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The Impact of the Use of Technology in International Rail Freight Transport on Transport Processes

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ABSTRACT

Transport is an integral part of any company. Nowadays, there is a great emphasis on the use of environmentally friendly modes of transport. In addition to being one of the environmentally friendly modes of transport, rail transport can carry large quantities of various goods over long distances. In order for rail transport in Slovakia to be able to compete with other modes of transport, it is important that Industry 4.0 elements are applied in the technological processes at railway stations. The aim of this article is to draw attention to the impact of the introduction of Industry 4.0 elements into the transport process in rail transport. The premise of the research task is based on the experience with the introduction of intelligent sensors in rail transport in some European Union countries. On the basis of the analysis of the use of information and communication technologies in railway transport, the article carries out a technological evaluation of the design of the wagon control unit in the transport process with regard to the speed of processing a shipment in a border-crossing station.

KEYWORDS

technology processes; industry 4.0; international transport; freight transport, railway.

1. INTRODUCTION

The transport sector plays a key role in the development of society as a whole. The need for transport depends on many aspects, such as the transport of goods, passenger mobility, the logistics sector and others. Therefore, transportation becomes an essential and integral element in connecting the clients and the supply chain team through logistic means.

The period of the COVID-19 disease pandemic shows the enormous importance of rail freight transport for the Slovak Republic. The need to improve the quality of rail freight transport and increase the efficiency of transport processes is inevitable. It is not only a question of increasing the competitiveness of rail freight transport in national transport, but also international transport.

The international rail freight transport of the Slovak Republic has a great advantage due to its location within Europe. Many international means of transport could pass through the Slovak Republic, but it is questionable whether Slovakia can compete with its neighbours in terms of infrastructure and the length of time of individual transport processes. Border-crossing stations handle trains, not only national but also international ones, which either enter, leave or pass through our territory. Today, road transport makes use of many of the elements offered by the emerging fourth industrial revolution. To grow the number of transports and increase the speed of train processing at marshalling yards, Industry 4.0 elements must be also applied to the transport processes at railway stations. Many transport processes are currently carried out by employees without the help of intelligent devices. The implementation of sensors, sensors, drones, interconnection of elements through the Internet of Things and interoperability of information systems would be some of the possibilities to improve and speed up transport processes in all kinds of railway stations, not only at border-crossing stations.

In this paper, a wagon control unit is elaborated and characterised. Since the introduction of this element affects not only the national transport but mainly the faster processing of foreign wagon consignments, an analysis of the entry of wagon consignments to Slovakia from third countries is made. The last part consists of the influence of the application of the wagon control unit on the technology of processing of the entering train.

2. INDUSTRY 4.0 TECHNOLOGIES IN RAIL FREIGHT TRANSPORT

We are in the midst of a significant transformation of manufacturing regarding thanks to digitisation. This transition is so compelling that it is being called Industry 4.0, to represent the fourth revolution that has occurred in manufacturing [1]. The first industrial revolution came with the advent of mechanisation, steam power and waterpower. This was followed by the second industrial revolution, which revolved around mass production and assembly lines using electricity [2]. The third industrial revolution came with electronics, IT systems and automation, which led to the fourth industrial revolution, associated with cyber physical systems [3].

Industry 4.0 describes the growing trend towards automation and data exchange in technology and processes within the manufacturing industry, including: the Internet of Things (IoT), the Industrial Internet of Things (IIoT), cyber-physical systems (CPS), smart manufacture, smart factories, cloud computing, cognitive computing, artificial intelligence [1]. The fourth industrial revolution also relates to digital twin technologies [2, 3]. Industry 4.0 encompasses a wide range of both legacy and new technologies that can work together to create one big digital world. For a systematic analysis of the various defined elements of Industry 4.0, see "Industry 4.0 Technologies Applied to the Rail Transportation Industry: A Systematic Review" [4].

There are a number of methods that can be used to capture technological processes over time for international rail transport processes. Such are the critical path method and Gant chart process plotting. The critical path method (CPM) is one of the basic deterministic methods of network analysis. Its objective is to determine the duration of a project based on the length of the so-called critical path. CPM allows facilitating efficient time coordination of sub-activities, which are interdependent within a project. The authors of the article "Organisation of Railway Freight Transport: Case Study CIM/SMGS between Slovakia and Ukraine" used the critical path method in their research [5]. In the article "Augmented Reality as a Tool in a Train Set Processing Technology", the authors used technological procedures without graphical representation to describe the processes [6]. A further example of representing processes in time is the possible use of a combination of technological procedures together with a graphical representation, namely Gantt's line graph. Each process has a graphical time length. Such a method can also be found in the book Technology of Railway Stations by Majerčák [7]. We decided to use the Gantt chart method in our research for a clearer understanding of the transportation processes.

