Logistics 4.0 and supply chain 4.0 in the automotive industry

Krasimir Markov\textsuperscript{1} and Pavel Vitiemov\textsuperscript{2}

\textsuperscript{1}University of Ruse, Department of Engines and Vehicles
\textsuperscript{2}University of Ruse, Department of Management and Business Development

krmarkov@uni-ruse.bg

Abstract. The Industry 4.0 technologies give real benefits to the plants where they are implemented such as performance improvement, costs and delays reductions. The automotive plants are among the factories that could implement most of these technologies. Industry 4.0 can affect all of the processes which happen in the automotive industry manufacturing plants – engineering, production, logistics, management, etc. Analysis of all of the processes in one article is too complex task and due to this the paper is focused only on logistics and supply chain. The aim of this article is to investigate the potential possibilities for implementation of Logistics 4.0 and Supply Chain 4.0 in the automotive industry plants, in particular in Bulgaria. Specially designed survey was used as investigation method. It consists of two groups with proposals and assumptions. The survey was conducted by 12 automotive industry logistics experts who are on 6 different logistics positions. The results show that the production visibility (assembly lines connected to internet) and blockchain technologies have the biggest values to the logistics and supply chain. But the cybersecurity and faulty data are the main challenges in front of them.

1. Introduction
The automotive industry is one of the most engaging and dynamic industries. It is developing extremely strongly and it is open to new technologies which would rise the production rates and which would provide better control. Industry 4.0 is one of these new technologies. Industry 4.0 includes additive manufacturing, advance robotics and cobots, artificial intelligence, augmented reality, human-machine interfaces, machine-to-machine communication, blockchain, internet of things, cloud stored data, internet of services, digital transformation, autonomous vehicles, drones, etc.

Key factor in it is the usage of connectivity and communication among of devices. The industry 4.0 technologies together with real-time data would transform the whole manufacturing process in every industry including also the automotive industry.

The goal of this article is to investigate the potential possibilities for implementation of Logistics 4.0 and Supply Chain 4.0 in the automotive industry plants, in particular in Bulgaria based on unique survey that has been conducted by 12 automotive industry logistics experts.

The paper is structured as follows: In the section in terms of related work are listed the main lessons following the smart manufacturing and smart factory and the challenges in the implementation of Logistics 4.0. Section 3 shows our approach to conduct a unique survey by automotive industry experts in terms of possibility for implementation of Logistics 4.0. Section 4 describes an analysis of the results of the survey. The conclusion of the investigation is placed in the end of the paper.
2. Related work

Characteristic feature of Industry 4.0 are the intelligent networks based on cyber-physical systems. Cyber-physical systems are physical and engineering systems which operations can be monitored, coordinated, controlled and integrated by computing and communication systems [1]. It relies on interaction between physical and network devices such as sensors, actuators, control units and communication devices. The general structure of cyber-physical system is shown in figure 1. The implementation of Internet of Things can affect the interaction between the cyber-physical systems and the way of their monitoring, controlling and managing. By this way it could contribute to more effective and cost efficient production [1][10]. There are three features of the Internet of Things – context, ubiquity and optimization [11].

There are two more terms in the literature connected with Industry 4.0 – smart manufacturing and smart factory. The smart manufacturing is the use of cyber-physical systems together with Internet of Things. The smart factory refers to the close connection between products, machines, transport systems and people [10]. The smart factories could give numerous opportunities and benefits including highly flexible mass production, real-time coordination and optimisation of the supply chain, reduction of delays and costs, emergence of brand new business models and services [4].

Industry 4.0 can affect all of the processes which happen in the automotive industry manufacturing plants – engineering, production, logistics, management, etc. Analysis of all of the processes in one article is too complex task and due to this the paper is focused only on logistics and supply chain. The terms Logistics 4.0, Smart Logistics and Supply Chain 4.0 have been introduced according to Industry 4.0. These terms refer to the usage of logistics together with cyber-physical systems and Internet of Things. From technological point of view the implication of Logistics 4.0 is not aiming to replace the humans but to avoid inaccuracies and to have faster processes with easy shared information in real time [1].

