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Balancing Requirements between the PSO and the Infrastructure Manager

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Abstract: The sustainability of rail transport is a highly debated topic. Historically, there has always been strong political support to maintain even lightly used regional lines in operation. However, the economic situation and increasing demands for rail safety have introduced new challenges, including the fundamental question of whether to continue operating a line or discontinue it. So far, no simple solution has been applied across the board. Nevertheless, there are already some Public Service Obligations (PSOs) planning for the next 10 to 15 years, putting pressure on the infrastructure manager to implement measures that guarantee a specific system travel time on the line. If these expectations are not met, they may consider shifting transport services to alternative modes of transport in the medium term. One such region facing this challenge is the Hradec Králové Region, where a thesis was developed to analyze the regional route Doudleby nad Orlicí - Rokytnice v Orlických horách. The study focuses on the technological requirements for achieving the necessary system travel time, which is also the primary goal of this paper.

Keywords: Infrastructure, public service obligation, railway transport, simulation, timetable

1. Introduction

Liberalization of rail transport brings many new issues and challenges that must be addressed primarily by the infrastructure manager in cooperation with those who order the rail transport services (Public Service Obligator). Together, they establish the conditions for carriers who provide services to end users, i.e., passengers. This is no easy task, as the layout of railway lines in the landscape largely determines the demand for this mode of transport [1]. Consequently, many PSOs face the same fundamental question: Which mode of transport should be operated on a given route? Is rail transport sustainable, or should it be replaced by bus service on lines with low demand? This strategic decision is particularly relevant for the infrastructure manager, who plans infrastructure investments with a time horizon of 10 to 15, considering that returns on these investments often extend beyond 20 years. Therefore, the infrastructure manager and the PSO should cooperate and act responsibly, that is, predictably. This transport strategy is also closely linked to the demographic development of the region. Without good transport connections (supply), the demographic potential decreases [2]. This is supported by the literature [3], where the research focuses on investments in regional lines in the context of future GDP growth. The study formulates hypotheses on the relationship between investment and regional GDP growth, as well as between accessibility and regional performance. Both hypotheses were confirmed. Similarly, [4] researched regional performance and transport accessibility across 186 NUTS regions in 19 European countries. The conclusion was that regions with higher accessibility show higher performance.

The solution to this problem from a transport perspective involves the well-known vehicle-timetable-infrastructure triangle approach, as shown in Figure 1. Specifically, it examines the infrastructure conditions under which a given vehicle can operate according to the desired timetable. The PSO is responsible for specifying the requirements regarding the timetable or travel time that must be met for the service to be ordered on the selected route. In the next step, the carrier assesses whether a vehicle (train set) is able to meet these requirements, given the current state of the infrastructure. If no suitable vehicle exists, the infrastructure manager must assess the required adjustments (such as upgrades to signaling systems or increasing track speed) and quantify the associated costs. In public transport, effective coordination between different modes of transport at transit nodes is critical. In literature [5,6], this problem is solved using optimization of transfer times. The final step involves a strategic, often political decision regarding whether these modifications provide sufficient social benefits to justify funding with public funds. Cost-benefit analysis (CBA) is the most used method.

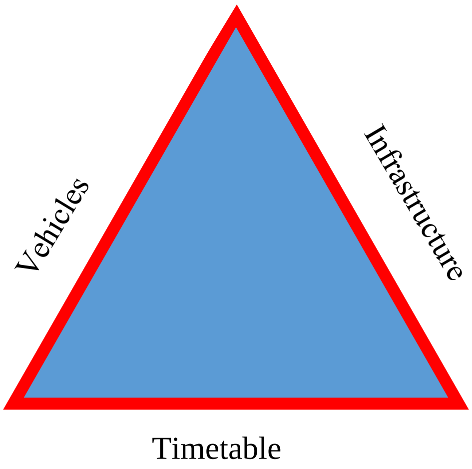

Fig. 1 Triangle vehicle-timetable-infrastructure. Source: authors

It is clear from the above procedure that a strong relationship between the infrastructure manager and the PSO is essential for the effective functioning, development, and sustainability of rail transport. This assertion is supported by international scientific studies that address similar issues. For example, [7] discusses the coordination of interchanges at a junction station. Among other topics, it also highlights the need for infrastructure modifications, though these changes are treated as fixed values for the mathematical model. On the contrary, the literature referenced in [8] considers infrastructure development and customer requirements as equivalent input variables. Other studies [9-11] focus more on the customer's perspective and needs rather than optimizing the triangle's three vertices. The Czech Republic is not the only country to face this issue. A case study [12] presents a Slovak solution to a similar problem, albeit using an analytical approach rather than simulation.

