low cost (Li, 2018). Augmented reality is a key technology for the development of smart manufacturing. One of the main advantages of augmented reality is that it can help workers to accomplish several tasks, making it possible the shift from mass production to mass customization. However, it is still not clear how these promises can be fulfilled in an industrial scenario. In particular, the question about which display solutions fit better the industrial constraints remains open (Uva, 2018). Digitized technologies with artificial intelligence and automated supermarkets run by collaborative robots (cobots) working without human supervision have sparked off new debates: what will be the impact of extreme automation, turbocharged by the Internet of Things, artificial intelligence and the INDUSTRY 4.0, on Big Data and omics implementation science? The Internet of Things builds on broadband wireless internet connectivity, miniaturized sensors embedded in animate and inanimate objects ranging from the house cat to the milk carton in smart fridge, and artificial intelligence and cobots making sense of big data collected by sensors INDUSTRY 4.0 is a high-tech strategy for manufacturing automation that employs the Internet of Things, thus creating the Smart Factory.

Extreme automation until “everything is connected to everything else” poses, however, vulnerabilities that have been little considered to date. First, highly integrated systems are vulnerable to systemic risks such as total network collapse in the event of failure of one of its parts, for example, by hacking or internet viruses that can fully invade integrated systems. Second, extreme connectivity creates new social and political power structures. If left unchecked, they might lead to authoritarian governance by one person in total control of network power, directly or through her/his connected surrogates (Ozdemir, 2018). With the advent of INDUSTRY 4.0 maintenance strategy faces new demands to avoid the hysteresis of the conventional passive maintenance mode and the non-feasibility of the periodic preventive maintenance mode. In view of the inherent polymorphism of manufacturing systems and with the objective of maximizing benefits, there is important to proper a novel cost-oriented predictive maintenance based on mission reliability state for manufacturing system (He, 2018).

3. Analyse and research of production employee’s knowledge in digitized production environment

Digitization has already enhanced productivity and quality in many industries. Based on the various forms of cooperation, general requirements for communication and cooperation concerning production processes are required. Radical new influence on employee’s economics has the communication, information and knowledge generation and organisation of production operations by digitized workplaces and layouts (Karl, 2018). Employee’s knowledge of the selected attributes of virtual world in smart shop floor enable store data, process data, communicate, and cooperate with each other in real time. Every physical entity in the smart shop floor is regarded as an autonomous intelligent logical unit that performs operations guided by distributed control functions (Tang, 2018).

Today’s industrial enterprises are confronted by implementation of INDUSTRY 4.0 concept with basic problem – stabilised manufacturing and supporting processes. In the world of traditional industrial firms, there is another revolution. It is characterized by the transition from sophisticated factories to smart factories, complex manufacturing processes and systems supporting digital and virtual process and production technologies. Computer-driven digital management processes monitor physical transaction processes, creating the original computer copy of the 3D virtual reality process, which is the basis for designing and managing production systems. Physical objects thus become digital objects transformed in the form of digital data into horizontal and vertical information networks and in the form of virtually shared data that serve as a basis for real-time added value creation.

The result is more flexible processes, optimal real-time production schedule, effective multivariate production. Important part of digital literacy by employees confronted with INDUSTRY 4.0 processes there is the ability of machine learning, image digitization, data aggregation, visualisation techniques, as well as the knowledge of job standards for process/realised product operations testing, automation, management of datasets (Sherren, 2017).

Without people engagement, there isn't possible to ensure the digitized communication between employee's and digitized production technologies.

Key interests of scientific research were derivatives from the individual interview, realized during 2017-2018 in 300 industrial companies in Czech and Slovak Republic. Interest groups were production directors, masters, supervisor, team leaders, machine labour. Formulation of core research hypothesis for the identification of production process digital literacy by employment:

- H1 Interoperability - cyber-physical systems link each other's human activities to compact, intelligent processes that communicate with each other on a digital basis
- H2 Virtualization - by sharing virtual copies of production systems, online digital sensors create data that can be used in virtual 3D planning and control simulation models, while providing data for 3D product prints in real-world production
- H3 Decentralization of process management - the ability of cyber-physical systems to make real-time decision making in the form of a digital manager
- H4 Real-time data availability of the digital manager - the definition of services claimed by manufacturing processes and systems provides full electronic support for on-line production process management
- H5 Modularity - Flexible adaptation of smart plants and smart manufacturing technologies to change production requirements, effective change management with support of digital manager

The questionnaire survey also highlighted the fact that the automation and digitization of production and supporting production processes is also important in setting up a process of digitization of production processes, where the knowledge and experience of employees of selected workplaces can be used with a high efficiency to continually increase the performance of production processes. Here is a demonstrably high assumption that the production technology is eligible for the subsequent digitization of processes in connection with the digital setting of the worker's position. It also has the potential to create new qualifications for workers in digitized production.

