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POSSIBILITIES OF IMPLEMENTING AUGMENTED REALITY IN RAILWAY FREIGHT TRANSPORT

Abstract. The analysis of technological procedures in transport and logistics with the aim of innovating the usual procedures is an ongoing process, not only in the present. The development of information technology in recent decades has created new opportunities for innovative procedures, but the innovations themselves do not take place as quickly as the development allows. There are many reasons for this, from the point of view of operational safety to the relevance of technological progress to rail transport. Based on the analysis of technological processes in rail freight transport at the Žilina - Teplička marshalling yard and the characteristics of Augmented Reality, the aim is to assess the possibilities of implementing Augmented Reality technology in the conditions of the processing procedures of sets of vehicles of the destination train in freight transport. The implementation options will be evaluated based on their feasibility in three variants. The implementation of augmented reality must always represent a simplification, acceleration, or cost reduction of the usual technological procedures.
Keywords: railway freight transport, augmented reality, train set process, destination train

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Introduction

Augmented reality is a virtual-real space that combines the real environment in which the user is physically located with a virtual environment that is made up of elements such as two-dimensional or three-dimensional images, videos, texts or audio tracks. The type and scope of the virtual environment differ according to the type of augmented reality and the purpose of its use by a specific user. According to this pair of criteria, suitable technical equipment is also selected, which is used for the use of augmented reality - most often these are devices equipped with a camera, such as smartphones, tablets and "Smart Glasses" - that is, glasses that are equipped with semi-transparent glasses that transmit the image of space, on which the user is looking at, which makes them different from glasses used, for example, in virtual reality (Bulková, et al., 2022).

Based on the technical equipment used, the view of augmented reality can be divided into two basic parts - direct and indirect. When looking directly, the user looks directly at the real environment, in which, with the help of suitable accessories, he can also see virtual elements - most often, these accessories are glasses equipped with semi-transparent lenses. However, these accessories can also be specially modified contact lenses or a VRD (virtual retinal display) system, which projects virtual elements directly onto the retina of the user's eye (Čujan, et al., 2020). The second view of augmented reality is called indirect, since when using this view, the real space is captured by the camera of the device (most often a smartphone or tablet) and the user looks at it on the screen, with a virtual element already added (Lukáč, et al., 2020).

1. Technology of Augmented Reality in railway transport

Currently, augmented reality technology is being developed and used, for example, in the SPACE1 system, which is used and tested by the Rail Cargo Carrier company. This technology allows an employee to perform routine tasks related to working with railcars faster, more accurately and more efficiently (Hall, et al., 2015). The hardware used by the employee makes it possible to scan his field of vision, while the artificial intelligence installed in the software can identify a specific car based on the recognition of its UIC number in a predefined format. After loading a specific wagon, it is possible to start the technical inspection itself, while with the help of artificial intelligence, the detected facts are recorded directly in the folder of the specific wagon. Defects or abnormalities detected during the technical inspection can be consulted with a colleague or superior directly from the track via wireless communication (Space1, 2021).

In addition to voice communication, the SPACE1 system also enables image transmission between devices - an employee in the office can view the field of view of the employee in the railway station on the monitor, as well as share his computer screen with the employee in the railway station. With appropriately chosen hardware, it is possible to replace the classic hand-held radio carried by railway employees at work with a communication device integrated in augmented reality hardware. Depending on the determination of a specific message, it is possible to select the addressee of a voice call, or its type – it is possible to use a personal as well as a group call. Acceleration of individual operations is also possible thanks to voice control of the augmented reality hardware. In the case, for example, of preparing a report on the train composition, it is possible to choose a technological solution that allows the employee at the track to work in "offline" mode - the data is updated using a private network when the hardware is not in use and is located inside the building in reach of this network (Space1, 2021).

The advantages of using augmented reality used in technical inspections are (Space1, 2021):

- free hands of the employee,

- reducing the error rate of employees and increasing the reliability of reports on technical inspections of wagons.



Fig. 1. Display of augmented reality options when retrieving the UIC train number from the employee's field of vision (space1.it, 2021).

