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IMPLICATIONS OF THE "INDUSTRY 4.0" CONCEPT ON MANAGEMENT PRACTICE

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Abstract

"Industry 4.0" concept was developed to meet the challenge of technology progress in the field of data processing, artificial intelligence, robotics and cyber-physical systems. This concept changes the production systems to serve efficiently various customer demands. The major obstacles for successful implementation of "Industry 4.0" from a CEO perspective are unclear economic benefits and excessive investments and lack of qualified employees. The readiness to adopt new approaches in engineering, management and education defines national strategies for the forth industrial revolution progress. The new concept of manufacturing builds integrated and customer-oriented supply-chains, so the outputs and inputs go beyond processes boundaries. The radical change in manufacturing design requires a new set of skills for engineers, managers and employees. Management experiences a substantial shift from functional-based to customer-value oriented logic. Meaning of efficiency and effectiveness, scope of planning and control, organizational design for power and task distribution, communication patterns and coordination networks challenges profound changes both in meaning and form. More flexible and complex environment, patterns for instant coordination, priority for autonomous decision-making require new skills and new attitudes for employees and managers to exploit all benefits of "Industry 4.0".

Keywords: Industry 4.0, smart factory, digital manufacturing, cyber-physical systems, organizational design, customer-oriented supply chain, efficiency, management paradigm

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Introduction

The concept of "Industry 4.0" emerged as a framework for strategic development of industries in fast-changing technological environment. While first introduced at the Hannover Fair in 2011 the concept addressed the concerns that having enjoyed the leading positions in engineering and machine building for many years the German industrial sector was lagging behind its competitors in the international markets in the digital era. General recommendations and principles for policy-makers and industrial strategists under "Industry 4.0" program were developed and introduced in the 2013. These principles focused on extensive use of digital technologies inside the production cycle from design to recycling and utilization and in more broad scope of industrial cooperation patterns. The digital technologies range from Internet of things, Artificial Intelligence to Cyber-physical systems, Big Data analysis and Cloud computing (Erboz, 2017).

New technologies make a profound impact on engineering aspects of the modern industry. But the forth industrial revolution will not succeed in achieving its goals without changes in management practice from top bottom. The first industrial revolution shifted production from hand power to steam and water power, from craftsmanship to machinery. But the first industrial revolution not turned workshops into industries, but also created management in the terms as we know it today. Within its pursuit for efficiency the scientific management perfectly accomplished needs of businesses to revolutionize ways they arranged the production of goods. The second industrial revolution progressed within development of extensive transport and communication networks, notably railroads and telegraph. The invention of conveyor accelerated the standardization process both inside and outside production lines. The mass production approach spread among industries and moved into agriculture and service. The management responded with extensive organizational and behavioral studies, which focused on structural issues of combining people, technologies and resources. As the competition intensified, markets became global and supply chains established management biased towards strategic and marketing issues with more focus on value than pure efficiency. The third industrial revolution brought digital technologies in the forefront of production innovations. Computers became an integrated part of production processes. They changed the existing industries and created many new digital businesses. The vision and leadership, teamwork and flexibility marked the management developments in the brink of the new century. The forth industrial revolution means not only development of the digital technologies but the formation of the digital infrastructure. There are no more division between traditional and IT industries, the information and communication are at the core of every business (Weking et al., 2020).

As the second industrial revolution the forth one focuses on infrastructural issues which have to match the new industrial power brought by new technologies, but instead of railroads and telegraph lines, there are data processing and internet. But the forth industrial revolution goes far beyond digital infrastructure, it makes fundamental changes to mode of productions, industrial relations and value-creation process. Information and communication break the boundaries among firms, which got involved in a common production process, based on coordination, cooperation, data sharing and value creation. Management shall level its competences up to new challenges.

The mainstream of management practice goes around functional structure. Century-old organizational design still dominates the business landscape as it provides efficiency, control and strategic focus. But it curtails communication, complicates cooperation and limits flexibility. As the forth industrial revolution concept gets adopted by more and more companies worldwide the traditional management loses its capabilities to elaborate effective and efficient solutions.

