

# Carriage of The Future

Stredná odborná škola dopravná Martin-Priekopa

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## *Introduction*

Railway transport is a necessary part of everyday life for many people. The diversity of travelers is truly great - whether young people travelling to school or other activities, families with kids going on a trip, older generations on their way to doctor and vacation, also passengers travelling for work responsibilities. In order to save this wide spectrum in trains and not make them travel individually, railways must be able to conquer. One of the first important conquering facts is to have powerful and newer rolling stock, which needs to offer above all safety, comfort and efficiency.

The goal of our work was to propose the carriage in the eyes of a young person within the rolling stock of Železničná spoločnosť Slovensko, which needs to fulfill criterias of regional transportation and bring modern touch for the passengers.

# ***1. THE CONCEPT OF ROLLING STOCK IN RAILWAY TRANSPORT AND ITS IMPORTANCE***

Mobile technical base in railway transport is a collective name for the mobile fleet of driving and driven rolling stock that the carrier has and uses for the operation of railway transport (i.e. locomotives, wagons, technical maintenance vehicles, etc.). Wagons are further divided into passenger and freight.

The vehicle fleet is an important factor in both passenger and freight transport, but in the transport of passengers, in addition to reliable transport, it also creates a driving experience that significantly influences their first impression and subsequent choice of transport mode for the next journey. Of course, its technological and innovative solution contributes to this.

## ***1.1 ANALYSIS OF ROLLING STOCK' FLEET AND PASSENGER NEEDS***

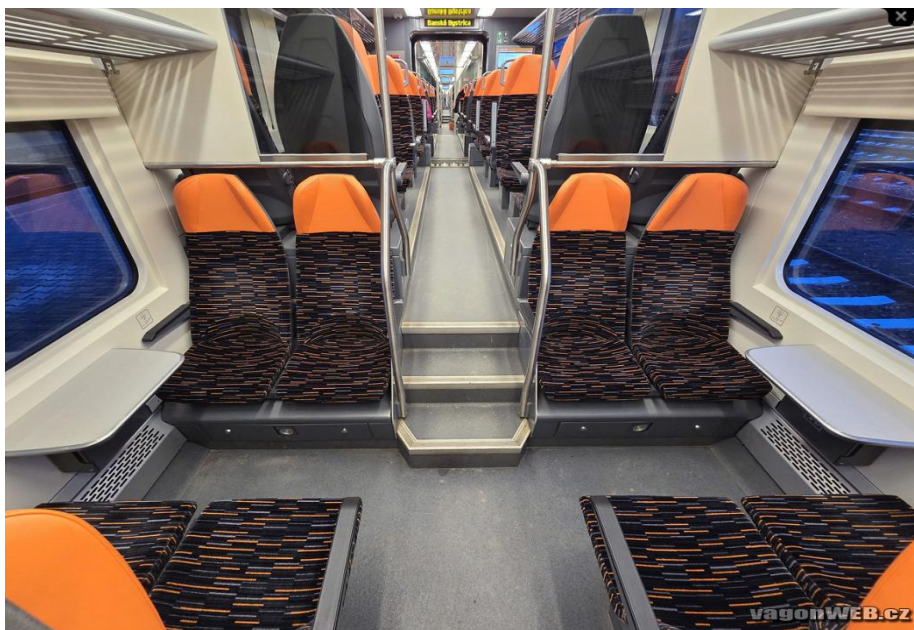
The global market for railway rolling stock is very diverse, offering carriers and passengers a wide range of options.

Transporters have a choice of several hundred companies that manufacture and possibly maintain railway rolling stock. The international market leader in the production of passenger rail vehicles is, for example, the globally known Siemens, the Swiss Stadler, or the Canadian Bombardier. However, the Czech Škoda Transportation is also gradually expanding, and the Slovak railway repair shops ŽOS Trnava, ŽOS Zvolen and ŽOS Vrútky are also in operation, which mainly deal with the modernization of rolling stock. Each manufacturer will offer a different technology and it is therefore up to the carrier to set its priorities and whether these priorities are suitable for each passenger.

