ASSESSMENT OF INTERMODAL TECHNOLOGIES OF TRUCK AND TRAILER COMBINATIONS HANDLING ONTO RAILWAY WAGONS

Abstract
The first part of this article presents stages of technological processes of horizontal handling of truck and trailer combinations onto railway wagons, utilising such methods as: Rollende Landstrasse, Flexiwaggon and Modalohr. The results related to handling processes in the form of average completion times of individual operations have been presented in tabular form. A simulation of handling processes for a train composition consisting of 20 wagons has also been run in order to realistically depict time differences depending on employed technology. The second part of the article is a comparative overview of technologies mentioned above, e.g. using the criterion of costs related to purchasing of wagons or adapting terminals or types of transported vehicles.

Keywords: horizontal handling, Rollende Landstrasse, Flexiwaggon, Modalohr, intermodal technologies.

1. Introduction

Nowadays, with a growing volume of transport services, which is the result of lack of time to organise transport, increasing competition related to the speed and lower costs of deliveries, the increase of pollution emission and road congestion, intermodal transport seems to be the perfect and reasonable solution. It plays an increasingly important role in transportation on a global and European level. However, despite the development and the vast availability of modern handling technologies, there is a group of intermodal transport units which constitutes a third-rate part of this system. This group consists of road-rail combined transport in which semi-propelled truck and trailer combinations are used.

The horizontal handling technology is used most often in Sweden, Switzerland, Austria, German, France, Spain, and Italy (Kwaśniowski et al., 2008; Stokłosa, 2010). Thus, the aim of this paper is to assess intermodal technologies of horizontal handling of truck and trailer combinations onto a railway wagon. The presented comparative analysis of Rollende Landstrasse, Flexiwaggon and Modalohr technologies is to show which of them is the most efficient, which is related to the individual average completion time of horizontal handling and the distribution of costs related to investment in these technologies.
2. The research part

The research has been carried out in the form of an observational and measurement study of handling technologies of a self-propelled truck and trailer combinations. The collected data and information will serve as a good basis for comparative analysis and assessment of examined processes of horizontal handling of a road tractor with a semi-trailer onto railway wagons. In order to collect the necessary data, ten directly independent from one another, but complementary observational and measurement studies were undertaken. The research has been carried out in a manner, which by no means interfered into the processes of horizontal handling technologies, thanks to which disturbances in these technological processes have been eliminated and the likeliness of repeating real completion time of individual operations being the subject of research has been increased.

The research problem is the assessment of intermodal technologies of handling of truck and trailer combinations onto railway wagons. The subject of investigation is horizontal handling techniques (Rollende Landstrasse, Flexiwaggon, and Modalohr) of tractors with semi-trailers onto railway wagons. The research aim, on the other hand, is to determine completion time of individual processes of horizontal handling and operations which make it up, as well as to compare them with respect to engineering and economic features.

Observation and measurements have been taken in three different intermodal terminals which are located in:

- Wörglin Austria – Rollende Landstrasse system;
- Östersund in Sweden – Flexiwaggon system;
- Orbassano in Italy – Modalohr system.

The topic of research has been carried out by different employees working at those terminals and as drivers, due to which changes and differences occurred because of skills, enabling to average the measurements taken within the borders of the actual completion of the examined process.

3. Completion time of handling in case of Rollende Landstrasse

The examined horizontal handling process of a tractor with a semi-trailer onto a railway wagon, employing Rollende Landstrasse technology consists of five main operations (Korzeb and Kostrzewski, 2012):

- Operation I – bringing the train composition to the intermodal terminal and leaving it in the specified place on hard ground;
- Operation II – opening of the rear side of a wagon and placing direct ramp against it as well as latching coupling systems between the ramp and the wagon;
– Operation III – a tractor with a semi-trailer enters the wagon through the direct ramp. The truck and trailer combination moves along the train composition;

– Operation IV – the truck and trailer combination is placed in the specified position (specified wagon) and protected from uncontrolled moving by means of wedges and possibly belts or chains as well;

– Operation V – unlatching and removing the direct ramp from the head of the wagon and closing the rear side of the wagon, implying that the train composition is ready to go.

