

Process stabilization – key assumption for implementation of Industry 4.0 concept in industrial company

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Abstract: *Implementation of Industry 4.0 concept based on the real stability of horizontal (business) and vertical (digitized) enterprise processes. Special attention will be given in this paper to the process stabilisation model including their core pillars, next to the identification of basic metric for evaluation of process model stability. Results presented in this paper based on the research project and survey realised in more industrial companies.*

Key words: process, stabilization, interaction, functionality

1. Introduction

Actual production environment in modern industrial enterprises is in today's time strongly influenced by the fact that the system oriented process thinking and increasingly digitalisation and automatization of manufacturing environment are critical for next times prosperity and competitive ability of internal and external manufacturing and enterprise processes. The importance and requirements of correct functionality all active process parameters grow every day radically. If we lose sight of the compass connected with implementation of Industry 4.0 concept in the industrial enterprises and do not focus on our company from the value-adding processes point of view, we will get lost.

In recent years, we are speaking a lot about Internet of Things and about Industry 4.0 concept. All initiatives in this field are concerned on the right process parameters compatibility. By implementation of both concepts we are confronted with core requirement: to have stable processes in manufacturing and by manufacturing supporting enterprise processes. Many scientific papers describe the future state, but we need to find the right way, how to prepare our industrial enterprises for input (implementation stage) of Industry 4.0 – we are speaking at this place often about revolution in managing, thinking and living in the frameworks of our traditional business models. Daily in our practice we can monitor the important change: computers will no longer be a tool, but in each industrial enterprise they will be “a digital management”. And if we will initialise this state in the framework of Industry 4.0, we need to have aligned designated internal and external enterprise processes. Future target is a vision of adequate digital functionality.

The term Industry 4.0 stands for the fourth industrial revolution, the next stage in the organisation and control of the entire value stream along the life cycle of a production technologies. Fundamental here is the availability of all relevant information in real-time through the networking of all instances involved in value creation as well as the ability to derive the best possible value stream from data at all times. Connection of people, objects and systems leads to the creation of dynamic, self-organised, cross-organisational, real-time optimised value networks, which can be optimised according to a range of criteria such as costs, availability and consumption of resources (Dorst, 2016).

“The Industry 4.0 is the way to improve production processes, to higher the productivity for batch size equal 1, to reflect the individual demand and short term wishes. It helps to reduce lead time and time to market. It helps to reduce product development time and ad-hoc networking within cyber-physical systems. It helps to transparent in the real time, to make faster and flexible decision making, to archive global optimization in development and production” (Basl, 2016).

1.1 Theoretical background of Industry 4.0

Industry 4.0 concept can be characterized through the following words: big data, networking, digitalization, automation, Wi-Fi connection, cloud computing. A lot of effort will be invested in the restoring of old data to the latest IT standards. Special layers are used to transfer the experience of all

employees into comprehensive IT systems. A lot of money will be invested in development of exclusive software solutions that help us in industrial enterprises look forward to the digital future.

At the same moment, we are confronted in our modern industrial enterprises with the same situation: we have the old non-stable structures, machines, processes, employees. We will know answer on the important question: "How we can get from the present state of the analogue manufacturing to our vision of digitalized company – a company of Industry 4.0?" Instead getting fit for the new future, companies are investing in the grandiose and complex IT projects. The degree of waste increases, instead sinking. As long as companies are not strategically adapting their processes to the challenges of the digital world while keeping an eye on the added value, they will inevitably fail in their digitalization projects. The value creation logic follows two core parameters: processes optimization and processes digitalization. By process optimization is our target to define and stabilize all processes and by process digitalization we are looking for right managed "self-regulating" control mechanism, from the customer through the production process to the supplier. If the digitalized processes are not stabilized, we automate the production of waste. If we are not able to reduce the complexity through the optimal managed process self-regulation, we will not cope with the complexity and in the amount of data that is no longer to be controlled.

