

THE POSSIBILITIES OF RAILWAY TRANSPORT UTILIZING AS A BACKBONE NETWORK OF INTEGRATED PASSENGER TRANSPORT SYSTEMS

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The aspects of utilizing of railway transport as a backbone network of integrated passenger transport systems are solved in the contribution. The basic requirements on this railway transport service are specified in the contribution. The main attention is focused on creating of line structure of the integrated transport systems. The location of interchange points is also accented in the contribution. The theoretical presumptions are also illustrated in the way of convenient practical examples.

Key words: integrated transport system, railway transport, interchange points

1 Introduction

The integrated transport systems of public passenger transport are seen as advanced type of transport service organization. It is also essential in the case of competition between individual car transport and public passenger transport. The independence for passengers connected by the individual car transport has to be compensated by a well-organized and coordinated system of public transport [3].

The railway transport is also seen as the competitive transport mode for creation of backbone network of the integrated transport system, because technical characteristics of railway (e.g. capacity, speed, operating reliability, environmental impacts) are seen as appropriate.

2 The Main Features of Railway

There are following especially technical features of the railway transport and of the railway infrastructure essential for reliable operation in the frame of the integrated transport system.

2.1 Structure of Railway Network

The structure of railway network in solved area is one of the most important features. The structure of railway network has to be in consonance with the structure of main transport flows in the area. This is seen as the main precondition for successful establishment of railway as the backbone transport mode for the integrated transport system.

Sometimes it is able to be also influenced by some administrative restrictions, e.g. when the localities in surrounding of the railway line are incorporated in another administrative district with the regional centre out of the railway line.

On the other hand there are able to be found the restrictions by that the natural transport relations are disconnected on the borders of administrative regions.

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Both of these facts are limiting for railway transport service and it can be solved in the way of creation of interconnected structure of transport network with convenient and easy conditions for all passengers without any restrictions connected with regional borders. Only in that case it is possible that the transport flows will respect the existing and always unchangeable transport infrastructure.

The topology of railway network is important in generally point of view as well. It is necessary to estimate this fact in relation to substituting modes of transport. The backbone line has to be competitive. There are able to be found some factors [4] utile for this estimation:

- distance,
- travel time,
- costs.

In the case of distance there it is not so important the absolute distance from the point A to the point B, but more important is the relation between distances realized by railway and by each possible substituting mode of transport (e.g. bus service, municipal public transit, individual car transport, bicycle transport, walk). The relation is mentioned in the formula (1).

$$k = \frac{L_{rail}}{L_{subst.m.}} \quad [-] \quad (1)$$

where: k is factor representing relation between distances [-],

L_{rail} is distance by train [km],

$L_{substm.}$ is distance by substituting transport mode [km].

It is necessary to minimize this value in relations with majority of potentially substituting transport modes for successful establishment of the railway as the backbone mode of transport.

The construction of the travel time relations is similar as the construction of the distance relations. It is recommended to utilize the time-based indices, because travel time is able to be represented also as the function of distance and also of some other factors (e.g. travel speed, interval on line, local infrastructure conditions, specific requirements implemented in the time schedule).

The cost-based estimations are necessary in the case that there are not integrated fare systems on compared lines. It is able to be occurred also in the case of unified fare in the situation that the fare is based on distance or on travel time. In this case there is possibility of different prices by using of different lines and it has to be estimated. It is sometimes useful to express it as generalized costs also in the cases that it is necessary to incorporated lost time of passengers, costs for interchanges etc.

2.2 Capacity of Railway Lines

The capacity of railway lines in suburban areas will be also very often mentioned as a serious problem. There is often an interaction of all types of railway transport on this line segments from regional passenger transport over the freight transport up to possible development of high speed railway transport in the future.

All of the line segments proposed as the backbone network of the integrated passenger transport systems have to be completely estimated also from this point of view. There is also another problem occurred, because the common estimating methodologies (SŽDC D24) [5] are not adequately

representative for state-of-art situation in the railway transport (especially in the frame of improved frequency time schedule).

