Managerial decision-making in the era of Industry 4.0

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Abstract: *Fourth industrial revolution also known as Industry 4.0, is a concept that significantly influences the entire operation of businesses and management. It necessitates changes in individual managerial functions, not excluding decision-making. In management theory, managerial decision making is defined in terms of content through descriptive and normative theories. The aim of the presented article is to examine the normative and descriptive understanding of decision - making in the context of adaptation of individual approaches to changes in the business environment - especially adaptation to technological progress related to the fourth industrial revolution. An overrated aspect of decision-making in this era is its rational side due to the rapid development of computer technology and the availability of rich software support. On the other hand, there is a tendency to bring to the decision-making process the involvement of all involved, collective judgment, the ability to learn from the development of the situation or openness to feedback. The understanding of the decision-making process thus moves from its traditional concept to a new understanding, which includes the above-mentioned factors. Development leads to their integration in the form of a direction that does not yet have a name but means a synergy of rational decision-making and critical thinking and reasoning in the context of descriptive theories. The overall optimal result of the decision-making process is influenced by objective criteria through a rational-normative model, environmental characteristics and subjective influences, personality, and cognitive complexity of the manager.*

Keywords*: FOURTH INDUSTRIAL REVOLUTION, INNOVATION, MANAGEMET, DECISION-MAKING*

1. Introduction

The dynamic development of the 21st century has brought another revolution in the form of digital transformation of the business world. We are talking about the fourth industrial revolution, commonly referred to as Industry 4.0 [1 - 3]. The term can be understood as a completely new revolutionary stage, which aims at the full integration of operational systems and information and communication technologies (ICT) - especially as the Internet of Things (IoT), creating so-called cyber-physical systems (CPS) [4, 5]. Thus, according to previous claims, Industry 4.0 is a unified system of information technology, people, machines, and tools that ensures the smooth flow of goods, services, and data in a controlled manner through the value chain, activities with a high level of autonomy and a high level of ability to transfer relevant information for decision-making [6,7]. Other studies add that the concept of Industry 4.0 describes the increasing digitization of the entire value chain and the resulting interconnection of people, objects, and systems through the exchange of data in real time [8,9].

For this reason, implementing Industry 4.0 is an important strategic decision, and before making such an important decision, executives must assess the readiness of the companies to implement Industry 4.0 [10,11]. It is considered a high-tech strategy [12], where continued dynamic developments in various areas are raising expectations for the performance of those systems in terms of reliability and responsiveness to support decision-making [13,14].

It is the management decisions made by executives in an Industry 4.0 environment that have an important impact in the areas of implementation of modern technologies, control and analysis of necessary data, data security, risk management, compliance with established regulations, etc. [15].

The aim of this presented article is to identify, at a theoretical level, changes in managerial decision-making in the context of the impact of the fourth industrial revolution, through the available scientific literature. Given the need for constant additions and changes resulting from the development of society and the necessary changes in the environment, but also in the thinking and behavior of business management, such as the current crisis, but in its background emphasizing the impact of computerization, knowledge, mutual trust between partners, development and involvement of people and with regard to the emphasis on the need for qualitative methods due to the uniqueness of the tasks and variability of the environment, it is our intention and main goal to examine, critically evaluate and provide our own views on rational-logical (normative) and descriptive decision-making in the current understanding of managerial decision in the conditions of the Industry 4.0.

2. The Fourth Industrial Revolution

The modern phenomenon was originally introduced in Germany, then adopted by other countries [16,17]. Countries have set up programmes to support the development and deployment of Industry 4.0 elements. In Germany, where the whole revolution started, "High-Tech Strategy 2020" has been introduced, in the United States we are talking about the "Advanced Manufacturing Partnership", in China "Made in China 2025", and in France the program "La Nouvelle France Industrielle" [18 - 22].

Industry 4.0 is oriented towards new technological trends in the manufacturing industry. Technological phenomena such as automation, robotics, nano- and biotechnology, advanced materials, the Internet of Things, artificial intelligence, 3D printing, big data, etc. are creating strong impulses for structural change in many industries and sectors and are driving significant changes in society. The fourth industrial revolution marks the transition from a phase of simple digitization to innovation based on combinations of material, digital and biological technologies [23].

According to World Economic Forum founder Klaus Schwab, Industry 4.0 is creating a world in which virtual and physical systems of production interact flexibly on a global scale [24]. Based on the above, we can say, that the main aim of Industry 4.0 is the production of cyber-physical systems (CPS), which is based on the integration of heterogeneous data and knowledge [16,17].