In recent times, traditional manufacturing is upgrading and adopting Industry 4.0, which supports computerization of manufacturing by round-the-clock connection and communication of engineering objects (Shafiq, Sanin, Szczerbicki, Toro, 2016). Decisional DNA-based knowledge representation of manufacturing objects, processes, and system is achieved by virtual engineering objects, virtual engineering processes, and virtual engineering factories. Decisional DNA features as tools for effective Industry 4.0 implementation can facilitate in real time critical, creative, and effective decision making.

Manufacturing IT and Industry 4.0 is the Fourth Industrial Revolution with a potential of 12 bn Euros in Germany's chemicals industry (Gentner, 2016). But Switzerland is currently the best prepared of all countries in Europe. Many of the ideas are still very vague. As projects in Manufacturing IT and Industry 4.0 are different from the classical technical projects other strategies, for example agile project management, are necessary to secure success.

The fourth Industrial standard is based on advanced automation and robotics, sensor based computer technology, interconnected by wireless communication, and supported by big data solutions (Sandengen, Estensen, Rodseth, Schjolberg, 2016). Effective management and human cooperation i.e. teamwork and all processes will be increasingly important in the future. There will be important new form of industrial standard in relation to overall equipment effectiveness (OEE), predictive maintenance and total performance related to all equipment in the industrial factory processes. Not a few highly automated machines, but the system as a whole. OEE is a well-known standardized tool for performance measurement throughout the industry. In order to utilize data systems as ERP (Enterprise Resource Planning) and PLM (Engineering Systems), they must be integrated with business systems. Management normally acts on the bases of facts and financial performance. In most companies increase profit is the overall goal. Future management systems aim for a fully integrated and automated data flow based on advanced sensor technology. Increased use of digital systems enables quicker and better decisions.

Building upon the integrated design as a tool and process for innovation capacity in the current industrial development paradigm, there is necessary to design new ways of management of business practices and value creation (Gerlitz, 2016). Business models and value creation in SMEs is driven by design, innovation management and strategic management in the context of entrepreneurship. Through the Industry 4.0 can SMEs accelerate their growth target and become more innovative, innovation being the move towards sustainable competitiveness and smart growth.

The proliferation of cyber-physical systems introduces the fourth stage of industrialization, commonly known as Industry 4.0 (Wang, Wan, Zhang, Li, Zhang, 2016). The vertical integration of various components inside a factory to implement a flexible and reconfigurable manufacturing system, i.e., smart factory, is one of the key features of Industry 4.0. The smart factory is characterized by a self-organized multi-agent system assisted with big data based feedback and coordination.

Internet-connected technologies are crucial for the creation of value added for organizations and society (Roblek, Mesko, Krapez, 2016). With the development of the Internet, the Internet of things is central to the new industrial revolution that leads to the Industry 4.0.

In the Industry 4.0 framework based on IoT and smart manufacturing, it is essential to support factory automation and flexibility in harsh or dynamic industrial environments (Lin, Deng, Chen, Chen, 2016). State-of-the-art technology suggests building a controlled work-space using large-scale deployment of wireless sensors.

2. Research targets

Production system oriented on the implementation on Industry 4.0 concept must fulfill following parameters:

- Information background – integrated information systems should create virtual reality managed by digital technologies in real time and place
- Communication platform – machines, technologies, processes, information and material flows should connect effective virtual information world with real technological world
- Operational management – optimal performance of production system in according to the problem solving and decision making with right integration of human
- Production management – integrated value chain oriented on the standardized decision making and autonomous operability of production components
- Data security of integrated systems
- A high degree of reliability and stability of realized production processes without integration barriers
- Production systems IT maintenance
- In according to the proposal of process stabilization model we identify following testing hypothesis:

1. Industry 4.0 concept bring the expected cumulative benefits from digitization in the form of lower costs and increased revenues.

Our survey was realized in 120 industrial companies in Czech and Slovak Republic (40% automotive, 30% mechanical, 20% external supply for automotive, 10% other industry).