The analytical capacity estimation in consonance with the SŽDC (ČD) D24 methodology [5] is based on the formula (2) in general point of view.

$$n_{\max} = \frac{T}{t_{\text{occupation}}} \quad [\text{trains/time period}] \quad (2)$$

where: n_{\max} is maximal number of trains to be served on the solved infrastructure element [trains/time period],

T is calculating time period [minutes],

$t_{\text{occupation}}$ is occupation time of infrastructure per one train [minutes].

The problem is that the complete calculating period can not be utilized for going of trains, because the departure-times set up by the improved frequency time schedule have to be respected and the nonutilizable interspaces are occurring.

For that reason the more detailed estimation provided by simulation model is recommended. Every operational scenario is able to be estimated in the concrete conditions and with respect to local specifics.

2.3 Capacity of Railway Stations

The capacity of railway stations, especially the capacity of tracks with platform edge, will be also a problem if the station will be established as node of integrated improved frequency time schedule.

Problem is that the station is occupied by passenger trains only a few minutes per hour around the axis of symmetry (Fig. 1), but the station is occupied by all of trains together (Fig. 2). There is necessary to have a number of tracks with platform edge no less than the number of directions is. On the other hand the transfer (interchange) time for passengers is minimized, because all of transfers are ensured in direct way from train to train with minimized time of waiting.

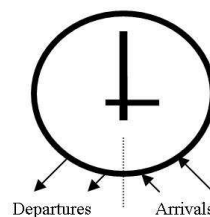


Fig. 1: Coordination of Trains (x:30) in Node of Integrated Time Schedule

Source: Author

This aspect is also able to invoke a problem with analytical methodologies for capacity estimation [5], because of uninterrupted calculating period. The degree of occupation is usually very low. For instance in the case of example mentioned on the Fig. 2 the degree of occupation is 0.21 (total time of occupation per one train is 13 min), but recommended value range for occupation degree is 0.5 – 0.67.

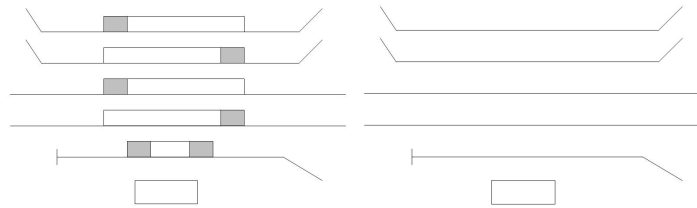


Fig. 2: Simplified Plans of Tracks Occupation for Moment of Coordinated Interchange ($x:30$) and the same Station for other Time Periods. Source: Author

The estimation of capacity of tracks with platform edge is essential for implementation of integrated improved frequency time schedules and establishment of nodes of this system. It is able to be done in the form of case study (oriented on construction of the tracks occupation schemes) or in the form of simulation. In the analytical methodologies there are disproportions caused by calculations with uninterrupted calculating period as it has been mentioned above.

2.4 Rolling Stock

The important role is also played by the structure of rolling stock. The operative push-pull trains (especially electrical or diesel units, e.g. Class 471) with level access with wide doors for quickly exchange of passengers in stations are appropriate for the operation of backbone railway lines of the integrated transport system [7]. The push-pull system is able to have positive impact for capacity or for transport technology. Shortening of trains reversion in final stops is possible in this case and (in extreme case) any tracks for overtaking in these stations are not necessary. It is also visible on the Fig. 2 that manipulations with trains (e.g. reversions of locomotives) are able to compound the capacity problems mentioned in the section 2.3 of this paper.

Second point of view is quality of rolling stock and also of the transport infrastructure, because the successful transport has to be attractive for passengers. On the other hand the operational economical evaluation of used rolling stock is also very important.

3 Location of Interchange Points

Location of interchange points between rail (backbone) and other (feeding) lines is problem limited from various points of view. Some requirements imposed on the interchange points are mentioned in the following sections.

3.1 Integrated Improved Frequency Time Schedules

The location of interchanging points is limited by travel times on the edges of the transport network [7]. The edge travel times have to be integral multiple of half time interval between transport services to ensure coordination of trains (or buses) in the interchange points. The travel time on the network edge has to be approximately the same in both directions.

