THE CONCEPT OF RESTORING RAIL TRAFFIC ON LOCAL RAILWAYS IN MOUNTAIN AREAS

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Abstract

At the end of the last century the local railway lines in Poland were closed. The traffic suspension on lines to attractive tourist destinations were closed too. The reason was lack of light rail vehicles that could climb hills on foothill and mountain railways, adapted to the decreasing number of passengers. On the other hand, limiting the admissible speed limits has limited the attractiveness. It was caused by unsatisfactory technical condition of the rail infrastructure. The road congestion has grown therefore the environment has been polluted. As a result, tourism development has been limited. Guided by the principle of sustainable development, taking into account the possibility to generate passenger streams, leads to the conclusion that communication on foothill and mountain regions should be based on the pro-ecological electrified railway, supported by complementary network, which would be served by electric buses and Park&Ride solutions. Therefore, the aim of the paper is to present the methodology of railway restoration taking into account boundary conditions of the transport system. In this paper the possibility of reactivation of service on one of mountain route in Poland was proposed. Based on microsimulation analyse which uses the equation of motion, the journey time and - as a result - railway timetable was established. Using geographic information system (GIS) tools the location of Park&Ride Parking and new station was proposed. The possible further development of transport system was discussed.

Keywords: Railway infrastructure, railway timetable, traffic restoring, microsimulation

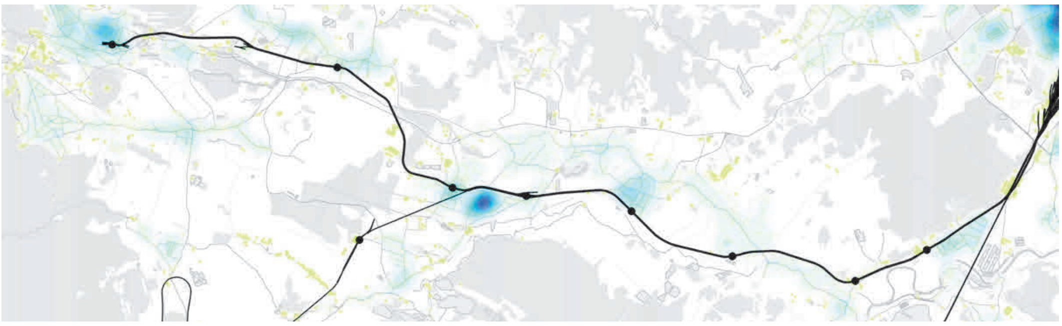
1. INTRODUCTION

The 1990s and the beginning of the 21st century were a difficult period for the railway system in Poland [1]. Due to the lack of light multiple units, high operating costs of train sets assembled from diesel (or steam) locomotive and railroad cars, deteriorating technical condition of the infrastructure determining the reduction of speed limits the rail traffic and low level of service in access points was suspended. The phenomenon took place especially on local rail lines, which were located mainly in west and south Poland, including Sudetes and Carpathian Mountains. Popular tourist destinations were deprived of access to railway system. Passenger traffic was taken over by road transport which is characterized by the occurrence of many risks [2]. There are especially many of them on winding, narrow mountain routes. Compared to other modes of transport, rail transport has many advantages [3] that are particularly evident in mountain areas.

Nowadays, when EU funds are available, when light multiple units are available on the market [4], when models are being built to simulate, correct and improve the work of elements or entire transport systems [5,6], when various entities expressing willingness to cooperate in organizing transport [7], reactivations of service on local rail routes in mountain areas are possible and the development of existing connections is supported [8].

2. POTENTIAL FOR RESTORING RAILWAY PASSENGER TRAFFIC

The railroad environment may change during a period when rail traffic has been suspended. New resorts have been created and new residential buildings have appeared. Directions and intensity of travel related to work and study have changed. Using the data of the geographic information system (GIS) the location of stops and stations was checked for their spatial availability and location of population centres. Results of accessibility analyses are shown in **Figure 1**. Upper figure (A) presents population distribution. The more inhabitants, the more intense the blue colour clusters. Lower figure (B) shows walking time to existing stations. The less intense the shade of red, the greater walking time. For the least intense colours, the walking time is 15 minutes.