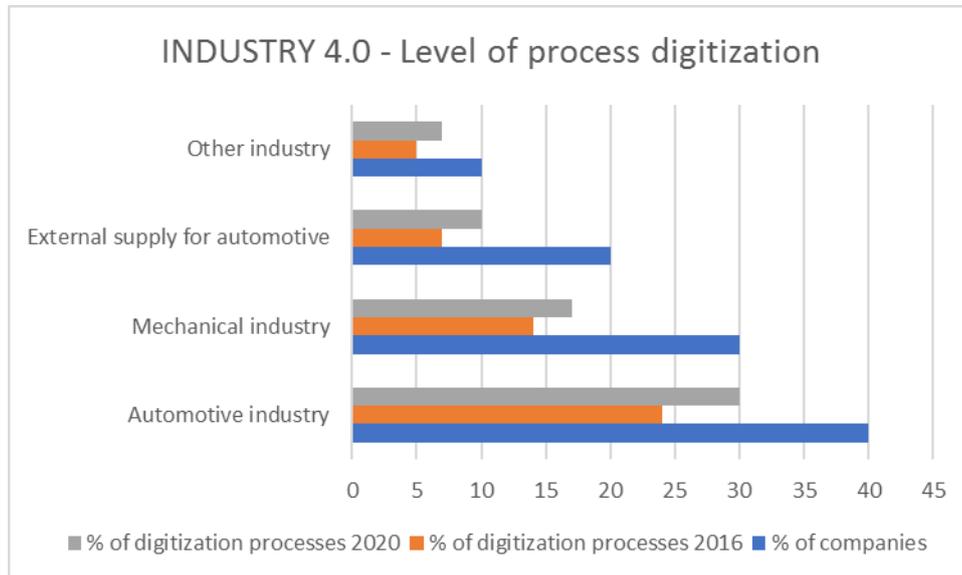


Fig. 1: Industry 4.0 – Level of process digitization – comparison 2016 and 2020
(source: author)

Results verified mentioned hypothesis and showed, that positive cost regulation and revenues management lies in optimal combination of advanced connectivity (14%), better “internet of things” services (26%), computer integrated processes (35%), cloud computing and advanced automation (15%) and user-friendly process standardization (15%). Right combination of all mentioned parameters secures and bring the potential of lower cost and increased revenues.

2. Industrial company has identified the core processes for implementation of Industry 4.0 concept.

Verification of given hypothesis has brought a clear signal to the issue of identification of key business processes. The hypothesis was not confirmed, because all companies have identified key processes mostly in relation to the production process (horizontal core processes), but not in according to the implementation of Industry 4.0 concept as supporting managerial company process (vertical processes).

In according to the identification of core processes we mentioned by our survey the fact, that a lot of people in industrial companies have a problem with right understanding of the “process” definition. Traditional we are oriented on the production processes, supporting processes or we distinguish between managerial or operational processes. In the environment of Industry 4.0 concept we should make radical change in our thinking, because we are speaking about digital company – digital culture – digital processes. According to this fact we speak about new type of “process content” according to the digital enterprise environment. From our survey we achieved secondary the following knowledge: most industrial companies have respect before traditional enterprise culture, standards infrastructure, intellectual property protection by workplace, personnel leadership and coaching. This is in direct correlation with traditional model of personnel security or personnel integrated management and decision making processes. By this processes was the responsibility and delegated competencies by human, now in the Industry 4.0 concept there is necessary to transfer all important operational business competencies, responsibilities connected with production processes planning, scheduling and organization to the computer technologies and digital processes.