In the case that the travel time on the edges is not suitable; it is possible to create interchange point with one of these restrictions:

- the interchange coordination between backbone and feeding lines is created only in one direction of the backbone line,
- the feeding line is served (two times often) and the connections are created to both directions of backbone line separately.

Both of these cases have to be estimated from the points of view of passengers transport flows and capacity, because it will cause time losses for part of passenger flow in the first case or it will create costs for operation of additional connections in the second case. The demand-oriented transport models are able to be used as the support for decision-making in this field [4].

3.2 Capacity and Equipment of the Stations

The stations established as interchanging points have to be of sufficient capacity as it has been mentioned in the section 2.3 of this paper. The number of tracks with platform edge and the transport capacity of whole station are significant.

The equipment and comfort of the station (e.g. waiting hall, information centre and additional services) are also very important factors for acceptance of the interchange by passengers. The range of additional services is depended on the number of passengers using the station (interchange), but in all cases the standard level of comfort has to be ensured. The passengers are very sensible on the quality of interchange points and naturally on the quality of the whole transport process as well.

3.3 Interconnection of the Networks

The location of the possible interchange point has to be accessible for all transport modes connected in this point. For that reason there are some infrastructure requirements for ensuring of accessibility of interchange point. It means for instance that the railway station has to be connected on road network by the road accessible for bus operation.

3.4 Creation of Line Structure and Solving of Interchange Points Location

As follows from above mentioned presumptions, there are able to be found only a few locations (railway stations) fulfilling the conditions for interchanging. This problem is also accentuated by the fact that the railway infrastructure already exists and it is usually unchangeable in the most cases. For that reason the problem can be expressed as a discrete location problem.

The location of interchange points can be simply based on scanning methods with searching through all possible variants. The variants are examined by some technological indices (e.g. travel time, travel distances, costs) and its total expressions for all passengers in the integrated transport systems.

If there is solved large area, model of linear programming is able to be constructed. There is a presumption that the surrounding of railway line segment will be covered by input set of possible lines connected in interchange points. The input set of lines is usually consisted of a number of potential lines. The final set of lines for realization is created by linear programming model in the way of reduction of input set of lines. More information about construction of models are mentioned e.g. in [1] or [2].

4 Practical Illustrations

There can be found some convenient practical examples to illustrate the questions of railway as a backbone network of integrated transport systems. Some facts mentioned in these examples are able to be generally accepted.

Integration of railway transport into city public transit system has got two technological aspects. The main is to create a backbone network of city public transit system and the secondary purpose is to make quality interconnection between regional railway system and the city transit system.

The first purpose is able to be seen for instance in Prague or in Brno, where the railway transport creates fast and capacity backbone of city public transit system on some transport relations.

There are able to be found some preconditions for successful establishment of railway as the backbone of city public transit system.

4.1 Comparison with Substituting Transport Modes

Firstly the railway has to be a more convenient mode of transport in comparison with substituting transport modes as it has been mentioned in the section 2.1 of this paper. The comparison of railway and city public transit on selected relations in the cities or suburban areas are mentioned in the Tab. 1.

The comparison is made from the point of view of distance (D), travel time (T) and number of interchanges on transport route (I). The relational comparing factors for distance ($k_{dist.}$) and travel time (k_{time}) between railway and city public transit are constructed. In the case that there are more ways how the connection by public transit is able to be realized, the arithmetical average is mentioned. The morning one-hour transport peak (from 6 till 7 AM) is selected as a calculating time period for the comparison.

There it is able to be seen that the parameters $k_{dist.}$ and k_{time} are depended on concrete situation. It is relevant because the railway has got various parameters case to case.

Tab. 1: Comparison of Railway and City Public Transit on Selected Relations.