The "Industry 4.0" concept was developed as an attempt to elaborate a comprehensive response of corporate management and policy-makers to innovations in the field of digital technologies. These technologies develop in four major directions: internet of things, artificial intelligence including cognitive computing and smart factories, big data and block-chain technologies for providing information on demand, cyber-physical systems with augmented reality smart sensors and high-speed mobile communication. "Factory 4.0" design incorporates the engineering concept of the future manufacturing. Cloud computing enables cyber-security issues and big data processing. Advanced manufacturing systems within extensive use of robotics, smart sensors, autonomous machinery, advanced materials and 3D-printing deliver fast, efficient, flexible and responsive production, which, along with digitalized logistics, can serve various customer needs. The new production paradigm leads to mass customization as “large batches” with few variants to “lot size 1” custom products. That is the only competitive advantage in the digital era – serve every customer in a fast and efficient manner. The production implies “modularization” – plug and produce solutions in discrete and continuous processes. But without the next block – “collaboration” – as product design and production design occur in parallel, it is impossible to shorten the production cycles. As the manufacturing systems become “adaptive”, so machines and production concepts react in a flexible way to new requirements, true customization can happen. As humans and production plants use Internet technologies and communicate directly without hierarchy, “point-to-point communication” establishes as the digital ground for new manufacturing. Only way to make production efficient and sustainable is to make it pass its burdens. Efficiency is not within operations any more, but relates to a supply chain – from raw materials sources to every customer and even further to recycling and utilization. The major benefits of the “Industry 4.0” come from enhanced productivity through optimization and automation; from real-time data for real-time supply chains in a real-time economy; greater business continuity through advanced maintenance and monitoring possibilities; higher quality products as a result of real-time monitoring, Internet of things-enabled quality improvement and robotics; better working conditions and superior sustainability; personalization opportunities that will earn the trust and loyalty the modern consumer.

Literature Review

The mainstream research of Industry 4.0 concerns the technological and infrastructural issues within organization as the concept substantially transforms production systems both in technology and management. The empirical applications of the technologies developed under Industry 4.0 concept revealed that existing management practices contradicted the basic principles of Industry 4.0 concept, like free and instant share of information about order parameters, value-based control measurements, inter-functional decision-making on process levels, and more significantly: network pattern of authority as opposite to hierarchy one.

Deloitte made an extensive research on business readiness to implement Industry 4.0 concepts and revealed the major areas of concern: intellectual property rights, personnel skills and attitudes, functional structure of resource allocation and vagueness of economic returns (Deloitte Development, 2018). Many authors defined management implications for Industry 4.0 framework on industry, organizational and departmental levels. Lu (2017) detailed the impact of Industry 4.0 technologies on various managerial practices. Weking et al. (2020) outlined the shifts in business model needed to adopt Industry 4.0 and stated general police guidelines to implement them. European commission initiated several studies to define the state of Industry 4.0 adoption an different industries and countries. Notably Smit et al. (2016) performed a profound research on Industry 4.0 impact on economy and business. The leading consulting companies and government agencies on industrial policies and economic development addressed the issues of management implications of Industry 4.0 concept. Bloching et al. (2015) in a study of Federation of German Institutes studied the digital transformations in industries and related managerial issues. PWC (2016) defined opportunities and challenges industries faced to adopt digital technologies. Many sectoral researches addressed industry-specific issues within Industry 4.0 impact on operational, managerial and technological processes.

Though most of the papers stated the need of the profound shift in manufacturing process design, supply-chain patterns, product development cycle, functional cooperation and human resource development, the topics about the general management approach transformation to secure efficiency and competitive advantages in the Industry 4.0 framework remained out of focus. The successful implementation of the Industry 4.0 concept into business practice requires not only technological improvements, human resource development and process redesign, but the rethinking of the basic principles for efficient management practice and attitudes mostly formed in pre-digital age. The purpose of the article is to set the dimensions of managerial transformations both in practice and attitudes to adopt Industry 4.0 approach, considering decision-making process, organizational structure design and target parameters for control and evaluation.

Empirical Research Review

PWC (2016) conducted a research about main challenges for the successful implementation of “Industry 4.0” by survey of business executives. 46% of respondents pointed as the major challenge the unclear economic benefit and excessive investments. 30% of replies addressed the lack of qualified employees. 26% of executives mentioned the lack of standards, regulations and forms of certification. 22% and of respondents were worried by unclear legal situation with use of external data and 19% – by unresolved questions concerning data security. The low maturity level of required technologies and too slow expansion of basic technologies was admitted by 20% and 13% of executives. The lack of prioritization or support by top managers was admitted by 18% of respondents. And only 6% mentioned the insufficient network stability and data backup (Koch et al., 2014). The survey revealed that among technological, legal and economic aspects of the “Industry 4.0” implementation, the last ones prevailed. As about technological issues the concerns are not mostly about technologies themselves, but about sufficient qualification of the employees. The legal aspects addressed data sharing and security issues.