(A)


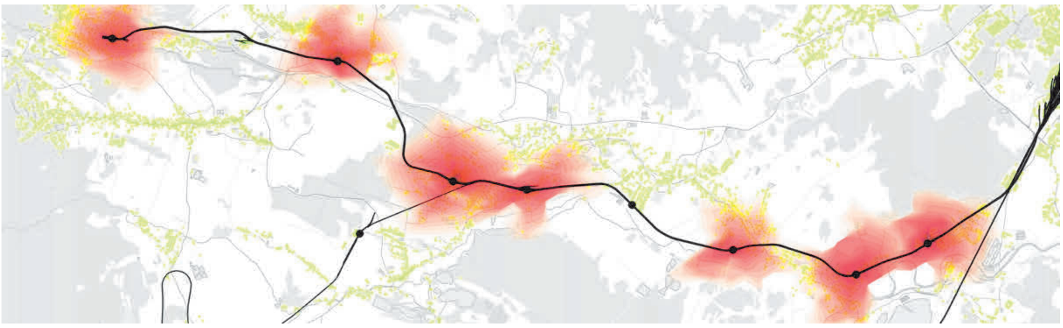
(B)


Figure 1 Population distribution (A) and pedestrian isochrones for reaching railway stations (B) [own study]

Analysis have shown that an additional railway station should be built in localization 7.4 km during restoring. The location provides passengers with the right level of service in all components of the transport access system and allows them to achieve functional readiness [9,10].

Every day 1911 people move in circular migrations solely due to occupational activity between the communes which cross concerned railway line. This is a significant passenger potential. Moreover, holiday resorts have prepared 12,000 beds, which are used by more than 300,000 tourists every year. The number of visitors is constantly increasing.

3. TRACTION CALCULATIONS

A microsimulation model calculating the train motion equation was built using MATLAB Simulink. Realised calculations are called tractive calculations. They are the basics for planning transport system and its offer due to the fact that they determine parameters of the train movement.

3.1. Train motion equation

Execution of tractive calculations reliant on the equation of motion solution [11,12,13] enable the determination of rational parameters of rail line and timetable:

$$F(v,S) = m \cdot k \cdot \frac{d^2v}{dt^2} \tag{1}$$

where:

F - resultant force (N)
m - mass (kg)
k - coefficient of swirling mass (-)

$F(v,S) = Z(v) - W(v) - I(S)$ - for accelerating (2)

$F(v,S) = \left(-\left(B(v) + W(v) + I(S)\right)\right), Z(v) = 0$ - for braking (3)

$Z(v) = W(v) + I(S), F(v,S) = B(v) = 0$ - for cruising (4)

$F(v,S) = \left(-\left(W(v) + I(S)\right)\right), B(v) = Z(v) = 0$ - for coasting (5)

where:

B - braking force (N), I - additional resistance effort (from profile of line) (N), W - basic resistance effort (N), Z - tractive effeort (N)

The equation of motion (1) can be noted as [14]:

$$S = m \cdot k \int_{v_1}^{v_2} \frac{v dv}{F} \quad (6)$$

$$t = m \cdot k \int_{v_1}^{v_2} \frac{dv}{F} \quad (7)$$

These calculations, called also minimal-time-travel, allow to determine the changes in vehicle velocity versus its traction properties and external conditions. On its basis it is possible to determine the technical travel times of individual sections, which are necessary to propose the timetable.

3.2. The equation of tractive calculations

Traction calculations were made for the 31WE emu. The calculations assume that the train moves at maximum velocity v=60 km/h due to the assumed infrastructure parameters. Part of results are shown in **Figure 2** and **Figure 3**.