1. Assessment of the implementation possibilities of augmented reality in the technology of processing destination train sets

Each technological procedure in freight rail transport consists of a series of connected operations. These operations are chronologically ordered to create a logical and safe procedure that will allow the most economical possible solution for moving wagons on a specific session (Brumerčíková and Šperka, 2020). However, since the transport flows of goods, the railway network or the technical means used in railway transport are not constant over time, it is desirable to innovate the technology of work and the technical procedures arising from it (Gašparík, et al., 2016).



Fig. 2. Illustration of a suitable hardware solution for creating augmented reality (Smith, 2018).

The technological procedure by which the destination train is processed begins even before the arrival of the train itself, namely by notifying the head of the shunt of the first or third advancing advance, the commercial inspectors and the team leader of ZSSK CARGO, a. with. about the train arrival time from the train dispatcher (ZSSK CARGO, 2019). The operating supervisor subsequently organizes the work of the operator's employees designated to perform a technical and transport inspection of the train, transits and shunt for the clearance of screws. It will also determine the order of the train for decommissioning. The operator's employees are notified with the help of their team leader and are required to expect the arrival of the train at the designated locations (Borodin, et al., 2023; Pečený, et al., 2020)

After the arrival of the train, the technical office clerk takes over the transport documents and train documentation from the locomotive driver.

After the train stops, before the locomotive is unhooked, the operator secures the set against spontaneous movement by tightening the locking brakes. Wagon inspector of the operator informs the team leader about the number of secured brakes, their order in the set and the 12-digit number of the wagons. The team leader will then record this fact in the Train list. The train list with additional information about the safety brakes will be sent by the team leader to the operating supervisor and a copy to the wagon inspector. The operating supervisor records this information in the operating supervisor's timetable and leaves the e-mails in the electronic mail for archiving.

The operating supervisor then informs the head of the shunt of the 1st or 3rd shunting reserve about the security of the wagons. The locomotive driver informs train dispatcher 1 about the actual posting of the locomotive. The latter, in cooperation with the second train dispatcher, controls the movements of the departing locomotive. The end signals are taken by the wagon inspector of the railway operator.

The operator's employees are taken to the technical and transport inspection after being notified by the team leader. The transport inspection is carried out by the clerk of the technical office for all destination trains.

The technical inspection is carried out by the wagon inspector designated trains, always following instructions from the team leader. During the transport inspection, the operator's employee will ensure the correct marking of the wagons. In the case of a request to divide a group of empty wagons, he will ensure that even after the group is divided, the first and last wagons of the group are marked with wagon stickers. If any deficiencies are discovered, the technical office clerk will immediately report these deficiencies to the team leader, who will explain them to the commercial inspectors. The technical office clerk will notify the team leader of the completion of the transport inspection. The technical inspection is carried out by the operator's wagon inspector. On the wagons, he monitors the condition of the front surfaces of the hoops and rims of the integral wheels. Wagons on which technical defects are detected are marked by the wagon inspector with repair stickers on both sides of the wagon. The wagon inspector informs these wagons to the team leader, who informs the operating supervisor, who then informs the commercial inspectors. The Wagon inspector will notify the team leader of the completion of the technical inspection, including all changes to the wagons.

Team leader will notify the operating supervisor of the completion of the technical and transport inspection, who will mark this fact in the operating supervisor's chart and invite transit workers to perform the inspection for ŽSR.

Commercial inspectors perform an inspection of the destination train in the entrance and transit group,

proceeding simultaneously in pairs, each proceeding from one side of the carriages. If it is not possible to comply with this due to the reduction of the occupation of the workplace during the shunt, this inspection is carried out by one commercial inspector. The exit group of tracks is always inspected by one commercial inspector.

At the beginning of the tour, the commercial inspector in the PSION mobile device is a new sorting list The commercial inspector writes down the classification on the track on a PSION mobile device.

Wagons marked with Prohibition of driving over a marshalling hump are removed from the set of the destination train in the entrance group by the order of the operating supervisor by the 1st or 3rd advancing backup. The removal of wagons from the set of the destination train is reported back to the operating supervisor by the shunt leader of the 1st or 3rd shunting reserve. Discarded wagons will be rearranged on the order of the operating supervisor from the entrance group and placed in the departure trains by the 3rd advancing reserve.

Wagons that will not be splitting of trains over a marshalling hump are moved by the operating supervisor directly to the designated tracks in the directional group.