Next will be tested the following through digitized technologies managed tasks (results achieved by individual interview in 300 industrial companies, the results in the table are summarisation of important answers and further scientific dedications):

Table 1: Core tasks realized by employment in digitized technologies (source: author)

Specification of production order	Setting up and digitizing of identification codes for product parts and relevant types of production operations Creating digital bindings of the "product - manufacturing process" Providing comprehensive digital inputs and outputs
Production portfolio management by production cell	Identification, setting up and standardization of the collaborative platform for the digitally controlled manufacturing process Flexible simulation of the production process Database of availability and performance parameters of production technologies
Production planning and scheduling	Setting up and standardizing the platform and procedures for digital decision making Personalization / Setting up the e-carrier of digital links Install and manage cloud storage of production data
Flexible job organization	Multi-level, digitally-organized production scheduling in real time Organization and administration of data analytics in real time Creating online error identification and fault elimination
Production process realization	Online Workplace Performance Monitoring Scheme Optimizing material and information flows Digital management of production processes
Customer satisfaction	Setting up a digital protocol for testing the quality of the manufactured product, the production process being carried out Creation of digitally controlled process improvement systems

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Research results can be summarized follows:

H1

Under “human activities” we understand all activities connected with preparation of production plan – realization of production order by workplace – expedition of order to customer with strong cooperation with computer aided production system. “Human” should know the rules and standards of communication with computers and digitized machines. An industrial company has clearly identified processes that it wants to integrate within Industry 4.0 in according to the interoperability of employees integrated in the digitized production technologies. The verification of this hypothesis has confirmed that most industrial companies are uniquely focused on the identification of key horizontal processes, oriented directly to the design and management of production processes, and other supporting processes on the vertical line only marginally. The key processes digital literacy abilities and competencies necessary to implement the Industry 4.0 concept were marked:

- Integration of production planning and management - 26% of companies
- Digitization and automation of manufacturing processes - 18% of companies
- Quality management online in manufacturing processes - 14% of companies
- Flexible real-time production organization - 12% of companies
- Adequate personification of production processes and on-line organized communication and management of production processes - 11% of companies
- Optimal setting of supply chains linked to manufacturing processes - 11% of companies
- Setting up maintenance systems and on-line monitoring of machines and equipment - 10% of companies
- On-line reception and production organization based on customer order specification - 10% of companies

H2

An industrial company has virtualized production and supporting processes, enabling to the staff simply electronically managed designing, planning and organization of production tasks on flexible production basis. An absolute prerequisite for implementing the Industry 4.0 concept is the company's ability to have stabilized key manufacturing processes. Forty percent of companies in the automotive industry spoke out of this hypothesis, for the engineering industry 82% of the companies confirmed the validity of the hypothesis, 92% were declared by subcontractors for automotive companies and 56% were for the other industry category. In summary, the automotive sector has the greatest need to stabilize key processes.

In according to the identification of important virtualized knowledges and skills there were identified following:

- mechatronics digital literacy - primarily, production technology focuses on minimizing downtime and cost savings in the presence of flexible, modular and casting tools that are able to quickly change ideally while running technology and quickly adapt to new manufacturing settings. This also means that these process elements will claim minimal interference within a defined industrial engineering when integrating into existing production processes. We use the "Plug-and-Play Paradigm" principle for this installation. Because the sub-production modules are heavily dependent on each other and vary greatly, there must be a mechanism to automatically identify, identify and evaluate the typology of the production system.
- provision of modular procurement infrastructure in conjunction with the possibility of mutually combining selected production modules universally and with minimum configuration costs, there must be adequate procurement infrastructure within a given system architecture that takes the appropriate functionality in procurement processes and management of procurement of production modules. These include energy procurement, data routing and comprehensive security management (security means the safety of used and transferred production dates between workplaces, suppliers and customers). The procurement infrastructure itself must be modular in order to have the required flexibility of production facilities and not just the source of process conflicts
- skills with designing of individualized mass production - Production technology is able to operate economically even with lower production batches. The architecture of the digital process scheme must assume a solution that makes it possible to uniquely identify manufactured products and then optimally link them in the production process. The solution must enable the production modules to individually structure and process the assigned production parameters. At the same time, it is necessary to maximize product and varied varieties - the processes

integrated in the production module are assembled so that they can be realized through specific parameters in the widest possible variety

