Intelligent management of supply chains and outsourcing in mechanical engineering under "Industry 4.0" conditions

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Abstract. Mechanical engineering industry has recently been seriously affected by achievements and progress of artificial intelligence and by extremely rapid evolution of Industry 4.0. Considering that the market will rapidly change in the coming decades, the only way to preserve and strengthen market positions for enterprises, is the transformation of production processes within the framework of new technological trends and integrated networked cluster ecosystems.

1. Introduction

Technological progress has always influenced business, for example, due to productivity boost because of replacing human labor with machines. Continuous progress in the field of information technologies and related areas should dramatically change both the essence of labor activities and the way of our life in general. The potential power of combination of artificial intelligence technologies and “Industry 4.0” leads to global consequences and challenges that need to be solved fairly quickly and should be overcome in order to preserve and develop the business. The evident decision is to make the necessary changes in the project management methodologies.

Nowadays an active implementation of intelligent integrated technologies happens in modern mechanical engineering. And it concerns both the production chain and supply chain management [1,2]. Such an interconnection of digital and physical systems has united almost everything: from design and product planning to supply chains and production. The popularity of this approach is due to the short lifecycle of manufactured products, as well as because of high level of customer focus under the conditions of fierce competition.

Digitalization opportunities become important while providing activities of joint production networks which can better adapt to future dynamic markets. With the increasing prevalence of Internet technologies, production systems are transformed into so-called cyber-physical production systems (CPPS). They include a network and autonomous components with the local control of intelligence, which can communicate autonomously with other devices, machines, production modules and products through open networks and semantic descriptions. Thus, traditional rigid hierarchical production will be replaced by a decentralized self-organization, where application of reengineering will allow to create much more flexible production systems.

Besides, for design purposes, dynamic adjustments and reconfigurations of the production system, equipment and software can be performed much more quickly. Also production components can be easily removed or added during product manufacturing. This will allow to better meet the unpredictable demands of the market or to respond flexibly to haltings and failures.
The goal of this paper is to analyze how intelligent information technologies (IIT), developed within the framework of the “Industry 4.0” projects, and related cyber-physical systems do impact and change principles and methods of supply chain networks managing and outsourcing.

2. Artificial Intelligence and Industry 4.0
Over the past years and decades, computers have constantly transformed both workplaces and society itself. Information technologies have become a vital part of our everyday life and work, changing job descriptions, initiating new business models and processes, and also changing their viability over time. Employees, as well as enterprises, need to be able to quickly adapt to stay competitive and in demand. Changing conditions and markets has always been difficult and problematic for businesses and employees, therefore, to answer the question about the difference of “fourth industrial revolution” from the previous ones it is necessary to understand reasons of wide distribution of the artificial intelligence.” Artificial intelligence is not some other type of computer that can do something new. Artificial intelligence tends to imitate and replace human thought processes and create a “learning” virtual computer that can replace human decision-making, i.e. this is an attempt to copy the human thought process by the computer. Artificial intelligence, by means of machine learning, can independently learn and adapt, just like a person [3].

Conception become widely renowned due to the victory of artificial intelligence based program over the “Go” game world champion, although the idea itself and the threat of people replacement by intelligent machines were already discussed in the second half of the last century [4]. However, the “fourth industrial revolution” increases this threat. Due to the wide applying of such technologies as 3D design and printing, Nano-Tech BioTech the labor productivity has grown much. Along with flexibility and convenience, production and supply cost simultaneously goes down [3], what leads to an “economy of abundance” [5].

In the future, company location will no longer be a problem, and two business partners can participate in any venture enterprise, starting production immediately after signing contracts and starting deliveries. At the process of production planning one can reveal the possibility to take into account the potential of outsourcing and supply chain management. Growth of three-dimensional design usage and progress in three-dimensional printing, along with new developments in the field of materials science, undoubtedly, give an unprecedented degree of flexibility to all production innovations.

