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Setting up a system for effective monitoring of the performance of concession contracts in the public passenger transport

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Abstract

The implementation of public passenger transport as a public service obligation is based on concession contracts between the operator, i.e. the Public Transport Authority, and the contractors. The key task of competent Public Transport Authorities is monitoring the implementation and assessing the effectiveness of the service. Public passenger transport has an increasing role also in the transport aspect of energy savings and the reduction of pollutant emissions. The research in this article shows the infrastructure transport model consisting of two parts: the bus line optimization and the use of vehicles with alternative propulsion systems. It has been proven that for a successful development of public passenger transport as public service obligation, the results from both types of research need to be compared and the best joint effects identified and implemented.

Keywords: public passenger transport, hybrid drive, regeneration energy, air pollutant emissions

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1. Introduction

Presentations of the research in this article derive from the field of public passenger transport management, which is performed as a Public Service Obligation of Public Passenger Transport (PSO_PPT). Usually, public passenger transport is managed through management companies, Public Transport Authority (PTA). Since this is a compulsory public service, the competent PTA carries out subsidization of those lines the revenue of which does not cover the costs. In addition to providing the necessary financial sources, the management of public passenger transport also includes determining all the conditions and obligations for implementation, as shown in Figure 1. The requirements and conditions, as well as the method of allocating financial resources, must be specified in the concession contract between the operator and the contractors. Research in relation to the search for the best public transport operators has shown good effects of introducing competitive public tenders (Mouwen and Ommeren (2016)), (Velde et al. (2008)).

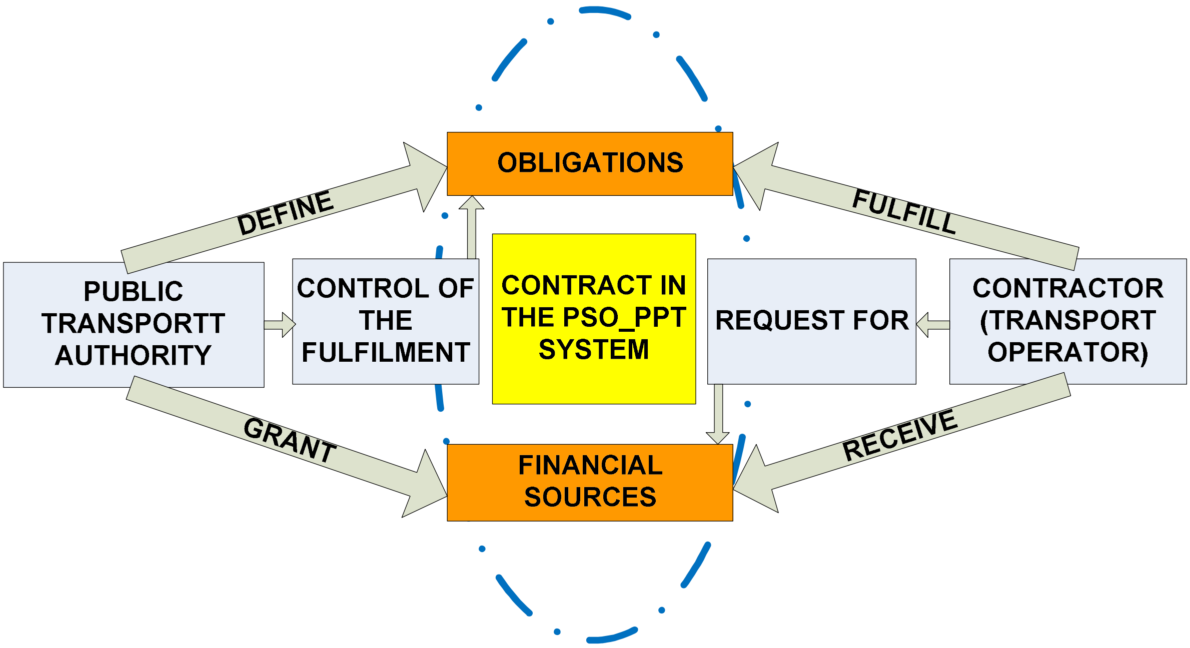

Fig. 1 Contractual relationship between Public Transport Authority and Contractor

