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The Role of Process Management in the Context of Industry 4.0

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Abstract

Process Management or Business Process Management (BPM) ideas published in a book Hammer's Business Process Reengineering Concept, are implemented in many businesses nowadays. Process management helps companies achieve quality, time, and cost goals. In quality management systems, the concept of process management is the core integrates into the performance and risk management system. On the other hand, an interesting research question is what is the role of process management in the context of the 4th industrial revolution and smart factories. The number of solutions for automated processes in the smart factories will be increasing, and due to this fact, traditional management tools and techniques should be revised. Business process management is one of them. Based on this fact, we have tried to answer the research question — What is the role of BPM for Industry 4.0? — in this paper. This research question deals in this article, which focuses attention on selected aspects of BPM within the Industry 4.0 concept. The paper also attempts to mention the impacts and needs of current technical education in this area.

Keywords
Business Process Management, Industry 4.0, Engineering Education, Quality Management

1. Introduction and motivation

Industry 4.0 is nowadays a topic of research and interest for many universities, research institutes, and businesses. Research focuses on how this concept is implemented in practice. It requires, in particular, the transition to the digitization of business processes and their ICT support. In particular, the use of cyber-physical systems, which allow to simulate reality and implement digital twins for virtual machine control, including robots and processes, is discussed.

One of the prerequisites for the successful implementation of this management concept is the understanding of processes in the company and the description of process models. Experience shows that these process models could be used to implement information systems to support the management of all business activities, from operations management to supply chain management. In the past, many businesses have also focused on supporting the implementation of process management as a way to help them achieve their goals in terms of quality, cost, and time. The concept of business process management has been adopted for quality management standards. Due to this reason, many companies implemented this concept for their management.

Based on the mentioned facts, the research question has been formulated. The core research question is What is the role of business process management (BPM) for Industry 4.0? This paper deals with an answer to the formulated research question.

2. State of the art

2.1 Industry 4.0

The Industry 4.0 concept has been known for a long time. The basic idea is to create "Smart Factories" that will use cyber-physical systems. They will take over the repetitive activities that have been performed by humans until then. The big problem of the implementation of Industry 4.0 is digitization and integration (digitization and integration of any simple production-trade relationship up to digitization and integration of complex interconnected production-trade chains).

Companies, therefore, have to face this difficult challenge. How to best perform digital transformation? How to implement technologies that are adaptable and simultaneously as flexible and agile as possible for your organization?

From this perspective, the use of Business Process Management (BPM) is more than appropriate and will help effectively respond to challenges and requirements.

2.2 Business process management nowadays

Process management is an essential part of management. Process management must be following the stated strategic goals of the organization, design, implementation of process architecture, and defined metrics. It needs to be aligned with organizational goals and management training so that they can effectively manage these processes.

In today's world, companies of all sizes and types confront with high competition. To remain competitive, improve their results, adapt to the market use Business Process Management (BPM), to improve processes. So we can say that Business Process Management is a systematic approach to mapping, analyzing, and improving processes.

With the adoption of the fourth industrial revolution and its Digital transformation, society must adapt to changing technologies. Here we can again see the benefits of BPM. In the short term, BPM helps organizations reduce costs and increase efficiency. It can mean higher revenue and growth for this organization. In the long term, BPM helps to create a competitive advantage by improving organizational agility. Using BPM can help increase the efficiency, agility, and success of any organization in the private and public sectors.

2.3 Benefits of BPM

It is crucial to realize that BPM is a combination of practices and methods that focus primarily on increasing the value of a company by improving its processes. It can be simple (e.g., defining poorly described processes, making changes, finding possible improvements) or significantly more complex (such as complex reengineering of business processes). We can mention that using BPM brings many benefits to businesses (Ubaid and Dweri, 2020). This section discusses some of the significant benefits, that can expect with BPM:

A) Agility

One of the critical features of BPM is that it facilitates the design of processes. The proposed processes are flexible. BPM supports flexibility in making process changes at a minimal cost. Processes can be easily customized to meet an organization's requirements. Very often, organizations confront the need for change. Changes may become necessary as a result of new regulations, market requirements, or new ways of working. People and organizations need smarter yet faster decision-making. Problems need to be resolved faster, and communication needs to be more productive.

B) Productivity

BPM supports the automation of repetitive elements and regular procedures. It is possible to eliminate bottlenecks with the introduction of parallel processing and with the removal of unnecessary steps. Thanks to its employees can spend more time on core activities and does not have to deal with support functions (processes). It also increases productivity. It focuses primarily on achieving goals by improving management, control, analysis, and modeling tools. By investing in new tools it helps companies increase productivity. It is necessary to identify technologies that provide increased production efficiency and integrate them into business and infrastructure.