The preparation of a set of wagons for splitting of trains is carried out by the shunter-preparer, who was designated as the leader of the shunt of the 1st reserve at the beginning of the work shunt. Based on the sorting list, the shunter-preparer loosens the screws and disconnects the brake hoses in the places where the screw will be suspended between the wagons during sorting. In addition to this activity, it also gradually releases the brakes of all wagons in the set (except for the parking brakes). After completing the preparation of the set for deployment, he will notify the leader of the shunt of the 1st reserve of this fact.

The hump yard supervisor, after checking the created sorting system, issues an order to end the sorting process. The shut up of the shunting locomotive to the set is carried out by the shunter designated by the leader of the shunt of the 1st reserve. After the locomotive is attached, the shunter releases the locking brakes, or removes the devices securing the set from the tracks. Consent for the movement of the shunting part is granted by dispatcher 1 after the construction of the shunting road. The movement of the moving part is controlled by the leader of the movement of the 1st reserve. The moving part must stop in front of the landing sign even if the sign allows moving. After stopping the moving part in front of this signal, the shunt leader must request permission to start decommissioning from the warehouse supervisor.

After sorting out, if the application does not end sorting out automatically (usually in the case when not all wagons on the sorter have been sorted out), the depot supervisor will perform this operation manually.

The technological procedure and its time consumption can best be illustrated using a Gantt chart, which is preceded by the creation of a table with the relevant technological operations and their time consumption. The time standards for operations and operations were modeled for the considered train consisting of 30 Eas series wagons, which will be divided on a marshalling hump into 10 branches of 3 wagons each. Table 1 shows Technological procedures of processing destination train.

Table 1. Technological procedure of processing the destination train with time data of individual operations (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

No.	Operation	Begin [min.sec]	Duration [min.sec]	End [min.sec]	Execute
1	Notification of employees	0.00	0.51	0.51	Train dispatcher
2	Train ensures to the station	0.51	3.00	3.51	Locomotive driver
3	Submission of documentation	3.51	11.13	15.04	Technical office clerk
4	Safety of train set, Distance locomotive	3.51	16.11	20.02	Wagon inspector/ Locomotive driver
5	Technical inspection	20.02	100.48	120.50	Wagon inspector
6	Transportation inspection	20.02	45.00	65.02	Technical office clerk
7	Notification of end inspection	120.50	0.53	121.43	Operating supervisor
8	Inspection for ŽSR	121.43	22.43	144.26	Commercial inspectors
9	Create sorting list	121.43	31.48	153.31	Operating supervisor
10	Loosening screw coupling	153.31	38.30	192.01	Shunter-preparer
11	Suspension shunting locomotive	192.01	0.54	192.55	Shunter
12	Control and conclusion sorting list	192.55	1.05	194.00	Hump yard supervisor
Together 194.00 minutes					

Figure 3 shows the process and time-consuming technological procedure of processing the destination train.

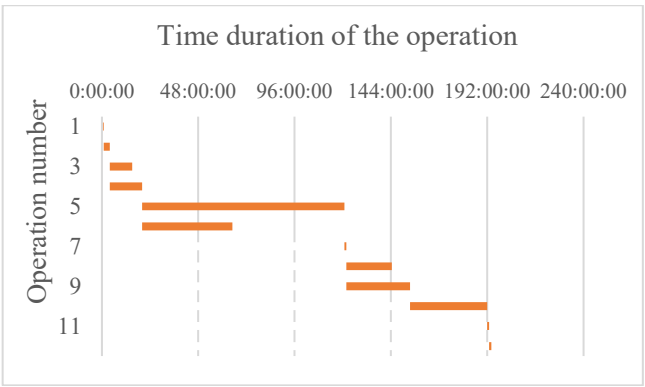


Fig. 3. Graphic representation of the progress and time-consuming technological procedure of processing the

destination train (Source: author using ŽSR, 2015a,b,c; ŽSR, 2021)

2. Proposal of technological procedures when using Augmented Reality in the technology of processing the destination train

Operator:

The first proposal is devoted to the adjustment of the existing technological procedures of the operator. For operations that have been selected as suitable for innovation, the observed benefit is primarily the saving of employees' working hours. Operations that were not affected by the implementation of augmented reality technology were left in the proposal in their original wording and time-consuming so that they corresponded to the initial state.

