Transport technic and technology
Volume XX Issue 1 Year 2024
DOI: 10.2478/ttt-2024-0003

THE ECONOMIC AND ENERGY IMPACT OF SLOW ORDERS IN SLOVAKIA ON RAILWAY OPERATORS

Abstract: This paper looks at the current state of the railways in Slovakia and the economic losses which result from trains passing through locations with an increased incidence of sections of line with slow orders imposed. A calculation of time and financial losses due to a high number of slow order sections will be performed. We shall also focus in more detail on the development and related financing of Railways of the Slovak Republic (ŽSR) and make a number of comparisons with some neighbouring countries. Attention will also be paid to the actual status of completed and unrealised projects in the most recent period, exploring the reasons behind project delays and cancellations. The paper will also calculate how individual train journeys along slow order sections translate into actual operation. The actual impacts on railway operators will also be examined in terms of economics, time, and energy, with an emphasis on the sustainability of current practices and potential areas for improvement.
Keywords: railway, economic losses, infrastructure, investment, slow orders

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Introduction

The railway infrastructure in Slovakia has reached a critical point due to long-term insufficient funding, which is characterised by extensive problems that prevent further development of the railways. This not only results in operational inefficiencies, manifested in frequent delays, reduced travel comfort and ageing tracks, but also highlights the critical need for sustained investment. The speed of upgrades is currently slow and routine maintenance or minor repairs usually take a long time.

Strategic documents produced by the Slovak Ministry of Transport discuss insufficient investment and obsolescence of infrastructure. However, despite the announcement of large-scale modernisation plans promising investment, the actual progress is minimal and predominantly very slow. The current rate of modernisation required to meet infrastructure needs is assumed to be between 60 and 100 kilometres per year. The real progress, however, is limited by financial constrains to a mere 20 kilometres per year, indicating a notable discrepancy between the strategic aspirations and practical results.

The consequent operational limitations put a strain on the infrastructure and railway operators by through rising direct and indirect operating expenses and increasing energy consumption due to the frequent braking and restarting of the train.

1. Current state of the railways in Slovakia

The current vision for Slovak railway transport is summarised in the Slovak Strategic Transport Development Plan, produced by the Ministry of Transport, Construction and Regional Development of the Slovak Republic. This document, however, dates back to 2016, and so it is evident that Slovakia does not have much time to implement what it says (MDVRR SR 2016).

In this document, the Slovak ministry states that the local network is struggling with a wide range of problems in terms of infrastructure, and this shows that the ministry was already aware of the difficulties at this time, even pointing them out itself. However, looking at the present day it is evident that there have been no significant changes since this time. Slovakia's 2016 Strategic Transport Development Plan notes that the domestic debt in maintaining Slovakia's infrastructure is huge, but it does not put a figure on the debt. Those who wrote the document state that the long-underfunded maintenance sector was already being reflected in numerous delays, travel comfort and the condition of the domestic rolling stock.

The document called for basic principles of sustainable financing of the railway sector to be put together. The document literally states: "The railway transport infrastructure must be modernised, and there must also be a clear future-focused operating concept." (MDVRR SR, 2016).

Slovakia made progress in dealing with the problem of its underfunded railway infrastructure in 2021 when another important strategic document was published, which Slovakia wants to apply in order to renew and revitalise its railways. This plan envisages an investment of around 8 billion euros in Slovakia's railways between 2022 and 2030, equivalent to roughly 192 billion Czech crowns (MDVRR SR, 2021).

1.1. Insufficient space of change

Slovak analysts claim that the required pace of renewal of Slovakia's railway infrastructure is currently at least between 60 and 100 kilometres per year. The problem is that public finances are also very tight in Slovakia, especially at the current time. There is a lack of funds, and according to analysts from Ekonomický deník it is only realistically possible to repair around 20 kilometres per year. This is significantly below what is required (Ekonomický deník, 2021).

As such, until 2030 the Slovak authorities are counting on using the funds for the revitalisation of lines and

modernisation of the TEN-T corridors. Slovak officials decided to divide up the projects into four main categories according to the impact they have and their importance (Ekonomický deník, 2021).

But in 2021, the Slovak ministry stated that the implementation of most of these steps would not begin until after 2025. At the same time, however, one should also take account of the fact that current priorities within Slovak railways also often reflect which political parties are in government at any particular time. Since the Slovak government, like those of other countries, undergoes regular changes, these objectives may also change. In this regard, we can see how previous Slovak political leaders intended to pass the responsibility for Slovakia's railway network on to their successors. (MDVRR SR, 2021).