- internal and external network connectivity procedures possibilities and their service ability - the existence of a fast IT connection allowing transparent viewing of ongoing production processes, identification of error messages, subsequent activation of functions oriented primarily to the elimination of errors, thanks to these functionalities can be optimized in real time. The intersection information point must take the integration function and all relevant information and setting parameters directly from the manufacturing device, which then logically configures the standardized schema. At the same time, this intersection declares the interdependence of the production facilities, their parameters and functionalities. The architecture of the manufacturing system assumes the flexible integration of IT system for planning, control and optimization of production facilities through the modular setting of parameters and system elements. Newly developed IT systems must allow for a relatively quick and cheap integration of intersections and consequently a seamless modular functionality of all production facilities integrated in the production technology.
- the goal of system architecture is the economic production of individual products under the conditions of mass production. The manufactured product is the starting point for the concept of manufacturing processes. Complexity and product variability define the number and layout of production modules as part of the production process.
- the product specification is implemented with a view to product digitization (Product-ID), which allows direct connection to digitization of production processes and active control of production processes. In this context, the following specifications are included:
 - Electromechanical specification - a mechanism for loading and describing a digital product
 - Information and technical specifications - creation of digital product model

Each production module has a specific manufacturing, assembly, test or test process. Depending on the needs of the complex manufacturing process, it is possible to set individual parameters exactly. Depending on each product claiming an individually set manufacturing process, the individual manufacturing modules must be mutually compatible, relatively adaptable and cost-effective in terms of optimal interconnection.

H3

The goals for decentralisation of process model were validated through the qualitative and quantitative research as follows:

- create a comprehensive digital process map and digital management
- clear and functional coordination of the production plan according to flexible production rules in conjunction with available production capacities and supporting production processes (production planning, logistics, quality, maintenance)
- defined on-line prioritization of operations and tasks in connection with optimal sequential planning and implementation of "just in sequence optimization" manufacturing orders
- marked physical objects (technologies, machinery, tools, and tools) have their item in a digital manager who schedules them for production operations and controls according to their assigned ID
- cooperative scheduling and organization of production in the triangle "customer - producer - supplier" works optimally through the web interface, this interface actively and reliably utilizes the created interactive environment and data warehouse
- an adequate process model is set to optimize the planning process, organization and production management by using large data warehouse and cloud computing to ensure customer satisfaction in real time (delivery of production order by given time schedule)
- determined on-line optimal combination of supplier deliveries following on-line order / order specification from the customer, including current logistics delivery costs
- continuously improving customer relationship and enhancing customer intelligence through programmable customer service storage with the intention of better programming of production capacities and their more efficient use in real time

H4

Real data time availability is based on the successful implementation of digitized technologies in the production process environment. The definition can be considered as key: "E-production is an Internet application in manufacturing. E-production is not just automation of production ("digital production") but an effective link between automation and Internet technologies (Hwaiyu, 2004). The concept of slim production in the link to agile production

and constraint theory understands the implementation of e-production as a transformation of mass production into a group of flexible and efficient manufacturing processes. The goal of lean manufacturing is to produce only what the customer requires and at the same time minimal production costs. Restriction theory requires optimizing material and information flows while minimizing bottlenecks in production. Both of these models are entirely dependent on the ability to adequately anticipate future production requirements and the setting of an optimal "pull" system, which assumes:

- implementation of the Manufacturing Execution Software (MES) in order to coordinate production scheduling and scheduling, set process quality and manufactured products, deploy SCADA / HMI systems for data capture and analysis in functional machine-to-person interface with respect to productivity of production technologies, management of maintenance and warehouse management
- adequate interconnection of the MES system with the ERP system (Enterprise Resource Planning), which brings to the system the organization and control of the flow of the source requirements in the production process, which subsequently interconnects with the parameters of the supply and customer chain in the form of on-line Internet communication.

Implementing this infrastructure for building e-production brings many positive effects: 25-60% material stock reduction, 30-45% reduction in cycle times, 17-55% WIP inventory reduction, 35-55% reduction in administrative preparation of the planning process and production control (Hwaiyu, 2004). The indisputable fact of e-production is computer-aided production planning and organization (CAD, CAM, CAPP), especially if we work with a huge amount of production data and we strive to meet flexible requirements according to the daily forecast. As can be seen, linking data management, virtual reality and interfacing between simulation and customer demand is a prerequisite for this phase.

