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Professional paper

Influence of wagon control unit on economics benefits in the freight railway transport.

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***Abstract* – At present, the world economy is experiencing major technical and economic changes. In the field of rail transport, the challenge is the implementation of information and communication technologies, i.e. the incorporation of Industry 4.0 elements into the operation of rail transport. An important part of this is their mutual global integration. The aim of the article is to economically assess the introduction of the Industry 4.0 element of the wagon control unit into the transport process in rail transport. The premise of the research task is based on the experience of implementing intelligent sensors in rail freight transport in some countries of the European Union. Based on the analysis of the use of information and communication technologies in rail transport, an economic evaluation of the design of the wagon control unit will be carried out in the article.**

Keywords – **railway transport, digitalization, Industry 4.0**

I. INTRODUCTION

The world of "Industry 4.0" is built on the principle of communication and cooperation between machines, people, products, equipment and logistics systems. All active elements such as material, systemic, human resources within the in-house Internet form an in-house network. All individual active elements that act within individual processes represent an in-house network. However, connecting individual elements to the network is preceded by the implementation of an increasing range of sensors. These are mainly sensors that provide a more thorough and perfect picture of the current state of the monitored or monitored environment.

The revolutionary nature of Smart Industry systems and the industrial Internet of Things lies in the synergies of four key principles: interoperability, decentralisation, intelligence and reconfigurability. [1]

II. CHARACTERISTICS OF THE CONCEPT OF "INDUSTRY 4.0."

The present era is on the brink of a technical revolution. This new technical revolution can make a significant difference to our lives. One of the changes may be the way we communicate and the way we work. To its extent, scale and complexity, this transformation will be as fundamental to all mankind as any other technological change from the past.

The technological advances of human society could never be stopped. Since the Industrial Revolution, which began in late 18th century England, society has become unrecognisable thanks to technology.

A. History of Industry "4.0."

In the 1960s, a new kind of economy was created in England. Human work in manufactory began to be gradually replaced by the first more complex machines, and gradually new factories were created. [2-3]

The industrial revolution had major consequences. Cities demolished walls, built factories, new neighborhoods were created, people moved to cities for work. Railway lines, ports have been built. Feudal society gradually decayed. [2-3]

The second industrial revolution began in the 19th century and was related to the discovery of electricity and its use in the process of production via the assembly line. [2-3]

In the second half of the 20th century, there was a rapid development of science. Scientific research has become a very important source of development for society. This stage is also characterised by the widespread use of fossil fuels. The globalisation of the economy is another important trend of the turn of the 20th/21st century. Information evolution is usually understood as the period of development of management, computer and communication technology as the next stage of the Industrial Revolution. [2-3]

In 2011, the German Research Association for Science and Economics (Forschungsunion Wirtschaft-Wissenschaft) came up with a research programme aimed at keeping Germany as a high-tech country. The program was called Industrial Revolution 4.0 or Industry 4.0. This program was first presented at an exhibition in Hanover in 2011. Industry 4.0 should reflect the societal change caused by connecting the physical, virtual and social worlds. It is a nationwide change affecting industry, technical standardisation, security, education, the legal framework, research, links to social systems, the labour market and demands on workers, their education and specialisation. [2]

B. Main elements of the concept " Industry 4.0"

The main essence of Industry 4.0 is no new and groundbreaking technological invention, which will produce parts more quickly in the production process. A profound systemic change in the production process is important. Its primary task is to streamline, clarify and deeper link the production process. [2,4]

The main changes on which the concept of Industry 4.0 is based are communication environment, environmental identification, extensive data collection and custom instrument decisions. However, the current turbulent period in industry confirms that new technologies and innovations have become a necessity not only for the development and progress of businesses, but also for the sustainability of their current processes. Technologies with the greatest impact on business processes include the Internet of Things or its application to the industrial environment. At the same time, the Industrial Internet of Things is at the heart of the smart factory and smart industry concept. [2,4]

However, the current turbulent period in industry confirms that new technologies and innovations have become a necessity not only for the development and progress of businesses, but also for the sustainability of their current processes. [2,4]

Industry 4.0 is built on two main pillars. The first main pillar is digitalisation. The second also important pillar on which Industry 4.0 is built is the application of exponential technologies. [5]

The revolutionary nature of Smart Industry systems and the industrial Internet of Things lies in the synergies of four key principles: interoperability, decentralisation, intelligence and reconfigurability. [6]