Transport Relation	Railway			City Public Transit			$k_{dist.}$ [-]	k_{time} [-]
	D [km]	T [min]	I [-]	D [km]	T [min]	I [-]		
Praha								
Klánovice – Masaryk. n.	18	25	0	25	46.3	1	0.72	0.54
Radotín – Smíchov	9	9.7	0	11.1	18.3	0	0.81	0.53
Horní Měcholupy – hlavní n.	12	18	0	14.7	34.7	1.2	0.82	0.52
Brno								
Královo Pole – hlavní n.	11	14	0	5	17.2	0	2.20	0.81
Chrlice – hlavní n.	9	9	0	8.3	18.3	0.3	1.08	0.49
Plzeň								
Bolevec – hlavní n.	6	10	0	5	17	0	1.20	0.59
Doudlevice – hlavní n.	3	6	0	4	9.8	0.3	0.75	0.61
Chrást u P. – hlavní n.	12	12	0	10	25	1	1.20	0.48

Source: Author, based on the Time schedule IDOS 2008/2009 [6].

4.2 Location of Railway Stations

Second fact essential for successful incorporating of railway transport into city public transit system is appropriate location of railway stops and stations. There is an important fact that the density of railway stations per square km is usually lower than e.g. density of city public transit (PT) stops.

The distance for walk access has to be appropriate and suitable for majority of passengers. Otherwise the incorporating of railway transport into the city public transit (integrated transport system) will be seen as compounding by passengers.

The illustrational comparison of access distances and densities of stops is mentioned in the Tab. 2 for selected cases located in Praha, Brno and Plzeň.

The access distance is constructed as distance from the centre of area (e.g. square) to railway station. In fact the average and representative access distance can be longer, it is depended on the urban structure of the area.

Tab. 2: Comparison of Densities of Stations and Stops

Place	Area [km ²]]	Number of PT Stops	Number of Rail. Stops	Density [stops/km ²]		Access Distanc e (rail.) [km]
				PT	Rail	
Praha Klánovice	2.7	6	1	2.22	0.37	1.2
Horní Měcholupy	5.4	7	1	1.30	0.19	1.1
Radotín	3.5	20	1	5.71	0.29	0.4
Brno Královo Pole	4.1	15	1	3.66	0.24	1.2
Chrlice	1.5	6	1	4.00	0.67	0.5
Plzeň Bolevec	5.0	18	1	3.60	0.20	1.4
Doudlevice	0.6	6	1	10.00	1.67	0.7
Chrást u Plzně	1.5	2	3	1.33	2.00	0.5

Source: Author.

The accessibility of railway stations is influenced by various factors as follows from the Tab. 2 mentioned above. There is also visible that the railway has more difficult position in the comparison with the city public transit. There are seen two ways for solution of this problem.

The construction of new railway stops is the first way. The new railway station or stop has to be estimated from the point of view of available space, required investments or costs, capacity of railway line, extended travel times of trains etc.

The second way for minimizing of negative impacts connected with establishment of railway as main mode for transport service is creation of feeding bus lines connected to railway.

There is able to be found also the context of defined quality standards for transport service in selected region.

4.3 Frequency of Railway Services

The frequency of railway services is also one of the most important factors, because in the comparison with city public transit the railway has got a longer time interval between transport services. For that reason the time distance is longer. The longer time for waiting has to be compensated by a shorter travel time by train than by using of the city public transit.

The overview of average intervals (AI) between transport services for selected integrated railway lines and substituting routes of city public transit is mentioned in the Tab. 3. The calculations are made for period of morning transport peak (6 – 7 AM).

The total time of transport is calculated according to formula (3).

$$T_{travel} = 0.5 \cdot AI + T \quad [\text{min}] \quad (3)$$

where: T_{travel} is travel time (time of transport) [min],

AI is average interval between transport services for morning traffic peak [min],

T is average time of ride in vehicle [min].

The extent of transport services is modeled by the factor 0.5, because it represents the waiting time in the case of random access of passengers (they do not respect or know the time schedule when they are planning their trips). [4]

Tab. 3: Travel Times on Selected City Routes.

Transport Relation	Railway			City Public Transit		
	AI [min]	T [min]	T_{travel} [min]	AI [min]	T [min]	T_{travel} [min]
Praha						
Klánovice – Masaryk. n.	15.0	25.0	32.5	20.0	46.3	56.3
Radotín – Smíchov	10.0	9.7	14.7	10.0	18.3	23.3
Horní Měcholupy – hlavní n.	15.0	18.0	25.5	5.2	34.7	37.3
Brno						
Královo Pole – hlavní n.	20.0	14.0	34.0	5.2	17.2	19.8
Chrlice – hlavní n.	30.0	9.0	21.0	7.5	18.3	22.1
Plzeň Bolevec – hlavní n.	63.0	10.0	41.5	5.6	17.0	19.8
Doudlevice – hlavní n.	67.0	6.0	39.5	4.9	9.8	12.3
Chrást u P. – hlavní n.	30.0	12.0	27.0	40.0	25.0	45.0

Source: Author, based on the Time schedule IDOS 2008/2009 [6].