These challenges require new approaches in engineering, management and education. Employees, executives, industrial strategies, government policy-makers need to elaborate and adopt these approaches in the environment of high-speed digital technologies development (Roland Berger Strategy Consultants, 2015). The experience of different countries shows a great variety in “Industry 4.0” strategies. If we concentrate on Europe, we can see that Germany, Switzerland, Ireland, Sweden, Finland and Austria are frontrunners of the concept. These countries have relatively high share of manufacturing in GDP and higher index of readiness for “Industry 4.0” adoption. Most of industrialized Central and East European countries like Czechia, Hungary, Slovenia, Slovakia, and Lithuania are less ready for new technologies despite the large share of manufacturing in the GDP and form a group of traditionalists. France, Belgium, Netherlands, Norway, Denmark, Great Britain demonstrate high rate of readiness for the “Industry 4.0” implementation while manufacturing share in GDP is relatively low. These countries are grouped as potentialists. Spain, Portugal, Italy, Croatia, Poland, Latvia, Estonia have low share of manufacturing in GDP and do not prepare their industries for new technologies. This group of countries is regarded as hesitators (Roland Berger Strategy Consultants, 2015). Despite the different rating all countries face the same challenges and elaborate similar strategies. These strategies aim to align governmental policies, industrial relations patterns, technology and investments programs as a comprehensive framework for common efforts to use new digital technologies in the most efficient ways regarding sustainability, competitiveness, customer satisfaction. These strategies rely not only on government efforts, which focus on legal aspects, but mostly on efforts of industrial agencies, which can arrange transfer of best practice of new technologies and develop solutions for new industrial design. The role of educational system concerns the qualification issues and general approach for preparing engineers, managers, IT specialists. Only integrated efforts can make "Industry 4.0" strategies to succeed.

The most concern of business representatives is about implementation of "Industry 4.0"is about vague perspectives of economic benefits and expectations of excessive investments in the digital infrastructure and technologies. This concern reflects the fundamental change in business models, caused by the forth industrial revolution. Markets are no more a common place, where aggregate demand meets aggregate supply. Every single customer is source of demand with specific parameters. The dominance of mass production paradigm as the most efficient way of producing goods is not relevant any more. Customization becomes the most important competitive advantage. But to provide a product tailored for a certain customer requires flexible supply-chains with light-speed communication and adaptive processes at all stages. That contradicts the traditional rule for efficiency as smoothing the operations, streamlining the flows and standardizing the outcomes. The digital technologies of the "Industry 4.0" deal with these challenges to combine flexibility and efficiency. So the benefits it brings can be traced along the whole supply-chain, not in the context of a single process or company. That is the reason why businesses cannot estimate economics gains from new tech as these gains do not fit into traditional financial and operational categories. But the investments in the tech are still within companies. And investments are huge. But the only way the investments in the new digital technologies may turn efficient they shall be made simultaneously along the supply-chain by all the participants under the common framework (Nyenno and Grinchenko, 2019). By not doing that any company risks to make excessive investments with limited impact on the performance of the supply-chain. Here is the root of the uncertain economic outcomes of "Industry 4.0" for businesses. The traditional managerial economics was not designed to reflect the processes, which go beyond the company boundaries.

Concept Review

Under the third industrial revolution the businesses used the digital technologies to improve existing operations, to make equipment more productive, reduce inventories and waiting times, to reduce defect rates, to shorten production cycles and to optimize factory layouts. The computers changed the way businesses conducted their operations, but not the operations themselves. But within the progress of data transmission, data storage and data processing technologies companies gradually adopted more integrated approach to data sharing and coordination (Lu, 2017).

Lean production and Kanban systems gained a wide acceptance due to new technologies. These systems and other similar approaches contributed to development of digital infrastructure. But more important they provided cooperative multi-flow fast-response customer-oriented platforms for modern management. As more and more functions within production were computerized, more and more data through more sophisticated sensors automatically gathered in real-time, more and more complicated algorithms got used for data processing businesses felt the importance to integrate all digital technologies into a comprehensive approach, which arranged operations in a very different manner compared to functional management. This approach got a full support from "Industry 4.0" concept. The concept and strategies behind it provided technological solutions, such as cloud computing, artificial intelligence, Internet-of-Things or blockchain for resolving engineering tasks. But it become not just a new approach or concept, but a next industrial revolution by radically changes about how manufacturing operations are managed, planned, controlled, estimated and integrated. Data is the next production factor and it stands along human resources, capital and land.