C) Efficiency

With BPM support, is better visibility and transparency of business processes. It is, therefore, possible to focus on inefficiency. We increase efficiency and, with these, save our resources. At the end are better designed, optimized, and monitored processes. The main focus is on process automation (automating repetitive low-value processes), IT

outsourcing (significantly improving the quality of IT services and reducing its costs), setting achievable goals (setting motivating goals based on real analysis).

D) Compliance & Transparency

Organizations need to be compliant with industry, government regulations, and directives. BPM supports the rapid implementation of these requirements, helping to avoid potential delays and thus avoid possible sanctions and penalties. Organizational processes are transparent, visible, and fully accessible for employees.

E) Customer Focus

Thanks to optimized processes and higher productivity, we can better focus on the customer. We can better respond to his proposals, create solutions faster, and adapt to them. Customers determine the success or failure of our company. If we ignore them, someone else will come who will not ignore them.

F) Measurability

All processes are measurable and can be compared with results at any time. BPM provides reporting and analysis tools. Processes can be quantified, optimized, and used as support for effective decision making. Types of process performance metrics (efficiency, effectiveness, capacity, productivity, quality, profitability, competitiveness, value indicators)

G) Technology Integration

BPM tries to bridge the communication gap between user and IT support. The main effort is to use standards (e.g., BPMN). This is especially important when implementing Industry 4.0.

BPM is not software; it is a way of working. In its concept, it enables companies to be proactive and agile. The processes are better visibility and transparency and can be optimized. Activities are organized in individual processes and can be managed very well from a strategic, organizational, and technological point of view Škrinjar and Trkman (2013). Everything can be integrated into the technology chain to achieve Digital Transformation 4.0.

2.3 Industry 4.0 in relation to BPM

With the upcoming evolution in the industry, it is necessary to assess what BPM technologies adapted or improved to be suitable for application in Industry 4.0. The paper (Sishi and Telkukdarie, 2017) presents the context with Industry 4.0 and BPM. The other papers connected to this problem.

The paper (Petrasch and Hentschke, 2016) proposes for suppliers and manufacturers to use a advantage of new technological concepts, e.g., Cyber-Physical Systems (CPS), Internet of Things, and Cloud Computing (CC). This can bring the possibility of creating new products and services to reduce costs and increase productivity. Industry 4.0 is comprised of three basic parts Embedded Systems (ES) / Cyber-Physical System (CPS), Internet / Cloud of Things (IoT / CoT), and Service-Oriented Architecture (SOA) / Internet of Services (IoS) / Cloud Computing (CC). Progress in the development of some of these systems has brought them into the current world. Smart Factory or Smart Manufacturing is not just a term but gradually becomes a reality.

To fully implement them, some aspects are not covered, such as standardization, specification, and modeling languages. This paper (Roseman and Brocke, 2015) deals with a modeling language, especially for Industry 4.0, in short, “I4PML”. Also, a method for the specification of Industry 4.0 application using “I4PML” and “UML” is described in this article. Paper results are that user’s needs and business goals are considered as a first step. Before any technological investments are made in hardware or software, the focus goes to the concept for an industry 4.0 application. Concept specifications should include the description and model of business processes and data structures. As Industry 4.0 is currently in the early stage of development, there are aspects like security, usability, availability, reliability that needs to be considered when using for application in Industry 4.0. Devices and services play a crucial role in the business process, so their specifications must be present.

Other paper (Bocciarelli et al., 2017) is focused on A BPMN extension for modeling Cyber-Physical-Production-Systems in the context of Industry 4.0. The paper presents an approach how to specify and manage resources associated with the business process, which supports Cyber-Physical Production System. Paper also contains a proposal of notation to define actual entities in the design stage, which performs the process activities and their non-functional properties. This notation extends a current Business Process Modeling Notation (BPMN), and because of

that analysis can be executed on simulation of the Cyber-Physical Production System. An analysis is focused on reconfigurability, adaptability, and reliability of the Cyber-Physical Production System. Model-Driven Architecture (MDA) principles and standards are exploited to propose this notation. Because of this, they are exploiting considerable advantages such as easy customization and improved automation are obtained. In the end, there is an application example where the business process supports the execution of the Cyber-Physical Production System. The result of this work is an approach in metamodeling for the characterization of Cyber-Physical System resources in Industry 4.0 business process. BPMN metamodel extension is presented and used for managing resources involved in the business process, which is executed by the Cyber-Physical Systems. This system can be assembled with different components such as sensors, actuators, communication interfaces, control units, and other more. The aim of the proposed approach is to provide support to model complex structures. Analysis of model focuses performance and reliability of the business process at a design stage, and then an evaluation is performed considering the impact of every component in the structure.