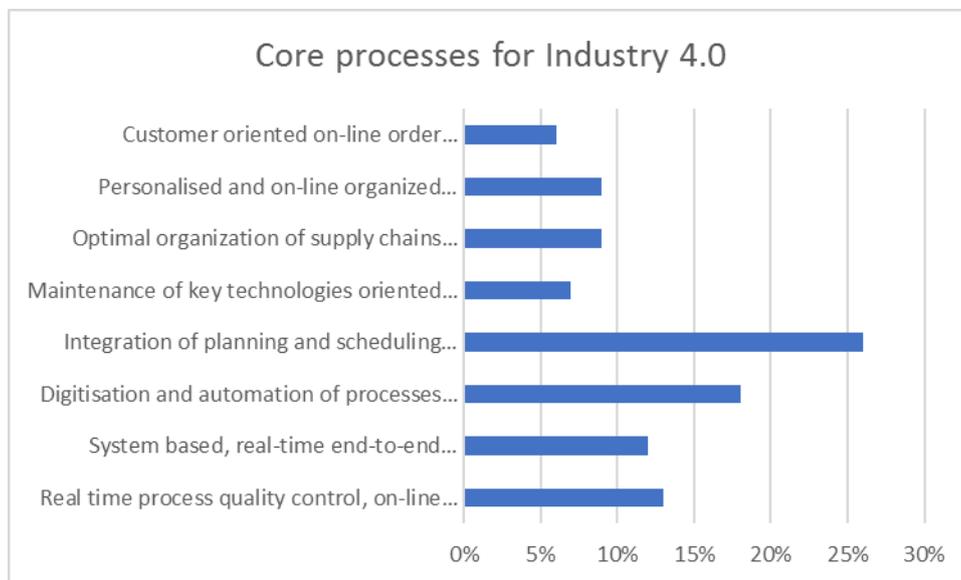


Fig. 2: Identification of core processes for Industry 4.0 implementation – process standardization and stabilization (source: author)

3. Industrial company has a clear vision about process steps and core process stabilization pillars before the implementation of Industry 4.0 concept.

A lot of companies have clear vision about content of Industry 4.0 concept, they are waiting on positive experiences from other companies, that absolved first stages of implementation process. The realized questionnaire showed the accuracy of given hypothesis with an important signal to give to the companies more knowledge and skills from successful industrial companies having experiences with first implementation steps.

Where is in enterprise competent to identify the vision and define process steps of Industry 4.0 by concept implementation? This was our principally question during realization of our research in industrial enterprises. Basic impulse for this question was the fact, that we know responsible person as a director in each enterprise for the production department (evtl. production process), but we don't know the director for implementation of supporting business processes – for example – for implementation of new IT projects. In more companies we found during our survey product responsible person for implementation of IT project (78%), in better case for implementation of Industry 4.0 concept (14%). From point of process stabilization this is a crucial moment, because nobody from product managers can't be responsible in industrial enterprises for combination of

horizontal and vertical integrated processes. Firstly, as we can see, we should identify right person, which will be responsible complexly for the process of Industry 4.0 concept preparation and implementation.

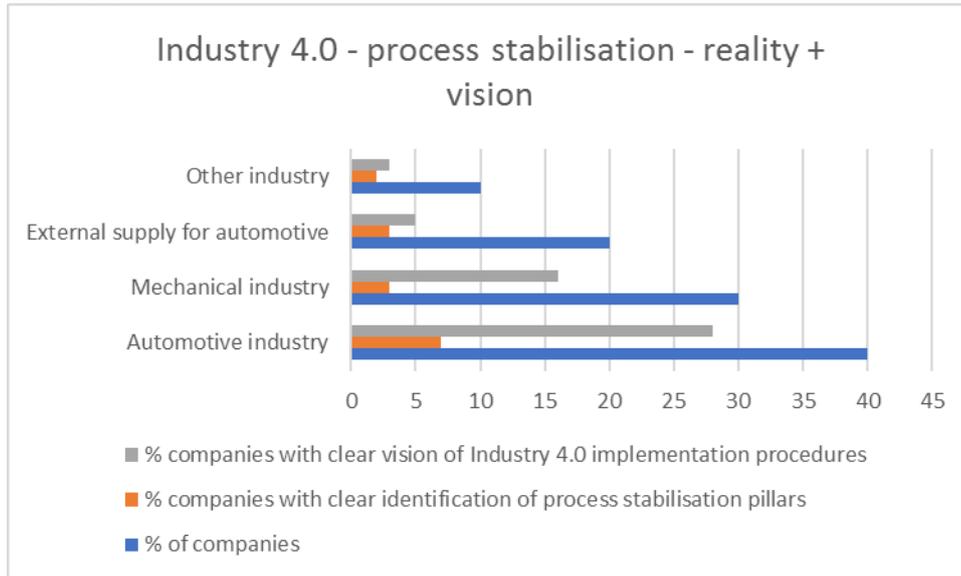


Fig. 3: Industry 4.0 – reality + vision – comparison between number of industrial companies
(source: author)

3. Process stabilization model

Definition: Process stabilization model build a background for preparation, implementation, testing and improvement of complexly integrated vertical and horizontal enterprises processes, connected with installation of digitized business processes.