The obtained average completion times of individual handling operations of the truck and trailer combinations with the help of Ro-La technology have been presented in Figure 1. Total completion time of this process was: 20 min. 29 s (1229.09 s).

![Fig. 1. Pareto chart of completion time of handling processes in Rollende Landstrasse system. Source: own work.](image)

From the analysis of the above results and Pareto chart it can be noted that the longest completion time has been observed in operation II (opening of the rear side of a wagon and placing direct ramp against it, as well as latching coupling systems between the ramp and the wagon) and operation V (unlatching and removing the direct ramp from the head of the wagon and closing the rear side of the wagon). It is caused by the fact that one or two employees of the terminal have to be involved in this operation, they have to unlock and lock the side of the wagon, place, latch, and unlatch, and then put the direct ramp, equipped with a bogie powered manually, away by hand.

Total completion time of handling of a single truck and trailer combination onto a wagon in Rollende Landstrasse system amounts to 20
minutes, which will grow proportionally in the case of handling of a greater number of tractors with semi-trailers, as has been shown in the simulation further in in this paper. A relatively long completion time of horizontal Ro-La handling process is a significant disadvantage which cannot be overcome because of a series of handling of truck and trailer combinations.

4. Completion time of handling in case of Flexiwaggon

The examined horizontal handling process of a tractor with a semi-trailer onto a railway wagon with the aid of Flexiwaggon technology consists of five main operations (Korzeb and Kostrzewski, 2012):

− Operation I – bringing the train composition to the intermodal terminal and leaving it in the specified place;
− Operation II – lowering supports of the rotating platform and activating its rotating mechanism;
− Operation III – lowering the direct platform and supporting the rotated platform on projecting support legs;
− Operation IV – the tractor with a semi-trailer enters the wagon through the platform;
− Operation V – folding away support legs and direct platform and rotating the platform with the truck and trailer combination to a transport position, then folding away supports of the platform.

The obtained average completion times of individual handling operations of truck and trailer combinations by means of Flexiwaggon technology has been presented in Figure 2. The total completion time of this process was: 10 min. 4 s (603.58 s).

![Fig. 2. Pareto chart of completion time of handling processes in Flexiwaggon system. Source: own work.](image)

The above analysis of completion time of vertical handling, utilising Flexiwaggon technology, shows that the operation, consisting of folding away
the direct platform and supports of the platform, is the most time-consuming. It is the reason of the complexity of construction and operation of the wagon, which has to overcome greater mechanical load under the effect of the pressure of the truck and trailer combination. These loads affect hydraulic rams, as a result of which their operation is slowed down, and folding away of the direct platform and rotation of the platform last longer.

The time needed to put the wagon into the handling position and then to transport position is similar only in case of work without any load, which usually is pressure applied by the truck and trail combination or a trailer itself.

Total completion time of handling of a single truck and trailer combination onto a wagon in Flexiwaggon system amounts to 10 minutes that is two times less than in the case of Ro-La. Therefore, this system is better in terms of speed of execution of handling processes. Its additional advantage is a possibility of a parallel operation of truck and trail combinations in a number, which is appropriate to conditions that are at the disposal of the intermodal terminal (usually 8-10 places where wagons can be handled simultaneously). It enables to process several trucks and trailer combinations onto or from wagons at the same time without prolonging the completion time.

5. Completion time of handling in case of Modalohr

The examined vertical handling process of a tractor with a semi-trailer on a railway wagon by means of Modalohr technology consists of six main operations (Korzeb and Kostrzewski, 2012; Figure 3).

