

## **The Importance of Interchange Terminals between Public Transport Subsystems on the Outskirts of City: Case Study Pardubice**

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### **Abstract**

The paper focuses on the issue of public transport interchanges on the outskirts of city. Public transport terminals located on the outskirts of cities serve to create nodal points of transport connecting regional and city subsystems of public transport. The construction of new terminals in the existing transport network requires a detailed analysis of the operational concept of all modes of transport to be served by the terminal. In the city of Pardubice (Czech Republic), a new public transport terminal is being considered in the northwest part of the city outside the walking distance from the city centre. Two sites are proposed (Rosice nad Labem and Semtín) adjacent to the railway stations. The Rosice nad Labem site has a better connection to rail transport (2 lines; both long-distance, and regional segment), but no connection to urban public transport. The Semtín site, on the other hand, has a connection to the trolleybus backbone of the urban public transport, but there is only one railway line and only regional segment. It is therefore necessary to assess the situation comprehensively and choose the more suitable from the given locations. The key is to assess the sensibility of interregional transfers to urban transport to reach destinations within the city. The aim of this paper is to evaluate the suitability of the location of considered public transport terminal in the northwest part of the city of Pardubice. The evaluation will be based on traffic assignment methods taking part of four step transport demand modelling.

**KEY WORDS:** *private transport, public transport, public transport terminals, terminal location, transport concept*

### **1. Introduction**

The development of public transport is one of the important factors in increasing its attractiveness. A suitable organisational concept for public transport is one of the basic prerequisites for its proper functioning. An important factor is the knowledge of transport demand and the routing of transport flows. One of the elements for the development of public transport in cities is the modernisation and construction of interchange terminals.

Pardubice is a regional city of the Pardubice Region, located in eastern Bohemia. Pardubice has approximately 92 000 inhabitants. The city of Pardubice is imaginatively divided by the Elbe River into a northern and a southern part. In the future, the southern part of the city will be equipped with 4 public transport terminals: “Masarykovo náměstí” terminal, the A terminal for public transport at main railway station, the B terminal for regional buses, and the “Jih” terminal on the street “K Vápence”, which is planned. The public transport terminal A and terminal B are located at the main railway station, which is an important transport hub. The Masaryk Square terminal is located in the centre of the city. The northern part of the city has terminal “University”, which is located at the university complex there. Within the Sustainable Urban Mobility Plan of the Statutory City of Pardubice called “ParduPlan” [1], there is an effort to improve the transport system within Pardubice, including transport relations with other neighbouring cities, especially with the another regional city of Hradec Králové, with which the city of Pardubice is in a bicentric relationship. Another terminal in the northern part could be built in locations (parts of the city) close to railway stations, Rosice and Labem or Semtín zastávka, in order to provide passengers with a transfer between different transport modes without long walking distances (10+ minutes). These two locations are on the outskirts of the city, i.e. outside the city centre. The ParduPlan identifies the following problems in these locations:

- lack of public transport stops at the stations, or the stops are far apart;
- lack of connections between public city transport and rail transport;
- the absence of public city transport turntables, P+R intercept car parks and bicycle storage facilities;
- in the case of Rosice, the lack of connections to the Polabiny district and the university, and the station is difficult to access for non-motorists;
- in the case of Semtín, the existing interchange, although existing, is considered inconvenient due to the walking route, especially to the “Setmín, zastávka” stop and the current frequency of passengers in public transport implies considerable potential.

Both possible terminal locations will be assessed in this document. The key is to assess the routing of traffic flows and the sensibility of transferring from interregional services to public transport to reach destinations within the city. The suitable option will be selected for the location of the new terminal in Pardubice with help of SWOT analysis (Table).

## 2. State-of-Art Level of Knowledge

Publications with the topic of public transport terminals often focus on transport surveys, statistical databases, traffic modelling, and theoretical knowledge from own observations to define a traffic model for a specific terminal.

The paper [2] highlights the importance of the individuality of each new terminal, its incorporation into the location and role of the terminal, including the number of transport modes that meet within. Connectivity is an important aspect between urban and suburban transport of any type (public transport buses, trams, and subway vs. suburban rail and buses), which affects the intensity of transfers. The efficiency of a terminal is not only based on the quality of connectivity, but also on the spatial location of the platforms of each mode of transport and, as a result, their synchronisation. In the case of individual transport and P+R car parks, their application pays the most in terminals in sparsely populated parts of the city close to the main arteries.