The objective of the process stabilization model is to propose a mechanism by which a clear structure of processes realized by implementation of Industry 4.0 model is made, a strategic aims and objectives are identified, activities are sequenced and prioritized and the resources required are identified. It is designed in according to the right management and coordination of all realized processes from the planning procedures to the realization procedures.

By model development we take into account the following fundamental principles:

- Knowledge of principles of system oriented digitalized model of processes and process elements based on Industry 4.0
- Clear vision in according to the digitized operations, data delivery safety, data complexity, digital standards, norms and certificates
- Standardization of maintenance system for computerized and digitalized processes and operations through MES and MRP
- Skills with a human and his activity in the digitized processes by workplace

Important part of each model definition there is the first diagnosis of the production system, identification of core parameters connecting with stabilization, standardization of production processes, operations, workplaces, machine technologies, information and material flows, layouts, human. Right availability all process components build background of next process stabilization from the Industry 4.0 concept point of view.

From the Industrial Engineering point there is important to implement the same methods of management and process improvement: methods, which we used for management and process improvement in production processes should be the same for management and implementation of computerized or digitized technologies. That means, firstly we should take into account parameters as system oriented thinking, simultaneous process management and organization, process owner, workplace identification and other important facts, that are crucial for the right functionality of proposed technologies or systems integrated into production processes with strong connection on digital technologies.

In according to the stability we identify important knowledge: each stabilized process or process pillar is confronted in real practice with the phenomena of allowable values for each defined index or relevant process parameter. Process stabilization model can be used than as a tool for process new definition or as a preventive tool for process management, in most cases we can use it for daily operative process management, when some unforeseen process conflicts occur.

Structure of process stabilization model:

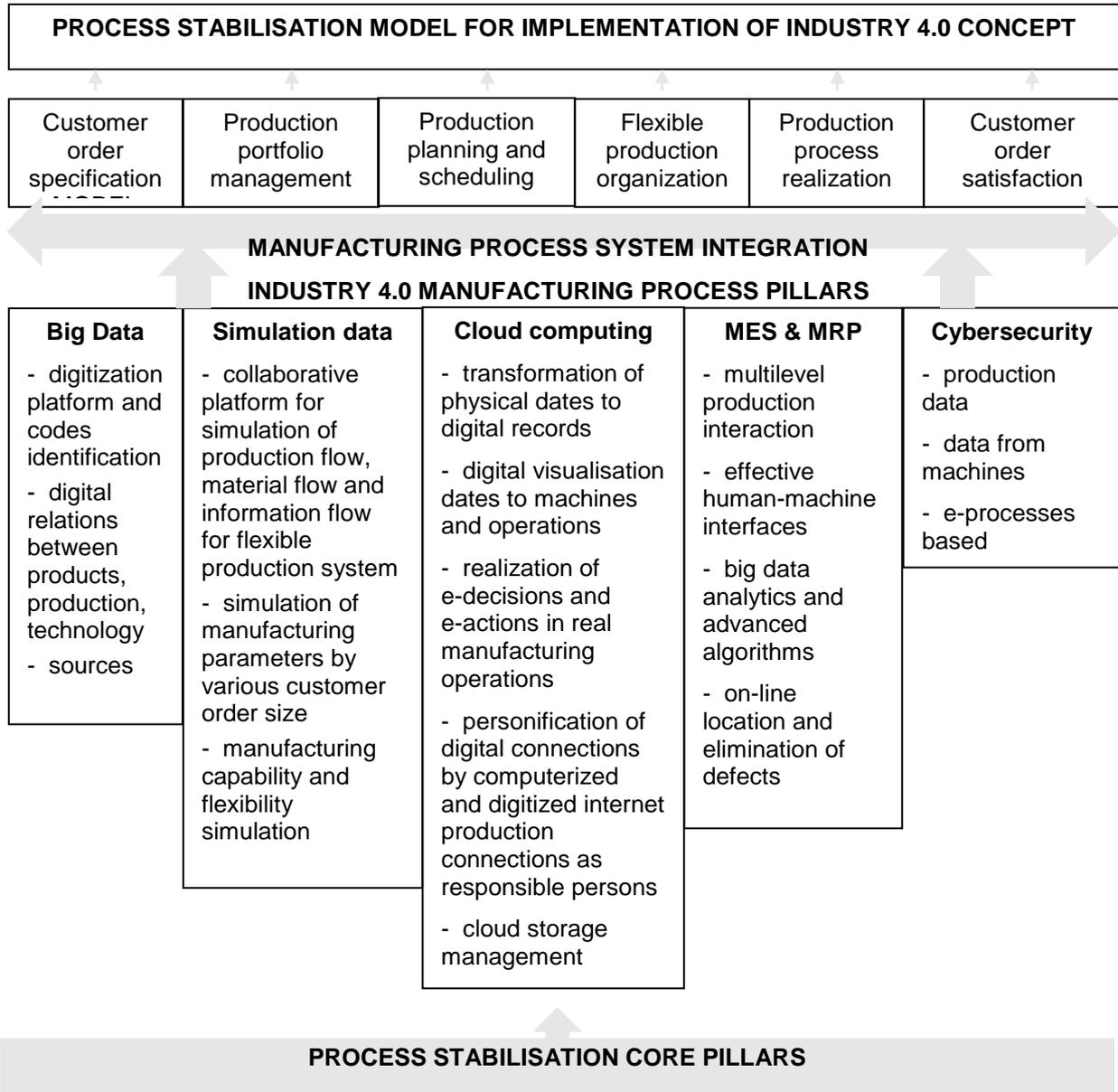


Fig. 4: Process stabilization model structure for Industry 4.0 concept implementation in industrial company (source: author)

Process stabilization model proposal targets are concerned on following criterions:

- Coordination of production plan in according to the flexible production processes with available production capacities in production and supporting manufacturing processes
- On-line task prioritization and optimal sequencing between digitized processes and manufacturing workplaces (“just in sequence optimization”)
- Physical objects are referenced, scheduled and managed by an ID
- Co-operative production planning in triangle “customer – producer – supplier” realized by web developed interactive digitized environment and data storehouse

- Optimization of production planning and scheduling through utilization of big data storehouses and cloud computing technologies in according to the customer order satisfaction in real time
- Optimization of supplier connections, transport and logistics costs
- Improvement of customer relationships and customer intelligence through the programmed on-line connection before production process
- Storage and inventories are regulated by different ID types for each component and by product component number through optimal virtual dynamic behavior knowledge
- Effective data maintenance, data security and responsibility for timeliness of data
- Assigned human responsibility for each component integrated in process model in according to the management and organization of each component

In according to this model proposal there is important to develop measurable metrics for identification of value added from Industry 4.0 concept in the industrial company environment. Through this metrics we are able to evaluate positive effects of computerized and digitized production. Following a proposed process stabilization model we identify following metrics for adequate evaluation of results achieved in the process of Industry 4.0 concept implementation:

Tab.1: Process stabilization metrics – evaluation tool for process stabilization model