These elements include operators, maintenance workers and managers, production and transport equipment, components and semi-finished products, input materials, finished products, as well as workplaces and warehouses, production lines or various information systems. Thanks to the Internet of Things and modern industrial, the so-called Smart Industry, systems also

integrate information and communication technologies with production technologies. The broader concept of digital transformation of enterprises is based on the interconnectedness of individual elements leading to horizontal and vertical integration of processes. The digital transformation of businesses enables businesses to automate and optimize individual processes. [6]

One of the basic pillars of Industry 4.0 is exponential technologies. Exponential technologies are technologies that help to increase efficiency and productivity sharply. These include, for example: neurotechnology, nanotechnology, biotechnology, new energies, 3D printing, sensoring, ICT and mobile technologies, artificial intelligence, advanced robotics or drones. [6]

Today, additive technologies are becoming an active element of industrial production. Their usability is also growing sharply in higher repeatability productions. In the process of additive production, the product is created by application of layers to each other (3D printing). Its advantage is the possibility of non-continual production of differential products, the possibility of accurately determining the need for material for the production of a particular product. [7]

II. INTELLIGENT RAILWAY WAGON

The European Union aims, in one place, to create a multimodal freight transport network that provides cost-competitive, efficient and low-emission freight transport services. In some European countries, they have already started to address the achievement of this objective by a fleet of intelligent sensors and telematics.

In Germany DB Cargo, not only has it already started digitising its fleet, but it is already making progress. These are wagons with state-of-the-art telematics and sensors. Telematics modules, GPS, the use of RFID tags and NFC tags help freight wagons connect to the digital world. Upgraded wagons use mobile phones to transmit signals along the way. The data obtained from these means helps to obtain information about the condition of the load, temperature, humidity and other factors in the wagon. [8]

Another is a project called SmartCargo, which is implemented by an Austrian carrier. This project is about 13,700 wagons that will be gradually equipped with SmartCargo equipment. The facility provides comprehensive information throughout the freight transport process. The position sensor provides accurate GPS coordinates of the vehicle at predefined intervals. Also in this project is used 3D accelerometer sensor to detect shocks and monitor the transport of sensitive goods. Geofencig can send an instant message about crossing a predefined zone. Currently, about 300 wagons are already equipped with SmartCargo as part of computer tests. [9]

Currently, many companies already produce smart devices to track wagons. TrackCube 5, shown in Figure 1 from Cognid Telematics, is specially designed to detect the position of mobile objects using GPS without external power supply. It can monitor, locate and monitor railway vehicles. The source of this device is an integrated lithium battery, which is replaced at the end of the period of operation. The advantage of TrackCube 5 is the operating temperature, which is about -25ºC up to 75ºC. [10]

Fig. 1. TrackCube 5. [10]

X-RAYL® SOLAR POINTER Serie 17 is shown in Figure 2. It is a solar telematics device designed to communicate between sensors and positioning vehicles. It is made of machined aluminium and its construction meets the highest requirements. It also contains a lithium-ion battery, which gives it a very long lifespan. For perfect Serie 17 connectivity Indicators include NFC technology and wireless sensor connectivity using the 2.4 GHz band. Other data are also available, such as temperature, mileage, payload, door opening and more. Through geofencing, the customer is informed by e-mail or SMS notification as soon as the vehicle reaches predefined areas. [11]

Fig. 2. X-RAYL® SOLAR POINTER Serie 17. [11]

III. ANALYSIS OF TRANSPORT PROCESSES IN INTERNATIONAL RAIL TRANSPORT BETWEEN THE EU AND THIRD COUNTRIES

Rail transport was the dominant land transport system until the end of the first half of the 20th century. Strengthening the position of more flexible, less sophisticated and seemingly cheaper road transport has led to a massive onset of road mass and, ultimately, individual car transport. [12-13]

Transport processes in international rail transport can be described and characterized by technological procedures, which are carried out with wagon consignments at the state border of Slovakia and other neighbouring countries. The most important factors such as speed, safety and attractiveness depend not only on the technical base of the carrier or infrastructure manager, but mainly on the transport processes that take place in stations. [10,

14-15] It is therefore important that the current transport process is fast and prompt from the start of order creation. At present, at the beginning of the 4th Revolution, rail transport is lagging behind in the implementation of state-of-the-art approaches and technologies. This is due not only to the high financial burden, but also to the necessary expertise and preparedness of the staff. [10, 15-16]