As an example we can consider the first 3D-printed object in space made for the ISS [6]. Even today, you can already begin production as soon as the product is designed. You no longer need to create new production facilities, since the product can be manufactured on any three-dimensional printer and delivered to the addressee by a definite logistics company. In fact, the need for human participation can be limited to the approval of the design concept together with artificial intelligence that solves all other issues - from fully automated production to the delivery of finished products to client by unmanned cars and drones. Naturally, all these global changes will have a huge impact on the whole business scheme, which will largely be outsourced to artificial intelligence. The workplace of the future will differ significantly from the modern corporate world.

3. The influence of artificial intelligence to project management in mechanical engineering
The transfer of stereotyped repetitive tasks that are performed by deterministic algorithms (for example, accounting) to an artificial intelligence just the first step. Abilities of artificial intelligence systems to learn and self-educate can, in the long run, make it possible to adequately replace an entire army of white-collar workers. Company owners may come up (and many have already come up) to the idea that instead of hiring one or a few hundred people, you can buy one artificial intelligence system that will never get sick, be absent, or complain about working conditions. In this case also there is no need to solve all the complex and often poorly predictable problems arising around the team. System maintenance and upgrading costs for such an artificial intelligence system will be insignificant compared to labor costs and related administrative activities. Cost, as known, was one of factors for
outsourcing and transferring of manufacturing to countries with low labor costs. [7]. Considering that even the bibliographic work at some university was transferred to artificial intelligence [8], it is easy to imagine that many other similar jobs are under serious automation “threat” by artificial intelligence [9].

If an artificial intelligence system can accurately assess a project, perform tasks, perform outsourcing, for example, like WorkFusion suggests, then, literally no work can be protected from being replaced by artificial intelligence. WorkFusion Platform combines machine learning with crowdsourcing to automate data processing. WorkFusion software is embedded into business processes and it attracts resources of remote employees to perform tasks and uses results to train artificial intelligence, which then takes over the fulfillment of all these tasks.

Deep Learning is a branch of machine learning, based on the model of human brain neurons interaction and in fact is an artificial intelligence, which is not inferior to human accuracy in performing tasks. And it is superior to people by an amount of work it can perform. For project management, this would mean execution of all work types (for example, highly qualified analysis and risk planning and other related tasks) faster and more comprehensively than any of the strongest team of project managers could even dream of. Considering the sad statistics of numerous failures in this area, artificial intelligence can really significantly increase work productivity and reduce its cost.

The methodology of flexible production in combination with artificial intelligence and materials science will allow to organize localized and economical production in a short time and taking into account its specifics. To a large extent, it can be organized without the participation of a human, who, in this case, will only have the auxiliary role of “machine operability” ensuring. How can the sustainability of human labor be improved and counteracted to machine labor replacement? In [13], it is suggested to consider creativity, social intelligence and management of operations as main arguments that can counteract to the replacement of human labor by machine labor. In addition to the new jobs associated with the maintenance and formation of these intelligent supply chains and networked outsourcing, the above arguments ensure that people would retain their jobs, although perhaps in a slightly modified form.

4. Business transformation under conditions of rapid changes
Whenever the economic environment undergoes rapid and dramatic changes, there are winners and losers. Considering realities of the upcoming challenge, it is necessary to act now to become leaders and drivers of serious market changes. To use capabilities of the artificial intelligence properly, you need to evaluate carefully and critically what kind of business we do represent and where we want to be when the “smart factory” will become an objective reality. Failure or refusal to solve these problems in this case is not a suitable option: competitors will become more active and force other market participants to follow their example or to drop out of the competition.

We can already see this effect even today, but to a lesser degree. Why do clients have to put up with the fact that you can not deliver to them what they want, when they want and how they want. In this case the key to success is to create a value. Only innovative, flexible and customer-oriented competitors of your company will remain on the market. Thus, transforming of your business and yourself is a task that should be started right now in order not to fall behind forever.

Corporate strategy is needed, which, ultimately, will ensure sustainable market success, offering the necessary value to customers. Offers of “value and usefulness” to customers will be the main goal and future distinctive advantage which are necessary for planned results achievement and also for interactive communication with client.

Value and usefulness are much more than just buzz words that identify valuable offers to your clients. Exactly they will be the key factor for future success on the market. Obviously, all products are becoming more and more interchangeable from the technical side. Literally, it does not matter which one gadget, for example, do you buy since all the offers are almost identical.