PROCESS STABILIZATION METRICS for Industry 4.0 concept implementation
Identification of all core process components integrated in Industry 4.0 concept
Availability of all required functionalities of computerized and digitized technologies
Number of available services integrated in digitized data and cloud system
Number of intelligent drive units integrated in the Industry 4.0 concept
Defined technical functionality, virtual functionality, communication capability and model process structure
Communication ability verification by each Industry 4.0 system component
Standardization of e-connections, standardization of input and output process parameters
Number of objects managed through digitized technology in one e-chain (ID-chain) and by one ID-administrator
Number of process conflicts in pre-implementation stage of Industry 4.0 concept (technical conflicts, technological conflicts, interface conflicts, data cybersecurity)
Number of total digitized processes in production
Number total digitized machines integrated in Industry 4.0 chain
Defined human responsibility for each process component integrated in the Industry 4.0 chain
Throughput time of production process before Industry 4.0 implementation
Throughput time of production process during Industry 4.0 implementation
Real time of system communication by realization of production process through Industry 4.0 system
React time on delivery of system components availability for realization of production process after input of customer order into system (specification and commitment of customer order)
Operative cost for order processing in digitized environment
Testing and validation of digitized processes in according to the flexible planning and organization of production process
Ability to re-plan the production process virtually by given instructions through ID competencies for flexible production organization
Availability of all relevant data and on-line data corrections availability in integrated process

PROCESS STABILIZATION METRICS for Industry 4.0 concept implementation
components
React time on process defect in system between process component owner (ID) and digitized workplace in production (identified by ID)
Grade of standardization of interfaces and abilities of units for and digitized regulation of flexible production system
Number of domain borders integrated in digitized environment for production system
Stability and security of defined standards, technological and technical rules, mutual process e-communication and e-management
Number of digital certificates for authentication of realized operations
Number of identities with login data for maintenance and management of operational Industry 4.0 system
Definition of system responsibilities for human – guaranty of system timeliness and usability
Number of virtual instances for recovery functions and security incidents elimination in Industry 4.0 system

Process stabilization model should bring in the practice positive effects in the area of customer order specification, production planning and organization. We can develop our internal calculation model of benefits achieved after implementation of first stages of Industry 4.0 as follows:

Industry 4.0 system real availability:

$$ISA = PD - ST - PSM \quad [\text{minute}]$$

(PD - planned time of availability, ST – service time, PSM – preventive service maintenance)

Throughput time of e-process operation

$$TePO = IITS + DeOP + WTSR + IINO \quad [\text{minute}]$$

(IIS – instruction input time in the system, DeOP – duration of e-operation, WTSR – waiting time on system reaction, IINO – instruction input time for next e-process operation)

Average reaction time on the system incident

$$ARTSI - TSU - ID - IE \quad [\text{minute}]$$

(TUS – Time of system unavailability, ID – incident diagnosis, IE – incident elimination)

Index of data completeness availability for process realization in Industry 4.0 system

$$DCA = SRDO / RDI$$

(SRDO – Number of successful realized digitized operations given into systems as requirements, RDI – Returned no realized digitized operations)

Complex model of process stabilisation for implementation of Industry 4.0 concept:

$$\text{Max ISA} = 0,2 \text{ COS} + 0,1 \text{ PPM} + 0,2 \text{ PPS} + 0,3 \text{ FPO} + 0,1 \text{ PPR} + 0,1 \text{ COS}$$

$$BD_{COS} + BD_{PPM} + BD_{PPS} + BD_{FPO} + BD_{PPR} + BD_{COS} = 1,0 \text{ (Big Data Condition)}$$

$$SD_{COS} + SD_{PPM} + SD_{PPS} + SD_{FPO} + SD_{PPR} + SD_{COS} = 1,0 \text{ (Simulation Data Condition)}$$

$$CC_{COS} + CC_{PPM} + CC_{PPS} + CC_{FPO} + CC_{PPR} + CC_{COS} = 1,0 \text{ (Cloud Computing Condition)}$$

$$MM_{COS} + MM_{PPM} + MM_{PPS} + MM_{FPO} + MM_{PPR} + MM_{COS} = 1,0 \text{ (MES\&MRP Condition)}$$

$$CS_{COS} + CS_{PPM} + CS_{PPS} + CS_{FPO} + CS_{PPR} + CS_{COS} = 1,0 \text{ (Cybersecurity Condition)}$$