The logistics could be define as to deliver the right product/s to the right customer/s in the right location/s and time. The introduction of Logistics 4.0 can change the process in different ways – faster speed with using of autonomous vehicles and drones, higher reliability, lower operating costs by using inventory monitoring and refilling smart sensors (smart shelves with weight sensors), improve efficiency because of delays reducing, smart transportation with delivery time reduction and vehicles emissions reductions [8]. The main applications of Logistics 4.0 can be in the resource planning, warehouse management systems, transportation management systems, intelligent transportation systems and information security [1]. Logistics 4.0 application model is shown in figure 2. Some of the sensors that could be used in Logistics 4.0 applications include RFID, LIDAR, accelerometers, GPS, cameras, humidity sensors, etc. [10]. The existing logistics concepts such as JIT/JIS and Kanban could be improved with the implementation of Logistic 4.0 [4].

The supply chain 4.0 has the following features – extensive use of Internet of Things, constant visibility of the complete supply chain from all participants, a possibility of accurate verification of the supply chain coherence by blockchain technology, a possibility of dynamic optimisation of supply chains and suppliers [10]. The blockchain technology has significant potential to improve supply chain processes [5]. The main reason for this is the possibility for simultaneously sharing of the information and documents between all companies in the supply chain. Additionally it could reduce the delays and the incorrect data in the documents.

The introduction of Supply Chain 4.0 reduces the lead-time of the whole chain [3]. It can also affect the Engineer-to-Order industries which also include the project lead-time [7].

Sustainable Supply Chain 4.0 can be formed only if the entire business is connected digitally [6]. Dossou (2018) suggests a reference model for transition to supply chain 4.0 of small and medium enterprises where the sustainability is placed as kernel for improvement.

According to Torbacki et al. (2019) there are ten key performance indicators divided into three perspectives – Industry 4.0 with the three indicators (supply chain, production planning and reconfigurable manufacturing), Logistics 4.0 with four indicators (Internet of Things in logistics,
warehouse, intelligent transportation systems and data safety) and Sustainability with three indicators (economy, environment and society).

Figure 1. General structure of cyber-physical system [1].

Some of the challenges in front of the introduction of Industry 4.0 are the cyberattacks, faulty data, safety regulations and privacy issues [8]. It has to be also noted that some of the Industry 4.0 technologies would have negative impact on the performance [9]. This depends from the context of the company.

3. Resources and methods

The first thing which had to be done in the investigation was the selection of Industry 4.0 technologies which are more likely to be implemented in the logistics of the automotive plants. The selected technologies are advance robotics, artificial intelligence, machine-to-machine communications, Internet of Things, blockchain, cloud stored data and autonomous vehicles.

Based on the literature analyze in the previous section, the survey is common used method for evaluation of the possibility for implementation of Logistics 4.0. Taking this into account, the investigation uses a specially created survey in order to achieve the purpose. The survey consists of two groups. One of the group considers only the possible potentials and has seven proposals. The other group considers the possible challenges and has seven assumptions. Each proposal has answers with points from 0 to 2 (0 point to “disagree”, 1 point to “agree”, 2 points to “already implemented”). Each assumption has answers with points from 0 to 2 (0 point to “disagree”, 1 point to “agree”, 2 points to “already is problem”). The sum of the points gives the result of the respective proposal or assumption. The survey proposals with the linked to them technologies are given in table 1. The survey assumptions with the linked to them technologies are given in table 2.

Some of the proposals are opposite to the assumptions – proposal 1 is opposite to assumption 1, proposals 4 and 5 are opposite to assumption 2, proposal 6 is opposite to assumptions 3, 4, 5 and 6, proposal 7 is opposite to assumption 7.

The survey is conducted by 12 automotive industry logistics and supply chain experts from 2 automotive plants in Bulgaria. They have six different work positions and all of them were with different work experience in the logistics and supply chain field. The experts were asked for their Industry 4.0 level of knowledge before the creating of the survey. This was done in order to create more clear proposals in the survey and to get accurate answer from the experts. In the end of the investigation the logistic managers were asked additionally which technology would give the best delay reduction and the percentage of the reduction. The experts work position, work experience and knowledge are shown in table 3.
Table 1. Logistics 4.0 potential proposals.