We will present a wagon control unit for railway freight wagons within the article.

2.1 Characteristics of the wagon control unit for freight wagons

Relevant information on rail traffic is currently recorded using individual sensor systems. They are mostly separate independent systems that do not send any information to each other. However, telematics systems for so-called intelligent rail freight wagons with integrated multiple sensors and modules in one complete wagon control unit are more efficient [1].

Processes and operations are automated by means of a processor located in a protective box on the wagon cabinet [2]. The processor is also an essential part of the wagon control unit and an obvious element of all smart devices [8]. Compatibility with various systems on the market and uniqueness of the wagon control unit is the basis for the success of this telematics equipment on the market. Therefore, there will be several important elements in the wagon control unit [5].

Digital marking of wagons is most effective when using the wagon control unit together with a connected Global Positioning System (GPS) module and connected RFID tag. Marking wagons with RFID tags would be shortened by the time of creation, printing and gluing of wagons, wagon stickers in case of international trains. In the RFID tag and the internal memory will be entered all the necessary information which is on the classic paper wagon sticker. Also, in the transport of dangerous goods, all important information about the wagon consignment is entered there. Part of the monitoring of the train entrance, e.g. on the skid, entrance, directional or departure group of tracks, is also an RFID token installed in close proximity to the track [3].

By marking the wagon with the wagon control unit, it will not be necessary to draw up a paper sorting system when removing wagons from the train. An electronic sorting class in the information system will be created and made available to employees [3, 9]. Based on the fact that the wagon will be marked with a wagon control unit, the authorised employee will see in his Personal Data Assistant (PDA) which wagon needs to be followed by which wagon to disconnect the air cables from the brakes [10].

2.2 Transport procedures at the railway station

Technological procedures in rail freight transport must be assessed on the basis of the type of station, the importance of the station and its train-building role [11]. In intermediate, section and train-operating stations, the technology of working procedures differs. Intermediate stations are characterised by operations such as entrances, exits, crossings, crossing and overtaking of passenger and freight trains [1, 2]. Sectional stations are generally train-creating stations and delimit a dispatching circuit or stations where train requisites are exchanged. Marshalling yards are train forming yards equipped with special equipment for marshalling and forming sets of vehicles, including the handling of through trains [9, 11].

In the railway transformation process, activities related to the operation of the railway infrastructure have been allocated to the infrastructure manager [1, 2]. The operation of traffic on the railway is handled by the carriers [12].

The objective of the destination freight train operator is to perform all the technical, transport and other operations necessary to break up the train set [13]. The performance of all tasks associated with the processing of a destination train is dependent on reliable, high quality and accurate information on the composition of the specific train set. All this can be ensured by proper and timely preparation [5].

The Slovak employee on the Ukrainian side is obliged to draw up a handover list before the train departs for Slovakia. The handover list shall be made by the employee in the information system. Based on the pre-application, this document must be drawn up. The customs representative may draw up a Preliminary Declaration for the carload consignments based on the information on the handover list [1, 14]. Before the entry of a wagon consignment into the Schengen area, the pre-declaration must be lodged no later than two hours before the entry of the wagon consignment [1, 2].

Before the train enters the railway station of its destination, it is necessary to send a notification about the arrival of the train from Ukraine [1]. The employee of the destination railway station is informed by the dispatcher of the first border-crossing station, i.e. the destination station, about the expected train arrival time [2]. The staff member has information on the train number and the number of the entrance track where the destination train is due to arrive. The train is awaited by two authorised employees of Ukrainian Railways and one employee of Slovak Railways [9].

The arrival of the destination train at the destination railway station can be monitored using GPS equipment in the locomotive, using a drone with a camera and sensors placed on the rails. Alternatively, cameras could be placed on power line poles at a specific kilometre ahead of the railway station.

The authorised officer of the destination railway station draws up a transit declaration. The Ukrainian employee in the Slovak Republic takes over the accompanying documents from the driver [15]. The accompanying documents and the train documentation are all stamped after receipt [1]. The copies of the handover and transfer list are also signed afterward. An employee of the Ukrainian Railways hands the train over to the Slovak party for acceptance [2]. At that time, the relevant documents are also handed over [9].