In 2021, a list of specific priorities to be achieved by the end of the current century was published. According to this analysis, revitalisation should mainly focus on the main lines, including the Vrútky – Liptovský Mikuláš and Kraľovany – Lubochňa sections, and planned measures should make it possible to travel at speeds of up to 200 kilometres per hour on some lines. Trains should achieve these speeds, for example, on sections between the stations of Senec and Bratislava, and between Štúrovo and Nové Zámky, but because of the lack of funding, situations are being reassessed and modernisation up to a speed of 200 km/h does not currently appear to be very realistic (Ekonomický deník, 2021).

1.2. ŽSR

Railways of the Slovak Republic (Železnice Slovenskej republiky – ŽSR) has been responsible for the administration and operation of the railway infrastructure in Slovakia since the Czechoslovak Federative Republic split up in 1993. ŽSR was established as the successor to Czechoslovak State Railways within the territory of Slovakia. Until 31 December 2001, it was a unitary railway, meaning it ran both the railway lines and railway transport. Since 1 January 2002, the company has only been engaged in the operation, maintenance and modernisation of the railway line in its ownership. A closer look at the above indicators shows that, with a few exceptions, there have been no major changes over the last more than twenty years.

Table 1. Key indicators in relation to ŽSR in 2001 to 2022

	2001	2008	2015	2022
Electrified lines (km)	1536	1577	1587	1585
Construction length of managed lines (km)	3662	3623	3626	3626
Construction length of lines (km)	6885	6870	6871	6816

Source: ŽSR annual reports between 2001 and 2022, compiled by author

Table 2. ŽSR performance in 2015 and 2022

	2015	2022
Costs (in thousands of EUR)	453 085	702 509
Revenues (in thousands of EUR)	470 274	624 336
Business result (in thousands of EUR)	17 189	-78 173
Assets (in thousands of EUR)	3 499 638	3 966 210

Source: ŽSR annual reports for 2001 and 2022, compiled by author

Table 2 above shows ŽSR's financial indicators in 2015 to 2022. It is evident that the high inflation in recent years is one reason that the company's costs rose markedly between 2015 and 2022. The estimated value of assets owned also increased. However, in 2022 the company was struggling with a significant budget deficit. Given the needs and challenges faced by the Slovak railway network, the above amounts are insufficient and should be radically increased.

1.3. Investment and modernisation

Looking back at previous years, it is clear that the Slovak railway network was not a priority for Slovak politicians for many years, and this is reflected in the current situation in Slovakia. From 2001 until 2022, only 49 km of electrified lines were added in Slovakia, while the figure in the Czech Republic over the same period comes to a total of 322 km (Správa železnic and ŽSR annual reports).

Yet earlier investments could have ensured significant savings, something currently needed in terms of staff consumption, with more funds released for infrastructure development, with timely and efficient investments reducing maintenance costs. According to the latest verifiable statistics, i.e. from the split in 1993 until 2020, over 1,096 km of corridor line was modernised in Czechia, a total of 76 %, whereas this proportion for Slovakia was just 23 %, with just 188 km of line repaired. (vlaky.net, 2021)

Between 2000 and 2020, more than ten strategic documents were produced concerning the modernisation of railway corridors, and these included 34 objectives and deadlines for completion of the modernisation of three TEN-T corridors, yet not a single objective was achieved. Due to completely insufficient ŽSR state subsidies, the railway infrastructure is essentially dependent on EU funds to finance its projects. Between 1993 and 2021, a total of 1.6 bn euros was invested in modernisation, of which 85 % came from EU funds and just 15 % from the national budget and ŽSR loans. In comparison, over 6 bn euros was invested in the Czech Republic over the same period, with the national budget providing 43.3 % of this sum, 26.9 % coming from bank loans, and EU funds only comprising 29.8 % (vlaky.net, 2021).

In 2023, the budget for operating the railway infrastructure for ŽSR was set at 239.1 million euros, equivalent to 5.6 billion CZK. Since this amount would not even provide basic maintenance, a number of extra funds were made available over the course of the year, with the total sum of money received by ŽSR eventually coming to 444 million EUR (RAILTARGET, 2023). The Správa

železnic budget for 2023 is 31.9 bn CZK, and Austria's ÖBB, for example, has a budget of a total of 81 billion CZK (Zdopravy.cz, 2023). For comparison, ÖBB currently operates 4,965 km of lines. ŽSR operates 3,626 km of lines and Správa železnic operates 9,355 km of lines. ŽSR's underfunding is best seen in the following graph, which shows the amount of funds which different governments have provided to their railway infrastructure operators for management. These comprise funds both for investment and for ensuring operability. It also shows how much funding goes to each kilometre of line, and how much funds are provided per capita. The budgets are up-to-date at the beginning of the year: any additional funding for individual railways is not included to ensure clarity.