The carriage of goods between countries belonging to the European Union and other countries outside the European Union is subject to the SMGS and JPP CIM agreements. The organization of transport shipments and not only theirs, but also transport processes at the entrance, exit of wagon consignments take into account several provisions. Transport from non-European and Asian countries is characterized by a change in the transport regime. The organisation of transport and transport processes primarily means the preparedness and development of technological procedures for the processing of various types of trains. As the Slovak Republic lies on the edge of the Borders of the European Union, it is important that the technological processes in the border stations are optimally set up. The correct setting of technological practices in these stations for the processing of trains is necessary for the competitiveness of international rail transport and also for the promotion of an environmentally friendly mode of transport. [1, 12-13].

A. Technological analysis of the processing of the target train before the introduction of elements of Industry 4.0

In rail transport, it is necessary to evaluate the technological processes of work in terms of the importance of the station and its role in the train-forming. This section of the article elaborates on the technological procedure for the border crossing station in Čierna nad Tisou. The technological analysis is prepared for the target train entering the railway station Čierna nad Tisou. The train comes after a wide gauge from Ukraine to Slovakia.

The agent of the transport office of eastern Slovak translators in the railway station of the Čop before the shipment leaves the station is obliged to make a hand-over list in the information system. He is obliged to do this before the wagon consignment enters the railway station Čierna nad Tisou. It does this on the basis of a wagon pre-view and a shipment. On the basis of this information submitted, it is possible for the customs representative to create a summary declaration for wagon consignments. The summary declaration shall be lodged no later than two hours before the wagon consignment enters the European Union.[1,14]

Before the train enters the railway station, it is required to send a notification of the arrival of the train after a wide gauge from Čop. The agent of the transport office of East Slovak transhipments is informed by the dispatcher of the railway station Čierna nad Tisou about the estimated time of arrival of the train, the number of the train and the number of the entrance track to which the train arrives. The train expected are an agent of the Ukrainian railways (UR), a wagonmaster of Ukrainian railways and a wagonmaster of East Slovak transhipments. .[1,14]

Upon arrival of the train, a transit declaration shall be made by the authorized staff member. Accompanying documents will be taken over from the driver by the UR agent. After receiving all accompanying documents and train documentation, copies of the handover and transition list are stamped and signed. The UR agent offers the agent of the transport office of the East Slovak transhipment points a train to take over and hands over the related documents. If a wagon consignment is subject to excise duty, the agent shall notify the relevant competent authorities of this situation. .[1,14]

In the following operations, a transport inspection is carried out. The same agent who checked the transport documents should also be responsible for numbering the transitional list, according to the valid numbering system. In order to perform a physical inspection of the train, the VSP customs representative is obliged to deliver one copy of the transitional list to the branch of the customs office at ČNT. In cooperation with the operator of the East Slovak transhipments, the role of the second agent of the East Slovak transhipment transport office is to check the train composition. The train composition is checked via a radiotelephone. The external transport inspection is performed together with the inspection of the train composition. The agent of the transport office announces the beginning and end of the transport and technical inspection together with the result to the dispatcher of the Čierna nad Tisou railway station. It is extremely important that the inspection of the wagon consignment itself is carried out. The SMGS regulation allows one of the entities not to accept a wagon consignment if it is damaged or if it has an error specified in the regulation. Therefore, the inspection of the wagon consignment is performed by the agent of the transport office, who also performs an internal transport inspection. After checking the transport documents, the necessary documents are handed over to the customs agent by the agent of the transport office. These documents are checked on the basis of the customs office's own internal procedures and regulations. Upon receipt of the transport documents from the customs representative, the agent of the transport office of the East Slovak transhipments shall stamp part number 3 and 6 of the NL SMGS with an arrival stamp. The transport dispatcher will notify the transport dispatcher of the East Slovak transhipments about the takeover of the train. The agent of the transport office is also obliged to report to him the unaccepted wagons with their numbers. Subsequently, in the case of consignments that have been subsequently taken over, the agent of the transport office shall keep all documents from those additional consignments to the customs representative of the East Slovak transhipments for further processing Figure 1 shows the routing along with the Ganto graph for the target train. .[1,14]