There is able to be seen in the Tab. 3 that it is able to reach better travel times by railway then by city public transit in spite of above mentioned problems. On the other hand the values presented in the Tab. 3 also illustrate the offsetting relation between usually shorter travel time and longer interval between transport services provided by railway in comparison with the city public transit.

There is able to be found longer travel time by railway than by city public transit in three cases only. It is caused by the fact that there is a competition with parallel backbone tram (or trolleybus in one case) lines with short interval on these relations. On the other hand in the case of Plzeň there it is able to be caused also by longer interval between railway services on the single-tracked line segments.

4.4 Expression of Travel Time

The expression of total travel time is essential for all optimizing tasks in the field of railway transport or in the field of integrated transport systems.

It is able to be represented all of above mentioned factors by the total travel time, when the calculation of travel time will be extended by additional factors for complex estimation. It is able to be generally represented by the formula (4).

$$T_c^{VHOD} = t_p + t_z + t_v + \sum_{j=0}^{n_p} (t_{p_j} + t_{z_j} + t_{v_j}) + t_k + t_o \quad [\text{min}] \quad (4)$$

where: T_c^{VHOD} is total travel time [minutes],

t_p is time for accessing the stop [minutes],

t_z is waiting time on the stop [minutes],

t_v is time of ride in vehicle [minutes],

j is consecutive index of interchanges,

n_p is number of interchanges on the estimated route,

t_k is time of stay on the final stop of journey [minutes],

t_o is egress time [minutes].

It is defined that when there is no interchange on the journey, the index j is set to 0 and the times t_{p0} , t_{z0} and t_{v0} are equal to zero as well.

It is able to be visible that all main factors influencing the public passenger transport are able to be incorporate in this calculation. For instance the access distance is able to be incorporated in the time for accessing the stop (t_p).

It is also expedient to mention that the accessing (t_p , t_{p_j}) and waiting (t_z , t_{z_j}) times have to be extended by constant values for modeling of times for walks in the interchange points or for possible check-in procedures.

For the estimation of integrated transport system in the complex point of view is essential to calculate total travel time (T_{TOTAL}) for all passengers in the integrated transport system, see formula (5).

$$T_{TOTAL} = \sum_{i=1}^N T_c^{VHOD} \quad [\text{min}] \quad (5)$$

where: T_{TOTAL} is total travel time for all passengers in the system [min],

i is consecutive index of passengers,

N is number of passengers in the integrated transport system,

T_{ci}^{VHOD} is total travel time of i -passenger [minutes].

In practice this value is able to be acquired as a scalar product of time-based distance matrix and origin-distance matrix (O-D matrix). These matrices are essential components of every demand-oriented transport model based on the classical four-step method. [4]

The models in general are able to create support for effective planning of public passenger transport service (integrated transport systems). The all of above mentioned themes are able to be incorporated in the models and to be estimated in this effective way.

5 Conclusion

The paper is drafted as complex overview of basic features of railway transport important for integration of railway into the integrated systems of public passenger transport. The questions of capacity in the frame of integrated improved frequency time schedules, the questions of location of interchange points and also the questions of time estimation are mentioned in the paper. Some aspects are also illustrated on the practical examples with accent on illustration of relations between some factors.

The main aim of the paper is to point out some facts to be reflected by transport planning for effective establishment of railway as the backbone transport network of integrated transport systems.

The quality of organization of the integrated transport systems is one of the key factors in the competition between individual car transport and public passenger transport also with all connected side effects (congestions, pollution, sustainable development etc.). For that reason it is a pity that there are not often utilized all of the advantages of integrated and coordinated transport for increment of modal share for public passenger transport, because the problem is wider than the only modal split between individual transport modes.

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