An example of an in-depth analysis of contractual relationships between a PTA operator and contractors is shown in Figure 2. The PTA first prepares the PSO_PPT implementation system for a new concession period and invites potential bidders to submit bids. Usually, the main components of the bids are documentation relating to the preparation of timetables, cost structure and requirements for vehicles, drivers, etc. An integral part of the tender documentation may also include various initiatives and risks that, depending on the type of concession contracts, can be distributed in a different way between the PTA and the contractors. In the next phase, the coordination and detailing of the PSP_PPT implementation program for a new concession period is performed. After setting up the national timetable, the signing of the concession contract and the implementation of PSO_PPT are performed. Reporting on the implementation of this PSO_PPT, which consists of reports on work done, the number of passengers carried and revenue received, is the basis for the analysis before the payment of compensations and subsidies. The analysis of reports, the evaluation of the implementation of lines and the determination of the efficiency of the entire PSO_PPT are some of the key PTA tasks. All these analyses and research at this stage provide the basis for improving the effectiveness of implementation and are also the basis for the preparation of the system for new concession periods after the expiration of the existing ones.

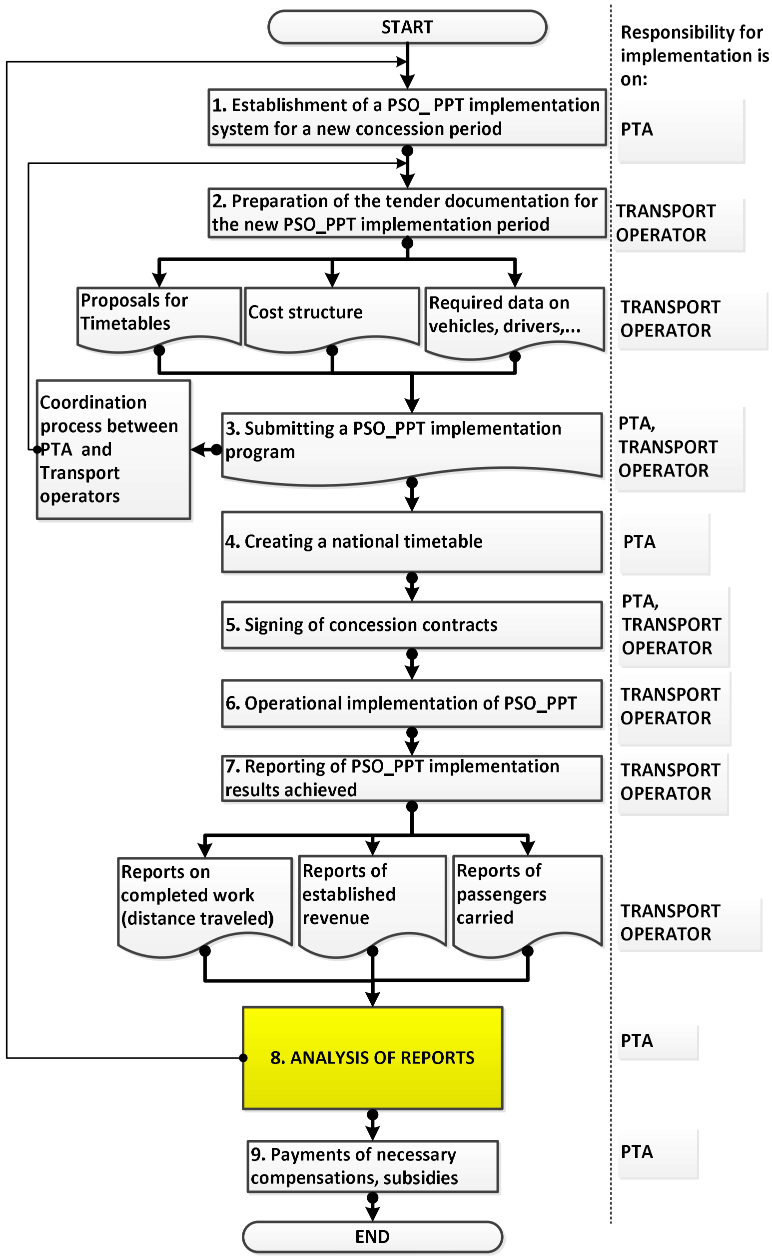

Fig. 2 Distribution of responsibilities in the implementation processes of PSO_PPT

2. Set infrastructure transport model

The public transport operator must carry out analyses of the existing PSO_PPT implementation and ensure optimal performance in relation to the available public funds. Therefore, in view of the specific circumstances from contractual relations, a model of monitoring and evaluation of the implementation of PSO_PPT lines should be set up. Such models are usually derived from the