Also notable is the issue of overemployment. While in the Czech Republic there are 17,125 employees for a total track length of 9,355 km, in Slovakia there are 13,340 employees running 3,626 km of tracks. This means that there are 1.83 employees per each 1 km of track, whereas in Slovakia there are 3.68 employees per 1 km of track. (Správa Železnic and ŽSR annual reports).

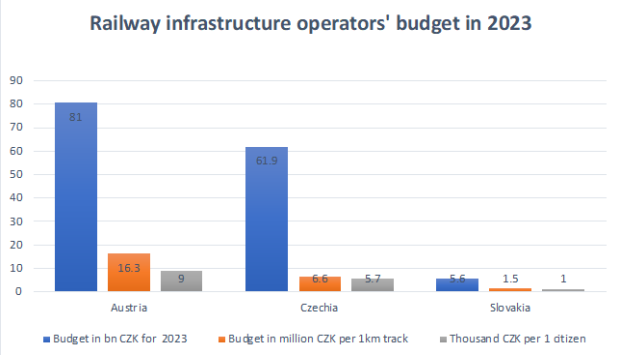


Fig. 1. Country budgets for railways

2. Economic losses as a result of slow order track sections

Individual journeys through slow order sections result in economic losses both to the carrier and also partially to ŽSR. For ŽSR, economic losses are mainly due to the excess energy consumed, which is necessary to restart the trains through sections with restrictions. When travelling on ŽSR infrastructure, carriers pay for electricity according to a preset price which is calculated according to individual train parameters, and which does not reflect actual consumption. If a train passes several slow sections where it has to restart repeatedly, it consumes more electricity than it pays for, and if the train's journey exceeds the consumption limit set for that particular journey, the excess energy consumed is charged to ŽSR.

The increased traction energy costs, however, are not the only extra costs associated with slow track sections. There are many more impacts for carriers, which significantly affect the economic viability of individual journeys. The more frequent braking resulting in more wear to brake discs and pads requiring more frequent maintenance of engines and carriages can be considered to incur relatively insignificant extra costs. What has a more significant impact on individual journeys, however, is trains being held up in bottleneck sections which arise with the progressive implementation of slow order track sections. These restrictions also lead to anticipated and unplanned track section closures implemented in order to resolve usually only the most serious problems, often making it impossible for freight traffic to pass through except at night. Often trains can't even use the track at night either due to maintenance and renovation work or sudden repairs requiring that the track not be used. This results in trains accumulating in larger stations, bottlenecking at junctions, and from the carrier's perspective significant transport delays, which can result in various penalties being imposed. With numerous delays, carriers also have to deal with restricted working time for their personnel with, for example, the train driver remaining standing at a section of track which is closed for a number of hours, instead of delivering the train to its destination. This means the driver's shift ends after driving only a few kilometres. The carrier must immediately find a new driver, or give the current driver a rest, increasing the cost of transport, and generally further delaying the arrival of the train at its destination station by several more hours.

Other damage related to the poor state of the infrastructure occurs to the engines and carriages themselves. Most often, these involve failures to shock absorbers, springs and overall running gear when passing places where there is track subgrade failure, with the rail sinking due to unstable subsoil, leading to shocks to the bogie.

Individual carriers have complained many times about the Slovak railway infrastructure in open letters to the Ministry of Transport of the Slovak Republic, asking that the issue be redressed as soon as possible. Czech Railways caused the greatest furore when they sent ŽSR a letter at the end of March 2023 in response to the derailment of a Pendolino 680 unit at Žilina railway station. In the letter, which the author of this paper has to hand, they write: "If this is not redressed within an acceptable timeframe, we shall be forced to claim increased costs for vehicle maintenance and the financial costs associated with emergencies which occur from ŽSR." The letter also included a list of identified critical locations, which, while only including places where Czech Railways engines and vehicles are present, still managed to total 17 sites.

