

# Innovative concept of loading bimodal trailers with the organization of a loading terminal

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**Abstract.** The article presents an innovative concept of horizontal transverse loading of bimodal semi-trailers by means of a transshipment terminal equipped with special the transshipment stands. An innovative switching station and a working principle improving the loading of bimodal trailers were described. The concept of the transshipment terminal equipped with several loading stands for bimodal semi-trailers is also presented. Various variants of organization of the terminal with horizontal transverse loading of bimodal semi-trailers are indicated. A preliminary computer simulation was carried out and the results are compared with the existing Polish system Tabor 1 and Tabor 2.

## 1 Introduction

Increasing traffic density is observed, due to the continuous development and growth of road transport. As a result, more and more pollutants, coming from exhaust fumes from combustion engines, are emitted [1,2]. To reduce environment pollution, the European Union's postulates presented in the White Paper encourage to look for new solutions that meet the "Vision of a competitive and sustainable transport system". One of the most important component of road transport is freight transport with the use of semi-trailers. Especially for this type of transportation an alternative solution will be presented. One of the possible solutions is the transport of semi-trailers by railway. It is of course possible to transport standard semi-trailers or containers on specially designed platforms. However, we must remember that the ratio of dead weight to the weight of transported goods, as well as the length of the train, does not put this type of transport at the top of the economic ladder.

And what about BIMODAL transport?



Fig. 1. Bimodal unit

Bimodal transport is a type of transport where an adapted semi-trailer, fixed with suitable adapters, is transported on railway bogies. Bimodal semi-trailer differs from the standard one and should be redesigned, according to the current road and railway requirements [3].

The main components of a bimodal semi-trailer are shown in Figure 2.

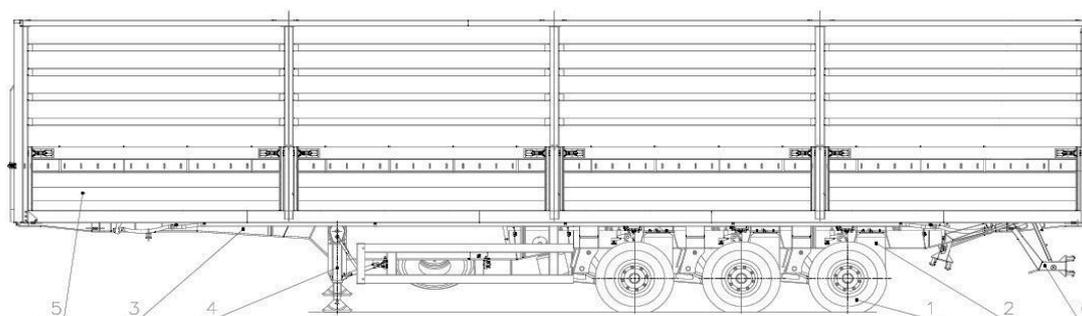


Fig. 2. Bimodal semi-trailer

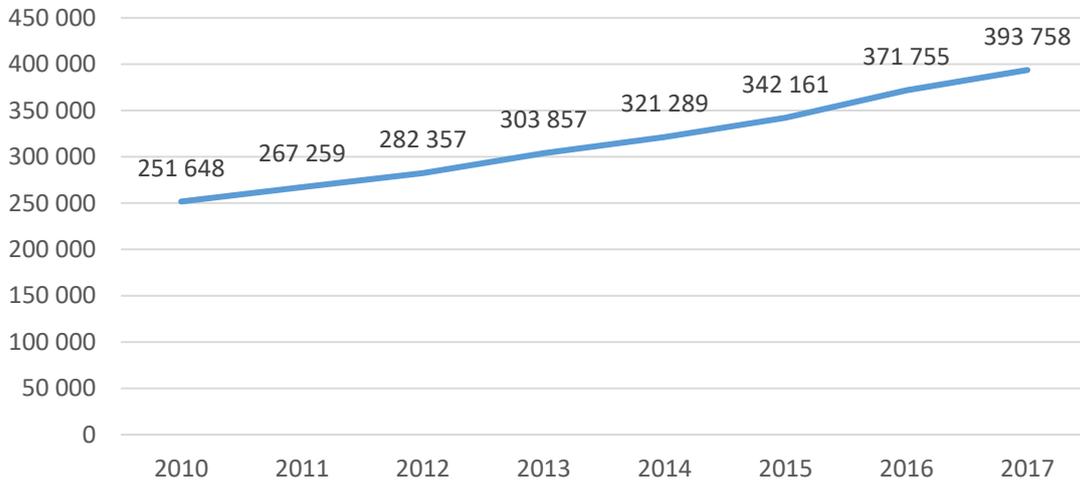
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These are:

- axles with road wheels (1),
- load-bearing bellows (2),
- semi-trailer frame (3),
- supporting leg (4),
- built-in body (5),
- tilting buffer (6).

We had should remember, that in Poland there is a

continuous increase of amount of semi-trailers, with important number of new semi-trailers. The increase in the number of semi-trailers is shown in Figure 3, referring to the data from the Central Register of Vehicles [4]. When designing new semi-trailers, we have the option of introducing structural changes that meet the requirements of rolling stock, which will allow us to gradually increase bimodal rolling stock.



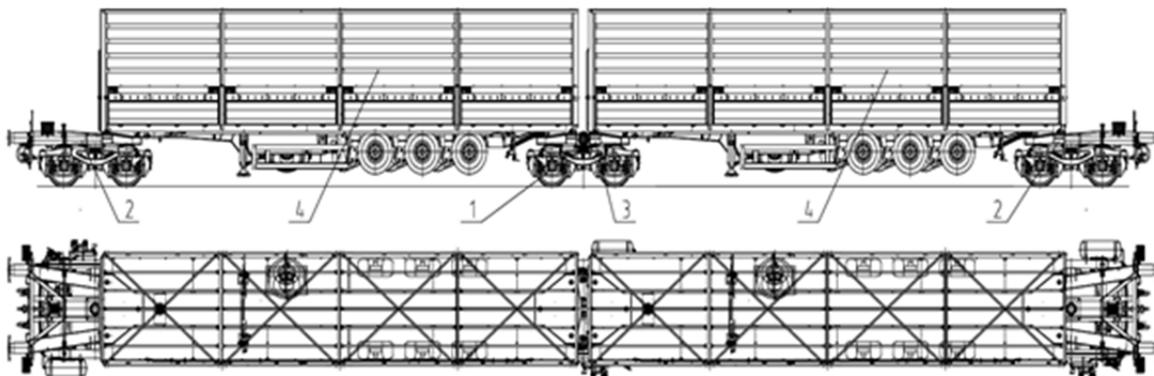
**Fig. 3.** The number of semi-trailers in road transport in Poland in the years 2010-2017

## 2 Bimodal fleet

The bimodal transport system is a qualitatively new technical solution for road and rail rolling stock, in which other design criteria and requirements as well as provisions on the basis of which road and rail rolling stock are designed and operated. The combination of these two systems into one bimodal system forces a correlation of requirements and restrictions in force separately for each transport system, e.g. in terms of permissible dimensions and masses, strength (road gauge - railway gauge, allowable road wheel load of the semi-trailer - allowable wheel set pressure on the track, higher strength requirements for a bimodal semi-trailer than for a road semi-trailer) [5].

Compared to other known modes of combined transport, the bimodal system has the following advantageous features [5]:

- low dead weight of rolling stock, i.e. the ratio expressed by the ratio of the weight of transported load to the weight of the rolling stock is the most favorable in the bimodal system
  - the smallest distance between adjacent loading units
  - the most favorable rolling stock gauge in the main zone, resulting from the position of the roof of the loading unit at a height limited to 4180 mm, measured from the rail head
  - the smallest length of the bimodal train composition
- Figure 4 shows a fragment of the bimodal train composition which consists of two end bogies, one middle bogie and two loading units [5]:
- bimodal bogies (1)
  - end adapters (2)
  - central adapters (3)
  - bimodal semi-trailers (4)