Of course, the attractiveness of public transport depends on journey times and adherence to set timetables. When changing at terminals, the transfer time plays a major role, which must not be too short to avoid missing a connection with a minor delay, but again not too long, which would increase the journey time. This has been addressed, for example, in paper [3], where linear programming was used to ensure path continuity in case of transfers. The transfer time depends on the walking speed, the density of the flow of passengers, the chosen transfer route (change in the horizontal direction of walking: elevator, stairs). The waiting time was calculated in the paper using the equation Eq. (1).

$$a = m_i - m_j - t_{ij}, \quad (1)$$

where  $m_i$  – arrival time of the 1st connection;  $m_j$  – arrival time of the 2nd connection;  $t_{ij}$  – the walking travel time (transfer).

The formula for the total transfer time can have different depths of accuracy. The more precise the formula is, the more walking times it contains between each time on the walking path, e. g. the path from the means of transport, walking down the stairs, walking between stairs, walking up the stairs, the path to the means of transport. Individual parts of the path are separated by sudden changes in walking direction, either vertically or horizontally. An important component of the calculation can also be the number of doors of the means of transport, the coefficient of use of all doors and the number of passengers getting off/boarding. For example, the issue of transfer time was addressed in the paper [4] using the equation Eq. (2).

$$T_p = T_v - T_{ch} - T_n, \quad (2)$$

where  $T_v$  – time required to exit the first means of transport [sec];  $T_{ch}$  – walking time to the second platform [sec];  $T_n$  – the time required to board the second means of transport [sec].

The paper [5] presents different perspectives on transport demand in public bus transport and presents the possibilities of modelling transport demand. Modelling of demand after public passenger transport takes a complex part of transport modelling. Data for this modelling can be based on:

- transport surveys of some kinds (focused on passengers living in modelled area, on passengers incoming to modelled area and on passengers transiting in this area or staying here for a limited time only);
- available statistical databases (like statistics of sold tickets or data surveyed by public census);
- application of technical devices installed in vehicles;
- general data can be specified by application of empirically defined procedures (methods for trip generation, trip distribution or modal split).

For the purposes of the paper, an analysis of other terminals in the Czech Republic (CR) and abroad (in Austria and in Germany) was also carried out.

### *Brno (CR)*

Brno is a regional city of the South Moravian Region, located in the south-east of the Czech Republic. Brno has approximately 396 000 inhabitants. The “Nemocnice<sup>1</sup> Bohunice” public transport terminal is located on the western outskirts of Brno. The hospital, the university campus and the shopping centre are in close proximity. Transfers can be made between public city transport subsystems (tram, trolleybus, bus) and suburban buses. The interchange is served by 1 tram line, 2 trolleybus lines, 6 bus lines within the public transport system and a total of 5 regional bus lines (No. 51, 401, 402, 405 and 406). There is also a P+R car park with a total capacity of 220 parking spaces [6].

### *Ostrava (CR)*

Ostrava is a regional city of the Moravian-Silesian Region, located in the east of the Czech Republic. The population of Ostrava is approximately 283 000 inhabitants. The newest transfer terminal Hranečník makes public transport in the city centre more efficient and contributes to the environment. The terminal enables transfers between suburban bus transport and public city transport connections. Tram and trolleybus services provide strong transport links from the terminal to the central parts of the city. The terminal is served by 4 tram lines, 2 trolleybus lines, and 17 bus

<sup>1</sup> Nemocnice is translated as hospital.

lines. The construction of the terminal required major changes in the line routing and timetables of the suburban lines. However, in the case of this terminal, it is possible to observe the reluctance of passengers to change from suburban lines to public city transport services [7].

#### *Pilsen (CR)*

Pilsen is a regional city of the Pilsen Region, located in western Bohemia. Pilsen has approximately 181 000 inhabitants. Two public transport terminals have been built in Pilsen: the Šumavská terminal at the main railway station and the terminal on náměstí<sup>2</sup> Milady Horákové in Slovany district.

The terminal at Slovany facilitates transfers between suburban buses and public transport lines to the city centre (6 city lines in total, including 1 tram line). These serve the directions Karlov, Borská Pole, Bory, University of West Bohemia and Doubravka. The terminal allows to increase the frequency of connections of suburban lines in the Pilsen agglomeration, which contributes to the reduction of the number of cars coming to Pilsen from the surrounding villages. Thanks to the direct connection to the tram, trolleybus and bus stops on Milady Horáková Square, passengers from the southern villages of Pilsen have significantly reduced the transfer time between these modes of transport [8].