The opportunities and benefits expected can be far-reaching in the form of highly flexible mass production, real-time coordination, optimization of value chains, reduction of complexity costs or the emergence of entirely new services and business models, or acceleration of decision-making [23].

On the basis of mentioned facts, we can conclude that technological progress and the related innovations play a challenging role in companies. The impact of Industry 4.0 transform into an increase of competitiveness of companies. It is the fourth industrial revolution that is transforming into significant changes in many areas that go beyond the industrial sector. Industry 4.0 is blurring the boundaries among human capital and technologies.

3. Managerial decision-making

Decision-making is one of the so-called ongoing managerial functions and we meet with this function in the implementation of each sequential managerial function (planning, organizing, leading people, control, etc.). It is one of the most important activities performed by business managers and is therefore often considered as core of the management. Due to its position in management, decision-making is focused on a very wide range of issues. We

emphasize that the issue of decision-making is in the center of attention of various scientific disciplines (economics, psychology, exactly oriented disciplines such as operations research, game theory, decision analysis and others), each of which seeks to provide a contribution to improving the quality and efficiency of decision-making. In the available domestic and foreign literature, we meet with a wide range of opinions, concepts, focused on individual areas of decision-making. The basis for defining the main groups are the constantly emerging and differing views on the issue, using of the degree of rationality and intuition in decision-making. This creates the rational and psychological (descriptive) framework of managerial decision-making.

From a historical point of view, rationality in decision-making, its basics and beginnings are generally known. Mainly, it was Von Neumann-Morgenstern‘s model of the theory of expected usefulness and its axioms (complexity, transitivity, continuity, monotonicity, substitution), which provided a very elegant and convincing framework for explaining economic choices. The American mathematician and statistician Leonard Savage identified normative theory with the problem is clear and unambiguous. The goal is clearly defined and achievable. All variants and consequences are known. The preferences are clear. Preferences do not change. There are no restrictions. The final selection maximizes the profit. Rational decision leads to 10 acceptances of the principle of rationality and thus held a strict view of the essence of normativity in decision-making. Other famous persons of scientific life, such as Friedman and Markowitz, monitored and tried to clarify some ambiguities in the function of usefulness, which reigned in decision-making for a very long time. The aim of the monograph is to look at rationality in the current period of Industry 4.0 and to examine the views of theorists on its place in the decision-making process.

In addition to normative principles, decision theory is also based on a description of decision-making. In fact, the decision-making process is seldom unambiguous and straightforward, most managers face many limitations, loops are formed in the decision-making process, and access to information is also problematic [25]. Descriptive theories seek to clarify how decisions in real life are actually made. It is a description, analysis and evaluation of decisions that have already been made, a description of their course, people‘s behavior in decision-making and the likewise. Decisions are not only governed by the rules of mathematical logic, but various abbreviations and heuristic solutions are applied, which then manifest themselves in deviations from rational thinking. The representative of this group of theories is the so-called prospect theory. We agree that psychological aspects play an important role in the decision-making process. Although the first theories and models of decision-making were provided by mathematics, statistics, and economics, they gradually „psychologized“ and a behavioral economy emerged. In the decisions-making process, decision-makers are very often influenced by various prejudices, states, or tricks of the mind, and even if they try to be rational in any way, they fall into their trap. They also think that they have so much experience and accumulated judgment that they can make intuitive decisions without any problems. Surveys also show that almost a third of managers rely more on „feel good“ than on rational problem-solving. Neuroscience has also become a new element and area of interest, penetrating decision-making, and posing a challenge for researchers. Its influence is considerable, and it introduces the depiction of brain processes in decision-making into the study of decision-making. Thus, a new scientific discipline - neuroeconomics - is developing. All these aspects create the psychological framework of decision-making. Opinions of the authors on their application, resp. the degree of application or involvement in solving decision-making problems varies. It is therefore not at all strange that modern management has to deal with this issue.