**Fig. 4.** Bimodal train unit

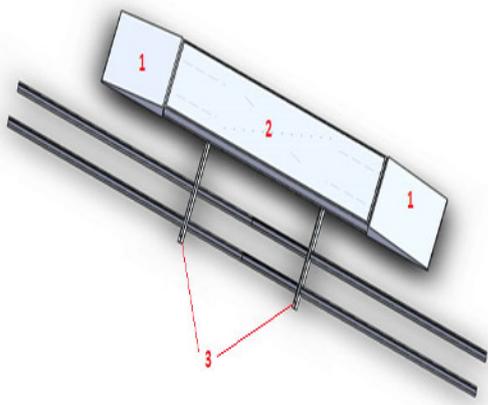
### 3 Innovative loading concept for semi-trailers

Loading of semi-trailers on the adapters is carried out in the following stages [3]:

1. Introduction of the semi-trailer on the loading stand,
2. Lifting of the semi-trailer to the maximum height with:
  - load-bearing bellows of tractor – front of the semi-trailer,
  - load-bearing bellows of semi-trailer – rear of the semi-trailer,
3. Lowering of the supporting leg of the semitrailer,
4. Take the tractor out under the semi-trailer,
5. Transverse movement of the central part of the stand with the semi-trailer to coincide of the longitudinal axle of the semi-trailer with the axles of bogies with adapters,
6. Lowering of the semi-trailer's body to support of the semi-trailer's frame on the adapters:
  - front of the semi-trailer using the supporting leg of the semi-trailer,
  - rear of the semi-trailer using the lifting bellows of the road axles,
7. Locking of the semi-trailers on the adapters,
8. Lifting of the road axles of the semi-trailer,
9. Locking of the road axles,
10. Returning of the central section of the transshipment stand to the starting position.

Transshipment stand for horizontal transverse loading of bimodal semi-trailers is shown in Figure 5 and consists of the following components:

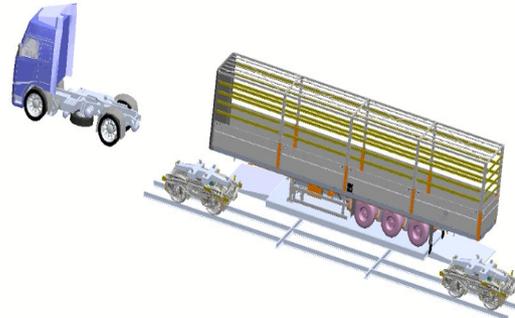
- ramps (1);
- central movable segment with guide rollers (2)
- guide rails (3)



**Fig. 5.** Loading stand for horizontal transverse loading of bimodal semi-trailers

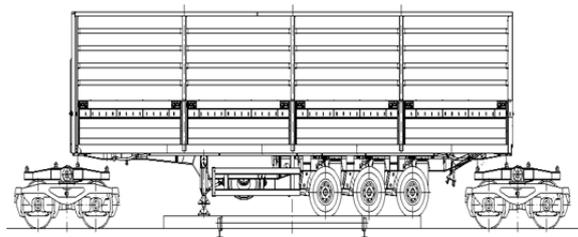
At the transshipment terminal, equipped with loading stands for horizontal transverse loading of bimodal semi-trailers, a tractor unit with a bimodal semi-trailer drives the semi-trailer into the middle segment of the semi-trailer loading stand using a loading ramp. When the trailer is in the right place on the middle segment, the trailer supports are lowered and the trailer and tractor are

disconnected. The tractor unit is then leaving a stand by a ramp on the other side of the middle segment. The bimodal semi-trailer is transported to the central axis of the railway track, where railway bogies equipped with semi-trailer adapters are placed, with the appropriate distance, as illustrated in Figure 6.



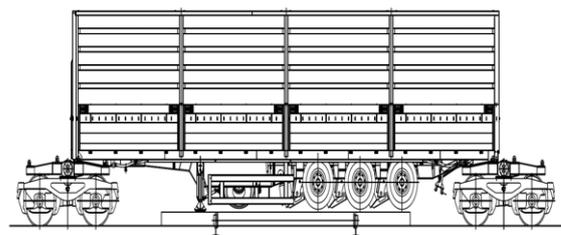
**Fig. 6.** Transport of a semi-trailer to the railway track

Figure 7 shows a semi-trailer in the axis of the railway track before lowering onto the adapters on the railway bogies.