"Industry 4.0" concept requires new skills for engineers and developers, managers and employees. Engineers need to apply new technologies in the best way and adopt them in existing manufacturing processes or create modified or completely new processes. But the main challenge is to integrate all technologies in a single production system operating within principles of "Industry 4.0". The distinctive feature of the forth industrial revolution is integration of all technologies into a flexible structure for every single production cycle to be operated in the most efficient way. Cloud computing, data-mining, smart sensors, artificial intelligence, the Internet of Things have a little impact on the design and efficiency of a manufacturing if being applied separately as it took place under the third industrial revolution. Engineers will become system integrators for large, heterogenic, multilayer production networks (Da Silva et al., 2019). If twenty years ago facilities defined networks, today networks define facilities.

Under the "Industry 4.0" requirements for employees' skills and competences will include new technological issues, but also new working and more importantly networking skills. Ability to build relations builds the capacity to establish efficient cooperation relations inside and outside of an organization (Stępień and Sulimowska-Formowicz, 2015). The notorious technology of the forth industrial revolutions cyber-physical systems (CBS) and related platforms CBS-technologies combine Internet of Things, robotics, smart sensors, computer-based algorithms for decision-making and controlling. These technologies make physical and software components interact in real-time, operate as a single system and transform production processes (Steden and Kirchner, 2018). In cyber-physical systems employees need to level up their data-processing skills, like identifying and providing suitable data; analyzing, interpreting, and evaluating data; integrating components and modules in complex technical communication systems; eliminating breaks in process data; parameterizing production orders; supporting hybrid systems. But cyber-physical systems change the basic principles of production processes. Decentralization prevails in both decision-making and controlling, coordination goes not along established value-chains but in ad-hoc basis, self-organizing teams replace planned and supervised operation units, production processes change from product-centered to customer-centered or order-centered, known as "customerization" (National Academy of Engineering, 2004). These changes transform task content, restructure work organization, use virtualization technologies extensively, rely on flexible working schedules. In this environment employees' professional development will follow the next paths: greater IT-competency, active problem-solving, communication and networking skills, abilities for self-organization, self-direction and self-control, innovative thinking and ability to consider the entire system (Deloitte Development, 2018). That means that the concept for life-long learning is gaining relevance. On-job training, knowledge-based technology transfer, best practice diffusion will contribute to the efficient integration of employees into "Industry 4.0" production process.

The management experiences even more challenging changes under the forth industrial evolution. The general management paradigm stands on four pillars: meaning of efficiency and effectiveness, scope of planning and control, organizational design for power and task distribution, communication patterns and coordination networks. "Industry 4.0" made a great impact on all four pillars. Several approaches to relevance and interconnection between efficiency and effectiveness are applied to shape the target specific goal-setting and control technics in manufacturing and other business practices. Performance measurement should be adapted to new challenges (Horobets, 2019). In the most general terms the efficiency is considered as best ratio of output to input. This definition is relevant for "Industry 4.0", but the idea of what the output is and hat the input is changes significantly. Marketing approach cemented the vision of the output as customer satisfaction. If measured this satisfaction relates to customer value. So the economic value of the certain product is defined not only by its features, but also by customer attitudes. There is no such a thing as a common customer value for a product, it variates in a context of certain customer.

Mass production era management neglected this concept of the value, concentrating on combination of the product performance features. So to measure the efficiency of a certain production process we need to trace it to the certain customer, as only this customer can put the value to the. The same logic is used for inputs. No supply chain or production process can be described as efficient or inefficient if not being attached to a certain customer. The actual management practice focuses on the efficiency of a certain process with all resources being used and the result in form of a product finished or not. The customer scope is almost absent in the middle and line management, as the strategy defines process design to build competitive advantages. The smoothness and rigidity of the processes of any kind, including manufacturing, was a prerequisite for its efficiency.

The third industrial revolution helped to make these processes more focused on their efficiency, but did not change the meaning of the efficiency itself. The flexibility of the production process was achieved by switching from one rigid mode to another stable mode. As the fourth industrial revolution implies flexible, ad-hoc coordination for creating a unique supply chain for every customer, the primary reason of efficiency of a process is its integration into this supply chain with minimal delay and the highest quality of outcomes (Bloching et al., 2015). This logic changes management attitude to the evaluation of the efficiency which is determined not by inbound features of the process but by external factors. The inputs in the process are not attached to a certain outcome. They define ability of the process to adapt to the supply chain it is integrated in. This requires more systematic, more context-oriented thinking of process managers. Middle managers, who distributed resources, and line managers, which supervise operations, shall keep customer requirement in sight to secure efficiency of their processes in charge. The repeating a sequence of operations is not the main target; every manager shall make a decision for every single process how to conduct it in the most efficient way. The process is efficient if it creates an efficient supply chain. That is a remarkable distinction from the traditional management attitude to efficiency.