The processing of train documentation and accompanying documents in current transport processes is still relatively largely paper-based, despite the significant digitisation efforts by companies and businesses. The compatibility of the systems of companies involved in international transport is therefore essential. Currently, an electronic consignment note is in operation, but in some cases the consignment note needs to be printed and data added or overwritten in the company's information system [1]. Industry 4.0 offers several technologies that can be used to link the separate information systems of different companies. One possibility is the introduction of fully electronic data interchange (EDI) [2]. The aim of EDI is to achieve the highest possible level of process automation through integrated data exchange and to avoid manual and paper-based business transactions [9]. EDI is used, among other things, for the exchange of orders between trading companies and manufacturers, as well as for invoicing processes, enabling real-time electronic transmission of invoices, their immediate checking and post-processing [16].

Many other business processes can be handled through EDI, including master data management, sending of various electronic documents, train documentation, waybills to all those involved in domestic and international shipments, as well as to other logistics service providers, providing shape information alerts or handling payment requests [16]. Standardised technology is the key that enables companies of any size, in any industry, in any country to exchange business data, no matter what communication channels, data formats and media they use [17]. Many companies have developed the industry-leading "TrustIT" solution for electronic archiving, which is designed as a universal repository for all types of archived data, regardless of origin, data format or the presence of an electronic signature. It enables long-term and professional archiving for a selected period of time, with guaranteed integrity and authenticity of the embedded data. The solution complies with all legislative requirements and regulations, and also follows EU-level recommendations. It is most often used for archiving tax documents, contracts, digitised documents, reports from data boxes etc. The archiving solution can be used as required in different modes and in different degrees of integration with other IT systems. Documents can be actively handled within the "TrustIT" user interface, accessed from third-party applications, or the electronic archive can form a stand-alone legislative insurance policy alongside existing workflow systems. "TrustIT" can be used as a service or as an inhouse solution [17, 18].

The operation that follows the receipt of the train from the Ukrainian side is a transport inspection. The purpose of the transport inspection is to detect and correct any transport defects found. The transport inspection is carried out simultaneously by two authorised staff of the destination railway station. Every single train is inspected by one such pair. The two shall proceed simultaneously, each on his side of the train, in sequence behind the wagon masters carrying out the technical inspection [1]. The first employee walks with a walkie-talkie on the handling side and reports to the second colleague the data on the carriage and the carriage labels, when he simultaneously checks this with the train inventory. He also checks this data against the data of the PIS (forwarding information system) application or reports the data for writing up. The handling side of the train set is the carriage distribution side [2]. The two employees who perform the transport inspection check the data out loud for accuracy. They also ascertain whether the seals have been broken or whether there are any loading or transport defects, various damages, losses of transported goods on the wagon. They check whether the wagons are covered with appropriate wagon stickers and also additional stickers. The employee who performed the inspection of the shipping documents should be responsible for numbering the transit list. Subsequently, the customs representative of the local district concerned shall deliver one copy of the crossing list to the customs office branch in order to carry out the physical inspection of the train. After the completion of the transport inspection and, therefore, the checking of the train documentation and accompanying documents, all the relevant documents are handed over to the customs representative [9].

Automation of many transport inspection tasks is feasible. The train documentation and accompanying documents can be automatically checked in the system as soon as the data is entered. The digitisation of documents for the entire supply chain has already been mentioned in the previous paragraph for the control of train documentation. Other transport inspection tasks can also be automated, but not completely. This is because they are partly dependent on the human factor [1, 2]. The inspection of the wagon consignment can be carried out by means of installed sensors, scanners and transducers with state-of-the-art technology. Checking for damage and breakage of wagon labels on railway freight wagons could be replaced. One possibility is to install wagon control units together with an RFID tag in a protective box. The details of the wagon control unit have already been described in Section 2.1. This would not only simplify the work of the staff carrying out the transport inspection, but also reduce the duration of the whole operation. This would have an impact on the overall processing time of the destination train at the destination station. All the information about the wagon consignment and the rail freight wagon is already in the information system when the order is placed. Checking for undamaged labels and seals on the rail freight wagon can be ensured by drone visual inspection. Inspection of the wagon consignment on a covered railway freight wagon can be provided by a fixed scanner at the destination station [1, 2, 9].

Once the transport inspection has been completed and all documents have been handed over to the authorised entities, a sorting note is usually issued. The sorting note is a document that specifies which tracks each wagon or group of wagons is to be sorted into. It indicates whether the wagon is loaded or empty and whether any special care is needed when moving the wagon [15]. The marshalling is created by an application in the infrastructure manager's system. Once the sorting list has been created, checked and then stored, it is automatically distributed to the designated workplaces [19, 20].