The terminal, located in street Šumavská near the main railway station, enables transfers between suburban bus and rail transport. This terminal has eliminated the more than three-kilometre long transfer between the train and bus stations. The terminal serves 19 lines of suburban transport. The integration of suburban and city lines in public transport is supported by the validity of tickets in both modes of transport [9].

#### *Hradec Králové (CR)*

Hradec Králové is a regional city of the Hradec Králové Region, located in the east of Bohemia. The population is approximately 93 000 inhabitants. The public transport terminal in Hradec Králové is located in the northwest part of the city approximately 300 metres from the main railway station. It is possible to transfer between public line transport (long-distance and regional) and public transport. The terminal is equipped with 7 covered platforms, 2 buildings with facilities for drivers and passengers, 20 parking spaces for buses and trolleybuses, parking for about 80 vehicles and a bicycle parking area [10].

#### *Graz (Austria)*

Graz is a city located in the southeast of Austria. The population is approximately 292 000 inhabitants. The Graz-Don Bosco public transport terminal is located on the southern outskirts of Graz. It provides interchanges between long-distance and regional rail transport, regional bus transport and public transport. The terminal is served by 2 long-distance rail lines, 5 regional rail lines (S-bahn), 5 regional bus lines and 7 public transport lines. The Graz Don Bosco transport hub also includes a car park P+R. [11].

#### *Ingolstadt (Germany)*

Ingolstadt is a city located in the southern part of Germany. The population is approximately 183 000 inhabitants. The public transport terminal at the main station is located on the southern outskirts of Ingolstadt. It provides interchanges between long-distance and regional rail transport, regional bus transport and public transport. The terminal is served by 5 long-distance rail lines, 7 regional rail lines (S-bahn), 9 regional bus lines and 7 public transport lines. The transport hub also includes a P+R car park for 800 vehicles and a B+R car park for 300 bicycles, a taxi stand and a shopping centre [12].

#### *Research conclusion*

At all terminals, there is an effort to integrate as many lines of all transport modes as possible with private (car) transport options, such as using taxis or parking your car in P+R car parks, or on the other hand leaving and locking your bicycles in bicycle racks or renting electric scooters. Terminals encourage a reduction in the use of private transport, leading to lower environmental impacts. The success of transferring these passengers depends most on the attractiveness of the public transport system and the supply of transfers (lines) at the terminal. In public transport terminals, the following should be available for passengers: platforms, crossings (above ground, below ground), lighting, railings, waiting area (shelter, benches), information stands (timetables), or catering facilities. For drivers/buses: access roads, departure roads and parking space for buses, servicing facilities (car wash, petrol station or small repair shop for minor malfunctions) and facilities for drivers in order to take statutory breaks comfortably.

### **3. Description of the Case Study**

This chapter describes the current transport system and infrastructure of both potential sites (Rosice, Semtín). Fig. 1 shows the entire case study with the stops and traffic routing marked. For clarification: the orange lines are aggregated city lines that share a route, the same applies by analogy to the suburban lines, which are deep dark blue.

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<sup>2</sup> Náměstí is translated as square.