**Fig. 7.** Semi-trailer in the axis of the railway track

The next stage of unit forming is to lift on and block the road wheels and semi-trailer supporting legs. In result, semi-trailer is placed on the adapters of railway bogies. The view of the trailer mounted on the adapters is shown in Figure 8.



**Fig. 8.** Semi-trailer in the axis of the railway track mounted on adapters

The middle segment returns to its original position and, after locking the pins on the adapter, the trailer is ready for transport on rail track.

### 4 Terminal organization

In the design of the arrangement of stands for horizontal transverse loading of bimodal semi-trailers, the only constraint that should be taken into account is the size of the loading terminal: the area where the rail head is at the same level as the maneuvering place.

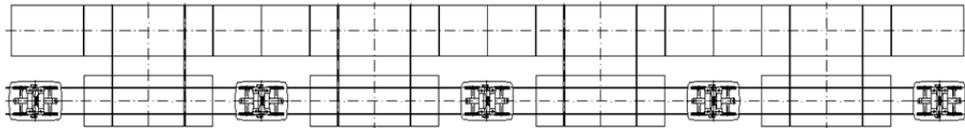
The first variant shown in Figure 9 is that the stands are located in series on one side of the track. With such an arrangement of stand, only small space of the terminal is occupied.

The second variant is shown in Figure 10. In this variant, loading stands are arranged alternately on both sides of the railway track. This variant facilitates the maneuverability of the tractor with semi-trailer.

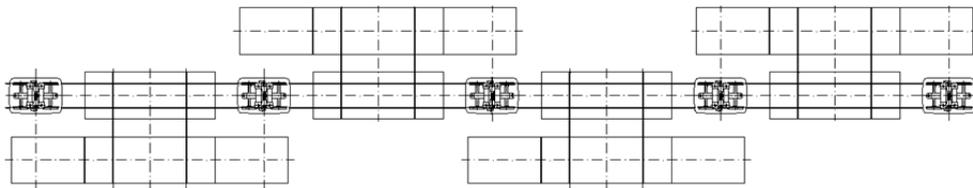
Figure 11 shows the third variant, where the loading stands are arranged alternately on both sides of the

railway track and offset by the width of the semi-trailer. This arrangement eliminates the need to maneuvering the tractor and trailer, which results in the easiest way to bring semi-trailers into loading stands.

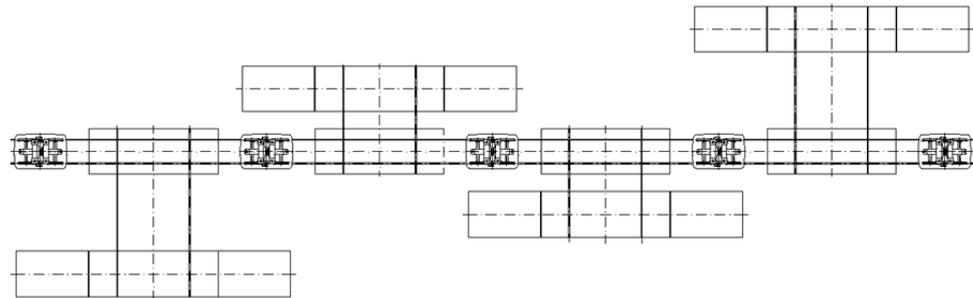
As mentioned above, the only limitation of loading stand arrangement is the size of the transshipment terminal. So, several more examples may be presented of organization of loading stands and transshipment terminal can be organized to operate simultaneously on two railway tracks.