The purpose of the technical inspection is to determine the technical condition of the vehicles and the condition of the loaded consignments on the open wagons [21]. The technical inspection is carried out by two technical staff of the station who are employees of the carrier. These staff members wait for the train at the beginning of the entrance track and observe the train from both sides. Already during the journey, the staff try to detect technical faults. When the train stops, the staff continue the technical inspection according to the relevant standards. The technical inspection starts from the end of the train, with each worker inspecting his side of the train. If minor defects are found on the railcars, the staff tries to correct the specific irregularities on the entrance tracks without having to take the train out of service [22]. In between, if rail cars are unfit for further travel, it is imperative that the rail cars be tagged with regulatory new repair stickers. Completion of the technical inspection shall be reported by the technical staff to the station controller who shall then record the time of completion in the station controller's schedule.

The technical and transport inspection on arrival of the train at the destination station is carried out simultaneously. In order to speed up the execution of these two processes, it is important that the tasks they consist of are transferred as far as possible to the latest technology. Freight train scanning technologies are currently at a very advanced level. Various sensors on railway freight wagons are also used to check the technical condition [23]. One solution to simplify the technical inspection of the target train is the use of the new generation of train scanners. A train scanner, e.g. VR FleetCare, is a solution for systematic inspection of a large number of rolling stock. Accurate inspections help to improve rail safety and achieve life cycle cost savings for rolling stock and rail infrastructure [24, 25]. A large part of rolling stock maintenance still involves manual checks carried out by humans. Our scanner solution performs a comprehensive check with millimetre accuracy in a single pass. The train scanner consists of 6,600 millimetre high scanning masts that are installed on both sides of the track and used to scan a passing train. The system automatically identifies and reports abnormalities such as broken parts, graffiti or incorrect loading [26]. The service enables accurate and efficient inspection of large masses. In practice, maintenance technicians do not have to spend time manually inspecting rolling stock and finding faults, because an AI-based system does it for them. The train scanner helps to allocate work resources directly to the unit that is causing the problems. The train scanner detects deviations and reports them to the station department in charge of rolling stock maintenance. More broadly, effective control activity that works reliably helps to ensure the safe operation of rolling stock without causing risks to passengers or the track. Potential problems are detected in advance [25].

The bar scanner technology scans the roof of the train, the bogies and a group of vehicles from both sides. The scanning is done with the train moving and the resolution is approximately a few millimetres [27]. The data is analysed and compiled for display in the browser user interface. In practice, the system looks for deviations such as incorrect loading, open hatches or graffiti. The report is made available to the station's technical maintenance department within 10 to 20 minutes of running. If any deviations are detected, the maintenance unit is alerted, and the rolling stock can be directed to the depot before the detected deviation can cause damage to the rolling stock or other traffic. Scanning columns can be installed virtually anywhere. The most suitable location is one where many trains pass [28]. Poles placed near the depot, for example, help detect damaged components and other parts that need attention before rolling stock enters the depot. Similarly, a train scanner can check rolling stock as it leaves the depot, checking for open doors or loading, for example. Many of these train scanners can be integrated into existing systems of entities involved in the entire supply chain [25].

After the technical inspection is completed, it is necessary to secure the vehicle sets of the target train against unintentional movement and separation of the locomotive. The purpose of this action is to prevent the traction unit from moving unintentionally along the siding [1, 2]. Subsequently, the shunting set is prepared, where it is necessary to unbrake the railcars braked by the intermediate brake and to allow the smooth uncoupling of the individual bogies during shunting [9].

The purpose of marshalling sets of railway freight wagons of a destination train is to move the vehicles from the set to the directional tracks, where the vehicles are assembled according to the individual directions of destination, by initial marshalling on the extraction track or at the marshalling yard [1, 2, 9].

The unloading of the wagons follows the unloading of the iron freight wagons. A message will be generated from the system when a wagon is brought in for unloading. The sub-tasks of the unloading process are very specific. The use of different handling equipment depends on the type of railcar and the type of shipment being transported. It is possible to use remotely operated autonomous vehicles or fully autonomous vehicles to bring the wagons to the unloading point [1]. An automatic coupling device would certainly be an advantage not only for the unloading but also for the unloading of rail freight wagons. The unloading of the wagon is carried out by the customer or by the carrier. The automation of the unloading, as well as the automation of the loading, depends on the type of goods and the type of the particular wagon. Semi-automated unloading is currently carried out in the case of bulk substrates, e.g. unloading of coal in ironworks by means of tippers. This also requires staff to move additional wagons. After unloading the goods from the wagon, the customer prepares the wagon for handover [2]. Current research towards the implementation of digital automated couplers on rail freight wagons has not yet been completed. Automatic digital coupling is a crucial component of contemporary and digital European rail freight transit. It will also guarantee that adequate power is provided for telematics applications and secure data connectivity throughout the train, in addition to increasing efficiency via automated operations. The introduction of digital automatic coupling is urgently required for the entire European rail freight industry and is a prerequisite for automatic coupling; the introduction of ETCS level 3 moving for freight trains; increasing the capacity of the entire system; decreasing the cost and duration of the process; enhancing the safety and reliability of the process; and laying the groundwork for the introduction of intelligent freight trains [28].