Within passenger rail transport in Slovakia, mainly complete units are deployed on regional transport trains, namely with electric traction of the 425, 495, 561, 660/661, 671/651 series and with independent traction of the 648, 813/913, 840, 861 series, in which the turnaround time is shortened due to their design, because the driver's cab is located at both ends of the unit - i.e. at the beginning and at the end. Most of them are low-floor and wheelchair accessible. They also provide easier movement for immobile passengers, and passengers with bicycles and strollers. The latest units of the 660/661 series also offer the possibility of refreshments in the form of a food vending machine.



**Pic. No. 1 Interior of the currently used electric unit 660/661**

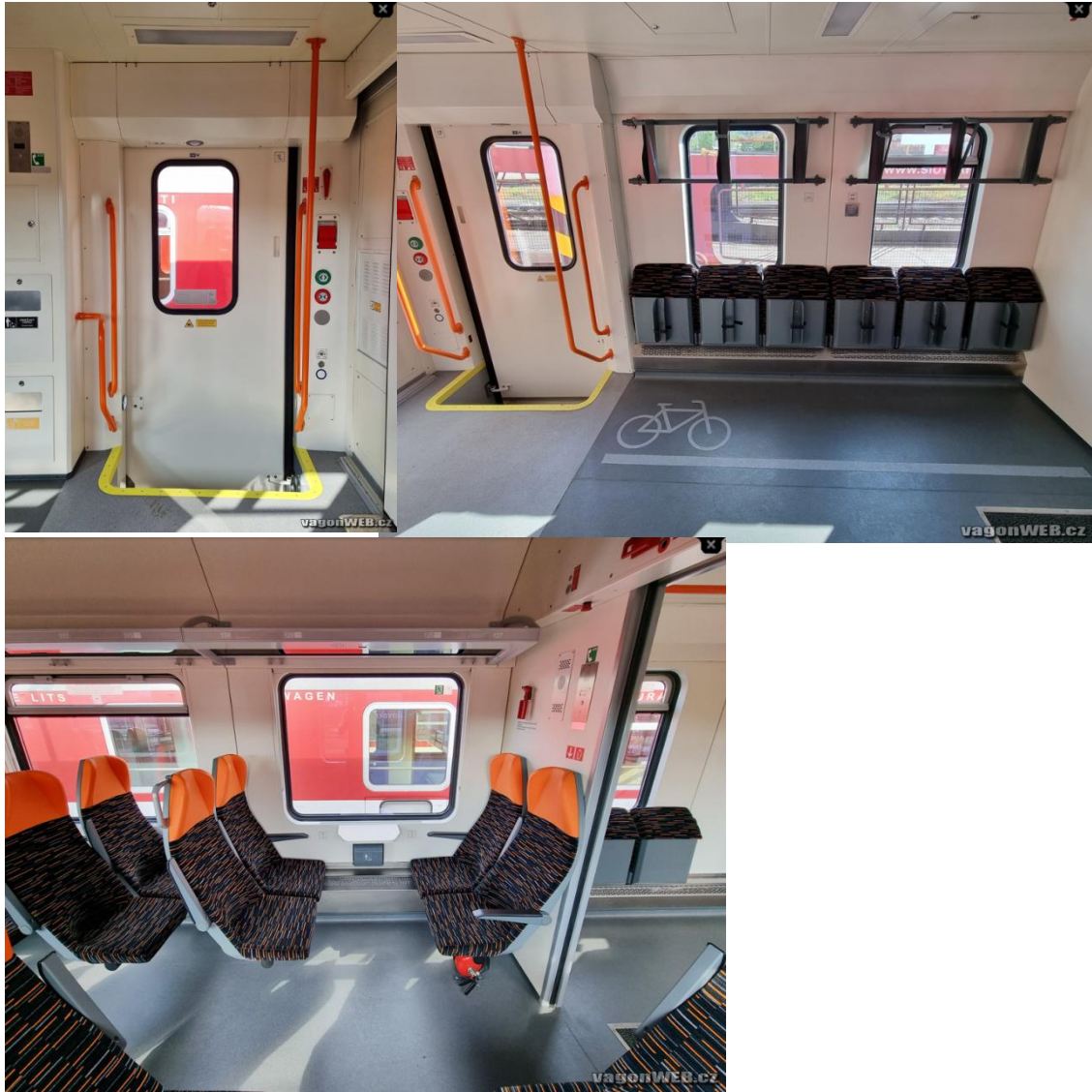


**Pic. No.2 Interior of the currently used electric unit 660/661**



**Pic. number 3 Interior of the currently used units (upper picture - 671, down pictures 861, 660/661)**

In this time ZSSK prefers units before classic carriage consists (that means carriages sorted in classic consist - locomotive + carriages) they prefer such units and over time they should gradually change. Besides this, in 2022 ZSSK bought 52 carriages of classic build, they bought it for regional transportation in the eastern part of Slovakia considering planning carriage order in classic form on these connections. Prognosis to the future still