In the technological process of processing the destination train, it is possible to implement augmented reality in the case of technical and transport inspections, or merging them into a single inspection, which replaces two separate inspections from the initial state.

In the proposal, the revised technical-transportation inspection is performed by a wagon inspector, who is equipped with a device for creating augmented reality. In this proposal, the wagon inspector also corrects the identified deficiencies and ensures that in the event of a division of a group of wagons, it continues to apply that the first and last wagon in the group is marked. Taking this fact into account, a surcharge to the original duration of the technical inspection performed by the wagon inspector was modelled in the duration of 0.15 min. for correction. The mark-up was obtained by expert estimation because this procedure is not currently applied and there are no standards by which the mark-up would be precisely determined. We consider 45 minutes of the technical office clerk's work saved. Slowing down the work of the wagon inspector, however, considering the logical and technical consequences resulting from the technological procedure, will increase the total processing time of the set of the destination train in the case of a modelled set by 18 minutes, which in the case of a lack of wagon inspector can negatively affect the performance of the establishment station. Table 2 shows technological procedure of processing the destination train using augmented reality by the operator containing the time requirements of individual operations.

Table 2. Technological procedure of processing the destination train using augmented reality by the operator containing the time requirements of individual operations (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

No.	Operation	Begin [min.sec]	Duration [min.sec]	End [min.sec]	Execute
1	Notification of employees	0.00	0.51	0.51	Train dispatcher
2	Train ensures to the station	0.51	3.00	3.51	Locomotive driver
3	Submission of documentation	3.51	11.13	15.04	Technical office clerk
4	Safety of train set, Distance locomotive	3.51	16.11	20.02	Wagon inspector/ Locomotive driver
5	Technical – Transportation inspection	20.02	118.48	138.50	Wagon inspector
6	Notification of end inspection	138.50	0.53	139.43	Operating supervisor
7	Inspection for ŽSR	139.43	22.43	162.26	Commercial inspectors
8	Create sorting list	139.43	31.48	171.31	Operating supervisor
9	Loosening screw coupling	171.31	38.30	210.01	Shunter-preparer
10	Suspension shunting locomotive	210.01	0.54	210.55	Shunter
11	Control and conclusion sorting list	210.55	1.05	212.00	Hump yard supervisor
Together 212.00 minutes					

Figure 4 shows the process and time-consuming technological procedure of processing the destination train by the operator.

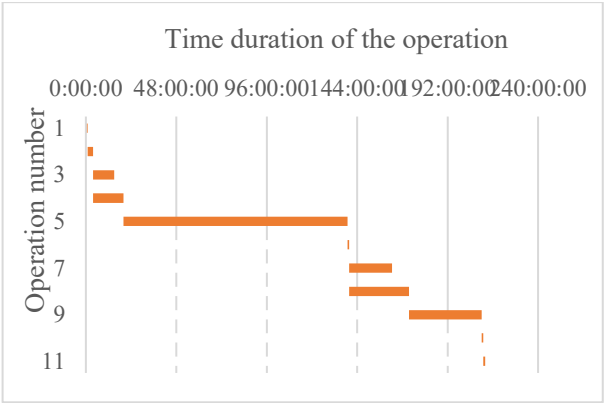


Fig. 4. Graphic representation of the progress and time-consuming technological process of processing the destination train when using augmented reality by the operator (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

Infrastructure manager:

When considering the use of augmented reality by the infrastructure manager, similarly to the first proposal, the monitored criterion is the saving of employees' working time. Suitable operations selected for the implementation of augmented reality technology are not as numerous as in the case of operations performed by the operator, but nevertheless they can provide a benefit in the form of savings in the monitored criterion.

A suitable operation for the implementation of augmented reality technology from the point of view of the infrastructure manager is the creation of a sorting list in the process of processing the destination train, based on which the set will be splitting of trains. The innovation under

consideration is the replacement of the PSION mobile device with a device for creating augmented reality, which will be used by the commercial inspector when inspecting wagons for ŽSR. Data on wagon numbers, or their directions are obtained already during this inspection by using a device that can record data faster than the currently used device. Another advantage compared to the currently used equipment is the free hands of the employee and the elimination of his mistakes due to inattention.