2. Data and Methods

In the present research, the Doudleby nad Orlicí – Rokytnice v Orlických horách line serves as a case study prepared based on the literature [13]. For this line, the Hradec Králové Region has set a 10-year horizon for achieving a travel time that allows for a turnover time of approximately 60 minutes. In practice, this means that the one-way travel time must be approximately 25 minutes. Currently, the travel time in one direction is 36 minutes, requiring a 30% reduction to meet this goal.

The research team has long-term experience with simulation. For this research, the authors decided to use several different simulation tools. The first was Viriato, a widely used tool for creating timetables and operational concepts. The other two tools, VlaDyka and Kango, are Czech simulation tools used by the infrastructure manager. These tools are designed specifically for the Czech railway system and are tailored to local conditions. One of the goals was to compare these three simulation tools and validate the Viriato tool for use under Czech conditions. This method has already been applied in the literature [14,15]. Correct model configuration is a critical success factor in solving simulation tasks.

2.1 Adjustments of Travel Times

The travel times are calculated while considering the conditions of the **Czech infrastructure manager** (Správa železnic) using the *VlaDyka* software. This SW works with the train dynamics and infrastructure parameters. For the needs of the PSO and passengers, these times are adjusted to account for factors such as rounding, train crossing, or system interchanges at stations. The research also calculated travel times using the Kango information system, which produced almost identical results to VlaDyka, as it is an older version of the same SW. At the University of Pardubice, the authors work with the Viriato SW tool, which is designed for timetable composition, and, in addition to infrastructure data, it uses vehicle data as inputs. The resulting travel times are shown in Table 1.

Table 1 Travel times. Source: authors based on [16] and SW Viriato, VlaDyka, and Kango

	Timetable 2023 (810)	**Timetable 2024 (814)**	**Viriato**		**VlaDyka**		**Kango**	
			814	**810**	**814**	**810**	**814**	**810**
Doudleby n. O.								
Vamberk	4	4	3.6	3.6	3.83	3.75	3.83	3.74
Peklo n. Z.	2.5	**3**	2.4	2.5	2.77	2.66	2.83	2.74
Rybná n. Z.	5	5	4.5	4.6	4.89	4.73	4.87	4.73
Slatina n. Z.	6	**5.5**	4.9	4.9	5.23	5.12	5.33	5.14
Pěčín	9.5	**10**	8.4	8.4	9.23	8.69	9.17	8.71
Rokytnice v O. h.	7.5	**7**	6.3	6.6	6.87	6.75	6.98	6.84
Total	**34.5**	**34.5**	**30.1**	**30.6**	**32.82**	**31.7**	**33.01**	**31.9**

The differences in travel times compared to the Timetable and VlaDyka are attributed to the dwell time at stops on request. The total travel times in Timetable 2023 is 34.5 minutes, while the Kango and VlaDyka tools indicate 33 minutes. The additional 1.5 minutes for stops on request bring the total to 34.5 minutes. As shown in Table 1, the travel times for Timetable 2024 are closer to the values calculated in the Kango application with the same sum in the Total row.

According to the literature [17], the research team encountered challenges in validating the Viriato SW due to the lack of official data inputs for Czech vehicles. The research team tried to calibrate the dynamic characteristics of the vehicles to match the travel times presented in Table 1. However, the difference between the actual vehicle and the simulation reached up to 4 minutes, i.e., 10%. This was evaluated as a statistically significant difference. Therefore, the authors decided to continue using only the VlaDyka tool.