The paper (Rehse et al., 2018) deals with an application case in the DFKI Smart Lego Factory. Paper is presenting an application case in model of Smart Factory build from Lego parts. Because of this model, there is an illustration of how can established techniques from Business Process Management (BPM) can provide answers to a new challenge rising with Industry 4.0. DFKI Smart Lego Factory is a fully automated "smart factory" build-out of LEGO® bricks. Demonstration of the potential of business process management methodology in Industry 4.0 is shown in three application cases which are proposed in this work. Application cases are following model-based management, process mining, and prediction of the manufacturing process in smart factories. Challenges that arise from presented specific application cases are conquered with business process management. The result of this work shows that suitable business process methods can address those challenges. DFKI-Smart-Lego-Factory can cover many real-life challenges and serves as a learning tool on how to better implement future concepts and projects. Potential of DFKI-Smart-Lego-Factory is far more significant, and presented application cases do not exhaust the field which Industry 4.0 provides.

Problems on Blockchain-based business process management (BPM) framework for service composition in Industry 4.0 present paper (Viriyasitavat at al., 2018). The authors mention that Business process management (BPM) is a tool to optimize business processes to reach a better performance of a system, for example, higher profit, quicker response, and better services. Industry 4.0 gives a requirement for a business process management systems to digitize and automate business process workflows and make interoperations of service vendors more transparent. BPM systems have a bottleneck in evaluation, verification, and transformation of trustworthiness and digitized assets. Blockchain technology is explored as a service in an open business environment, which should serve as an automated BPM solution. There is a proposal to transfer and verify the trustiness of business and partners by Blockchain technology. The paper contains an illustration of developed BPM framework how Blockchain technology can be integrated to provide many benefits when evaluating and transferring Quality of Services in the workflow composition and management. The result of this work expects an automatization of service selection and composition by BPM systems in Industry 4.0 to have more transparent interoperations of dynamic organizations.

In the current state, there is still a need for third-party certificates as an essential part of selecting and composing services for business projects. This need leads to a number of issues with BPM systems. Scalability is a barrier for the growing population of available services. Another one is the potential of transformation loopholes. When verification trustworthiness, a time delay can occur, which can be the next issue. The last issue mentioned in this paper rises in openness and security concerns. The biggest issue solved in this paper is to effectively solve the trustworthiness issue in the open business environment with Blockchain Technology. This work gives an in-depth look at Blockchain technology as an ideal candidate to replace third-party authorities. From this, a Blockchain technology-based approach is developed.

The paper (Hitpass et al., 2019) focuses on challenges rising from Industry 4.0 together with digitalization where business process management can be used as a systematic approach to identify, map, document, design, implement, measure, and control business processes. This gives more emphasis on IT systems as a support to improve, innovate, and manage processes. Every phase of product or service marketing, purchase, sale, and distribution through the internet will be backed by E-Commerce. With Industry 4.0, every logistic aspect will be digitized (e.g., purchase, sales processes), and business process and e-commerce need to be managed together, not separately. With revolution in the industry (Industry 4.0) we are experiencing a shift of paradigm from centralized to decentralized paradigm, which results in a big impact on the relation between BPM and e-Commerce.

There will be far more transparency from traceability and monitoring in production and logistic systems, more autonomy in the value chain links management, intelligence in activities or devices responsible for decision making and integration of all the payment services and business transactions and integration involving external agents that interact in the value chain. This overview of challenges establishes Industry 4.0 as a leader to a new kind of business processes and e-commerce. The trend is shown by decentralizing processes with more significant decision making autonomy, real-time control of the automated organizational processes, improved performance and quality of environment-integrated logistic organizational processes, and e-Commerce integration at each point as transaction enabler.

3. Implementation of Industry 4.0

It is important to realize that 4.0 implementation in industrial enterprises can not be done abruptly, but rather it is a gradual change. If we focus on the implementation of Industry 4.0 to the small and medium-sized enterprises, it is necessary to make this change in the several phases (Benesova and Tupa, 2017):

- Process analysis
- Data collection
- Horizontal integration and vertical integration
- Self-controlling system.

The related research question is "How principles of business process management can be applied in each implementation phase? The research results based on literature review is presenting in the next part in relation to each steps. The implementation of the BPM is described based on implementation of a Deming PDCA cycle (Plan-Do-Check-Act). This concept enables to achieve the requirements for process management system. Figure 1 presents activities for implementing each phase of PDCA.