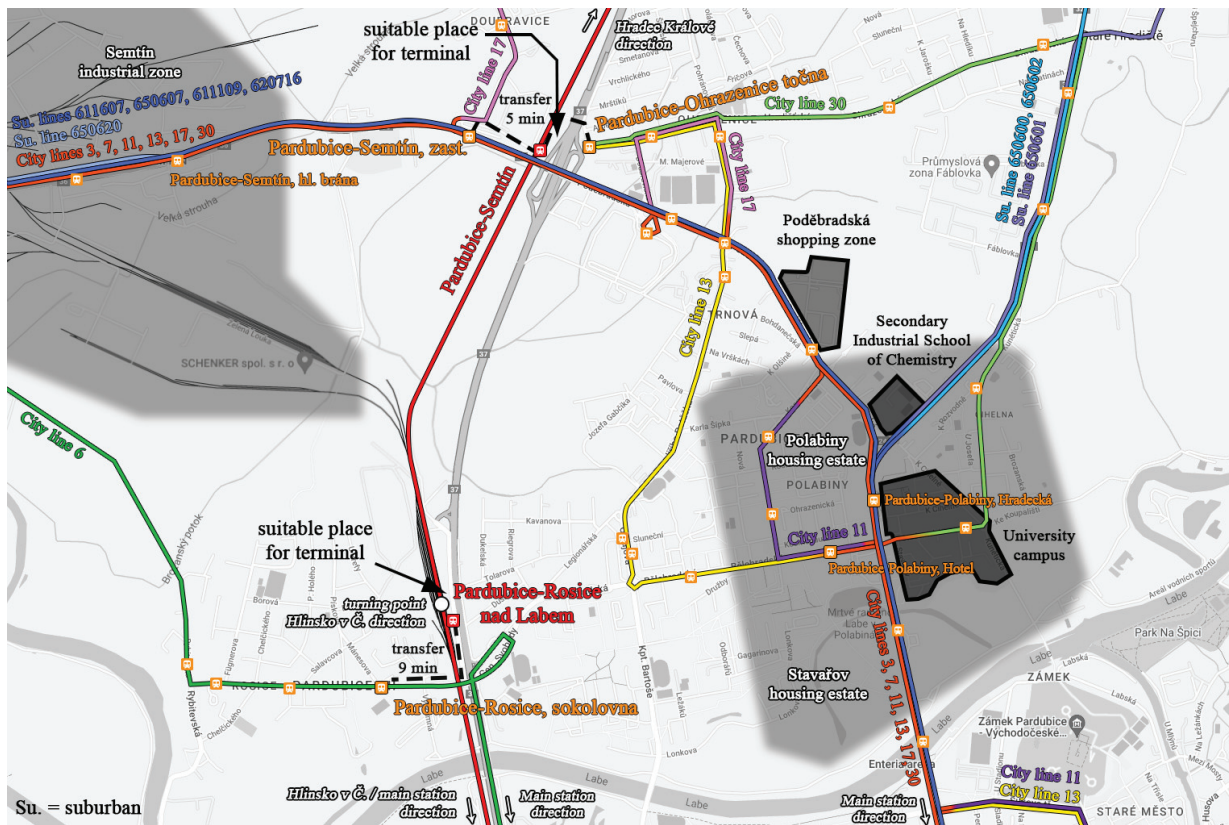


Fig. 1 Stops and transport lines of the case study (Source: authors, based on (13))

### 3.1. Rosice Location

The transfer from/to the train is managed by the closest bus stop “Rosice, sokolovna”, which is placed in the driving lane. The stop is partially equipped with shelter and the bench (one side of the road). The walking time to the train station from this stop is about 9 minutes at an average walking speed. The walking time between the train station and the public transport stop was done in the field. The crossing to the station is through a narrower footpath over a road bridge with a crossing point. There is no barrier-free access. The reconstruction of the Pardubice-Rosice and Labem station was completed at the end of 2022. The station received a new barrier-free platform, which will allow full use of barrier-free access between the train and the platforms.

#### *Public city transport*

The stop “Rosice, sokolovna” is regularly served by line No. 6 (Dukla, náměstí – Rosice, točna) with a traffic interval of 15/30 minutes on working days and 30/60 minutes on non-working days.

#### *Railway transport*

The Pardubice-Rosice nad Labem station is located on the railway line No. 031 (Pardubice hl. n.<sup>3</sup> and Hradec Králové hl. n.). The station also has access to the railway line No. 238 (Pardubice-Rosice nad Labem – Hlinsko v Čechách – Havlíčkův Brod). Therefore, it is possible to head north (Hradec Králové, Jaroměř, Liberec) or south (Slatiňany, Chrudim, Žďárec u Skutče, Hlinsko v Čechách and Havlíčkův Brod). For easier understanding of the train categories in the CR, the slowest regional passenger trains are referred to as “Os (Osobní)” and regional express trains are referred to as “Sp (Spěšný)”, and long-distance express trains as “R (Rychlík)”. The Pardubice-Rosice nad Labem station is served by 15 regional train lines (9 Os and 6 Sp train lines) and 1 R train line. The largest number of northbound connections (up to 37 in both directions) is on the Pardubice – Hradec Králové railway line, as these two cities have a bicentric relationship with each other. This has also determined the interchange of the Sp train line to Jaroměř via Hradec Králové, where the connections to Hradec Králové behave as Sp and from Hradec to Jaroměř as Os. In the south, the Pardubice – Hlinsko v Čechách line has the largest number of connections (up to 16 in both directions). This line covers the towns of Slatiňany, Chrudim and Žďárec u Skutče, which function as satellite towns to Pardubice. It is worth mentioning the Pardubice – Liberec R train line that runs through Hradec Králové. All train lines except the R line are in the public service order and operated by the national carrier České dráhy a. s. (ČD), the R train line is also in the public service order but is operated by the private carrier Arriva vlaky s. r. o. (ARR).