After the wagon is unloaded, the operations associated with the handover of the wagon will take place, such as cleaning and disinfection of the wagon, cleaning of the unloading site. The automation of these operations is questionable. It would be advisable to place sensors near the unloading points to monitor the arrival time of the rail freight wagon, the start and end of unloading. The information would be up-to-date and would be immediately recorded, evaluated, processed in further reports and documents [9].

The last operation is the decoupling of empty railway freight wagons. This can be done in the case of ownership of autonomous locomotives together with automatic couplers on railway freight wagons [2, 9].

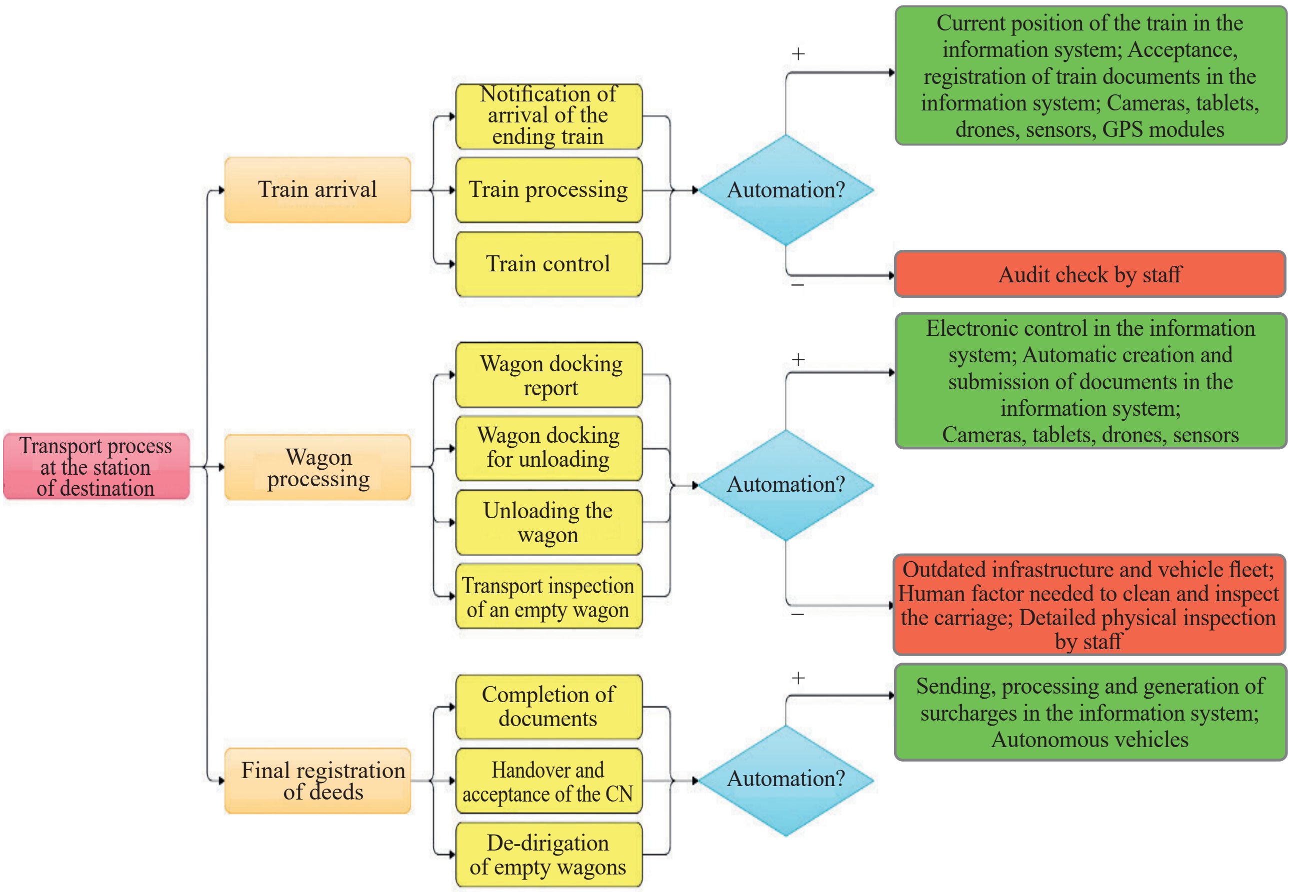

Figure 1 – Block diagram for integrating Industry 4.0 elements into the transport process