counts with deployment of classic consists, so the need to increase their comfort level to the motor unit level is more than welcome. These carriages have modern technologic elements and they allow more options of transportation. For example upgraded doors and seats by the side of the carriage, which allows easier entrance for physically disabled passengers or passengers with bicycle or a stroller.



**Pic. number 4 interior of currently used modernized carriages, which are placed to classic consists**

Despite this modification, they cannot fully replace low-floor units, because the sets deployed on some line sections are not compatible with the currently outdated platforms, i.e. they are not adapted to the boarding and exit doors.



**Pic. No. 5 Current view of a classic-style carriage in relation to the unreconstructed platform**

## **2. DESIGN OF THE WAGON DESIGNED BY US**

We named the wagon we designed: "Bdtheer". We based our design on the technical characteristics of the designation of passenger carriages, which are discussed in more detail in section 2.3.



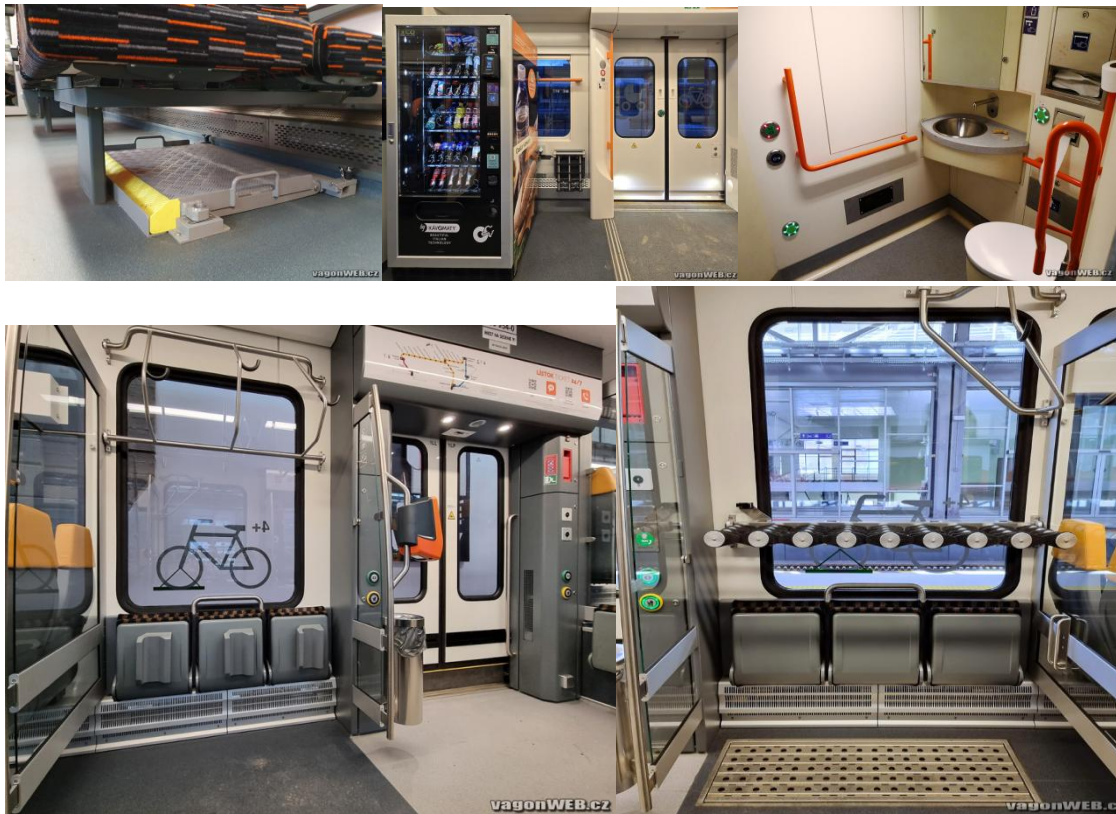
**Pic. No. 6 Visualization of the "Bdtheer" wagon designed by us**

Given the aforementioned preference for low-floor units, not only in regional transport, we took into account their technology and its advantages, which we subsequently transferred to the form of a classically constructed wagon in our design.