2.1.1 Adjustments of the Level Crossings

There are several options to address the issue of reducing travel times. From the carrier´s perspective, this could involve using different vehicles with better traction characteristics. On the infrastructure manager's side, many adjustments can be made, from eliminating speed restrictions and upgrading the track interlocking system to modifying the track trace. Each of these solutions comes with costs that must be considered and balanced against their impact on travel time adjustments. Figure 2 shows a speed/distance graph after removing speed restrictions (red line) along with level crossings (orange columns). The black sections are parts of the previous speed profile.

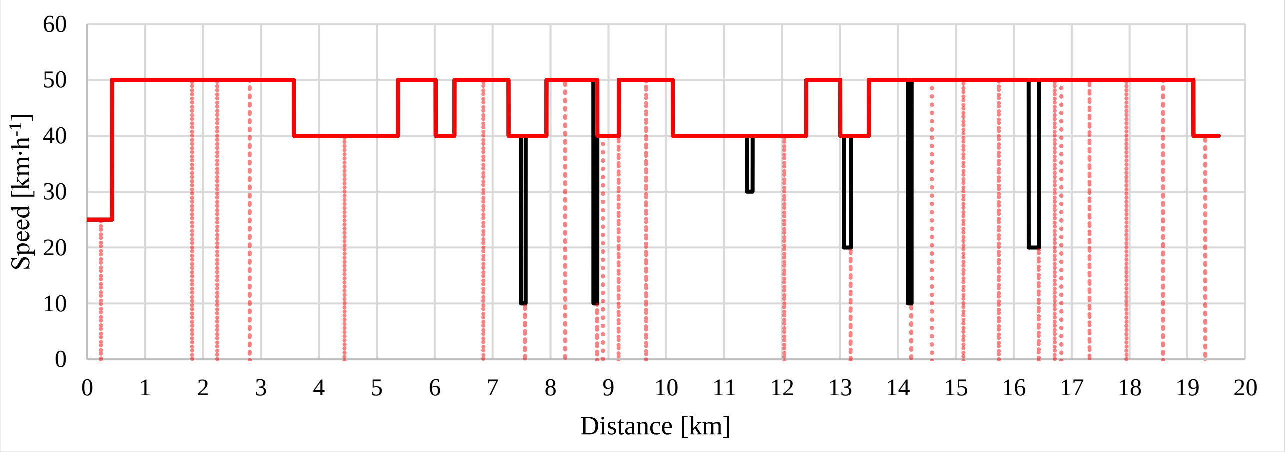

Fig. 2 Speed restrictions. Source: authors

2.1.2 New Vehicles - Regio-Shuttle of RegioSpider

Previously, DMU 810 and DMU 814 vehicles were deployed on this line, similar to those deployed on other local lines. The Hradec Králové region signed a contract with the Czech National Carrier (ČD) for the operation of regional train services, which included a requirement for new vehicles. In response, ČD signed an agreement with the Polish company PESA to purchase a new rolling stock, DMU 847, commercially known as the RegioFox. A comparison of the specification of these four vehicles can be found in Table 2. Both the DMUs 840 and 847 have a maximum speed of 120 $km \cdot h^{-1}$, but currently, the maximum speed on this line is 50 $km \cdot h^{-1}$.

Table 2 Vehicle parameters Source: authors

	810	**814**	**840**	**847**
Number of seats	55	84	61	210
Maximum speed [$km \cdot h^{-1}$]	80	80	120	120
Power transmission	Hydromechanics			
Number of engines	1	1	2	2
Power [kW]	155	242	265	750
Weight [t]	20.0	39.6	48.5	83.0

Unfortunately, this approach has had little effect, as the main limiting factor on this line remains the low speed and the speed restrictions imposed by level crossings with inadequate safety installation. A comparison of travel times for the different vehicles is shown in Figure 3.