To obtain data on wagons and routing, no surcharge was added to the time required for the inspection for the ŽSR, performed by a commercial inspector on a modelled set of the train, because the data collection takes place automatically using an augmented reality device. The considered saving is 30 minutes of the commercial inspector work when creating the sorting list and will be significantly reflected in the duration of the processing of the destination train compared to the procedure proposed when using augmented reality by the operator and the current state. Compared to the current state, the length of the proposed procedure is shorter by 4 minutes and 17 seconds.

Table 3. Technological procedure for processing the destination train with data on the time required for operations after the implementation of augmented reality at the infrastructure manager (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

No.	Operation	Begin [min.sec]	Duration [min.sec]	End [min.sec]	Execute
1	Notification of employees	0.00	0.51	0.51	Train dispatcher
2	Train ensures to the station	0.51	3.00	3.51	Locomotive driver
3	Submission of documentation	3.51	11.13	15.04	Technical office clerk
4	Safety of train set, Distance locomotive	3.51	16.11	20.02	Wagon inspector/ Locomotive driver
5	Technical inspection	20.02	100.48	120.50	Wagon inspector
6	Transportation inspection	20.02	45.00	65.02	Technical office clerk
7	Notification of end inspection	120.50	0.53	121.43	Operating supervisor
8	Inspection for ŽSR	121.43	22.43	144.26	Commercial inspectors
9	Create sorting list	144.26	4.48	149.14	Operating supervisor
10	Loosening screw coupling	149.14	38.30	187.44	Shunter-preparer
11	Suspension shunting locomotive	187.44	0.54	188.38	Shunter
12	Control and conclusion sorting list	188.38	1.05	189.43	Hump yard supervisor
Together 189.43 minutes					

Figure 5 shows the process and time-consuming technological procedure of processing the destination train by the infrastructure manager.

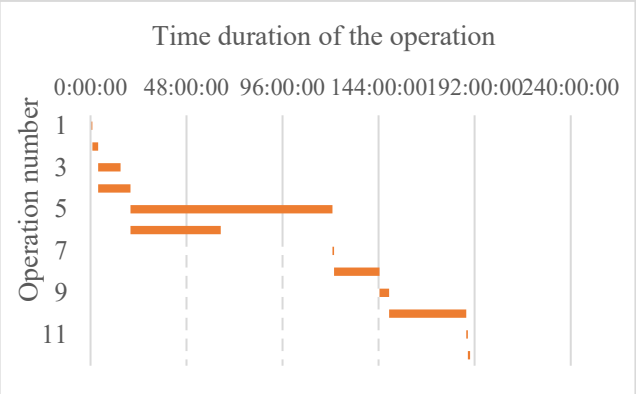


Fig. 5. Graphic representation of the progress and time-consuming technological procedure of processing the destination train with the considered use of augmented reality by the infrastructure manager (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

Operator and infrastructure manager simultaneously:

The third proposal is devoted to the simultaneous introduction of all the measures proposed in the previous two points, so that it is possible to achieve an even higher saving in the normal hours of work of employees, in this case for the infrastructure manager. The inspection for the ŽSR, which in the initial state is carried out after the inspection of the wagons by the operator, is replaced in this proposal by the technical-transport inspection of the operator. As a condition for the possible recognition of the operator's technical-transport inspection, the proposal envisages making a record of this inspection through a device that creates an augmented reality. This record is then provided to the infrastructure manager and archived as potential evidence for investigative authorities in the event of an emergency. In the case of a technical and transport inspection of the destination train, at least 12 hours, or until the moment when all wagons that were inspected during this inspection did not undergo another inspection, from which a record was made.

The replacement of the inspection by ŽSR with the operator's technical-transport inspection also assumes the creation of a classification based on the data obtained during this inspection.

The considered saving compared to the starting variant is 45 minutes of working time of the technical office clerk during the transport inspection, 30 minutes of the commercial inspectors work when creating the sorting list and 22 minutes and 43 seconds during the inspection for ŽSR. Along with saving manpower, the time required for the technological procedure is reduced by 9 minutes.