A visual representation of the analysis of the possibility of integrating Industry 4.0 elements into the transport process at the destination station is elaborated in the abbreviated process map shown in *Figure 1*. The figure shows the general transport processes at the destination station, which are further subdivided into their sub-tasks that make up the whole transport process. The green rectangles, which are shown in *Figure 1* on the right, provide the reader with options that can be used to automate or digitise the assigned processes. The red rectangles, also shown on the left side of the same figure, express the limiting factors in the implementation of Industry 4.0 elements.

3. INDUSTRY 4.0 CHARACTERISTICS IN RAILWAY TECHNOLOGY

In the previous section, transportation processes have been described in general terms with possibilities to incorporate elements of Industry 4.0 into specific processes. This section will focus on the specific application of the mentioned elements to the transport process of an incoming train from Ukraine to Slovakia to the border crossing station Čierna nad Tisou, which is also a train-forming station. This section contains technological diagrams of the destination train from Ukraine to the railway station Čierna nad Tisou.

3.1 Technological process before introducing the wagon control unit

In the following technology diagram, the technological procedure for a target freight train with 70 rail freight wagons is processed. *Figure 2* shows the technological procedure and the Gantt chart of an inbound freight train from Ukraine to Čierna nad Tisou on a wide gauge.

N.	Work operation	Perform	Duration [min]
1	transmission of a pre-current declaration	customs agent	
2	preparation of the transition and handover list	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

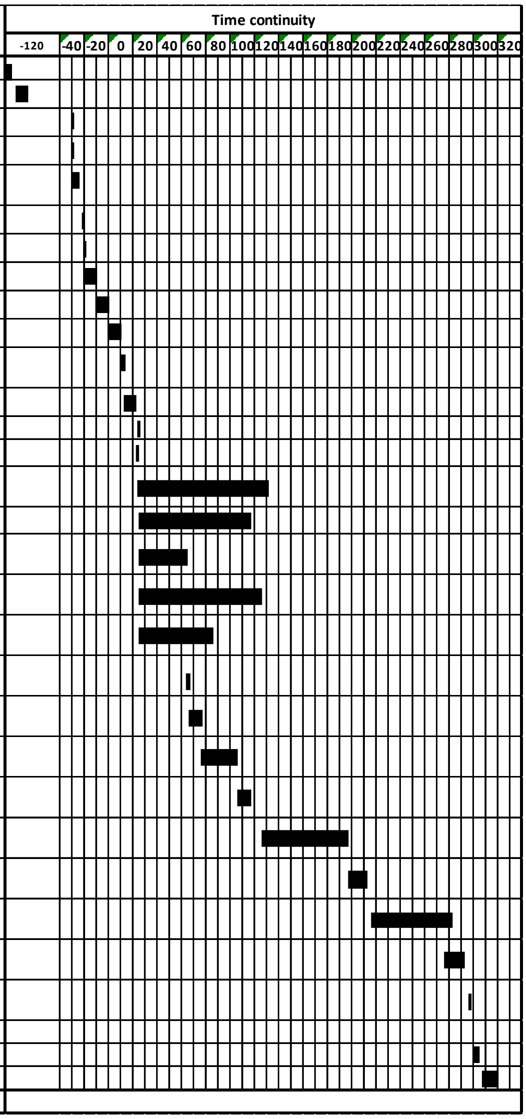

Figure 2 – Technological graph of the inlet freight train from UR to ČNT without design

On the basis of the internal customs (JN1, JN2 and JN4) process regulations, time standards were assigned to each task. Some of the transport process operations during the processing of the destination train can be performed at the same time as other operations, such as the technical and transport inspection. The total processing time of the destination train to the railway station Čierna and Tisou from Ukraine is 311 minutes for a train composition with 70 freight wagons.

3.2 Technological process after introducing the wagon control unit

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, removal or 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 wide-gauge train from Ukraine entering 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.

N.	Work operation	Perform	Duration [min]	Time continuity: -120 -40 -20 0 20 40 60 80 100 120 140
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	

Figure 3 – Technological graph of the inlet freight train from UZ to ČNT after design

An important factor in accelerating transport processes (mainly by streamlining) is their digitisation and automation. Based on the analysis, operations were detected in transport processes that can be partially or completely automated and digitised.