Scope of planning and control follows the shifts in efficiency definitions. Planning normally is made on the basis of goals and objectives: there is a plan for every goal how to achieve it. Control is made on the basis of resources: there is a report for every resource how effective it is used. Responsibility, which forms a management system in an organization, combines both directions towards goals and resources under the same authority. This system works perfectly in a world of standardized processes with attached outputs and inputs to a certain consequence of operations. If flexibility appears it destroys the structure of responsibility as it is extremely difficult to trace who is responsible for delivering the given result and use of given resources. In the concept of “Industry 4.0” success or fail is not attributed to a certain process, but the whole supply chain. And it is not constant, it varies for every iteration, for every delivery of products to a customer. As a process supervisor a manager needs to address factors beyond its planning and control to make the efficient decision about how to operate in a certain moment of time. Planning means not a scheduling and sequencing operations, but projecting capacities for future demands and bridging operations in a supply chain with instant coordination. Control focuses on in-time processing extensively. But more important is that control goes beyond the boundaries of a process itself. It needs to relate a result measured as a customer value to the process features and the whole design of supply chain. A line manager has a lot of responsibility as it defines the performance of the whole supply chain, but planning and control spread out of the authority boundaries. Communication and coordination are the core of planning and control, as a change in one operation or external factor of a supply chain requires simultaneous adaptation along the whole sequence.

Organizational design if we consider the traditional setup is mostly function-based. Every function forms a separate unit under the single authority to cover a distinctive set of operations. Production, finance, staffing, sales, marketing and other functions pursuit their own goals integrated in a single strategy. But functional boundaries always have been a major obstacle for effective and efficient management. Coordination among functions always has been a complicated task with no simple solution. The coordination links were slow as the logic of the functional management meant the priority of internal functional goals and objectives over the organizational ones. This justifies the hierarchy buildup of almost every business organization: line structure in the bottom, functional structure in the middle and some coordination and strategic structure at the top. This buildup of business organization has many advantages, comprehensive responsibility and resource distribution, competence concentration, easy scalability and tight procedures. But it hampers flexibility of operations and all three levels of management should react on the new circumstances simultaneously. The idea of “Industry 4.0” is to arrange operations not along vertical authority links but along horizontal process flows. It supports the concept of business ecosystem as a network-designed instead of pyramidal hierarchy of industry relations

(Goncharuk, 2017) and value-chain based industry development policies (Hrinchenko, 2020). Management shall not concentrate on functions, but rebuild organizations to precede many simultaneous process flows in real-time framework for inward and outward coordination. Managers used to be a decision-making centers for their scope of responsibility. The new arrangements of the manufacturing process make them more like a linking pin, which under the common requirements for the supply chain performance receives, distributes and use all necessary information to adopt the process for the current objectives.

The communication patterns and coordination networks are the key elements for a successful management strategy to adopt "Industry 4.0" technologies. The instant access to information about all related processes, about customer needs, about resourcing limits and capacity availability is the critical condition for "Industry 4.0" manufacturing design to work in an efficient manner. That is why almost every technology of the forth industrial revolution relates to data transmission, storage, processing issues. Information is a production resource today, but despite the traditional ones, it can be shared among all parties through a supply chain. Networking is the coordination priority, as it not a two-way communication today. Simultaneous efforts of many production units are required to form the process flow, which maximize customer value for every customer. Coordination means a mutual alignment, not just informing. Managers are guided not by authority levels, but by needs of the supply chain participants.

Conclusion

The "Industry 4.0" brings new technologies, which transform data into a powerful resource and create new relations between machines and humans. But the forth industrial revolution is not only about new technologies. It transforms the manufacturing system from top to bottom. From mass production it changes to a flexible customer-oriented system, integrating manufacturing and other operations in the single process to maximize customer value. These changes generate new requirements for workforce and managers. Both employees and managers need to operate in a more flexible, more complex environment, cooperate in a constant basis and make autonomous decisions within rapid and full access to all required information. New skills are absolutely necessary, but new attitudes too, especially for managers. Function-based management practice and hierarchical structures perform poorly under "Industry 4.0" framework. So networking, process design thinking, deep analytics and customer-oriented efficiency measurement systems are the management priorities. Without changes in management practice, employees' competence building the concept of "Industry 4.0" will not achieve all benefits it promises.

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