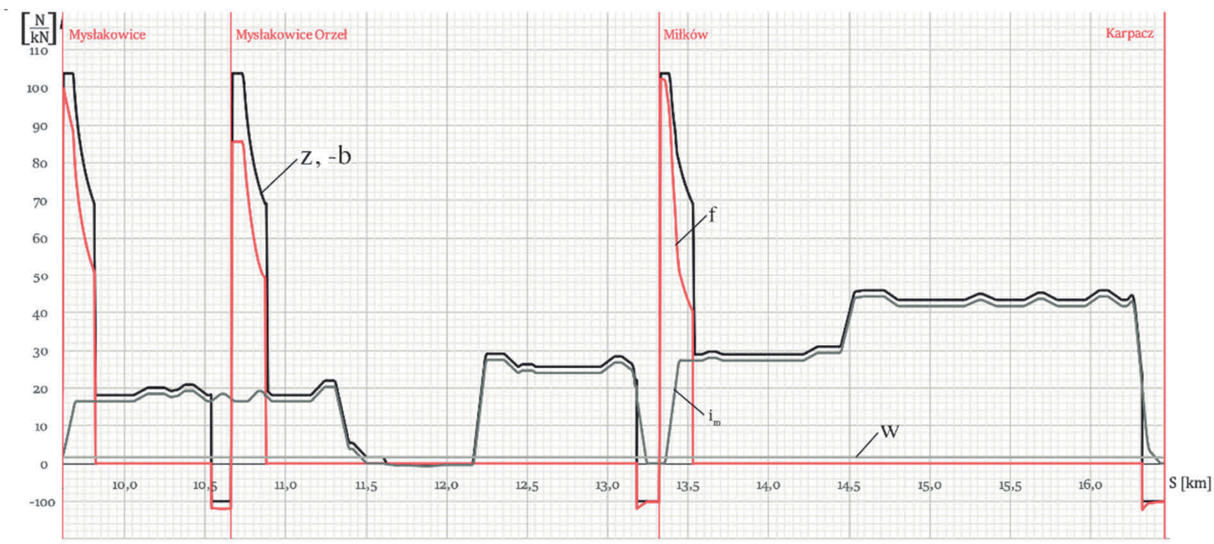


Figure 2 The value of the unit resultant force, tractive effort, braking force, basic and additional resistance effort of 31WE emu as a function of the distance [own study]

Calculations were carried out for the whole route, outwards and return. The calculations showed that the time needed for the multiple unit to complete the route outward (without stoppages, but taking into account stops and acceleration) is 18.77 minutes, return travel: 18.80 minutes.

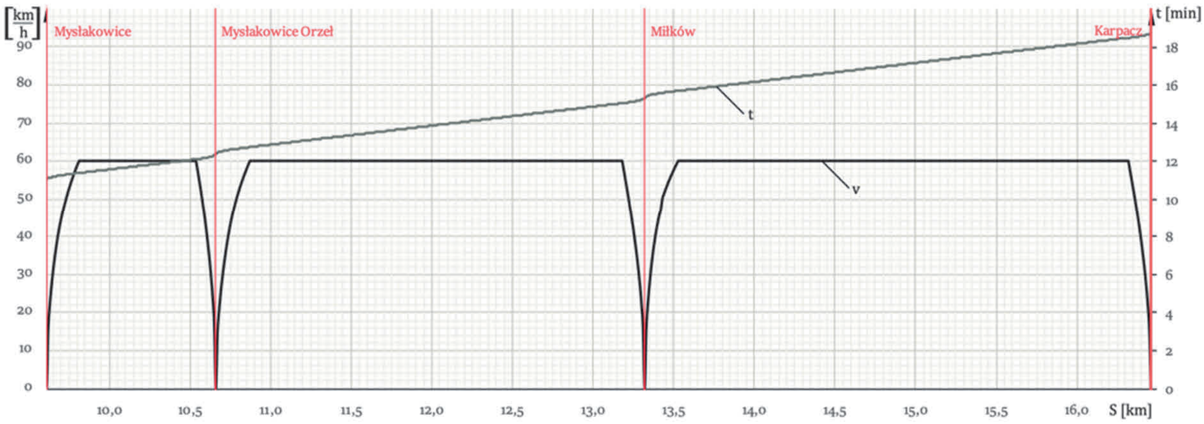


Figure 3 The value of the time and velocity of 31WE emu as a function of the distance [own study]