**Fig. 9.** Variant 1



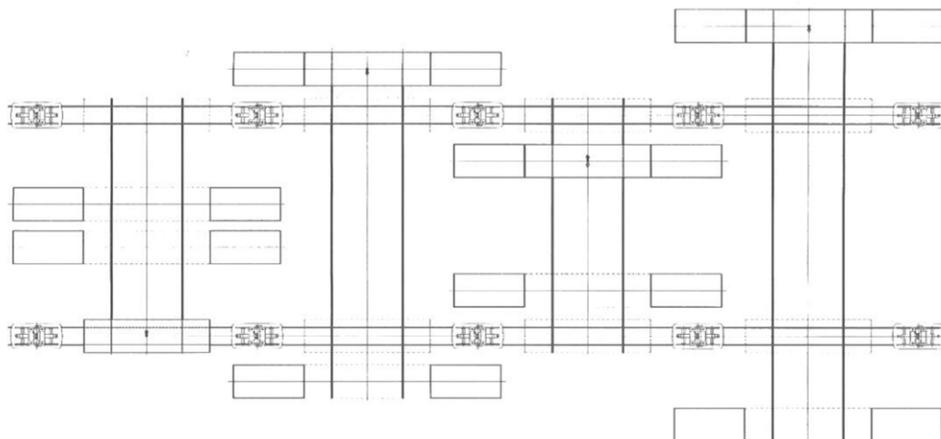
**Fig 10.** Variant 2



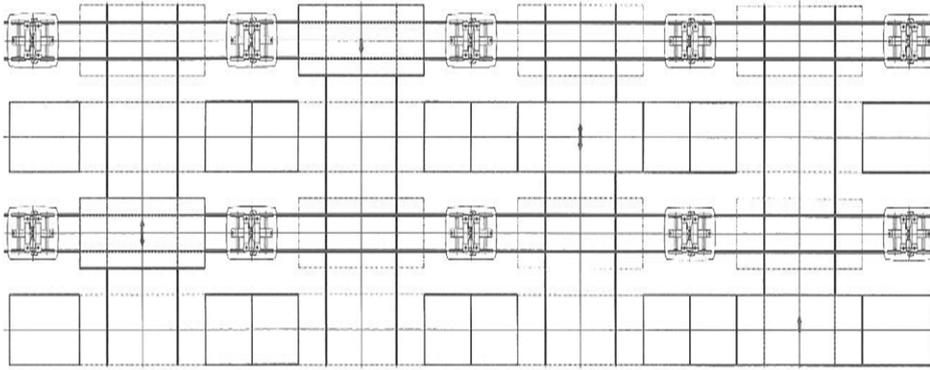
**Fig. 11.** Variant 3

The variants shown in Figs. 12, 13, 14 show two railway tracks with different arrangement of stations which are served by one central segment of the switching station for loading bimodal trailers. Each of the presented solutions for the arrangement of switching

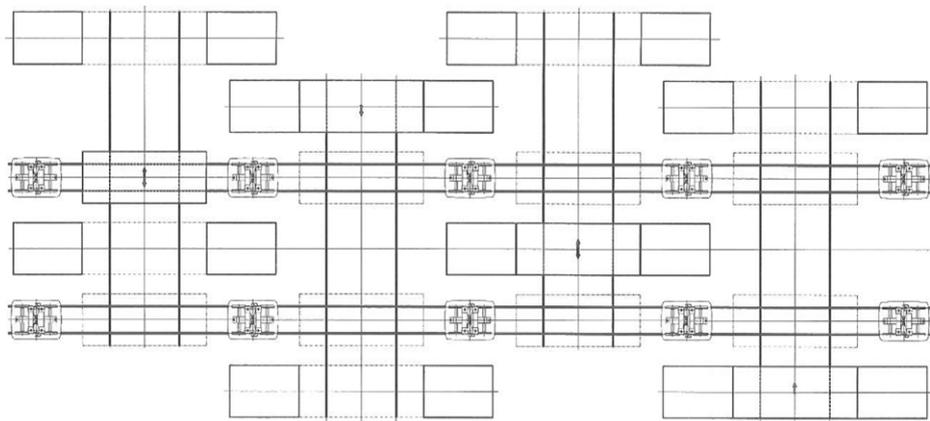
stations on the terminal eliminates various restrictions. Starting from the size of the terminal, through the ease of introducing the semi-trailer to the transshipment stand and ending with the skills of the operator of the truck tractor introducing the semi-trailer.