infrastructure bases on which the lines are running (Ambrož et al. (2016)). Therefore, it is necessary to know the itineraries accurately and, on the basis of this, to define the line sections with appropriate cartographic maps. In this way, we can accurately determine the distances and consequently the travel times between the individual line sections.

In our research, two types of experiments were carried out in two different pilot areas, as shown in Figure 3 (point 1.2.). In the first pilot region, we performed measurements of the value of the implementation of individual lines. Using optimization algorithms (point 2.1. and 2.2.), we found comparative analyses of these values and found the causes of deviations. In this way, the PTA could also set up measures to raise the value of the implementation to individual lines (point 2.3.).

The purpose of a more detailed presentation of the research in this article relates to points 3.1., 3.2., 3.3. and 4, as follows from Figure 3. As defined in the EU Strategies (European Commission (2018), Communication (2018), Corazza et al. (2016)), the objective is to reduce greenhouse gas (GHG) emissions by at least 60 % compared to those in 1990 and be firmly on the path towards zero. The operational program of measures to decrease GHG emissions by 2020 in Slovenia (Ministry of Environment and Spatial Planning, 2018) sets as an objective that traffic emissions are to be reduced by 15 % by 2030 compared to 2008.
Research in the field of alternative drives in buses shows that there are two different architectures suitable for hybrid vehicles – series and parallel architecture (Ranganathan (2018)). The research (Katrašnik et al. (2007)) shows the simulation of energy-conversion efficiency of hybrid drives and the characteristics from the fuel economic point of view. In the parallel system, the internal combustion engine and electric motor are independently connected through transmission. In the series system, the internal combustion engine is connected to a generator which charges the battery through a controller.