According to the safety measure resulting from the European standard 1302/2014, at least 3 emergency exits must be available for a capacity of more than 40 passengers. The

carriage therefore has two pairs of doors on both boarding sides, which, in addition to the extended form of the so-called "double doors", also have a low-floor form, which allows for simplified exit and boarding, especially for immobile passengers, but also for passengers with a bicycle, stroller or luggage.

When boarding through the low-floor doors, a lifting platform will be available (portable technology from the 861 and 480 series units), a vending machine with light refreshments, a toilet for immobile passengers and an extended space for 6x racks for transporting skis or bicycles, or strollers and luggage (technology of multifunctional racks with folding seats from the 495 series electric unit).



**Pic. No. 7 View of the components that the carriage designed by us should contain (bicycle holders, folding seats, boarding platform for disabled passengers, barrier-free toilets)**

In the raised part, separated by steps (technology from the 861, 660/661 series unit), there are seats for passengers with a capacity of 76 seats in a "two-seater" layout - this is a layout with space saving and use, the places for the disabled are located in the low-floor part in the form of folding seats, with a total number of 6. At the end of the carriages, the already mentioned boarding and exit doors will be located on one side, and on the other side there will be a luggage area (instead of a door) and a switchboard. Partition doors are not proposed in this carriage. For comparison, the current most modern regional transport carriages of the Bdmpr series, deployed mainly in eastern Slovakia, have a capacity of 84 classic seats and 9 seats with the possibility of folding seats.



**Pic. No. 8 A representation of the interior of the "Bdtheer" carriage designed by us, which would be similar to the current interior of a ČD carriage**

Passengers will have access to Wi-Fi, a 230V socket under each seat, also with a USB connection option and LED functionality indication, an information system, a luggage compartment above the seats and drawings of Slovak routes above it. Lighting in the form of strong and dim LED strips, air conditioning, heating and ventilation are proposed as part of energy saving in the form of automatic regulation according to external conditions, which will be recorded by sensors. Currently, signal permeability technology is mainly used for windows, which minimizes signal interference, and roller blinds are preferred to classic curtains for window shading.

For seats, we propose to use the current ZSSK scheme in a dark shade, where patterns can be adjusted according to the area of operation of the carriage. This scheme harmonizes in combination with light wood and gray wall material.



**Pic. No. 9 Visualization of the seats in the "Bdtheer" carriage designed by us**

Due to the proven price-quality ratio, we propose to use the chassis design from the modernized Bdmpz series wagons. These consist of 4 axles capable of reaching a speed of 160 km/h, with disc brakes and air reservoirs guided by a pipeline, an electromagnetic brake and batteries from the power supply.

## ***2.1 MODULAR ZONE***

The uniqueness of the wagon is created by its modular zone.

It represents an evolution in regional transport. It combines barrier-free, energy efficiency and modern services that offer greater multifunctionality and thus change the ordinary wagon.

### **Low-floor part**

It is located in the middle of the carriage and forms the heart of the entire carriage, which is in the same level with the platform. Thanks to this, it offers better boarding, alighting and movement for immobile passengers, as well as passengers with strollers and bicycles.

### **Smart Refresh**

The built-in snack or coffee vending machine with contactless payment is positioned so as not to obstruct the aisle.

### **WC Materix**

Spacious and vacuum toilet adapted for people with reduced mobility, equipped with a baby changing table.

## 2.2 Energy Saving

### **Energy consumption of the carriage (estimated consumption):**

Since it is a separated carriage, electricity is supplied via a high-voltage cable from the locomotive (co-called continuous power line)

### **LED LIGHTING:**

*Consumption: ~0.8kW*

**Reason:** Old OSRAM/Philips technologies (T8/T5 fluorescent lamps and old tubes) require a starter and a choke in addition to the power input. This in itself requires additional energy, which they convert into heat. The power input of one tube is 36 W + approx. 9 W loss in the choke = 45 W. The number of pieces needed is 40 fluorescent lamps with a hour consumption of 1.8 kW

LED lighting from SEC Nitra, the LED strip module itself does not heat up, has a constant temperature and does not deform the surrounding material with heat. The power consumption of one module is 15 W. By adding a lighting regulator, the car would be able to regulate the brightness itself. On a normal day, 40 LED modules would consume approximately 0.64 kWh per hour.