### 3.2. Semtín Location

The transfer from/to the train is managed by the closest public transport stop “Semtín, zastávka” or “Ohrazenice,

<sup>3</sup> The abbreviation “hl. n.” is for hlavní nádraží (main station).

točna". The "Semtín, zastávka" stop is placed as bus stop lay-by equipped with shelters and benches. The "Ohrazenice, točna" is final stop with exit stop and boarding stop. Only the boarding stop equipped with shelter and bench, although the current state of stop's quality is unsatisfactory. The walking time from the train station to both public transport stops is approximately 5 minutes. The walking time between the train station and the public transport stop was done in the field.

#### *Public city transport*

The "Semtín, zastávka" stop is served by 6 lines: No. 3, 7, 11 and 33 are trolleybus lines, No. 17 and 18 are bus lines. Line No. 3 is the backbone trolleybus line leading from the main railway station through the city centre to Lázně Bohdaneč. These lines connect the Semtín location to all parts of Pardubice. The link between Semtín location and the university campus, the high school site, the Polabiny housing estate and the commercial zone has a significant potential. These places of interest are located between the bus stop "Semtín, zastávka" and university campus (bus stop "Polabiny, Hradecká"). Line No. 3 has the largest number of connections: 52 connections during the working days and 36 connections on non-working days. Interval is 15 minutes on working days and 30 minutes on non-working days.

The alternative stop is "Ohrazenice, točna". This stop is a 5-minute walk from the "Semtín, zastávka". The "Ohrazenice, točna" stop is served by two trolleybus lines (No. 13 and No. 30). Line No. 13 connects Ohrazenice with the Polabiny housing estate and terminates at the Dubina housing estate. Line 30 runs from Ohrazenice through the university campus and the city centre to the main railway station. The number of connections and intervals on each line are shown in Table X. Line No. 13 has the largest number of connections: 73 connections during the working days and 45 connections on non-working days. Interval is 15 minutes on working days and 30 minutes on non-working days.

#### *Suburban transport*

There are 7 suburban bus lines running through the location or in its vicinity. Lines No. 650600, 650601 and 650602 turn off the main road just after the university and then share the route of the city line 30 before leaving Pardubice towards Hradec Králové through different municipalities according to their routing (figure 1). However, these are only school connections that are not routed to Semtín itself. Lines No. 650607, 611607, 611109 and 620716 already pass through Semtín: lines No. 650607 and 611607 are routed to Chlumec and Cidlinou, line No. 611109 to Hradec Králové and No. 620716 to Chrudim. An interesting feature is line No. 650620, whose services for workers terminate and start at the stop "Semtín, hl. brána"<sup>4</sup>, which is shown in the Figure 1, and it is in the industry zone.

#### *Railway transport*

The Pardubice-Semtín station, as well as Pardubice-Rosice nad Labem is located on the railway line No. 031 (Pardubice hl. n. and Hradec Králové hl. n.). This means that the northbound routes are largely identical, but the number of lines stopping in Pardubice-Semtín is only 2 (direction Hradec Králové and Jaroměř). Passengers going to other destinations, which are accessible from Pardubice-Rosice nad Labem station, have to change trains at least once either in Hradec Králové or Pardubice-Rosice nad Labem, respectively Pardubice hl. n.

## 4. Evaluation of Potential Terminal Location

The contemplated location of the public transport terminal on the north-western outskirts of Pardubice needs to be assessed also with regard to transport relations and transport flows in this part of the city. Among the most important institutions and places to which the main transport flows in the north-western part of the city are (hereafter as "places of interest"):

- campus of the University of Pardubice;
- the campus of the Secondary Industrial School of Chemistry;
- Poděbradská shopping zone;
- Stavařov housing estate;
- Polabiny housing estate;
- Semtín industrial zone.

For the paper, an effort was made to collect the necessary transport data, but this was limited by the commercial confidentiality under which, e. g. number of passengers flows belong. Using data from the two rail carriers (ČD, ARR), the county (Pardubický kraj), and the organiser of integrated transport system (ITS) OREDO, we came to the following conclusions. SWOT analysis was made (Table) for the paper.