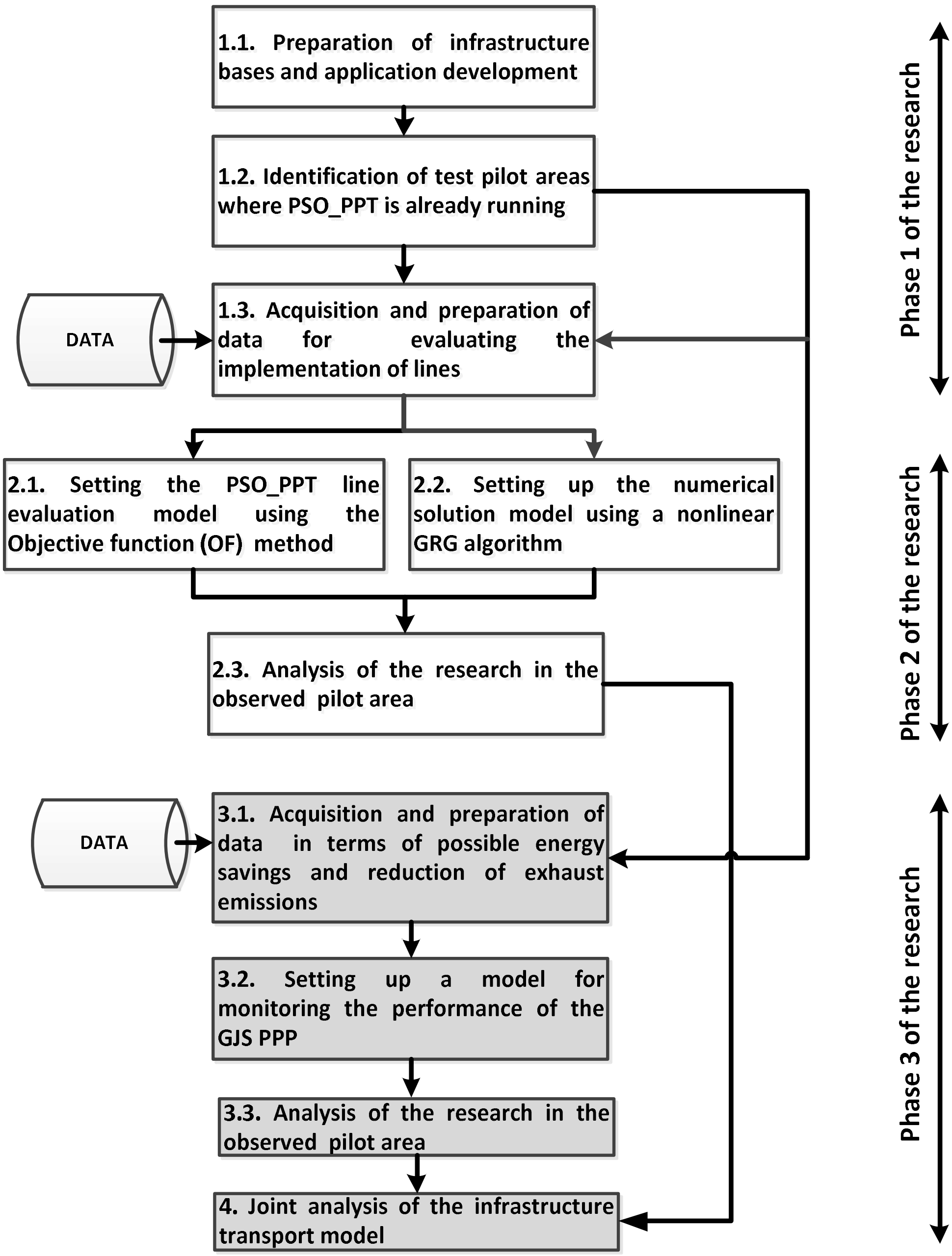

Fig. 3 Procedures for evaluating the implementation of lines and identifying possible alternative sources of propulsion of vehicle (buses)

2.1. Identification of a pilot area for carrying out research on the use of vehicles (buses) on alternative forms of drives

The purpose of carrying out the research on the use of vehicles (buses) on alternative sources of drives was to determine the influence of the elevation profile on which the PSO_PPT lines are carried out on possible energy savings during vehicle braking. Therefore, such a pilot area was selected in the hilly area, so that the line profile has characteristic ascents and descents, which gives the opportunity to regenerate the energy while braking the vehicle. The basic line characteristics are presented in Table 1 and on the map in Fig. 4.

Table 1. List of bus lines in the characteristic pilot area.