**Accessories:** LED strips in the floor (for safe movement in reduced visibility) and on the ceiling have minimal electricity consumption.

**At Night:** The ceiling lighting is turned off to almost zero level (in accordance with the emergency lighting regulation) and only the lighting in the floor area is turned on.

### **BARRIER-FREE VACUUM TOILET:**

Older manufacturers EVAC or Semvac.

**Older EVAC 2000 system:** Consumes approximately 40-45 kWh because the tanks are heated continuously.

**Power consumption:** Approximately 30 W - 50 W due to continuous operation of the toilet.

**Operation:** The toilet is operated before each use. Older types of toilets often have a phenomenon where, due to worn sealing, the toilets flush themselves, increasing the amount of energy consumed. In modern systems from Škoda, an important point for saving electricity is that ventilation in the form of fans and underfloor heating are not constantly operating in full capacity.

**Special Technology:** Heated floor in the toilet to prevent moisture and slipperiness.

**Summer mode:**

During the summer months, it is not necessary to heat the tanks, so the only heating during the summer months is the underfloor heating. However, the fan and vacuum remain in operation.

**Total consumption:** approximately 3.0 kWh.

**Winter mode:**

This is where the biggest difference compared to the old EVAC 2000 is visible, thanks to better cell insulation and an intelligent thermostat.

**Total consumption:** Around 15,0 kWh

**REFRESHMENT MACHINE:**

**Consumption:** ~0,5 kW (requires constant consumption of electricity for cooling purposes).

**AIR CONDITIONING AND AIR RECOVERY:**

Multifunction HVAC technology with low GWP, which, thanks to its location on the roof, can recover air and thus heat or cool it.

Air flows into the interior from top to bottom, providing a dust-free environment and better air circulation compared to being placed under the seats.

**Consumption:** ~12 – 18 kW (appliance with the largest electricity consumption).

**TOTAL CARRIAGE CONSUMPTION:**

During normal operation in summer/winter, an average consumption of approximately 22 - 26 kWh is expected.

**COMPARISON OF THE OLD CARRIAGE SERIES AND THE “Bdtheer” SERIES:**

<b>Components</b>	<i>Old series (Bdteer/Bdgteer)</i>	<i>“Bdtheer” series</i>	
Heating / Air conditioning	35 - 40 kWh	15,00 kWh	Double glazing and a heat pump complement the insulation and reduce losses.
Light	3 - 4 kWh	0,64 kWh	The electricity consumption of LED strips is minimal compared to the electricity consumption of light bulbs.
WC Equipment	1.5 kWh	1,6 kWh	Electricity consumption increased by the floor heating function.
Sockets/WiFi	1 kWh	1,5 kWh	Consumption increases due to adding Wi-Fi connection.
Vending machine with refreshments	0 kWh	0,5 kWh	Increased consumption due to the addition of the option to purchase refreshments
Total consumption	around 44kWh	around 19,27 kWh	The carriage we propose will reduce energy consumption by almost half.

## 2.3 Technical Drawing

The "Bdtheer" series of wagons is based on the technical characteristics for the designation of passenger carriages:

B: 2nd class carriage

d: Offer of bicycle space

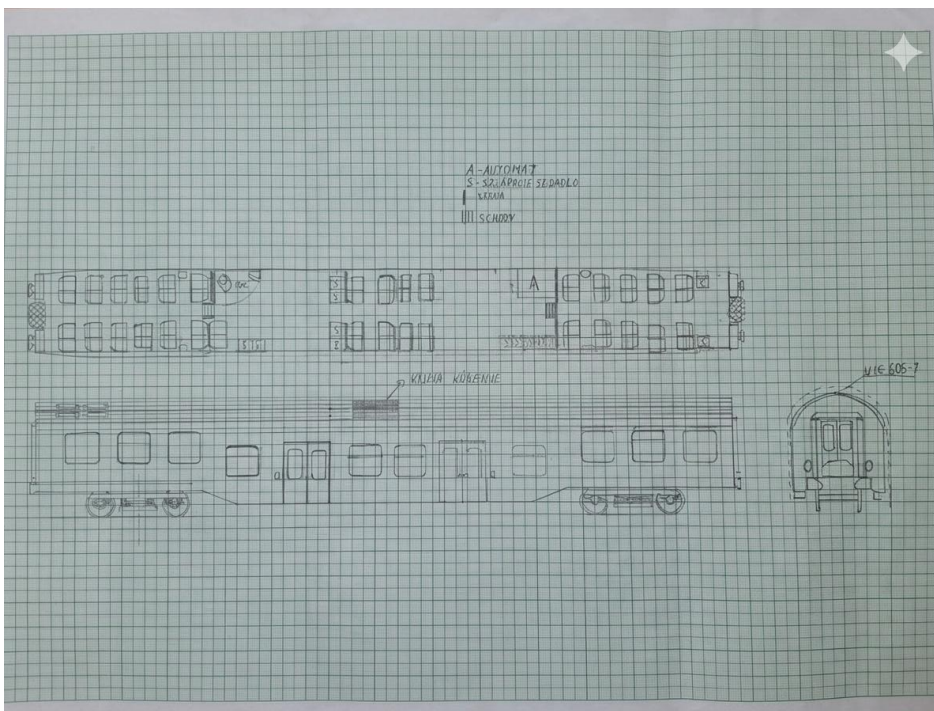
t: spacious passenger carriage for regional trains with a central aisle

h: carriage equipped with services for immobile passengers

ee: powered by power supply

r: air-conditioned carriage

The design of the wagon takes into account the safety criterion. The wagon is built to meet all safety criteria for deformation zones. For wagons of this type - low-floor - some criteria are more demanding than for ordinary wagons. In our design, after consultation with experts, the deformation zones are in full compliance with passenger safety.



**Pic. No. 10** Technical drawing of the designed wagon

The technical structural parts of this car, such as air conditioning and electrical installations, will be designed under closed covers, as is currently the case with new carriages being modernized. This is a safer, more aesthetic and more aerodynamic solution that meets new trends.



**Pic. No. 11 A look at the outdated solution of unclosed cabinets**



**Pic. No.12 A look at the modern solution for closed cabinets**

### **3. AREA OF OPERATION OF PASSENGER CARRIAGE**

We propose to operate our passenger carriage in domestic regional transport throughout the Slovak Republic. We perceive a real possibility of use mainly on trains of the Os and Rex categories, given that these are regional trains. These carriages could replace the carriages currently deployed on these routes in regional transport that are in a worse technical condition, or with minor deficiencies. Carriages with the technology we propose could also supplement the missing increased comfort offered by complete units of the 660/661 or 671 type and increase the capacity and number of connections, especially during peak hours. They can be used on both electrified and non-electrified railway lines, where modern complete units are not deployed.

A suitable example for use is the line from the second largest city of Slovakia - Košice to the Tatras, to the city of Poprad

=> line Košice - Poprad (- Svit),

where to date, newly - modernized carriages intended for regional transport, as well as carriages with older technology, are used.

It is on this passenger train line that the possibility of traveling in low-floor carriages or sets is missing, and the deployment of carriages from our proposal would simplify travel for both immobile passengers, parents with small children, people of retirement age, but also tourists due to barrier-free access.

We believe that our designed wagon could also be interesting for other carriers.

### **4. CALCULATION OF THE DESIGNED CARRIAGE**

<b>Costs</b>	<b>Revenue</b>
Estimated investment costs (Carriage costs) - <b>3 mil. €</b>	E.g. The average occupancy of trains between Bratislava and Košice is 70% (in our case 70% of the capacity of 76 + 6).  The ticket price is 20,20 € and with a daily mileage of 1000 km, the carriage can make one turn.
Service costs (maintenance) - <b>0,50 € / 1 km</b>	
Carriage modernization (carried out after 15 years of operation) - <b>40% of the purchase price</b> (technology, interior and GDP growth)	
Operation costs - <b>0,23 € / km</b> + <b>0,15 € / km</b> (road + traction electricity)	
Daily mileage of the carriage - 1000 km	
Carriage lifespan - 30 years	
Carriage operation - 363 days / year	

Diverse resources. We primarily work with two options for financing our wagons - financing with the help of resources from the EU recovery plan with the condition that they will be used for regional passenger trains, excluding commercial trains, or financing with the carrier's own resources, in our case the Slovak Railway Company with possible support from local governments and the Ministry of Transport.