N.	Work operation	Perform	Duration [min]
1	transmission of a pre-current declaration	customs agent	
2	vyhotovenie prechodového a odovzdvkového zoznamu	agent (ZSSK CARGO)	-5
3	train offer	dispatcher clerk (UR)	-2
4	fication of the time of arrival of the train at the control	dispatcher clerk I (ŽSR)	-1
5	notification of train arrival time and entrance track number	dispatcher clerk I (ŽSR)	-5
6	confirmation of receipt of the train	dispatcher clerk I (ŽSR)	-2
7	position of the entrance signal on the "free" sign	dispatcher clerk II (ŽSR)	-2
8	train journey from UR to checkpoint	engine-driver (UR)	-10
9	border control at the control post	authorized employee	-10
10	waiting and arrival of the train on the entrance track	engine-driver (UR)	-10
11	taking over the train documentation from the driver and handing it over to the authorized staff member	agent (UZ)	3
12	securing the train against running	switch supervisor	10
13	hanging the locomotive	engine-driver (UR)	1
14	removal of end signals	wagon master (UR)	1
15	technical inspection of the train	wagon master (UR); (ZSSK CARGO)	105
16	train list - entering into ISP	2 authorized employee	90
17	internal transport inspection- inspection of accompanying documents	shipping agent (ZSSK CARGO)	40
18	external transport inspection	shipping agent (ZSSK CARGO),agent (UR)	105
19	customs control of the train at the entrance track	customs officer,empl. (ZSSK CARGO)	60
20	delivery of documents and the transitional list to the customs representative	shipping agent (ZSSK CARGO)	2
21	checking the completeness of transport documents and delivery of the hand-over list	customs representative (ZSSK CARGO)	10
22	control of transport documents according to the internal regulations of the customs office	customs officer	30
23	receipt of transport documents from the customs office, inspection of transport documents	customs representative (ZSSK CARGO)	10
24	entering data from the SMGS consignment note into the ISP and delivering them	customs representative (ZSSK CARGO)	70
25	delivery of transport documents to the agent (ZSSK CARGO)	customs representative (ZSSK CARGO)	15
26	printing of local special-purpose stickers and sorters from the ISP and gluing of wagons on the entrance	transport warehouseman	65
27	confirmation of receipt of wagon consignments in the departure and transit list	shipping agent (ZSSK CARGO)	15
28	telephone notification to the dispatcher of the takeover of the train	shipping agent (ZSSK CARGO)	1
29	creating a sorter	dispatcher	5
31	delivery of the sorting machine to the shift manager	dispatcher clerk I (ŽSR)	5
32	preparing the train for decommissioning	shifting backup	15
Σ			311