Table 4. Technological procedure for processing the destination train with data on the time required for operations after the implementation of augmented reality at the operator and the infrastructure manager (Source: author, according to ŽSR, 2015a,b,c; ŽSR, 2021)

No.	Operation	Begin [min.sec]	Duration [min.sec]	End [min.sec]	Execute
1	Notification of employees	0.00	0.51	0.51	Train dispatcher
2	Train ensures to the station	0.51	3.00	3.51	Locomotive driver
3	Submission of documentation	3.51	11.13	15.04	Technical office clerk
4	Safety of train set, Distance locomotive	3.51	16.11	20.02	Wagon inspector/ Locomotive driver
5	Technical – Transportation inspection	20.02	118.48	138.50	Wagon inspector
6	Notification of end inspection	138.50	0.53	139.43	Operating supervisor
7	Create sorting list	139.43	4.48	144.31	Operating supervisor
8	Loosening screw coupling	144.31	38.30	183.01	Shunter-preparer
9	Suspension shunting locomotive	183.01	0.54	183.55	Shunter
10	Control and conclusion sorting list	183.55	1.05	185.00	Hump yard supervisor
Together 185.00 minutes					

Figure 6 shows the process and time-consuming technological procedure of processing the destination train by operator and infrastructure manager.

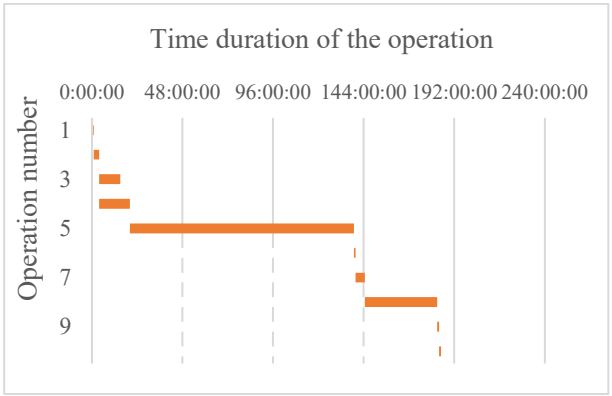


Fig. 6. Graphic representation of the progress and time-consuming technological procedure of processing the destination train after the implementation of augmented reality at the operator and the infrastructure manager (Source: author with the use of ŽSR, 2015a,b,c; ŽSR, 2021)

Conclusion

From the point of view of the overall evaluation of the individual proposals, the most important criterion was the saving of manpower to reduce the costs arising from the processing of wagons in the marshalling station. The reduction of the required manpower was achieved by adjusting technological procedures using an innovative technical equipment - augmented reality.

In the analysed technical procedures, the manpower of the technical office clerks of the operator's technical office and the infrastructure manager's commercial inspectors was saved. The disadvantage in all proposals is the addition of operations to the work of the wagon inspector, which increases the time required for the inspections he performs on the wagons.

In the first proposal, augmented reality technology was implemented in the operations performed by the operator. In the case of the processing of the destination train, the technological procedure was extended by 18 minutes, while the operations performed by the wagon inspector were extended by this time. The labour saving of technical office clerks was 45 minutes in the case of the destination train.

In the second proposal, operations suitable for the implementation of augmented reality performed by the infrastructure manager were selected in the technological procedures. The only technological procedure suitable for the implementation of augmented reality is the procedure by which the destination train is processed. With the considered saving of 30 minutes of commercial inspector work, it was possible to shorten the technological procedure by 4 minutes and 17 seconds in this proposal, considering the faster recording of wagon numbers in the case of creating a sorting list with augmented reality, as with the currently used PSION device.

In the third proposal, a synthesis of the previous proposals was proposed, or implementing augmented reality technology simultaneously in operations performed by the operator and the infrastructure manager. By modifying the technological procedures, the total duration of the technological process of processing destination trains was reduced by 9 minutes, while saving 92 minutes and 43 seconds of employee work.

Table 5 shows overview of the length of technological procedures in individual proposals with considered labour savings.

Table 5. Overview of the length of technological procedures in individual proposals with considered labor savings.

	Procedure	**Incoming train [min:sec]**
Current state	During	194:00
	Difference	-
	Savings	-
1st proposal	During	212:00
	Difference	18:00
	Savings	45:00
2nd proposal	During	189:43
	Difference	- 4:17
	Savings	30:00
3rd proposal	During	185:00
	Difference	- 9:00
	Savings	92:43

Constant innovation and improvement of technological procedures (within the limits of existing legislation and work safety) is a very important element for maintaining the competitiveness of rail transport compared to other types of transport, which can have positive effects for reducing the ecological burden on the environment.

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