![Pareto chart of completion time of handling processes in Modalohr system.](source: own work.)
According to Figure 3, the total completion time of the process equals 10 min. 36 s (635.84 s), which are devoted to the next operations:
- Operation I – bringing the train composition to the intermodal terminal and leaving it in the specified place;
- Operation II – raising and rotating the platform axially by 30-40 degrees;
- Operation III – a tractor with a semi-trailer enters the wagon;
- Operation IV – dropping off the semi-trailer from the tractor;
- Operation V – the tractor leaves the direct ramp;
- Operation VI – rotating the platform to transport position.

The above-analysed completion times of the handling process in Modalohr system and Pareto chart show, at first sight, the greatest disadvantage of this scheme. Namely, it is a long duration of bringing the train composition and placing it in the specified place in the intermodal terminal. The time constitutes more than 50% of total process completion time. It results from the necessity to maintain high precision by the operator of the train composition, who has to bring the wagons perfectly above sub-track cylinders. Positioning the wagons inappropriately can block cylinders which will not be able to lift and rotate the platform, which will result in a temporary stoppage and loss of time (the necessity to roll wagons away). That is why the operation is carried out with great precision, prolonging its completion time, but limiting error occurrence and the necessity to roll wagons away and unnecessary waste of time.

Another operation which constitutes more than 28% of total process completion time is the operation of dropping off the semi-trailer from the tractor. In this process the driver has to leave the cabin of the tractor, disconnect electric and hydraulic cables connecting the semi-trailer with the tractor, lower and latch support legs and go back to the cabin and go down the direct ramp after lowering the saddle.

Total completion time of handling of a single truck and trailer combination onto a wagon in Modalohr system is more than 10 minutes, which is two times less than in the case of Ro-La and Flexiwaggon. Its advantage is a possibility of a parallel operation of truck and trailer combinations in a number which is appropriate to conditions which are at the disposal of the intermodal terminal (usually 15-20 places where wagons can be handled simultaneously). It enables to handle several truck and trailer combinations onto or from wagons at the same time without prolonging the process completion time.

6. Simulation of unloading of 20 tractor and truck combinations in Ro-La, Flexiwaggon and Modalohr systems

Simulation has been run for a horizontal handling of 20 trucks and trailer combinations onto railway wagons in Rollende Landstrasse, Flexiwaggon, and Modalohr systems. Previously measured and calculated average time of
individual handling operations for individual technologies have been used in this simulation.

In the case of Ro-La system, truck and trailer combinations enter the wagon one after another in intervals amounting to the length of a single wagon, which translates to 33.4 seconds. A problem of rolling wagons does not occur here since, in this system, there is no interrelationship between loading and handling and selected individual posts. The results of the simulation have been presented on Gantt chart (Figure 4).

![Gantt chart of simulation of handling of 20 trucks and trailer combinations in Ro-La system. Source: own work.](image)
In the case of Flexiwaggon system, truck and trailer combinations enter the wagon simultaneously, but it has been assumed that the terminal has 10 individual stations where truck and trailer combinations can be handled and, therefore, it was necessary to roll wagons in order to handle all 20 trucks and trailer combinations. The results of the stimulation have been presented also on Gantt chart (Figure 5).

In the case of Modalohr system, truck and trailer combinations enter the wagon simultaneously, but it has been assumed that the terminal has 15 individual stations where truck and trailer combinations can be handled and, therefore, it was necessary to roll wagons in order to handle all 20 trucks and trailer combinations. The results of the stimulation have been presented also on Gantt chart (Figure 5).

**Fig. 5.** Gantt chart of simulation of handling of 20 trucks and trailer combinations in Flexiwaggon system. *Source: own work.*

In the case of Modalohr system, truck and trailer combinations enter the wagon simultaneously, but it has been assumed that the terminal has 15
individual stations where truck and trailer combinations can be handled, and, therefore, it was necessary to roll wagons in order to handle all 20 trucks and trailer combinations (Figure 6).