(COS – Customer Order Specification, PPM – Production Portfolio Management, PPS – Production Planning and Scheduling, FPO – Flexible Production Organization, PPR – Production Process Realization, COS – Customer Order Satisfaction)

Index values given in maximisation function: $0,2 \text{ COS} + 0,1 \text{ PPM} + 0,2 \text{ PPS} + 0,3 \text{ FPO} + 0,1 \text{ PPR} + 0,1 \text{ COS}$ build size of value added contribution to the whole complexly Industry 4.0 chain. These values were derived from the proposal, implementation, observation and testing of interval limit values by simulation project in the framework of RO Research Project, realized by Industrial Engineering and Information System Department by Tomas Bata University under title: “Parameters modelling for effective production and administrative processes in industrial companies based on Industry 4.0 concept”. This project is realised from 2016 and till

Necessary condition for implementation of proposed model is the deployment of relevant IT technologies as supporting tool for Industry 4.0 concept. All digitized applications should support the large quantities of data generated by machines, processes and human in according to the supporting and monitoring of target oriented processes. Important parameter there is the right functioning of internet connections that can make required outputs of production processes in real time. Reliable functionality of Industry 4.0 concept depends from regularly maintenance of computerized and digitalized functionalities all usable information technologies that can be serviced through cloud providers. These make all available IT technologies available for customer use online. Finally this influences the cost reduction of all necessary IT cost, connected with optimal functionality of Industry 4.0 concept.

4. Conclusion

Implementation of Industry 4.0 is in each industrial company connected with stabile definition of core production processes, strong dependent from stabile structure of supporting IT processes and technologies functionality. We speak here about highly automated production processes, which produce for various markets with strong degree of product specialization. All enterprises will have best competitiveness, couldn't be threatened and then they are looking for relevant technologies and lack of data security and standardization. Implementation of proposed process stabilization model assumes the availability of relevant and consistent input data, that are an important condition for next implementation of all necessary steps in Industry 4.0 concept. Big danger we can see in the possibility of incompatibility between various IT applications, used in industrial companies, this can radical influence the horizontal process and vertical process integration as a whole. Newest impulses for elimination of mentioned danger we can see in the higher orientation on the cloud services and standardization of interface connections (maybe without sensitive company data) reflecting occurred interface problems in preparation stage of Industry 4.0 concept implementation.

Industry 4.0 concept enables radical improve the productivity and efficiency of complexly production value chains, enable to focus on the creative and strategic oriented business activities. Positive effects we can see by workers – this concept enable to organize flexible work in production processes and contributes to higher satisfaction of employees at all enterprises levels through the better work-life balance. Generated potential savings for companies are radical, special in according to the investment and return of investment in the IT technologies, customer relationships, production process planning and scheduling and flexible production outputs effects. An important role play here the phenomena of “collaborative factory” enables to realize the jobs and process operations in virtual reality with use of mobile workplaces. Each master, supervisor, team leader or shop floor employee can use in their work the assistance of multimodal, user-friendly interfaces through the complexly oriented computerized and digitized technologies, used in Industry 4.0.

Industry 4.0 concept integrates the three key lines: internet of things, internet of services and internet of people – networks objects, people and systems. Optimal combination of strategic pillars will combine in the industrial company best principles from smart factory, business and social platforms. This combination guarantee right functionality of production process initialization, planning and scheduling and production process realization with according to the effective and real-time necessary data exchange, safety and reliability.

Greatest challenges that can be seen by successful implementation of Industry 4. 0 (according to the results realized in the framework of our survey in RO project: “Parameters modelling for effective production and administrative processes in industrial companies based on Industry 4.0 concept”) we observe in the following profits:

- right selection of functionality of used digitization technologies according to the universality of production process realized in industrial company
- more detailed process and work organization by workplaces through the integration of interfaces between system – workplace – human
- better data security and responsibility (ID, human) for data actuality and availability in real time
- great opportunity for employees to share their own experiences with colleagues and service specialists from IT supplier companies

In the future it will be crucial the effective cooperation between industrial enterprises, system suppliers with the goal to bring new impulses flows from Industry 4.0 industry.

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