Designation	Line	Length [km]	No. of bus stops	Travel time*
Line 1	Nova Gorica - Čepovan	35	19	1 h 5 min
Line 2	Čepovan - Šempeter pri Gorici	31	20	1 h 4 min
Line 3	Nova Gorica - Lokve	23	12	47 min
Line 4	Grgar - Šempeter pri Gorici	13	14	29 min
Line 5	Grgar - Nova Gorica	39	33	1 h 50 min
Line 6	Lokve - Nova Gorica	31	20	1 h 12 min
Line 7	Nova Gorica - Kal nad Kanalom	30	13	55 min
Line 8	Nova Gorica - Nova Gorica	36	22	1 h 17 min
Line 9	Banjšice - Nova Gorica	36	17	1 h 3 min
Line 10	Grgar - Nova Gorica	39	33	1 h 50 min

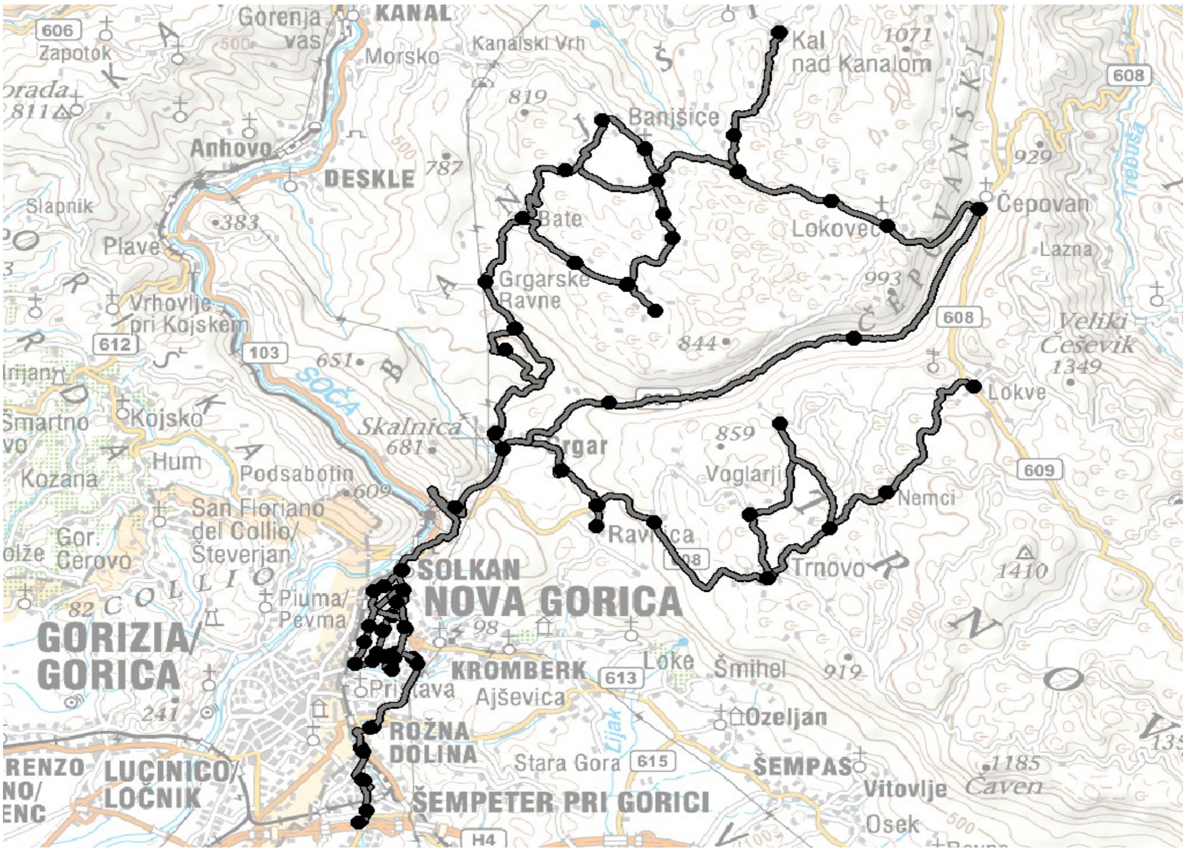

Fig. 4 The selected pilot area, comprising 10 lines of PSO_PPT for conducting research on the use of vehicles on alternative drives