One of the biggest restrictions on transport occurred in mid-November 2023 when there was a major disruption to traffic due to a slow order track section of 10 km/h being introduced across the entire length of Bratislava main station railway station, specifically from km 52.639 to km 54.903. Transit passenger trains were delayed by between 10 and 20 minutes, express trains left 5-15 minutes late, and some passengers trains left with delays of up to 30 minutes because of having to wait for priority trains to pass, while others were cancelled altogether. Freight trains were the last in the queue during the day, usually waiting for several hours at nearby stations.

The poor situation in nearby stations made it particularly difficult for the passage of freight trains. A slow order section of track with a 10 km/h restriction was also introduced on the first, second and fifth track switches at the following station of Bratislava Vajnory, through which principal traffic flows in the direction of Galanta, Štúrovo and Budapest. Because Bratislava Vajnory station is a reporting point for freight trains heading to Bratislava hl. st. and onwards to Kúty, meaning that all freight trains have to stop here to receive orders, this slow order section of track caused further delays. For freight trains, the TSR (Temporary Line Speed Restriction) on the second track at switch 28 from km 63.510 to km 63.545 was particularly problematic.

Our calculation shows that a 500 m-long freight train takes at least 2 minutes, 24 seconds longer to traverse this distance due to the TSR. It should be noted, however, that the point where the speed restriction begins and where the driver takes the order is separated by about 450 m, and so it is nonsensical and often impossible for a heavy train to be able to travel at the 40 km/h allowed up to that point. Realistically, then, the delay in this section alone came to approx. 5 minutes, which in the context of slow operation at the main station resulted in the freight train being held up for several hours due to heavy passenger traffic. The delay at Bratislava hl. st. was calculated in the same way. In this case, we worked with a higher speed of only 30 km/h, which applies over the whole track at the passenger station up to the entrance to the tunnels from the side of Bratislava Lamač railway station. The slow order section length was 2,264 metres, but for the calculation we used a length of 2,764 metres, as it is necessary to include the entire length of the freight train, which can only increase its speed after its end has passed the higher-speed line speed board. For the purposes of the calculation, a freight train of 500 m in length was used.

Table 3. Data slow order

TSR location	TSR length	original speed	TSR speed	delay
Bratislava hl. st.	2,264 m	30 km/h	10 km/h	12 min 27 s
Bratislava Rača	290 m	40 km/h	10 km/h	3 min 33 s
Bratislava Vajnory	35 m	40 km/h	10 km/h	2 min 24 s
Bratislava Nové Mesto	50 m	40 km/h	10 km/h	2 min 29 s
Bratislava Lamač	350 m	80 km/h	40 km/h	38 s

Source: author, compiled by author

The difference due to TSRs was over 12 minutes, which, given the busy nature of the hub through which all passenger and freight traffic is routed, greatly reduced freight traffic.

The situation was similar around Bratislava from the direction of Trnava and Žilina. The final railway station prior to Bratislava hl. st, Bratislava Rača, also had a speed restriction of 10 km/h on departures, except for through track 1 on the entire odd group of tracks, specifically applying to tracks 3, 5, 7, 9, 11, 13, 15 and 17 over a length of 290 m from km 6.960 to km 7.250. Trains arriving from Hungary from the direction of Rajka or from Austria from Kittsee also had a speed restriction of 10 km/h at the final station before arriving at the main station restriction section, specifically at Bratislava Nové Mesto railway station on the first track. It should be noted here that this slow order section could be avoided and did not have to be passed through. The only station which was the final one before arrival at the main station which did not have a TSR of 10 km/h was Bratislava Lamač, although here in the inter-station section there was a speed limit of 40 km/h on the first track between kms 51.250 and 51.600, and on the second track between kms 51.250 and 51.500. This fact, wherein besides the restrictions at Bratislava hlavná stanica there were also restrictions at all neighbouring stations or track sections, made traffic significantly more complicated.

Unfortunately, the situation is similar across much of Slovakia. The 2022 annual report shows that there were a total of 688 TSRs on ŽSR infrastructure, coming to a total length of 454,779 m. In 2021, there were 650 such places, with a total length of 354,538 m, showing an increase of more than 100,000 m in a single year. A significant contribution to these figures comprises slow order sections in stations, with, for example, several kilometres of track in the Štúrovo station area restricted to a maximum speed of 10 km/h. It should be noted, however, that the annual report gives a sum of slow order sections which have been introduced due to construction work, safety, consolidation, natural influences, the activities of other legal entities and technical condition, etc. Neither is the situation satisfactory in terms of PSRs (Permanent Track Speed Restrictions), which are introduced to replace long-term temporary track speed restrictions as a result of the unsuitable technical condition of railway lines and constructions necessary to ensure operation. In 2022, a total of 8 PSRs were introduced with a length of 9.669 m. In 2021 there were a total of 15 with a length of 20,589 m. Two PSRs located on the Kúty-Bratislava main line serve as examples. Both of these reduce the speed from 120 km/h to 80 km/h. The first PSR when heading from Kúty station is located between Sekule and Velké Leváre railway stations and applies from km 41.200 to km 33.800. The second PSR is located between Malacky and Zohor railway stations in the section from km 21.750 to 18.300. These two PSRs do not cause particularly large delays, at around 1 minute in the shorter section and 2 minutes in the longer section, but they do reflect the condition of the track on this main line.