Decentralized production and outsourcing will be two key functions for successful application of artificial intelligence in Industry 4.0. Today, we already have the necessary tools to solve such
bottleneck, for example, as a delivery, by implementing artificial intelligence methods into production and logistics. However, in order to truly get around such bottleneck, you need to have localized flexible production with decentralized capacity to work alongside the customer. At the same time, production must be sufficiently “smart” to automatically accept and execute orders using an intelligent system, reducing or completely eliminating the need for human intervention, besides making initial decisions [10-12]. Naturally, at the same time, considered above “lean” and ordered chain of value creation will be very vulnerable to external shocks, what makes viability the main task for the management team, whose functions should significantly differ from today's management.

5. New functions of management in Industry 4.0 environment
The transformation of production industry is called a revolution exactly because not just slight changes are taking place but radical ones: the industry is being restructured from top to bottom. Business models are changing, new companies are born, world-famous brands with a long history are obliterated if they do not have time to join the ranks of digital innovators. Customers have changed their behavior, they want an individual approach, unique products.

The type of required managerial specializations and their relative roles in the management team have been constantly changing since the modern corporations have emerged. And at the beginning there were no positions based, for example, on "equality" or "sustainability", because the need for them evolved only with time. As the business environment evolves, it’s necessary to develop, create, change, and replace managerial positions and responsibilities depending on emerging needs.

The actual need for management will be reduced to managerial and business functions, which depend on individual decisions and preferences. This “lean” approach to business management can only be resolved through a combination of artificial intelligence and Industry 4.0, and this is largely dependent on networked outsourcing within the production cluster [2,12]. Creating flexibility for decentralized production will eliminate the need to retain production capacity, which will actually begin to become a burden rather than an asset.

All together this will create a need for new managerial functions, as well as also will change the content and responsibilities list for all departments in company. Naturally, these functions will be largely supported by their own artificial intelligence systems. The human intervention should be carried out only at the very last stage and only if it’s necessary and desirable at all [14].

The main idea of Industry 4.0 and CPPS is to create self-organizing and self-adapting dynamic network structures of outsourcing and supply throughout the product life cycle in order to actualize the most flexible individual production with the costs matching to mass-flow production. This trend is already clearly visible in many key sectors of the global economy and political decisions are largely determined by the increasingly tough battle for markets of innovative products and services.

The adoption of Industry 4.0 is actively and effectively hampered by a number of factors, among which, apart from doubts about the digital data safety and requirement in large investments, one can also note insufficient qualification of personnel and customers at all levels, the lack of effective business processes and standards which allow to take advantage of the digital approach. And exactly this approach can provide new opportunities for small and medium businesses. For example, in mechanical engineering clusters, where flexibility and customer focus, combined with standardized networks of own production resources, allows not only to expand the segment of orders from large companies, but also to ensure own accelerated development because of additional investments and refresher training courses. Comprehensive automation, digitalization and intellectualization of main technologies that provide proper functioning of enterprise will ensure guaranteed growth in turnover, production flexibility, productivity and overall company efficiency. The main difficulty lies in the fact that implementation and usage of “Industry 4.0” technologies and cyber-physical systems will take place under the influence of various kinds of uncertain factors, for example, indifferent, targeted and associated with the uncertainty of goals at participants.

Uncertainty analysis of competitor actions can be based on multi-agent systems, various gaming models, methods of fuzzy logic. In these approaches, conflict management principles are
implemented, as well as taking into account the so-called “soft” factors that are hard to formalize, such as common goals, flexibility, trust, reputation, and so on. The digital revolution in supply chain management and outsourcing can lead to a real growth of business efficiency and to significant improvement of customer services quality.

Often, logistics and outsourcing companies use home-made information systems for the control of production processes and services that leads to significant costs and time losses. It is much more advisable to use a multifunctional renewable platform supported by a serious operator, by creating at the same time a single cooperation space between all participants in the outsourcing and supply chain.