| №  | Industry 4.0 technology                      | Proposal                                                                                                                                 |
|----|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1  | IoT/Blockchain/Cloud stored data            | The internet connection of the assembly line to the customer would increase his satisfaction due to production visibility.              |
| 2  | Machine-to-machine communications          | The internet connection between production linked assembly lines would increase the costs savings due to production traceability.       |
| 3  | Machine-to-machine communications          | The smart shelves with sensors would increase the production rates due to assembly line refilling shorter time.                       |
| 4  | Autonomous vehicles                        | The autonomous forklift would increase the production rates due to the shorter time for reaching and delivering the required pallets with parts. |
| 5  | Autonomous vehicles/Robots/AI             | The autonomous milkrun would increase the production rates due to shorter time and flexibility for delivering the required parts to the assembly line. |
| 6  | Blockchain/Cloud stored data              | The blockchain and use of internet portals for all companies in the supply chain would increase cost saving due to real-time information and documentation shared between all participants. |
| 7  | IoT/Blockchain/Cloud stored data           | Real-time GPS route optimization would increase cost savings due to transportation shorter time.                                      |

Table 2. Logistics 4.0 challenges assumptions.

| №  | Industry 4.0 technology                      | Assumptions                                                                                                                                 |
|----|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1  | IoT/Blockchain/Cloud stored data            | Cyberattacks over internet connected assembly line could break the production process.                                             |
| 2  | Autonomous vehicles/Robots/AI             | The use of autonomous vehicles and robots could result in employee’s replacement.                                                      |
| 3  | Blockchain                                 | The different standards among the companies in the blockchain could result in increase of the costs.                                  |
| 4  | IoT/Blockchain/Cloud stored data           | The use of blockchain and cloud computing could result in confidential data security leakage.                                         |
| 5  | Blockchain/Cloud stored data              | Faulty data inputed in the blockchain portals could increase the costs.                                                              |
| 6  | IoT/Blockchain/Cloud stored data           | Old version software could result in blockchain costs increase due to missing of information or security problems.                  |
| 7  | IoT/Blockchain/Cloud stored data           | GPS connection missing could result in cost increase due to transportation delays.                                                      |

Table 3. Automotive Industry logistics and supply chain experts.

| №  | Position     | Experience | Industry 4.0 knowledge |
|----|--------------|------------|------------------------|
| 1  | Logistic Manager | 21 years   | moderate               |
| 2  | Logistic Manager | 18 years   | moderate               |
| 3  | Disponent    | 10 years   | little                 |
| 4  | Disponent    | 7 years    | basic                  |
| 5  | Material Planner | 8 years    | little                 |
| 6  | Material Planner | 14 years   | moderate               |
| 7  | Forwarder    | 5 years    | basic                  |
| 8  | Forwarder    | 8 years    | basic                  |
| 9  | Purchaser    | 9 years    | little                 |
| 10 | Purchaser    | 12 years   | little                 |
| 11 | Seller       | 11 years   | moderate               |
| 12 | Seller       | 10 years   | little                 |
4. Results and discussion
The results of the survey are shown in table 4.

| №  | Proposal result | Assumption result |
|----|-----------------|-------------------|
| 1  | 14              | 11                |
| 2  | 9               | 4                 |
| 3  | 8               | 4                 |
| 4  | 7               | 8                 |
| 5  | 4               | 12                |
| 6  | 12              | 5                 |
| 7  | 8               | 4                 |

The results show that the proposal 1 has the biggest value. This is because the fulfilment of the customer orders has big impact on the customer satisfaction. Combining of order fulfilment with real-time production visibility has the potential to raise his satisfaction even more. That is why some of the automotive plants have already implemented the connection of some assembly lines by internet directly with their customers. The blockchain technology (proposal 6) gives additional advantage to this and it is also implemented in some of the automotive plants. In the same time the assumption 1 has one of the highest values. This indicates that if there are not any cybersecurity activities, the benefits could be totally lost. The other big problem which could happen is the faulty data which could be inputted in the blockchain portals (assumption 5). This would have impact over the all participants in the supply chain resulting with big delays and costs.

Most of the proposals have moderate values. There are two reasons for these values. The first reason is the high costs for the implementation (proposal 4). The second reason is the low/moderate benefits of the proposed technologies (proposals 2, 3, 7). It has to be noted also that the safety regulations for the autonomous vehicles have impact over the results for the respective proposals.

There is just one assumption with moderate value (assumption 4). Although all of the companies from the automotive industry use some internet portals where the documents are shared, there is high attention to the cybersecurity. It has to be carried out cybersecurity activities in the internet systems in order to avoid confidential data security leakage.