**Fig 6.** Gantt chart of simulation of handling of 20 trucks and trailer combinations in Modalohr system. *Source: own work.*

It follows from the conducted analysis that average completion time of horizontal handling of 20 trucks and trailer combinations in Ro-La system is 27 minutes, which is the longest time of all simulations. This time amounted to 20 and more than 21 minutes in Flexiwaggon and Modalohr systems, respectively.
7. A comparative analysis of intermodal methods of horizontal handling

The most critical technical parameters related to handling and rotating mechanisms, the type of transported transport units and terminal construction costs and costs of specialist wagons for selected technologies of horizontal handling are summarised in Table 1.

Table 1
Comparative analysis of horizontal handling systems: Rollende Landstrasse, Flexiwaggon, and Modalohr.

<table>
<thead>
<tr>
<th>Feature of horizontal handling technology</th>
<th>Horizontal handling system</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Rollende Landstrasse</td>
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<tr>
<td>Loading</td>
<td>A self-propelled truck and trail unit enters the wagon through the direct ramp and goes through all wagons to the front part of the train composition.</td>
</tr>
<tr>
<td>Handling</td>
<td>A self-propelled truck and trailer combination through demountable direct ramp starting from the front part of the train composition (going through all wagons).</td>
</tr>
<tr>
<td>Rotating mechanism of wagon platform</td>
<td>No mechanism.</td>
</tr>
<tr>
<td>Type of transported units and vehicles</td>
<td>Tractors with semi-trailers and trucks with trailers.</td>
</tr>
<tr>
<td>Costs of intermodal terminal construction</td>
<td>Low costs related to purchasing of a demountable direct platform.</td>
</tr>
<tr>
<td>The cost of special wagon purchases</td>
<td>High costs related to the acquisition of wagons on special sliding bogies.</td>
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</table>

8. Summary and conclusion

There are many technologies used to transport truck and trailer combinations on wagons, but the most advantageous, concerning completion of handling process and necessary load-handling devices are horizontal handling techniques. In Ro-La, Flexiwaggon and Modalohr systems load-handling devices are not used because they are based on propulsion systems of truck and trailer combinations and specialist wagons equipped with the mechanisms necessary to perform those operations.

The presented analyses of completion times of individual operations and whole handling process allow concluding that the most effective system for single truck and trailer combinations is Flexiwaggon system, which has been illustrated in Figure 7.

![Fig. 7. An overview of completion time of horizontal handling using particular systems. Source: own work.](image)

However, if to focus on the handling of several trucks and trailer combinations as has been presented in the simulations, time differences are not so visible since completion time of handling processes for 20 sets of truck and trailer combinations in Flexiwaggon and Modalohr systems is 20 minutes and 27 minutes in the case of Ro-La system. It results from the operation in which wagons are rolled, which is time-consuming, but necessary to handle a greater number of truck and trailer combinations. Intermodal terminals of Flexiwaggon and Modalohr systems, in general, have 10-15 individual stands. Nevertheless, we know from practice that a train composition usually consists of more than 20, and sometimes even 30 wagons. In such a case, Ro-La system can win when it comes to effectiveness as compared to the other two systems if the number of rolling operations will be greater than one, which will significantly prolong completion time of handling. In Ro-La technology, wagon rolling is not
necessary and that is why this system is more attractive in terms of handling trains consisting of a great number of wagons – at least 20. The remaining systems, on the other hand, should be used in case of smaller train compositions.

However, Flexiwaggon and Modalohr systems have a significant advantage which declasses Rollende Landstrasse system, namely each wagon can be handled separately which means that truck and trailer combinations can have their own initial and final stations in intermediary terminals that cannot be achieved without relocating other vehicles. Summing up, Flexiwaggon is the most effective technology since it works best in comparison to Ro-La and Modalohr and handles whole truck and trailer combinations, which is not true of Modalohr.

As far as the economic aspect is concerned, Ro-La and Flexiwaggon systems require only hard surface in terminals. Modalohr system, on the other hand, entails high costs of the steering mechanism of loading platforms which have to be built in the handling tracks. The situation diverts in the case of expenses related to the purchase of special railway wagons.

In conclusion, the presented multi-layer comparative analysis can act as a supporting element in the organisational decision-making process when selecting a particular intermodal transport system.

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References