4. Results

The area of decision-making, given the wide-ranging software support already in use, will be one of the areas most affected by the fourth industrial revolution. Various simulations can be used, virtual presentations, which, according to [26] to facilitate the decision on which processes would make the most of the investment in Industry 4.0 technologies. On the one hand, such virtual analyzes can represent significant cost savings without disrupting ongoing production processes. On the other hand, it represents a huge investment and consideration of costs and benefits. A thorough assessment of the overall effect of investments in industry 4.0 is one of the main obstacles to implementation in management practice [27,28]. It is important for the company to be able to define the requirements for a software solution. The second step should be the ability to modify the software according to the needs of the company. Last but not least, to find out whether the program is able to plan effectively also with regard to the product life cycle and possible changes by suppliers. It is questionable whether and to what extent companies in Slovakia are ready for this change. Business areas are also an area of interest not only within the decision-making function, but also in management. Industry 4.0 research has already highlighted the need to rethink existing business models due to the ubiquity of digital and new information technologies, increasing virtual communication and open communities [29]. The core of the business innovation model is the innovation process and the ability to identify a good idea, including the ability to transform such an idea into a business model that brings added value and generates revenue [30]. Competition for new business models should be designed to allow the use of data to improve industrial applications that benefit end-users. Companies have a high degree of responsibility, including the protection of confidential data. Breakdowns of data protection data and the use of private information for inappropriate and harmful purposes can 64 be destructive to business rumors. Industry 4.0 tools will be able to produce huge amounts of data that will improve decision-making, lead to early detection and prediction of problems. However, the whole process will be difficult to analyze the data. It is questionable how companies in Slovakia will be able and willing to invest in equipment that will be able to both integrate data and interpret it, of course. Currently, observations from the practice of companies applying Industry 4.0 indicate that the biggest obstacles are ignorance, when top management expects the implementation of advanced methods of management, diagnostics, prediction, but middle management, which should implement these changes, cannot realize visions with their knowledge, respectively to correct them and ultimately to correct their superiors in what the company really needs. Much of the attention in the scientific literature on decision-making in the context of Industry 4.0 is devoted to the manufacturing process, where the use of Industry 4.0 technologies such as the Internet of Things, augmented reality, extensive data analysis, machine learning and artificial intelligence can actually increase the autonomy of manufacturing systems, including operators and production facilities by supporting problem solving and other decision-making processes. The number of decision models that are used to find optimal solutions is increasing. Marr [31] states that decision-making processes will be able to be decentralized, which is related to the ability of cyber systems to make simple decisions and be autonomous. However, the literature lacks the described models that would analyze or evaluate the impact of Industry 4.0 technologies on decision-making processes. Rosin et al. [32] recognize the potential benefits of Industry 4.0 technologies for operational decision-making and propose a general model covering several types of autonomy that can be accepted by management, depending on the decision-making steps they want to strengthen in the use of technology. Based on the Mintzberg model, they proposed an ideal decision-making

process (Figure 1). It is adapted to the decision-making process, which requires the identification of a problem in a broader sense (problem or opportunity) in production.

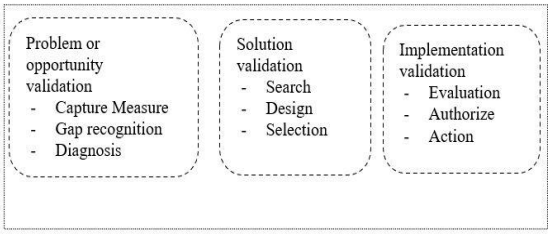

Fig.1 Decision-making process in an operational context.
Source: Rosin et al. 2016

This process involves three phases similar to Mintzberg: validating a problem or opportunity, validating a solution, and validating an implementation with the individual steps shown in the figure. This model of the decision-making process can then be used to define different types of autonomy and the use of Industry 4.0 technologies. Such technologies can help a workplace that include operators and / or machines to improve one or more steps in the decision-making process. Lin et al. [33] is based on Simon's four-phase decision-making model, including phases, in the conception of the decision-making model in the Industry 4.0 era intelligence, design, selection and implementation. The first phase is used to simplify and create knowledgeable assumptions about the real-world problem so that decision-makers can understand situations and correctly define potential problems or opportunities. The design phase includes selecting the appropriate model for decision analysis to find potential decision alternatives for the most likely scenario. The selection phase focuses on the application of algorithms to model-to-model solutions and finding solutions from decision-making alternatives. The implementation phase verifies the performance of the obtained solutions. The model is shown in Figure 2.