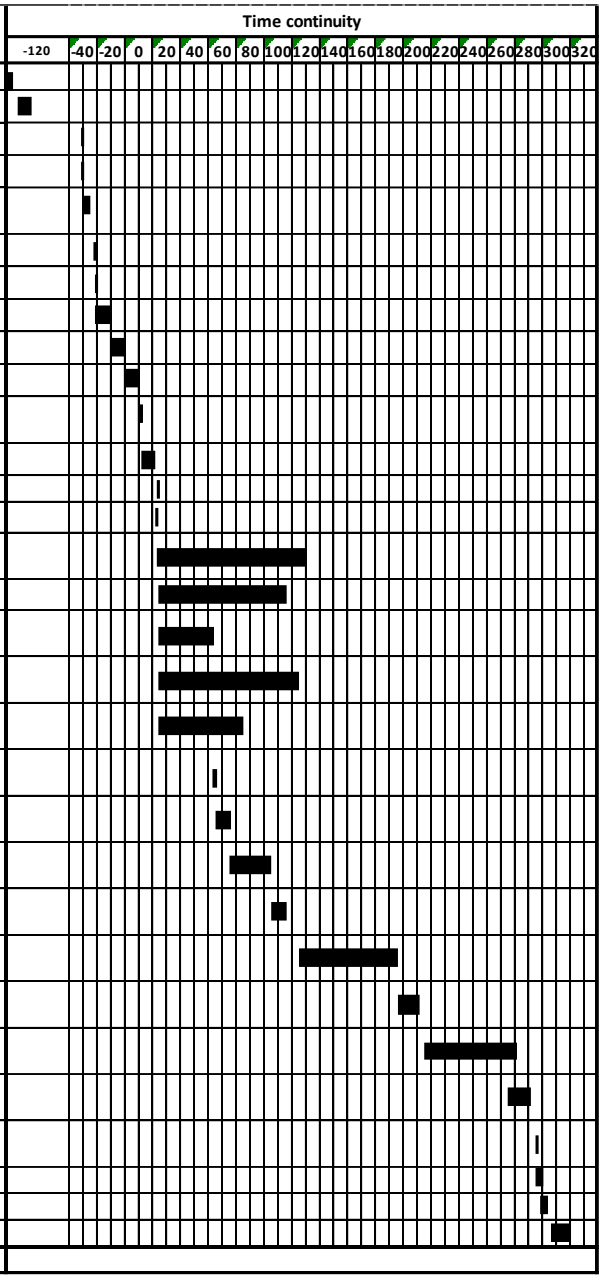

Fig .3 Technological graph of the inlet freight train from UZ to ČNT, after design. (source: [1])

B. Technological analysis of the processing of the target train following the introduction of elements of Industry 4.0.

After incorporation of the wagon control unit and other elements into the rail freight wagons of the carrier, the total processing time of the train is reduced by approximately 176 minutes. This value is greatly influenced by the reduction or removal, replacement of human labour with modern technologies offered by Industry 4.0. These are mainly transport process operations together with sending, checking, writing the necessary train documentation and accompanying documents. A technological graph of the entant train from Ukraine after a wide gauge to the railway station in Čierna nad Tisou after incorporating the design is shown in Figure 3. The total processing time of a freight train with 70 wagons is 135 min. [1]

N.	Work operation	Perform	Duration [min]
1	sending a preliminary customs declaration	customs agent	
2	preparation of a transition and transfer list	shipping agent (ZSSK CARGO)	-5
3	train offer	dispatcher clerk (UR)	-2
4	acknowledgment of receipt of the train	dispatcher clerk I (ŽSR)	-2
5	position of the entrance signal on the "free" sign	dispatcher clerk II (ŽSR)	-2
6	train running from UR to checkpoint	engine-driver (UR)	-10
7	border control at the control post	authorized employee	-10
8	ctation and arrival of the train at the entrance	engine-driver (UR)	-10
9	securing the train against running away	switch supervisor	10
10	hanging the locomotive	engine-driver (UR)	1
11	removal of end signals	wagon master (UR)	1
12	technical inspection of the train	wagon master (UR); (ZSSK CARGO)	105
13	control of accompanying documents and transport documents in the ISP	shipping agent (ZSSK CARGO)	10
14	external transport inspection	agent PK VSP (ZSSK CARGO),agent (UZ)	45
15	customs control of the train at the entrance track	customs officer,empl. (ZSSK CARGO)	60
16	confirmation of documents in electronic form	shipping agent (ZSSK CARGO)	1
17	telephone notification to the dispatcher of the takeover of the train	shipping agent (ZSSK CARGO)	1
18	praca s triedenkami	shipping agent (ZSSK CARGO)	2
19	preparing the train for decommissioning	shifting backup	15
Σ			135

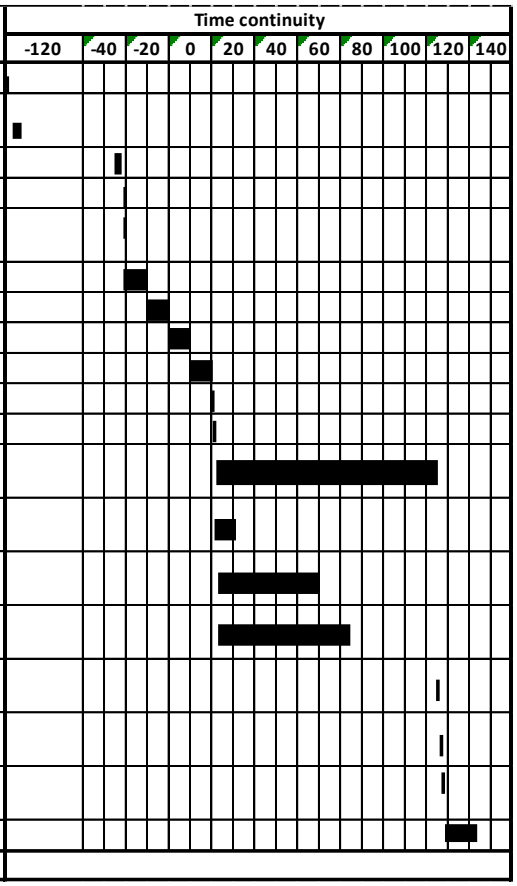

Fig. 4 Technological graph of the inlet freight train from UZ to ČNT, after design. (source: [10])