This paper deals with these two locations mainly because there is an existing railway network that contributes to the number of interchanges and possible transfers. The description of the SWOT analysis is as follows: Rosice is suitable for the location of the terminal from the point of view of the railway transport connection, since all regional and long-distance transport connections operated on line No. 031 stop at the Pardubice-Rosice and Labem station. The station is modern equipped and barrier-free. There are facilities for passengers and staff in the form of a station building. In the immediate vicinity of the station building there is a plot of land of approximately 1 500 m<sup>2</sup>. According to the Czech Republic Land Register, this land is owned by ČD, a. s. [12]. On the other hand, Rosice district is unsuitable from the point of view of suburban bus and city transport lines. Unfortunately, the advantage mentioned above is suppressed by the minimum number of road transport connections, which are directed to the main railway station, where all railway connections accessible from the station in Rosice start and end, so the passenger has no reason to change between these two modes of transport. In the construction of the case of the terminal and its significant use, it would be

<sup>4</sup> The "hl. brána" can be translated as "main gate"

necessary to introduce at least 2 public transport lines that go to the University and further towards Semtín district (industrial zone), one towards the city centre. The available land does not offer suitable parking spaces for private car transport.

Table

SWOT analysis of Rosice and Semtín locations

SWOT Analysis		
Location	Rosice	Semtín
Strengths	<p>large number of train lines modern railway station higher station capacity for passenger interchange more facilities for staff and passengers</p>	<p>large number of backbone city lines connections of suburban bus lines no additional lines are needed more land for terminal construction better connections to the places of interest travel time up to 3 times shorter to places of interest than from Rosice shorter walking time</p>
Weaknesses	<p>connection to public transport no suburban bus lines</p>	<p>only 2 train lines in the direction of Hradec Králové</p>
Opportunities	<p>ensuring connections rail/road transport creating new road lines to serve the places of interest</p>	<p>ensuring connections rail/road transport implementation of stopping the fast train line</p>
Threats	<p>suitable land is not owned by the city line network would get more complicated low attractiveness of rail/road transport transfer</p>	<p>suitable land is not owned by the city</p>

Source: authors.

However, the Semtín locations has several advantages of existing public city connections of 6 city lines (bus and trolleybus) and suburban bus connections of up to 7 bus lines. These connections are important because they are routed through the shopping zone on Poděbradská street, schools including the University of Pardubice in the Polabiny district and the housing estates of Stavařov and the industry zone in Semtín. And in addition, Semtín location has more free space (1,600 m<sup>2</sup>) to build relatively large structures such as transport terminals. According to the Land Register of the Czech Republic, this land is owned by Správa železnic, s. o. [12]. The transfer from road transport to train transport takes 5 minutes of walking time in Semtín than 9 minutes in Rosice at this moment. Furthermore, the connection to the places of interest is up to 3 times less than from Rosice; e.g. from Semtín to the University campus the travel time is only 5 minutes without a transfer (from Rosice around 20 minutes with one transfer). Although, there is a known drawback of Semtín location. Semtín has only 2 train connections, connecting Pardubice to Hradec Králové, and thus is making it less attractive for train passengers. The railway connections in Rosice are more complex and offer several train lines, including those routed to the south of Pardubice through Chrudim, Slatiňany, Žďárec u Skutče and Hlinsko v Čechách. Also, the fast train that stops there from and to Liberec. These connections cannot be transferred to Semtín due to infrastructure capacity and station capabilities except the stopping of the fast train. But the already mentioned drawbacks of Rosice, together with advantages, would not surpass Semtín's transport capabilities. This indicates out that Semtín is better suited to have a terminal rather than Rosice.

## 5. Conclusions

In our paper we addressed two locations where can be built a public transport terminal: Rosice and Semtín. Even if the Rosice is offering more train connections as the backbone transport mode, the usefulness of this advantages is negated by low number of connections of other transport modes (city buses and suburban buses). Adding these connections would make transport system more complicated and saturated with additional lines. Therefore, it is not viable to place it in Rosice even due to smaller free space (without possible parking places for private car transport) close to Rosice railway station. In addition, both parcels are not owned by the city, which will complicate the construction of the terminal. Evaluating locations in the outskirt of cities for building a public transport terminal to make connection for the region can be helpful to make right decision in terms of usability and rentability of transport systems and overall public transport. The evaluation can be helpful for representatives of Pardubice city and other cities with same decision problem in public transport field.

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