Figure 1 PDCA model

3.1 Process analysis

Process analysis is an initiative step. A company, as a first thing, need to map all the processes which are in the company and then transform them into a digital form that can transform every aspect of production. When the company needs to regulate or correct the process (e.g. production line), you have a digital copy of that process and adjust that almost immediately because machines will react instantly. Also, data from those processes can be evaluated in real-time. The process design and models are the result of this step.

New technologies of Industry 4.0 brings an important role in process design and process modeling. The new role is related with process digitalization. The term of digitalization of processes is related to smart factories or digital supply chain network. In the context of process management, digital transformation refers to transforming the business operations, services, and models. Digital transformation covers all processes in the companies, and the aim is to build a digital model of enterprise with the digitized process attributes (input, output, sources, and indicators). The companies should determine rules, methods, and standards for process analysis, modeling and digitalization. The aim of this step is a digital model of enterprise. The models can be deterministic, stochastic, uncertain but structured, or uncertain but imperfectly structured. Modelling tools can be categorised into business process chain-based type such

as Petri net, IDEFO, IDEF3, BPMN 2.0, ARIS-eEPC, etc.; formal description type such as WPDL, XML, process algebra, predicative logic, etc.; and object-oriented type such as IDEF4 and UML. The overall model is analysed on the individual models. Models would have to contain all process attributes and static and dynamic parameters such as process time, process threats, cost, etc.

This model should contain:

- Relationship between the cyber and physical layer.
- Description of the main processes (processes that create added value).
- Definition of support processes and autonomous control processes.

3.2 Data collection

Data collection is a vital part of industry 4.0 because there is a need to evaluate if a process is functioning correctly, and without feedback, there is no possibility to decide that. Data can be transmitted from PLCs, sensors; basically, from every part of a system, we can gather relevant data. Those data needs to be stored in a safe location and with industry 4.0, and for better accessibility, data are stored in the cloud and then send to certain IoT software. From this, a digital model of a factory or company can be made.

The data can be used for process monitoring. The main principles of the process monitoring system are described by many authors, and a lot of them discuss phrase process performance measurement. Process performance measurement is the combination of process, methodologies, metrics, and technologies to measure, monitor, and manage the performance of the process.

The implementation of IoT or Internet of Services, Process, and People (Internet of Everything) and related technologies help to implement a system for automated and real-time process monitoring. These technologies help to display the state of processes. The automated system of measurement enables storage data into a data warehouse, and we are speaking about the analysis of Big Data. Big Data analytics is the process of examining large and varied data to uncover hidden patterns, unknown correlations, market trends, customer preferences, and other useful information that can help organizations make more-informed business decisions.

Data can be used for:

- Process mining for automated weak point analysis.
- Right time monitoring.
- Dynamic organizational analysis.
- Process simulation.

3.3 Horizontal and vertical integration

Horizontal integration is happening inside of a company, and the best example is to integrate systems in factories and automate machines needed for manufacturing. It is possible to have an overview of the consumption of inputs in processes and other data concerning manufacturing. Because of this overview, it is possible to compare planned data to real data from the system and also compare a state of supplies. This allows a quick reaction either for a responsible person or a system to evaluate that supplies are getting low, and they need to be restocked. Or another point of view is that the company will be more flexible to customer needs because of digitalization and machine automation.

Vertical integration is another phase of implementing an industry 4.0. This phase is about a data evaluation and processing and automatization of vertical processes. Data gathered can contribute to better production management, which is one of many vertical processes that need to be automated. So the systems as a modular management system, manufacturing execution system, and enterprise resource planning system can establish business process execution.

The business process execution means that instances of a process are performed or enacted, which may include automated aspects. Automation of business processes is based on using Business Process Execution Language (BPEL). BPEL language is perfectly suited to a clear description of the processes by which processes can be then mechanically exercised. BPEL enables organizations to automate their processes (so-called service orchestration). BPEL language allows the description of the conduct and behavior of business processes as a sequence of activities, including their branches, which are engaged in the process, while these activities are represented by web services (WS).

The business process execution in terms of Industry 4.0 is related to the digital factory and application of the Cyber-Physical System (CPS). The rules and process model can be used for the definition of elementary relationships in CPS. The cyber level of CPS enables simulation of the process with using digital twins and makes an environment for processes execution.

The CPS implements these elements:

- Data acquisition and data processing.
- Machine to Machine communication.
- Human-machinene interaction.

3.4 Self-controlling system

The result of data collection and integrations is a self-controlling system. This system is almost autonomous with an overview of a responsible person (e.g., operator, maintenance worker) if any situation occurs, then he needs to correct it. The self-controlling system produces maximal productivity because the system can optimize itself. Benefits that can this implementation brings are more visible and optimized decision making, better planning methods, data analysis, remote monitoring, automation, proactive maintenance, and more significant agility. This is also related to the issue of business process improvement.