4. TECHNOLOGY OF INPUT PROCESSING

The introduction and creation of elements of Industry 4.0, such as wagon control units, affect all operational processes. The implementation of a wagon control unit on individual railway freight wagons is usable only with the full digitisation of all relevant documents and communication between the individual entities involved in the transport of the wagon consignment. Digital marking of railway freight wagons will largely accelerate transport processes in the processing of wagon consignments in international and domestic transport.

In *Figures 4 and 5*, two dependency graphs for the inbound train to the Railway Station Čierna nad Tisou are drawn to compare. The dependency graphs show procurement-transport activities and technical operations represented by a truck and a shunter. The vertical axis shows the processing time of individual operations in minutes and the horizontal number of wagons processed on the train.

The first dependency graph created for the inbound train without installing the wagon control unit is shown in *Figure 4*. The graph shows that the duration of transport activities and the work of the truck is increasing with the number of processed freight wagons.

Figure 5 shows a dependency graph which takes into account the operation of the wagon control unit on freight wagons, showing that the transport operations have been significantly shortened. For this graph, it appears that the influencing element are the technical acts performed by authorised employees.

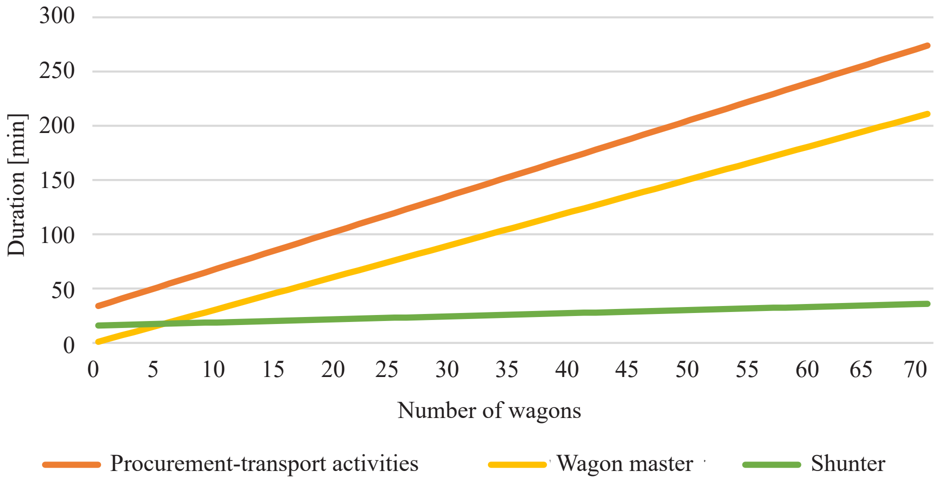

Figure 4 – Dependency graph of technical and transport-commercial operations of the entrant train before design

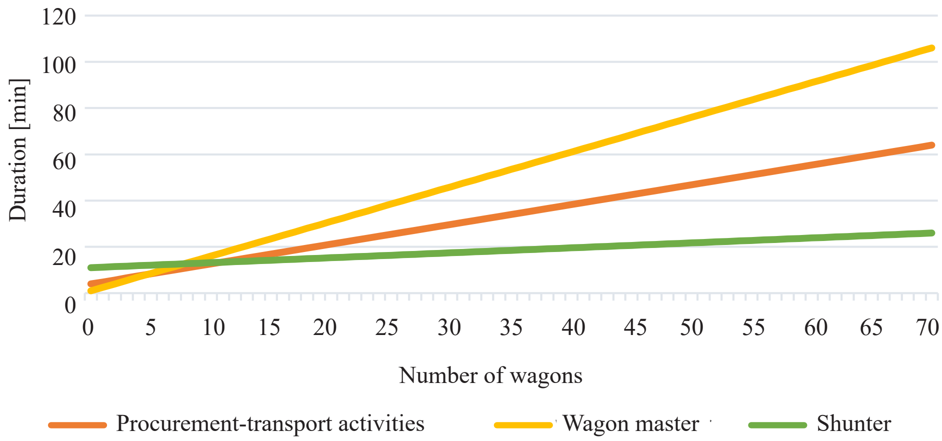

Figure 5 – Dependency graph of technical and transport-commercial operations of the entrant train after design

For the inbound train from Ukraine, the processing time has been reduced by more than half thanks to the wagon control unit. All operations in transport processes follow other operational processes, such as technical inspection. The efficiency and speed of wagon processing in international rail transport in the future also depends on the automation of this activity.