H5

Modularity – flexibility of production system is strong determined through the relevant parameters, oriented on the modularity – flexibility mapping:

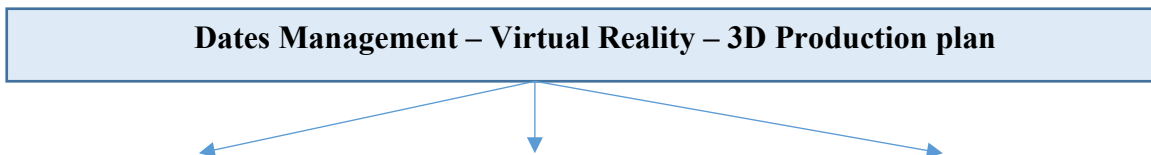
- On-line frequency of planning and re-planning of production requirements (shorter product life cycles and correspondingly desirable reduction of production lead times)
 - the time-consuming process of digital planning and scheduling (the need for a faster delivery to the customer)
 - Quality and reliability of scheduling and scheduling of production processes (reducing the cost of supporting production processes)
 - Flexibility of planning in the digital environment by better allocation and setting of competences for process and activity process holders (emphasis is placed on optimizing alternative production costs and utilization of technologically and digitally managed production capacities)
 - the complexity of the scheduling and scheduling process (essential condition is the optimal on-line communication in the chain "customer - production - supplier")
- For digital planning purposes, it is appropriate to have a built-in digitized infrastructure that determines the downstream effects of digital production technologies.

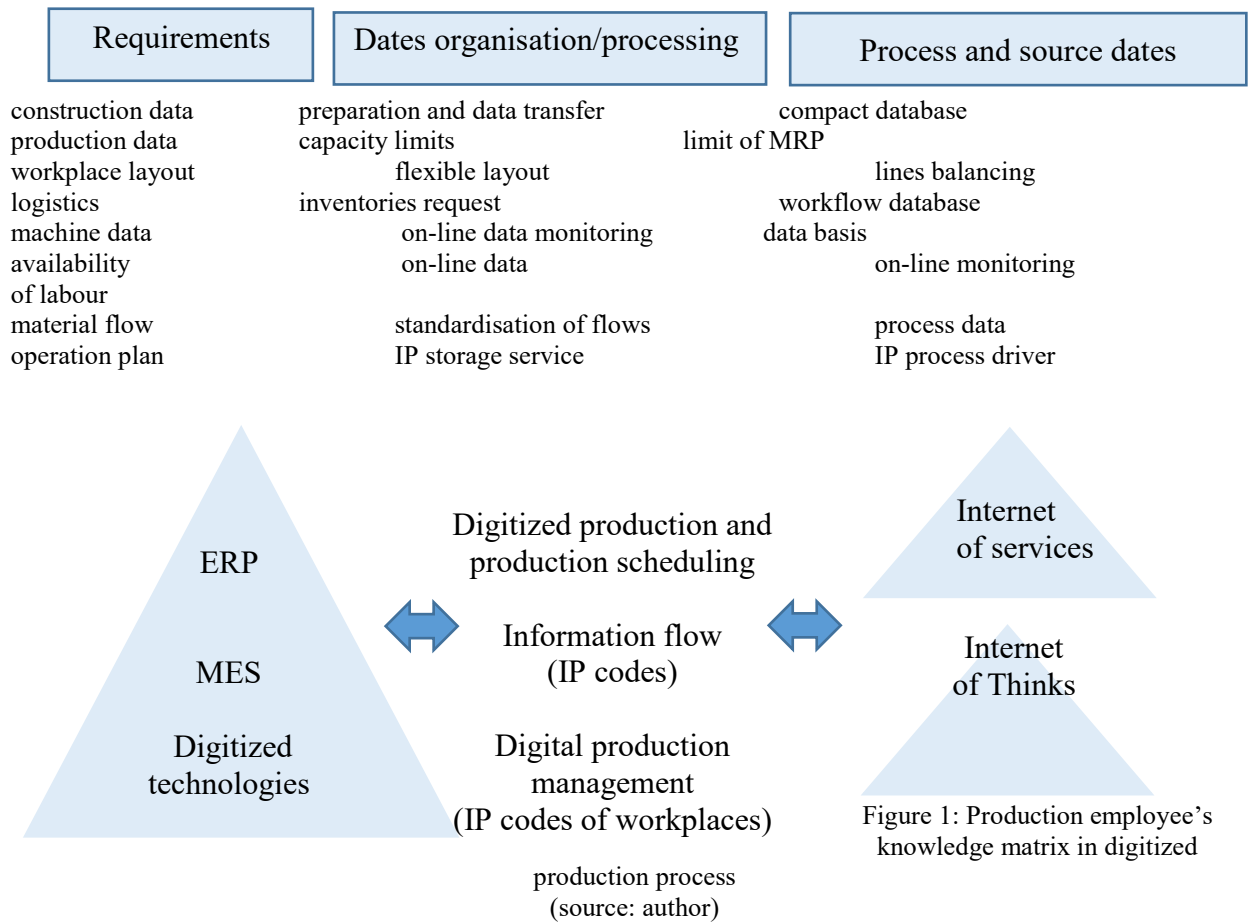
4. Proposal of production employee’s knowledge matrix in digitized production environment