In view of renewable and more economical management, we wanted to propose the reconstruction of decommissioned railway passenger carriages. Such modernization

would cost approximately 1.5 million, according to information. This represents more than 40% of the purchase price of a completely new carriage, considering the more extensive modernization due to the specific construction of the carriage.

## ***CONCLUSION***

Our proposal is to bring a modern touch and comfort for passengers to Slovak railway transport, but above all, the unique technology of a low-floor wagon of classical construction. In addition to simplified boarding and alighting of passengers, it also represents increased comfort and energy savings, which also brings financial benefits. This uniqueness is brought about by a combination based on the technological solution of a carriage of classical construction and complete units. Given the preference for complete units, but also their shortage, this carriage can partially replace them.

## SOURCES OF INFORMATION AND MATERIALS

[https://www.zos-vrutky.sk/vozne\\_sk.html](https://www.zos-vrutky.sk/vozne_sk.html)

<https://www.vagonweb.cz/>

<https://www.zeleznicne.info/view.php?cislocianku=2011020004>

Príloha č. 6 súčasných podnikov

Rozdelenie ŽKV na skupiny

Skupina	Riad	Špecifikácia
Vozne klasické stavby	všetky vozne klasickej stavby okrem vozňov špeciálnej stavby	vozne klasickej stavby klimatizované aj neklimatizované okrem vozňov špeciálnej stavby
Vozne špeciálnej stavby	všetky vozne špeciálnej stavby (úložkové, ložadlové, spoločenské, reštaurácie, bufetové, bistro)	vozne špeciálnej stavby klimatizované aj neklimatizované
HKV1	110, 162, 163, 199, 210, 240, 280, 350, 361, 364, 365, 381, 391, 725, 742, 750, 754, 757	motorové a elektrické rušne
HKV2	810, 811, 812, 813 813, 912 911, 912 405, 406	motorové vozne riadiace vozne prázdne vozne
HKV3	11ap, B11 (dvoglávkové, trojglávkové) 309	elektrické jednotky (TEZ, ošubricové železnica) - všetky rozchody motorové jednotky
HKV4	400, 401	riadiace vozne - súborová železnica - všetky rozchody elektrické motorové jednotky - elektrické vozne, vozne vozne
HKV5	071, 051 071 051, 071	viacnásobné vozne dvogľadné (Push-Pull, EPJ) elektrické vozne dvogľadné (EPJ) riadiace vozne (Push-Pull, EPJ)

- v prípade nadobudnutia nových riadov ŽKV rozhodne Obstarávateľ o ich zaradení do príslušnej skupiny

<https://www.uvo.gov.sk/vyhľadavanie/vyhľadavanie-dokumentov/download/886388/617363?cHash=acd2a51aa73a84b341b232e840fa7bd4>

Energy saving resources:

[https://resources.tridonic.com/PDB/Ressource/Web\\_TR/Archive\\_PDF/Ballasts\\_fluorescent\\_lamps/Magnetic/Magnetic\\_Chokes\\_2012\\_EN.pdf](https://resources.tridonic.com/PDB/Ressource/Web_TR/Archive_PDF/Ballasts_fluorescent_lamps/Magnetic/Magnetic_Chokes_2012_EN.pdf)

<https://www.atpjournalsk/>

<https://www.sec.sk/sk/produkty/osvetlenie-pre-dopravu>

<https://www.evac-train.com/en/products/vacuum-toilet-system/evac-2000/>

<https://www.evac-train.com/en/product/vacuum-toilet-system/>

<https://www.liebherr.com/en/int/products/aerospace-transportation-systems/rail>

<https://www.liebherr.com/en-sk/aerospace-and-transportation-systems/solutions-and-services/solutions-for-railway/low-gwp-hvac/low-gwp-hvac-7192047>

<https://www.evocagroup.com/en/our-brands/necta>

Consumption of sockets are taken from the operation of electrical units of the 660/661 series

- email communication with the Slovak Railway Company
- photos of wagons taken at the Vrútky Locomotive Depot with the permission of the Slovak Railway Company.