**Fig. 12.** Variant for 2 tracks operation



**Fig. 13.** Variant for 3 tracks operation



**Fig. 14.** Variant for 2 tracks operation

## 5 Computer simulation

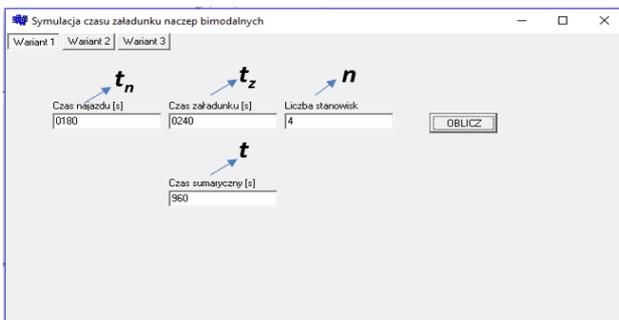
A preliminary general computer simulation was carried out using the BUILDER C++ program, introducing semi-trailers to switching stations and loading semi-trailers on railway bogies for three variants servicing one railway track.

- $t$  - total time
- $t_n$  - semi-trailer entry time
- $t_z$  - inroad time
- $n$  - number of positions

The calculation results for the three variants are summarized in tables 1 – 3.

**Table 1.** Variant 1

Lp.	List of activities	Summary time [s]
1.	Approach of the tractor with the semitrailer to the switching station	180
2.	The semi-trailer moves into the track axis and is loaded onto railway bogies	240
Total Time		960



**Fig. 15.** View of the program window for simulating the loading time of bimodal trailers for Variant 1

After calculating, the estimated time for loading four semi-trailers in Variant 1 will be

$$t = t_n \cdot t_z + n$$

where:

For the existing Tabor 1 and Tabor 2 systems in Poland [6], it was calculated that the parallel forming time of bimodal semi-trailers, whose equivalent is variant 1 in this article, is 850 seconds for one semi-trailer. To compare the Tabor 1 and Tabor 2 systems with the system equipped with loading stations, multiply the result by 4, because the proposed system has 4 loading stations. The obtained result of 3400 seconds is over 4 times longer than the innovative method of loading bimodal semi-trailers.

**Table 2.** Variant 2

Lp.	List of activities	Summary time [s]
1.	Approach of the tractor with the semitrailer to the switching station 1	90
2.	Approach of the tractor with the semitrailer to the switching station 2	280
3	The semi-trailer moves into the track axis and is loaded onto railway bogies	240
Total Time		520

**Table 3.** Variant 3

Lp.	List of activities	Summary time [s]
1.	Approach of the tractor with the semitrailer to the switching station	90
2.	The semi-trailer moves into the track axis and is loaded onto railway bogies 1	240
3	The semi-trailer moves into the track axis and is loaded onto railway bogies 2	320
Total Time		410

After comparing the three proposed variants, the obtained times clearly indicate that Variant 3, which was designed in such a way as to facilitate the operation of the truck tractor operator to introduce the semi-trailer to the switching station, obtained the shortest time to connect four semi-trailers. Detailed computational research with a breakdown into individual stages of bimodal formation will be carried out at a later stage of research.

## 6 Summary

In the 90s of the last century the bimodal system in Poland and in the world began to develop. In Poland the bimodal system called TABOR 1 and TABOR 2 was introduced. The Tabor 1 and Tabor 2 systems did not require additional loading devices at the loading terminal. The main disadvantage of this system was the time-consuming joining of the bimodal train, as well as the need to store semi-trailers in the parking lot. The long train preparation time resulted mainly from the complicated serial connection of the train unit. The

article presents an innovative system for loading bimodal semi-trailers and the organization of a terminal equipped with positions for horizontal transverse loading of bimodal trailers. Train formation and de-formation with use of transverse semi-trailer loading stands should significantly shorten the time of connecting a bimodal train. A transshipment terminal with several loading stands enables simultaneous loading of several trailers at the same time. Equipping the terminal with loading stands allows also the direct loading of semi-trailers, without the need of storing them in the parking lot. The proposed method of loading semi-trailers makes possible total or partial automatization of semi-trailers loading process. Creating the train composition with the help of horizontal transverse loading of semi-trailers significantly reduces the time of connecting the bimodal train as shown by the results of the simulation. The loading terminal with several switching stations enables simultaneous loading of several trailers. Equipping the loading terminal with switching stations also allows for efficient direct loading without having to store the semi-trailers in the parking lot first. The proposed method of semi-trailers reloading allows for full or partial automation of the semi-trailers reloading process.

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