The technological graphs and dependency graphs above show that equipping railway wagons with wagon control units will reduce the total processing time of the inbound train, but also that of the outbound train at the railway station in the Slovak Republic.

5. CONCLUSIONS

The impact of digitisation and automation of transport processes in international rail freight transport based on the Industry 4.0 concept was the main topic of this article. In the technology sector, rail car monitoring has not been in the current market for that long. As the world of technology is moving to a higher level every year, it is therefore important that research in the rail freight sector is moving in the same direction. As part of research into digitisation and automation, a number of tasks have been addressed. However, there is currently a lack of research on the implementation of Industry 4.0 principles in transport processes, mainly related to paper documentation and the involvement of all actors in the supply chain. Research on the use of various GPS devices on rail freight wagons, together with various add-ons to streamline the tracking and tracing, technical information on wagons and wagon consignments, is ongoing internationally. Only devices of a similar type are currently on the market and in research.

In the introduction of this paper, the characteristics of a wagon control unit have been elaborated. The next step was to develop a general analysis of the processing of wagon consignments on arrival in the territory of the European Union and the Schengen area from third countries. Based on the internal regulations of the carrier and the customs office, the technology of processing of the destination train to Slovakia from Ukraine was developed. The technological procedures specified in the station technology were developed for the border railway station Čierna nad Tisou. All time standards of the operations are also in accordance with the regulations.

Railway operation and station technology is in a more than unsatisfactory state. The train processing time, based on the developed technology, is 311 minutes. This time needs to be minimised if rail freight is to be competitive with road freight. Paper-based documentation, the carrier's information system or duplicated paperwork, not only in the case of the carrier but also when communicating with the customs office, is unacceptable in the current technological era. The advantage of the gradual introduction of Industry 4.0 elements will be more efficient, better, faster and more competitive rail transport. The introduction of Industry 4.0 principles into the processes will eliminate some inefficient operations in railway stations, such as sticking wagon labels on carriages. Customers will have immediate information about their shipment and in case of any confusion, they will be informed more quickly about possible risks.

Research on the introduction of Industry 4.0 elements and principles into rail transport technological processes is still at an early stage. It is essential to investigate the internal processes of shipments in transit. The processing time of these sub-tasks is lengthy for a number of them. Neural networks have already found their application in various fields, and the question is whether they can be applied to these internal processes in railway stations so that green transport continues to be sought after and promoted.

The cost of creating a control unit may not be high. However, these would not be the only costs if a decision was taken to introduce this control unit on rail freight wagons. A secondary cost would certainly be for installation and fitting to freight wagons. This decision would already be influenced by the financial situation of the railway company. The latter would evaluate in-house installation or the involvement of an external company. Other costs could arise for maintenance and solving problems with the equipment, as well as for staff training. An investment by the carrier into a wagon control unit only makes sense if the condition of interoperability of information systems between the freight railway company and other entities is fulfilled. The initial cost of introducing this technology would certainly be higher, but it is important to realise the benefits it would bring to the entire international and national rail freight transport sector. Further research would also be appropriate to look at a detailed economic evaluation of its implementation.

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Vplyv využívania technológií v medzinárodnej železničnej nákladnej doprave na dopravné procesy

Abstrakt

Doprava je neoddeliteľnou súčasťou každej spoločnosti. V súčasnosti sa kladie veľký dôraz na používanie ekologických spôsobov dopravy. Okrem toho, že železničná doprava je jedným z druhov dopravy šetrných k životnému prostrediu, môže prepravovať veľké množstvá rôzneho tovaru na veľké vzdialenosti. Aby bola železničná doprava na Slovensku schopná konkurovať ostatným druhom dopravy, je dôležité, aby sa v technologických procesoch na železničných staniciach uplatňovali prvky Priemyslu 4.0. Cieľom tohto článku je upozorniť na vplyv zavedenia prvkov Industry 4.0 do prepravného procesu v železničnej doprave. Predpoklad výskumnej úlohy vychádza zo skúseností so zavádzaním inteligentných senzorov v železničnej doprave v niektorých krajinách Európskej únie. Na základe analýzy využitia informačných a komunikačných technológií v železničnej doprave sa v článku vykonáva technologické zhodnotenie konštrukcie vozňovej riadiacej jednotky v prepravnom procese s ohľadom na rýchlosť spracovania zásielky v pohraničnej prechodovej stanici.

Kľúčové slová

technologický proces; priemysel 4.0; medzinárodná preprava; nákladná doprava; železničná doprava.