Process improvement is an important phase of business process management. The aim is the continual improvement of the business process based on monitoring and data collection. Especially in the context of digital processes, the identification of existing pain points can be realized through the performance of continuous software tests. The other definition explains process improvement is the proactive task of identifying, analyzing, and improving upon existing business processes within an organization for optimization, and to meet new quotas or standards of quality. The companies collect data not only from manufacturing processes but from all processes during the product life cycle.

The companies use several methodologies like Six Sigma, and Centric leverages DMAIC (Define, Measure, Analyze, Improve, Control), Lean principles etc. New possibilities of technologies of Industry 4.0 can effectively support the implementation of the mentioned methodologies. The selection of a continuous improvement methodologies depends on the overall strategy.

3.5 Summary

Table 1 is summarizing the role of business process management for the implementation phase of concept Industry 4.0. It is evident that the essential theoretical and practical background may be applied.

Table 1. Role of BPM

Implementation phase of concept Industry 4.0	**Role of Business Process Management**
Process analysis	Process design and modeling
Data collection	Process monitoring
Horizontal integration and vertical integration	Process execution
Self-controlling system.	Process improvement

For a successful implementation of the Industry 4.0 concept, it is necessary to create an implementation team with the appropriate competence and knowledge. The implementation team should include a process analyst or methodologist with the following knowledge (Benesova and Tupa, 2017):

- Project management
- Engineering and technology management
- Innovation management
- Risk and ICT management
- Business process management
- Soft skills – communication, creativity

4. Conclusion

The aim of this theoretical conference paper is to focus on the elements of a Business Process Management for implementation of the concept Industry 4.0. The concept Industry 4.0 and its technologies open new challenges for BPM implementation nowadays. The technologies based on CPS, IoT, Digital Factory, etc. help to improved processes

based on useful process measurement, simulation, and application of predictive models. The identification of role BPM in each implementation phase of Industry 4.0 has described in the previous chapter, and the chapter answered the research question: What is the role of business process management (BPM) for Industry 4.0? We conclude that Business Process Management is a relevant discipline nowadays, and with the concept Industry 4.0, the new challenges for its successful implementation are opened. The successful implementation of process management also plays an important role in application an integrated quality, safety and information security management system according to international ISO standards.

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Biographies

Michal Svehla is a vice president of the University of West Bohemia IEOM chapter. He is also a student of the doctoral study program at the faculty of Electrical Engineering University of West Bohemia in Pilsen. Before doctoral study, he earned Bachelor's and Master degree in the same University as mentioned above. His research interests include e-Health/healthcare, processes, optimization.

Jiri Tupa received his MSc (2002) and Ph.D. (2006) in Electrical Engineering from Faculty of Electrical Engineering, University of West Bohemia in Pilsen in Czech Republic. He is a Vice-dean of faculty and Senior Lecturer at the Department of Technologies and Measurement. Dr. Tupa is a member of executive management at Regional Innovation Centre for Electrical Engineering of the Faculty of Electrical Engineering at the University of West Bohemia in Pilsen. He is also PhD supervisor, reviewer of journal and conference publications and co-organizer of conferences. His research interests include Business Process Management, Quality Management, Risk and Performance Management in Electrical Engineering Industry, Industrial Engineering, Electronics Manufacturing and Diagnostics, Financial and Project Management, Copyrights and patents law, information law and transfer of IPR. Jiri Tupa is responsible for several international research and development projects with industrial and University partners.

The project RiMaCon - Risk Management Software System for SMEs in the Construction Industry is one of the important international projects. This project has received funding from the European Union's Seventh Framework Program for research; technological development and demonstration (2013-2017). The RiMaCon project's main goal is to implement a collaborative effort to promote the sharing of knowledge and competencies in a long-term strategic research partnership around the development, testing, and validation of a cost-effective and user-friendly risk management system for SMEs in the construction sector.

Frantisek Steiner was born in Rokycany in 1973. He was awarded an Ing. (MSc) degree in the field of Applied Electronics in 1996, a Ph.D. degree in the field of Electronics in 2001 and an Associate Professorship in Electrical Engineering in 2008. He is an Associate Professor at the Faculty of Electrical Engineering of the University of West Bohemia. He is the head of the Diagnostics and Testing Engineering Team at The Regional Innovation Centre for Electrical Engineering (RICE). His research fields include risk management, information security management systems and IT services management. He has published more than 120 papers and presented 45 contributions in 35 congresses.

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