2.2. Setting up a model to monitor the effects of potential energy savings due to regenerative braking

In the analytical part of the research, mathematical calculations were performed to overcome the following resistances during the bus travels along the lines on the pilot area: rolling resistance, aerodynamic resistance, slope resistance and inertia mass resistance. We calculated the total energy required to overcome all the resistances, which is marked as TEOR, and the energy saving potential of regenerative braking, which is marked as ESPRB.

$$TEOR = \sum_i((R_{Ri} + R_{Ai} + R_{Si}) \cdot (s_i - s_{i-1})) + \sum_j(R_{Ii} \cdot s_j) \quad (1)$$

- $TEOR$.. Total energy required for all bus journeys
- R_{Ri}… Rolling resistance
- R_{Ai}… Aerodynamic resistance
- R_{Si} … Slope resistance
- R_{Ii}… Inertia mass resistance
- $(s_i - s_{i-1})$.. The length of the concerned itinerary segment on the observed line
- s_j… Distance needed for acceleration/deceleration at bus stops

$$ESPRB = (\sum_k TEOR_k + \sum_n(R_{In} \cdot s_n)) \cdot K_{reg} \quad (2)$$

- $ESPRB$ … The energy saving potential of regenerative braking for all bus journeys per year
- $\sum_k TEOR_k$…Calculated energy saving potential of regenerative braking as the sum of only negative values of the required energy, those which, acting on the basis of the calculated forces of resistance, act in the direction of vehicle motion and offer the possibility of regeneration
- $\sum_n(R_{In} \cdot s_n))$… Calculated regeneration energy only when braking the bus prior to arrival at a station point and which is not included in the previous calculation of TEOR
- K_{reg}.. Regeneration coefficient as quotient between the experimental and analytically determined ESPRB

To enable calculations, a necessary basis was first provided based on the geographical features of each bus line (Cole (2016), Mahmoud et al. (2016)). For those segments, the slope inclinations and the route lengths were determined. Among the 10 selected lines included in the research, the measurements, i.e. the experimental part, were performed on Line_6 by acquiring and storing the vehicle diagnostic data from the vehicle controller area network (CAN) bus connector. The time history of the following values was significant: vehicle speed, detection of the brake switch and fuel rate. The bus stop locations were manually added to the log file by the operator. Measurements of the elevation profile of the driving route were performed with a GNSS device and synchronized with other measurements based on the recorded measurement times. In the CAN messages, speed and fuel rate values are recorded as calculation values, while detection of the brake application is recorded as a bit sequence (Blaž et al. (2019).

2.3. Results

The results of the experimental part of the measurements are shown in Figure 5. The relationships between the elevation profile of the lines (descent /ascent) as well as the necessary TEOR and possible TEOR energy savings are shown in Figure 6. On all 10 observed lines, 126,540 km are operated per year, which requires 199.4 MWh energy (TEOR) to overcome all the resistances. Final calculations have shown that on the selected bus lines, 14.1 MWh of the regenerated ESPRB energy could be used on an annual basis, which presents 7.1 % of the TEOR energy needed to overcome all the resistances.
Analyses have also been performed of the amount of emissions in the pilot area on an annual basis, assuming that on all bus routes only diesel and hybrid buses are used (Table 1). The results are based on the measurements of a bus company with a concession in Flanders, Belgium (De Lijn: CO 2 emissions (2018), De Lijn: emissions of our vehicle (2018)) whereby the following average values are taken account of: fuel consumption monitoring, compliance with the applicable emission standards, use of diesel-hybrid buses where possible and use of alternative fuels. Also emphasized is the fact that all bus drivers completed an eco-driving training.