An important factor in accelerating but mainly streamlining transport processes, but also transport processes, is their digitization and automation. Based on the analysis, operations were detected in transport processes that can be partially or completely automated and digitized. [10]

VI. ECONOMIC EVALUATION OF THE COSTS OF THE WAGON CONTROL UNIT

Research is currently underway into the use of various GPS devices on railway freight wagons, together with various additions to streamline monitoring, detection of information about wagons and wagon consignments. Our proposed facility is not offered in any of the Slovak or foreign companies. Only equipment of a similar type is currently listed on the market. Given that these facilities are relatively short on the European market, there is a competitive battle between the companies. The average price of such a device is around 200€. The price of current devices is influenced by several factors such as: battery type, storage storage, telecommunications modules, GPS locator and various other additional devices. After consultation with an unnamed company and an expert in information technology equipment, the price of our proposed wagon control unit was 255€. [1]

According to the 2014 annual report, ZSSK CARGO a.s. has a total of 13,566 freight wagons. Part of the freight wagons is the sole ownership of the freight carrier and part of the freight wagons is leased. After careful consideration with experts in the technical characteristics of the wagon, the wagon control units will be installed on individual types of wagons. [1]

Table I. divided rail freight wagons by type. Each type of railway freight wagon shall be given the number and estimated cost of purchasing the wagon control unit.

TABLE I.
THE COST OF PURCHASING A WAGON CONTROL UNIT FOR INDIVIDUAL TYPES OF FREIGHT WAGONS.

Type of wagon	Number of wagon	price (€)
Indoor	171	43 605 €
open	166	42 330 €
platform	1295	330 225 €
other	1	255 €
together	**1633**	**416 415 €**

The total cost of purchasing wagon control units for all rail freight wagons for the company would total €3,459,330. [1]

The purchase of wagon control units also incurs many other costs. This is the cost of fitting wagon control units to railway freight wagons. The installation of the wagon control unit may be provided by the carrier through its employees or by authorising another company for payment. It is therefore not possible to determine the exact quantifiable value of these costs. [1]

A failure occurs from time to time in each device, so it is important that the carrier has a trained employee at its place to repair and maintain these smart devices. Another option is to provide maintenance services by an external company. In the case of ensuring the maintenance and repair of these equipment by another entity, the misleading undertaking must take into account higher costs of this kind. [1]

Other costs include the costs of training the carrier's employees to work with wagon control units and accessories. As the carrier does not currently have such equipment available,

initial training costs are necessary. In the case of the training of specific employees, these costs would already be reduced. The interoperability of information systems of individual entities involved in the transport of wagon consignments is already a matter of course in this case. The carrier's investment in the intelligent wagon control unit is only relevant if the interoperability of information systems between the rail freight carrier and other entities is met. [1]

The installation of the wagon control unit on the wagon significantly affects the work not only of employees in railway stations, but also of employees of the infrastructure manager, customs office and other entities involved in the transport of the wagon consignment. [1]

As an example, the saved costs of employees in ŽST ČNT are calculated. According to the jobs, the average labour price per employee is determined by 1100€, based on the price of work. [1]

In Table II. there is a comparison of the costs of the carrier's employees in one working shift in ŽST ČNT before the execution of the proposal and after the execution of the proposal.

TABLE II.
COMPARISON OF COSTS BEFORE AND AFTER THE PROPOSAL FOR CARRIER'S EMPLOYEES

variant	of its motion	after the proposal
number of employees	24	18
total cost	26 400,00 €	19 800,00 €

The cost saved for freight carrier employees during one working shift is €6,600. In ŽST ČNT there is work on two 12-hour shifts. Annually, ZSSK CARGO would be able to save employees' costs specifically only in ŽST ČNT in the amount of 158,000€. Since the wagon control unit will have every single wagon, it will affect the technology of work and technological processes on the entire railway network. In that case, the cost of employees saved will be much higher. Wagon control units will benefit not only PPS ŽST ČNT but also other other railway stations throughout Slovakia. [1]

VII. CONCLUSION

The significant growth of automotive transport not only in Slovakia but also throughout Europe highlights its attractiveness. Given that rail transport is one of the environmentally friendly modes of transport, it should also be given greater attention. Industry 4.0 offers unlimited possibilities for installing many usable elements also in rail transport. The wagon control unit, which will facilitate and simplify many processes in railway stations, is only an illustrable example of this.

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