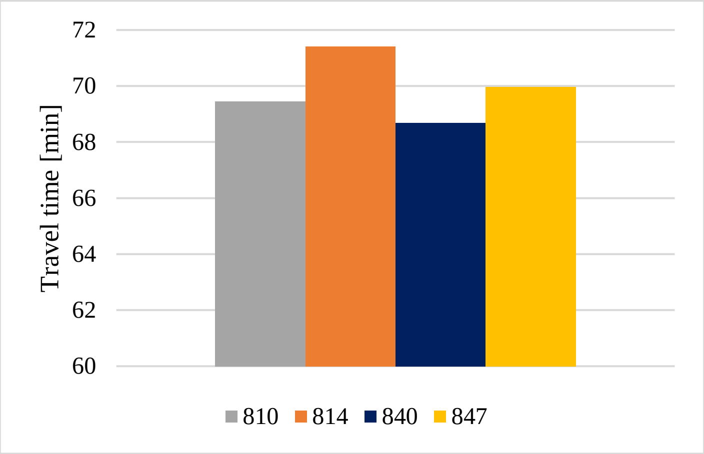

Fig. 3 Travel time with different vehicles. Source: authors

2.1.3 New Speed Profile

Another infrastructure measure to increase the track speed, which does not require any structural changes, is the elevation of the curves. This adjustment maintains the geometrical position of the track, meaning no relocations, new bridges, large excavations, or even tunnels. While this measure does require investment costs, the costs are relatively low, amounting to hundreds of thousands of CZK. In addition, the work can be carried out during regular track maintenance, which minimizes the duration of closures.

According to the literature [18], determining the potential speed increases involves calculating the equilibrium superelevation in the curve (see Equation 1).

$$D_{eq} = \frac{11.8 \cdot V^2}{R}, \quad [\text{mm}] \tag{1}$$

where: D_{eq} is equilibrium superelevation [mm]; V denotes speed [km·h^{-1}] and R is the radius of the curve [m].

The maximum allowable equilibrium superelevation is D_{max} = 160 mm, though the recommended value is D_{lim} = 150 mm. According to the literature [18], exceeding D_{lim}, is permissible when the ratio of the $\frac{\boldsymbol{V^2}}{\boldsymbol{R}}$ exceeds 12.71. This condition is called cant deficiency (see Equation 2).

$$D = \frac{R-50}{1.5}, \quad [\text{mm}] \tag{2}$$

where D is the equilibrium superelevation [mm], and R is a curve radius [m].

This solution increases the curve's track speed but, unfortunately, leads to a stepped speed diagram (see Figure 4). This is not ideal for the train driver, impacts energy consumption, and raises questions about the effectiveness of the short sections with higher speed, given the traction characteristics of the vehicles.

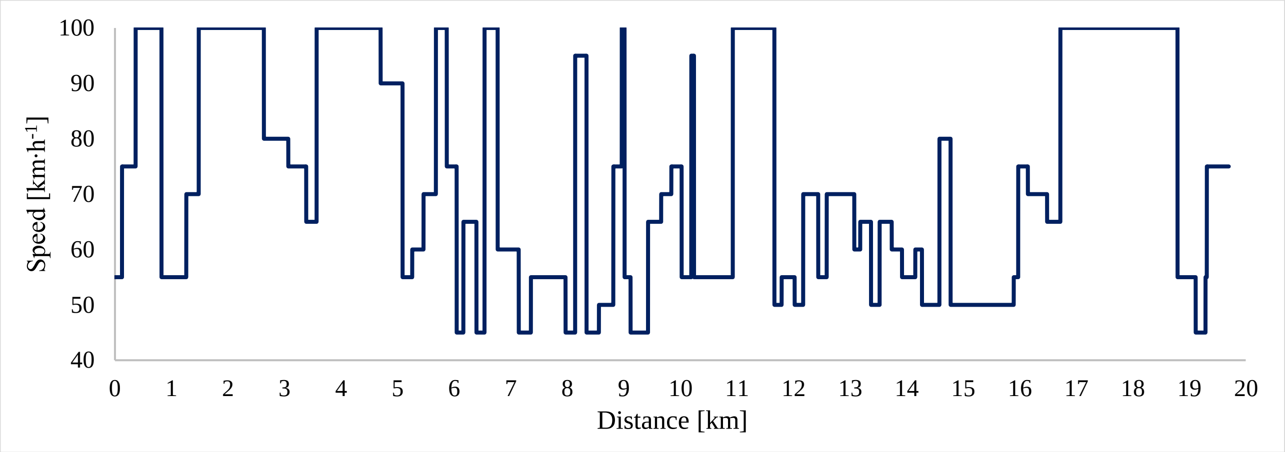

Fig. 4 Speed/distance diagram with the equilibrium superelevation. Source: authors