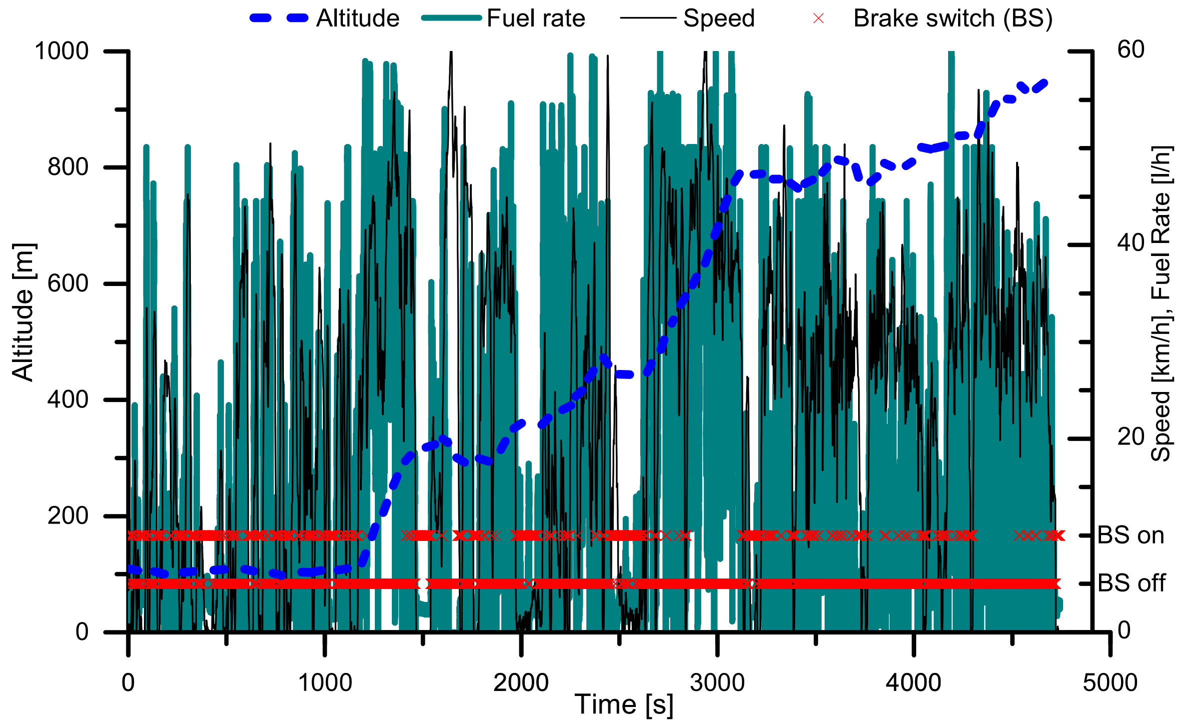

Fig. 5 The results of the experimental part of the measurements (Blaž et al. (2019))