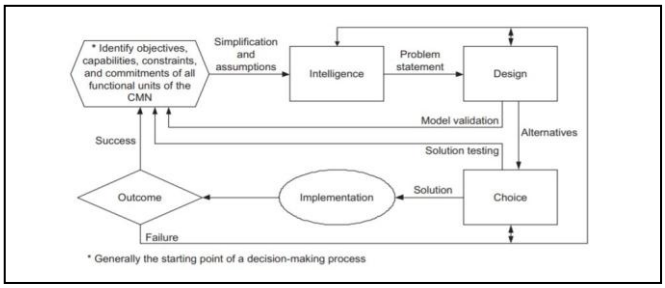

Fig.2 Decision-making model for Collaborative Manufacturing (adapted from Lin et al. 2012)

The fourth industrial revolution also brings a revolution to decision-making processes. The context of this revolution speaks of improving the rational side of decision-making through EBDM as a concept of normative theories. Of course, evidence-based decision-making as part of a rational approach to decision-making seems desirable. New analytical tools that Industry 4.0 offers for investigating „big data" promise to provide additional unbiased records. On the other hand, technological progress in improving the decision-making process is reopening issues related to facts, prejudices, and beliefs. For many years, decision support systems and technologies have aimed to improve the efficiency of human decision-making processes, strengthen rational thinking, and prevent prejudice, error, and bias. However, Industry 4.0 also makes significant progress in neuroscience, where cognitive research has highlighted issues of implicit cognition, psychological and naturalistic processes, and the impact of social cues as elements of human thought [34]. Decision support is therefore not just in rational models, but in complex cognitive and analytical decision support systems. Analysts or scientists who support research in decision support must consider descriptive aspects in the form of characteristics, behaviors, and attitudes of those who will use the analysis, systems, outputs and results. Industry 4.0 means emerging computational techniques appropriate for ‚big data', but also brings the need to discuss big data at the academic, legal, business or political level, focused not only on analytics and types of technologies in decision support, but also on prejudices, preferences and the ability of managers to think and judge [35, 36] . Some critics even predict that analytical and decision support tools will lead to the destruction of clear thinking, rational discourse, and moral behavior [35, 37, 38] Ekbia et al. [35] draws attention not only to analytics as an accompanying phenomenon of the current industrial revolution, but also to how we understand the numbers and how we subsequently interpret the results. More possible discussion and thinking is a possible solution to over-reliance on data. Discussion is recommended as a step or phase of a dialogue, multiperspective and discursive decision-making process. The decision-making process should not be based solely on personal opinion but should be supported by evidence. Decision-making requires impartial facts, expert analysis, and thoughtful commentary / discussion. Therefore, the challenge of future decision-making processes is to support decision-making through the use of brain function as a predictive organ capable of using mood, context, and social stimuli for active inference [39], rather than trying to deactivate these abilities. Decision-making scientists, management scientists, and information systems developers have not yet completed the task of predictably and effectively building computer support systems for the steps of logical thinking, classical argumentation, or group decision-making. Now, with the advanced analytical tools, virtually endless data repositories, and the fast-distributed computing technology at our disposal, we can consider scientific advances that are likely to demonstrate a wide range of things we still do not understand in the field of human cognition. Cognitive calculations are in their infancy [34] . In the scientific literature, in connection with approaches to people in the context of Industry 4.0 and work in teams or groups, several 68 concepts appear, related to the strategic use of technology and digital assets of the company to achieve the set goals. In recent years, researchers started to talk about concept of knowledge-oriented leadership [40], which is a combination of transformational and transactional leadership style. The essence of this type of leadership is the emphasis on learning and innovation, complemented by innovative role modelling, dissemination of knowledge, support for decision-making, delegation, consultation, and mentoring. Digital leader or Digital leadership helps organizations create workflows and business processes that enable the rapid deployment of new technologies, products, and services. However, being a leader in the digital age means not only technological implementation, but also digital understanding and building a digital culture. However, Oberer-Erkollar [41] states that, despite the clear naming of a leader in the Industry 4.0 era, there is a lack of comprehensive research and naming the competencies of leaders able to meet the challenges of the fourth industrial revolution. The virtual leader and leadership of virtual teams is gaining attention in connection with the change in the work environment and the rapid pace of progress in information and communication technologies. The requirements for this type of leadership move to the level of subsequent decision-making in a virtual environment, as well as the ability to manage a network of interconnected companies, design virtual operations, create and maintain virtual relationships with internal and external members or components, and ability to demonstrate it. Leading virtual teams is one of the main challenges, as it is very difficult for a team leader to directly manage the activities of each member due to their different geographical location. As a result, the leader must use different skills, delegate, and then motivate in another way. There is a high dependence on the skills of team members, on the identification of goals by team members, which is again very difficult to achieve in a virtual environment. A virtual leader cannot physically observe members and should be creative in order to practically follow members' expectations. The virtual leader must

have an intuition and sense of understanding that „electronic silence“ means consent and acceptance rather than inattention [42].