4. PROPOSED TRANSPORT OFFER

4.1. Scheduled travel time

The result of traction calculations is a component of the planned timetable. It is called according to the instruction [15] a component A of the of the train's travel time. The operating reserve is component B (for a passenger train it is 5 min for each 100 km of travel). Component D is the sum of stopping times at stops and intermediate stations, but the minimum commercial standstill time for an electric multiple unit is 0.3 min. The scheduled train travel time is presented in **Table 1**. Total scheduled train travel time is 22.4 min for uphill and for downhill ride.

Table 1 The total scheduled train travel time between stations [own study]

Portion of line	Scheduled time (min)						Portion of line	Scheduled time (min)					
	Uphill			Downhill				Uphill			Downhill		
	A	B	D	A	B	D		A	B	D	A	B	D
A-B	3.7	0.1	0.3	3.7	0.2	0.3	E-F	2.3	0.1	0.3	2.3	0.1	0.3
B-C	1.7	0.1	0.3	1.8	0.1	0.3	F-G	1.4	0.1	0.3	1.4	0.1	0.3
C-D	2.0	0.1	0.3	2.0	0.1	0.3	G-H	3.0	0.1	0.3	3.0	0.1	0.3
D-E	1.6	0.1	0.3	1.6	0.1	0.3	H-I	3.5	0.2	-	3.4	0.1	-

4.2. Proposed timetable

Considering the capacity of stations [16] and railway line [17], technically possible train cycle [18,19] time and passenger potential [20], it is proposed to start a total of 18 pairs of shuttle trains on the route per working day, which translates into train operation of 592.6 km. It is planned to implement travels at hourly rate. On Saturdays and Sundays, it is proposed to launching 12 pairs of connections a day with 120 min. interval on mornings and evenings and 60 min. interval for the rest of the day. The timetable should be verified by the carrier and the organizer of the transport. It is reasonable to use a balanced scorecard [21] and modelling transport network using the selected graph theory domination concepts [22]. The train timetable so prepared must be assessed in terms of dependability assessment of system [23].

Hourly cycle time of railway timetable is very convenient for passengers, provides a satisfactory passenger offer and allows to operate the line using only one emu.

4.3. Investments accompanying revitalization

The road system - especially during the tourist season - is overloaded. Difficulties are caused particularly by parked cars. As a result, it is justified to construct a Park&Ride car park located in the immediate vicinity of one of the initial access points to railway line. It is proposed to provide parking spaces for 500 vehicles in the first stage. Tourists will be able to park their car in the parking and continue their journey by train [24].

In order to increase access to the railway line, it is proposed to launch a bus line. The line will connect the last station (which is located peripherally) with the town centre. Bus timetables should be coordinated with train arrivals and departures. Such initiatives undertaken in transport, but also in logistics, are support [25] system performing in a system of systems [26].

5. CONCLUSION

It is possible to restore traffic on the analysed railway line. The reestablishment of railway passenger traffic is favoured by the appearance on the market vehicles that were not available at the time of suspension. Due to the changing environment of the railway line and the change in population density in the area under consideration, it is reasonable to build a new railway station and start an additional, complementary bus line. The increasing number of tourists who can now reach the resorts only by car means that the narrow mountain streets will be increasingly crowded by vehicles. It is therefore justified to build a buffer car park near one of the initial stations of the railway line.

Traction calculations carried out using the MATLAB Simulink environment allowed proposing a railway timetable. It is proposed to start a total of 18 pairs of shuttle trains on the route per working day and 12 pairs per non-working day.

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