2.1. Energy consumption along slow order sections

The following is a measurement of energy consumption when driving along slow sections. This was undertaken in the following way: first, the electricity consumed by the engine when travelling from the end of the speed restriction section to the maximum speed allowed with 80 % relative thrust was calculated, while the distance needed for this was also calculated. Subsequently,

the kWh consumed to maintain train speed was measured on an identically graded section of the same length that was required to increase speed. These two values were subtracted, and the result was ascertained.

Example 1:

The measurement was carried out on 5 November 2023 on train 57740 on the Sekule - Velké Leváre section. The engine was a Siemens ES64F4 390 001 with a working electricity meter. The load comprised a set of 31 empty Tagnpps grain wagons. The transport weight of the train was 738 t with a length of 478 m, while the weight of the set without the engine was 651 t with a length of 459m. A section was chosen where trains have to start from a speed of 80 km/h.

The initial electricity meter reading before acceleration to the line speed after exiting the PSR section showed 886 kWh. After acceleration from a speed of 80 km/h to 100 km/h, which the engine achieved with 80 % relative thrust over a length of 0.9 km, the meter showed a reading of 930 kWh. Subsequently, it was measured that in order to maintain a speed of 100 km/h over a section of 0.9 km, 8 kWh of electricity was consumed. This value was subtracted from the value measured when speeding up from the slow section, and the difference calculated, i.e. 36 kWh, represents the electricity consumed every day by the train as a result of the speed restriction. When starting the same train from a PSR of 50 km/h, the difference was 70 kWh. The calculated values may seem negligible, but if the train were to operate in this manner over the whole year, even if this occurred only once a day, its consumption solely because of these two PSRs would come to 155,000 CZK at current prices. But there are many more speed restrictions, and many more trains, and this implies that TSRs and PSRs result in extra electricity consumption of tens of millions of crowns each year.

In addition, we contacted a number of carriers to ask if they could provide us with the costs to hire engines and drivers. If a carrier hires an engine or driver on an ad-hoc basis, i.e. only for a specific train service, the cost of the latest Vectron 193 class engines comes to around 90 EUR for an hour's lease, while a series 189 engine comes to around 80 EUR per hour. An hour of work by an external driver ranges around 40 EUR, while an hour of work by the carrier's own driver is an average of 30 EUR. These amounts are calculated on the basis of information provided by the carriers, although it should be noted that they are almost identical.

The above information indicates, for example, that standing in front of Bratislava hlavná stanica railway station, which occurred during the day for a period of over 5 hours due to train accumulation, where the carrier has loaned an engine and driver, will make the transport more expensive, reducing profits for a single train by around 600 euros. If, however, the driver were to make use of maximum allowed working hours and take rests or wait for the next driver, then the extra costs come to thousands of euros for a single train, something that must have a major impact when the situation recurs, especially for smaller carriers.

Conclusion

This study looked at the economic impacts of slow order track sections on railway transport in Slovakia, highlighting the poor state of infrastructure and the urgent need for its revitalisation. The findings show that the current pace of railway infrastructure renewal is extremely inadequate considering the requirements for modernisation and maintaining safe and efficient railway operations. The results of economic loss calculations show that slow order track sections cause significant financial losses for carriers, leading to unplanned extra operating costs. As the paper indicates, insufficient funding of ŽSR has a much greater impact on operations than it might at first appear. Investment in modernising the railway infrastructure is essential not just in order to increase the speed and safety of railway operation, but also in order to reduce economic and energy costs associated with slow order track sections as a result of the poor condition of the railway infrastructure. For these reasons, some carriers have already diverted transportation, with trains routed outside ŽSR infrastructure. The root cause of these problems is evidently insufficient funding of ŽSR by the state.

To conclude the paper, it should be noted that the situation in regard to slow order track sections is one which is constantly changing, and some of the information given above may not currently apply.

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