This general model can be used to set external as well as internal digitized processes. Based on the above general model, the above-mentioned general model of scheduling and scheduling of production can be specified as follows:

Table 1 Pillars of knowledge matrix (source: author)

PRODUCTION PLANNING	PARAMETERS IDENTIFICATION	LAYOUT SCHEDULE	RESOURCE SCHEDULING	PROCESS DESIGNING
CAD	Product ID	Layout proposal	Production flow	CAE, CAM
CAM	Production ID	Capacity plan	Workplace	Digitized process
CAPP		Process map	Date inventory	Process standards
Process Simulation	3D Production Flow	Layout ID schedule	Ergonomics	Digitized layout





Horizontal integration focuses on manufacturing technology, machinery and equipment scheduling, human capacity scheduling, material flows, and on-going automation of workplaces, capable of working on-line and under the management of digital technologies. The result of planning is a complete process map of the digitized process in connection with technical, technological and human resources. Horizontal integration allows the elimination of isolated workshop activities while maintaining a complex manufacturing process by concentrating all the activities of the manufacturing process into one compact unit that is directly linked to the resulting vertical integration module. Each process map element has an accurate digitized label and description that allows digitized technologies to be flexible in planning based on on-line orders for a given production system.

Vertical integration provides the transfer of work instructions and the flow of information - from the simplest digital sensor to the workshop - to the corporate internet, cloud and other available technologies to support the digitization of production processes. It is good if these technologies are linked to MES, MRP, SAP. The main purpose of vertical integration is the elimination of excess data and the support of efficient online controlled information flows for digitally controlled production processes.

5. Conclusion

The future of production as it is envisioned by Industry 4.0 is characterized by small decentralized and digitalized production networks which are acting autonomously and are therefore capable of efficiently controlling their operations in response to changes of the environment and strategic goals. The nodes of such a network are so called smart factories which are connected to a larger value-chain network that fulfils a certain customer demand. Machines and materials are the assets that are located at the bottom line of the whole automation pyramid but are all well integrated through standardized interfaces. Materials and products are uniquely identifiable and locatable at all times during the manufacturing process and as well along their entire life-cycle. These smart materials and products are customized to a large extent at the costs of mass production (Erol, 2016). One of the key trends is that companies must pay more attention to the accuracy and timeliness of data for product development and their subsequent production

(Hou, 2017). If individual product components come from multiple manufacturers, digital technology and digitally managed production equipment must communicate effectively with one another. Here we talk about so-called digital networking technologies that claim different types of digital standards, and then new data transfer technologies among many industrial companies. Object Intelligence will be a completely new parameter, which we are starting to monitor very closely now, having a crucial impact on waste reduction, elimination of downtime, failure of machines and equipment. Just the tracking of sensors for each machine, digital technology or workplace delivers cloud-based on-line decisions to further run the production processes in real-time.

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Biographies

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Denisa Hrušecká is a senior lecturer and researcher at Tomas Bata University in Zlín, Department of Industrial Engineering and Information Systems. In 2009, she received a Master degree in Industrial Engineering and later, in 2014, she defended doctoral thesis focused on advanced methods for production planning and scheduling. Currently, her research activities concentrate on modern logistic concepts, Logistics 4.0, theory of constraints and advanced methods for production planning and scheduling, optimization of material flows, digitization in logistic processes and Event-B modelling of production and logistic systems. She has taught courses focused on logistics, production process improvement and business information systems for both Czech and foreign students. She actively cooperates with many industrial companies where she participates in practical projects focused especially on improvement of production and logistic processes.