Using simulation, it was found that while travel time significantly improved, additional adjustments would be needed to achieve the required travel time of 25 minutes in one direction. The comparison of the results from Chapters 2.1.1 and 2.1.3 is presented in Table 3. The values in Table 3 represent net travel times in both directions, excluding turnover time.

Table 3 Comparison of travel time (level crossings and equilibrium superelevation Source: authors

Vehicle	**810**	**814**	**840**	**847**
Level crossings [min]	64.5	65.5	63.5	64.0
Equilibrium Superelevation [min]	54.5	55.5	51.0	52.0

2.1.4 Other Solutions

The final option is the change of the track geometry parameters (further referred to as TGP), which requires higher investments or an upgrade of the train interlocking system to a version of the ETCS. Modifying the TGP allows for higher curves coupled with equilibrium superelevation, enabling increased speeds through the curves. All these adjustments respect the land owned by the infrastructure manager. Figure 5 shows the black line (previous speed profile) and the red line (new speed profile).

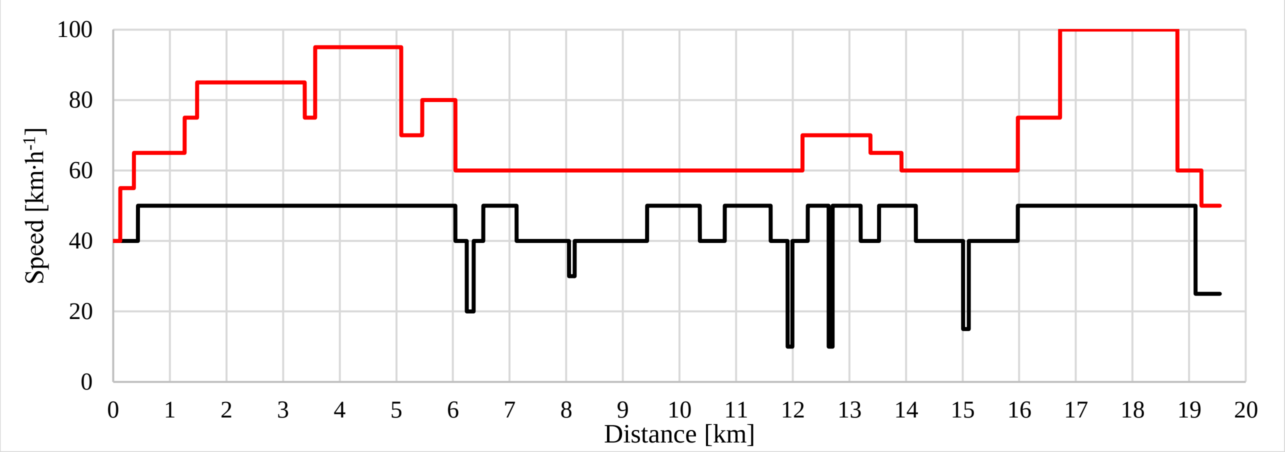

Fig. 5 Speed/distance diagram with modified track geometry parameters. Source: authors

This final adjustment is closely linked to the new ETCS L1 STOP interlocking system required for track speeds exceeding 60 km·h^{-1}. This ETCS version allows for a speed of up to 100 km·h^{-1}. Therefore, the last state of the simulation had a changed track geometry and updated interlocking system. This infrastructure setup allowed us to reach the travel time of less than 25 minutes for both the DMU 840 and DMU 847.

3. Results

This article emphasizes the need for a scientific and systematic approach when addressing issues related to public services. The implemented measures must be economically justified and achieve the desired results. If the limits imposed by modifications to the infrastructure are deemed unacceptable to the Public Service Obligation (PSO), alternative solutions must be considered. These alternatives may involve more substantial infrastructure adjustments or a shift in the mode of transport.