Modeling, optimization and big data analytics allow to form a complete set of technologies for creating an outsourcing network and a digital supply chain, by the identification of process state model for all processes in a real time. At any given time, the digital twin should display outsourcing processes and supply chain status compared to: actual planning data, necessary tools production, component production, transportation, inventory, demand and capacity. The digital twin can be used for making real time decisions, as well as for forecasting and planning of outsourcing. In fact, mechanical engineering company and firms that provide outsourcing and logistics services within the framework of this approach are integrated into a single mechanism for solving tasks of flexible customer-oriented production, while remaining full-fledged market participants at the same time.

For example, if an abnormal situation occurs either at the logistics center or at some cluster enterprise, this deviation can be seen by the risk monitoring tool and transferred to the simulation model to form alternatives. Digital twin simulation can help to reveal impact proliferation for emergency events in system and, besides, provides an effective and almost online adaptation of action plans in accordance with the situation.

6. Conclusion

Decentralized production and distributed outsourcing will be two key functions for the successful application of artificial intelligence in Industry 4.0 for the mechanical engineering. In mechanical engineering clusters, it is preferable to use a multifunctional updateable information management platform and to create a single cooperation space for all participants of the outsourcing network and supply chain. At the same time, simulation, optimization and big data analytics will allow to form a complete set of technologies for creating a flexible network of outsourcing and a digital supply chain, by the identification of process state model for all processes in a real time. And herewith, the digital twin will display and predict the status of outsourcing processes and supply chain compared to: actual planning data, necessary tools production, component production, transportation, inventory, demand and capacity.

References

[1] Bakhtadze N, Smirnova G, Sabitov R and Elpashev D 2017 Identification and simulation models in logistics control systems for production processes and freighting IFAC-PapersOnLine Volume 50 Issue 1 pp 14638–43

[2] Gulnara Smirnova, Rustem Sabitov, Boris Morozov, Shamil Sabitov and Natalya Elizarova 2015 To the problem of dynamic modeling and management in an integrated environment of the industrial cluster IFAC-PapersOnLine Volume 48 Issue 3 pp 1230-35

[3] Ford M 2015. Rise of the robots: technology and the threat of a jobless future Basic Books, a member of the Perseus Books Group New York

[4] Larabell J T 2016 The Rise of the Robots The New American 32 pp 10–17

[5] Sadler P 2010. Sustainable growth in a post-scarcity world: consumption, demand, and the poverty penalty Gower, Farnham, Surrey; Burlington, VT

[6] Rainey K 2015. Open for Business: 3-D Printer Creates First Object in Space on International Space Station NASA http://www.nasa.gov/content/open-for-business-3-d-printer-creates-first-object-in-space-on-international-space-station (accessed 11.24.17).

[7] Online resource: https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/operations/
[8] Condon W 2013 Large-scale assessment, locally-developed measures, and automated scoring of essays: Fishing for red herrings? Assessing Writing 18 100–108

[9] Kashapov N F, Khafizov I I, Nurullin I G and Sadykov Z B Influence of introduction of robotics on increase in efficiency of electrochemical production 2018 IOP Conference Series: Materials Science and Engineering 412(1) 012034

[10] Gulnara S. Smirnova, Rustem A. Sabitov, Ekaterina A. Korobkova and Shamil R. Sabitov 2017 Modeling production facility as a dynamic integrated interacting objects system Procedia Computer Science 112 965–970

[11] Bakhtadze N N, Smirnova G S, Sabitov Sh R, Sabitov R A, Elizarova N Yu and other 2016 Multi-agent Simulation of SWAP BODIES application in manufacturing supply chain IFAC-PapersOnLine 4 № 12 pp 1245–1250.

[12] Smirnova G S, Sabitov R A, Dolgui A, Bakhtadze N N and Sabitov Sh R Design of a Multi-agent System to Manage Relay Intercity Freighting 2016 IFAC-PapersOnLine 49 № 12 pp 1656-61

[13] Frey C B, Osborne M A, 2017. The future of employment: How susceptible are jobs to computerisation? Technological Forecasting and Social Change pp 114, 254–80

[14] Ruchkina E R, Gilmanshin I R, Kashapov NF, Galeeva A I and Krainova D R 2018 Modeling of the complete life cycle of raw materials in the mathematical apparatus of problem-oriented modification of color networks Petri-DN-networks IOP Conference Series: Materials Science and Engineering 412(1) 012059