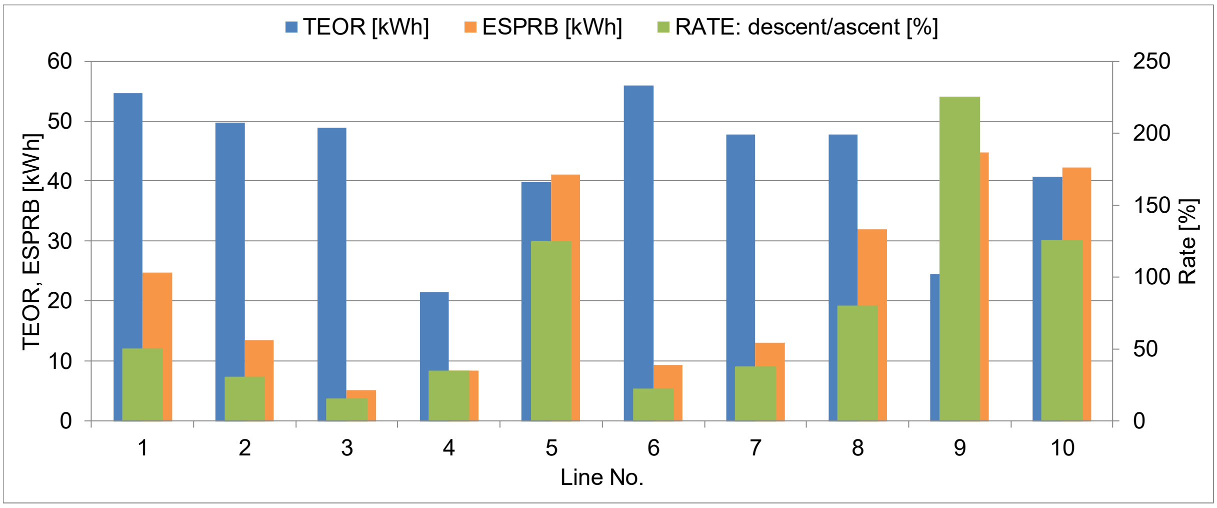

Fig. 6 Comparisons of energy shares in dependence on the descent/ascent rate for 10 lines in the observed pilot area (from Blaž et al. (2019))

Table 2. Comparative analysis of emissions for the treated 10 lines at the annual level according to sources (De Lijn (2018)).

Line no.	Distance travelled/ journey [km]	Distance travelled/ year [km]	Conv. diesel CO_2 emission [t]	Conv. diesel PM emission [kg]	Conv. diesel NO_x emission [kg]	Hybrid CO_2 emission [t]	Hybrid PM emission [kg]	Hybrid NO_x emission [kg]
1	35	12,000	12.68	0.96	144.00	10.15	0.77	115.20
2	31	23,280	24.61	1.86	279.36	19.69	1.49	223.49
3	23	18,900	19.98	1.51	226.80	15.99	1.21	181.44
4	13	5,520	5.83	0.44	66.24	4.67	0.35	52.99
5	39	5,880	6.22	0.47	70.56	4.97	0.38	56.45
6	31	13,600	14.38	1.09	163.20	11.51	0.87	130.56
7	30	26,560	28.07	2.12	318.72	22.47	1.70	254.98
8	36	9,400	9.94	0.75	112.80	7.95	0.60	90.24
9	36	7,200	7.61	0.58	86.40	6.09	0.46	69.12
10	39	4,200	4.44	0.34	50.40	3.55	0.27	40.32
Total:		126,540	133.75	10.12	1518.48	107.05	8.10	1214.78
Rate of hybrid / conventional diesel:						0.80	0.80	0.80

3. Conclusions

The challenge of PSO_PPT management is found to be extremely complex and requires a special professional approach, which is expected from the competent PTA. Procedures start with the process of selecting the best contractor PSO_PPT, whereby it is recommended to conduct competitive public tenders to find the best PSO_PPT providers. The procedures for the preparation of tender documents should specify precisely: implementation conditions, revenue and cost monitoring system, as well as additional initiatives and risk sharing.

The competent PTA must monitor the PSO_PPT implementation, adopt measures to improve the efficiency of the implementation of lines and prepare the conditions for a new period of implementation of this service after the expiration of the existing contracts.

This paper provides an overview of the situation and the research that result from the operational implementation of PSO_PPT and as follows from the relationships between PTA and transport operator. Namely, the PTA could prepare in advance such concession areas of the PSO_PPT implementation that the use of specific alternative forms of vehicle propulsion in the PSO_PPT system may have the greatest effects.

In our research we focused on the impact of the introduction of vehicles on alternative drive types (serial hybrid drive) on the performance of lines where the elevation profile is a key factor.

Research has shown the feasibility of carrying out such measurements and research in two areas. The first area is to determine the effectiveness of the implementation of lines through the evaluation system and the optimization of the implementation of lines. In doing so, comparative analyses of the calculated values and ranking of lines from the lowest to the highest values are performed.

Another area is the analysis of the introduction of alternative forms of drive vehicles in the PSO_PPT system.

The competent PTA should make an analysis of the use of such vehicles for specified periods. It is necessary to estimate the shares of investments in such vehicles, assuming lower energy consumption and emission reduction, as shown in the literature (Lajunen (2014)). In the final stage, the cost of such investments must be covered by the PTA through co-financing PSO_PPT.

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