The lowest value in the proposal has the autonomous milkrun (proposal 5). This is mainly because even if the milkrun is autonomous, a worker would still be needed to take the parts from the milkrun to the assembly lines. This could change only if the milkrun is combined with robots. Another reasons are the higher costs for autonomous milkrun and the safety regulations.

There are several assumptions with low values. The reasons are as following: the employees would monitor the autonomous vehicle and robot’s work (assumption 2), the standards are not problem for the experts mainly because the automotive plants are certified to the automotive standards (assumption 3), old software version is not normally used in high quality production factories such as the automotive plants (assumption 6), the short-time lack of GPS connection would not have significant impact over the transportation time (assumption 7).

According to the opposite proposals and assumptions it can be seen strong correlation between proposal 1 and assumption 1, proposal 5 and assumption 2, proposal 6 and assumption 5.

The autonomous vehicle was pointed from both logistics managers as the technology which could give the best delay reduction in the logistic process in the automotive plants. According to them there would be around 20% time reduction of the process. It should be noted that this does not mean 20% increase of the production rates.
5. Conclusion
The Industry 4.0 technologies give real benefits to the plants where they are implemented such as performance improvement, costs and delays reductions. Industry 4.0 can affect all of the processes which happen in the automotive industry manufacturing plants – engineering, production, logistics, management, etc. Analysis of all of the processes in one article is too complex task and due to this the paper was focused only on logistics and supply chain.

The aim of the article is to investigate the potential possibilities for implementation of Logistics 4.0 and Supply Chain 4.0 in the automotive industry plants, in particular in Bulgaria. The investigation approach consisted with specially designed survey which was conducted by 12 logistics experts from the automotive industry in Bulgaria who are on 6 different logistics positions. After the survey, some of the expert were asked additional questions.

The results showed that the production visibility (assembly lines connected to internet) and blockchain technologies have the biggest values to the logistics but the cybersecurity and faulty data are the main challenges in front of them. The results also indicate strong correlation between them. Although the autonomous vehicles have the lowest result in the proposals, they were pointed from both logistics managers as the technology which could give the best delay reduction in the logistic process in the automotive plants (around 20%). It has to be pointed that this does not mean the same increase of the production rates. The challenges in front of the autonomous vehicles are the higher costs for implementation and safety regulations.

Future work which will be conducted is the implementation in the automotive plants of some of the technology which has high or moderate result in automotive plant. The next work will be focused on assessment of the performance improvement and delays reduction in real production environmental.

Acknowledgement
The investigation is conducted with the support from project ΦΝΙ ΡΥ 2020-ΦΒΜ-01.

References
[1] Barreto L, Amaral A and Pereira T. 2017. Industry 4.0 implication in logistics: an overview. Procedia Manufacturing 13, 1245-52.
[2] Dossou PE. 2018. Impact of Sustainability on the supply chain 4.0 performance. Procedia Manufacturing 17, 452-59.
[3] Dossou PE and Nachidi M. 2017. Modeling supply chain performance. Procedia Manufacturing 11, 838-45.
[4] Hofmann E and Rusch M. 2017. Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry 89, 23-34.
[5] Issaoui Y, Khiat A, Bahnasse A and Ouajji H. 2019. Smart logistics: Study of the application of blockchain technology. Procedia Computer Science 160, 266-71.
[6] Manavalan E and Jayakrishna K. 2019. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. Computers and Industrial Engineering 127, 925-53.
[7] Muller JM and Voigt KI. 2018. The Impact of Industry 4.0 on Supply-Chain in Engineer-to-Order Industries – An Exploratory Case Study. IFAC PapersOnLine 51-11, 122-27.
[8] Tang CS and Veelenturf LP. 2019. The strategic role of logistics in the Industry 4.0 era. Transportation Research Part E 129, 1-11.
[9] Tjahjono B, Esplugues C, Ares E and Pelaez G. 2017. What does Industry 4.0 mean to Supply Chain? Procedia Manufacturing 13, 1175-82.
[10] Torbacki W and Kijewska K. 2019. Identifying key performance indicators to be used in Logistics 4.0 and Industry 4.0 for the needs of sustainable municipal logistics by means of DEMATEL method. Transportation Research Procedia 39, 534-43.
[11] Witkowski K. 2017. Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management. Procedia Engineering 182, 763-69.