In the case study of the line between Doudleby nad Orlicí and Rokytnice v Orlických horách, the PSO required a reduction in travel time to 25 minutes in one direction, equating to a total of 50 minutes for a round trip. Research revealed that achieving a travel time of approximately 55 minutes was relatively straightforward, with several potential solutions meeting this criterion. However, reducing the travel time to the required 50 minutes necessitated significant infrastructure modifications, most notably the installation of a new European Train Control System (ETCS) L1 STOP signaling system.

Investment costs are crucial in every decision made by the PSO and the infrastructure manager, as they determine the cost-effectiveness of a project using public funds. To consider a project viable, its cost-effectiveness must be favorable. In this paper, only the partial investment costs (Direct Investment Costs, or DIC) have been calculated based on the unit prices established by the State Fund for Transport Infrastructure. Financial projections extend to a time horizon of 2030, with specific values, including VAT, detailed in Table 4.

Under the status quo scenario, there is no need to consider investment costs in infrastructure, as this option solely involves the deployment of a new DMU. Another scenario (focusing on level crossings) requires minimal investment costs. However, the final two scenarios indicate investment costs of up to CZK 2 billion, representing a substantial amount for a line of this scale and significance. Such a large investment would require a corresponding significant increase in transport output to be justified [19].

Table 4 Investment costs. Source: authors

Variant	Total investment costs [mil. CZK]
Present situation	0.0
Level crossings	115.3
Track Geometry **without** ETCS	1,939.2
Track Geometry **with** ETCS	2,221.6

This article highlights the need for a scientific and systemic approach to addressing public service. The measures taken must be economically justified and have the desired effect. The PSO must accept the limits imposed by modifications to the infrastructure; otherwise, alternative solutions must be considered, such as more fundamental infrastructure adjustments or a change in transport mode [20].

4. Discussion

By examining several alternatives, it becomes clear that achieving a travel time of 25 minutes in one direction, or 50 minutes for a round trip, on the Doudleby nad Orlicí - Rokytnice v Orlických horách line is feasible, provided certain modifications are made to the track's geometrical position. A crucial requirement to reach this target travel time is the deployment of a new vehicle capable of fully utilizing the potential of the modernized line, where the track speed exceeds 80 $km \cdot h^{-1}$.

The Regio-Shuttle (DMU 840, RegioSpider) and the RegioFox (DMU 847) are suitable vehicle options. Both vehicles have a maximum speed of 100 $km \cdot h^{-1}$ and feature robust power transmission, which is essential for efficient acceleration on uphill sections. This upgrade is the only way to reduce travel time from the current 37 minutes to the target of 25 minutes. With the DMU 840, the total travel time would be 49 minutes, while the DMU 847 would achieve a total of 50 minutes.

Given that this line operates under simplified rail traffic control [14], a necessary condition is implementing the ETCS L1 STOP signaling system. This system would increase the maximum line speed from 60 $km \cdot h^{-1}$ to up to 100 $km \cdot h^{-1}$. Without this new signaling system, the minimum achievable total travel times would be 52 minutes using the DMU 840 and 53 minutes using the DMU 847. In such cases, the only way to achieve the desired total travel time of 50 minutes would be to alternately pass at the stops of Peklo nad Zdobnicí and Pěčín.

Therefore, investment in new rolling stock, advanced signaling systems, and necessary track modifications are essential to meet the target travel time. Only by integrating these elements can the line achieve the set efficiency goals, optimizing both travel time and service quality for passengers.

5. Conclusions

The cooperation of the infrastructure manager with the PSO and the carrier is essential across all transport modes. In rail transport, however, this interdependence is particularly crucial. This is not only due to the high costs of infrastructure reconstruction but, above all, to the prolonged inertia of individual processes and system decisions. In the case study, the research found that a travel time of 25 minutes, and therefore a round trip of 50 minutes, is achievable without the need for costly track relaying or tunnels; all construction works can be done on the land owned by the Czech Infrastructure Manager. In addition, it is necessary to equip the line with an appropriate signaling system.

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