5. Discussion

The Industry 4.0 is revolutionizing managerial decision-making processes through a high degree of automation and digitization of workflows. This will have a significant impact on competition not only for the companies, but for a part of countries‘ competition, which must make significant changes in preparation for business transformation. These changes also create new challenges for company management and for the adaptation of new tools and techniques applied in the implementation of individual management functions. Research in the field of the fourth industrial revolution neglects the deep managerial challenges that are the basis of its implementation. The most important issues we have defined in the decision-making function for the era of the fourth industrial revolution are: – decentralization of decision-making, related to the ability of cyber systems to make simple decisions and be autonomous, – building on evidence, not information and data, – greater need for critical thinking and reasoning, discussion, ability to interpret, – focusing on decision-making support not only in rational models, but in complex cognitive and analytical decision support systems – progress in neuroscience, decision-making support through the use of the brain as a predictive organ capable of using mood, context and social stimuli for active inference. The fourth industrial revolution supports decision-making with its tools. The creators of this support should try to strengthen the intended rationality of the target user while avoiding the introduction of „irrationality“ in the analysis and decision-making processes. Effective technologies must consider the complex social nature of decision-making as well as the multifaceted nature of evidence. Their knowledge and response create a space for learning about other contexts and impacts, especially in the social field. The authors agree that the fourth industrial revolution will have an impact on all areas of our lives, disrupting existing socio-economic structures. In general, forms of service provision will change, including new forms of education and professions - probably up to half of today‘s professions will disappear in 15 years and completely new ones will be born that we do not yet know exactly. Lifestyles will change, and so will ways of managing public affairs in general. Technological innovation, which is growing exponentially, will also lead to social innovation. It is therefore a great challenge for managers and scientists to examine what strategy to set when implementing concept 4.0, not only within the boundaries of their own company, but including the entire corporate ecosystem.

6. Conclusion

Decision-making is a key characteristic of a successful organization and one of the most important roles of a manager. The ability to make the right decisions is a complex phenomenon and represents an interplay of both rational and descriptive elements, taking place in social groups, within the framework of social relations in companies. Based on the amount of studied professional literature, we state that there is a predominant interest in the normative understanding of decision-making, and many authors try to examine in detail this area in decision-making processes in context of Industry 4.0. We are inclined to believe that analysis, automation, or adherence to precisely defined steps in decision-making processes are really necessary in today‘s information age, and we dare say that they are paramount with regard to the Industry 4.0 era. On the other hand, we strongly emphasize that the behavioral economy, its knowledge, and conscious incorporation into decision-making are an integral part of achieving an effective course of a rational process. Awareness of the fact that we can fall into one of the psychological 76 traps, the knowledge that the action of different types of emotions can significantly affect our decision-making, can significantly improve the quality of our decision-making processes. Due to the rapid development of computer technology and the availability of rich software support, rational approaches to decision-making lead to a re-understanding of their importance and also to a change in their understanding. There is a tendency to bring to the decision-making process the involvement of all involved, collective judgment, the ability to learn from the development of the situation or openness to feedback. The understanding of the decision-making process thus moves from its traditional concept to a new understanding, which includes the above-mentioned factors.

The problem of normative and descriptive theories in decision-making is addressed by many scientists, who highlight the positives of one or the other side of decision-making methods. In any situation, whether it is ordinary decision-making or decision-making in crisis conditions and at the same time in times of technological progress, it is not possible to overestimate only one aspect of decision-making. Development leads to their integration in the form of a direction that does not yet have a name but means a synergy of rational decision-making and critical thinking and reasoning in the context of descriptive theories. The overall optimal result of the decision-making process is influenced by objective criteria through a rational-normative model, environmental characteristics and subjective influences, personality, and cognitive complexity of the manager. In the decision-making process, rationality is mostly limited and is limited by the amount of information obtained. Therefore, this process is characterized not only by analysis, but also by constant evaluation, intuition, and political behavior.

6. Acknowledgement

This article is a partial output of research project VEGA no. 1/0017/20 entitled Changes in the application of managerial functions in the context of the fourth industrial revolution and the adaptation processes of enterprises in Slovakia.

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