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THE TRAM-TRAIN SYSTEM APPLICATION IN OLOMOUC REGION

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1. Introduction

Public transport in the Czech Republic still faces an increasing rate of individual transport use. As a result passengers are decreasing in Urban Public Transport and public transport faces delays because of traffic congestion. The most visible is the decrease in Regional Public Transport by reason of low frequency of connections and unsatisfactory passenger equipment.

Most European states have started to face this effect by implementation of transport service quality improvements and integrated transport systems, which are already successfully operated in many cities in the Czech Republic. The other step within integrated systems should be implementation of the Tram-Train concept.

2. Basic information about the Olomouc region

Olomouc with its population of about 105 000 is the fifth largest city in the Czech Republic. The city is the economical, industrial and administrative centre of the Olomouc Region. At the same time it is a very important transport junction: the Third Railway Transit Corridor (TEN-T Conventional line), another four railway routes into the region and high speed roads R46, R35. There are trams and buses operated in the city transport. Regional buses are integrated with the city transport in the “Integrated transport system of the Olomouc region” (IDSOK). Partners in IDSOK are the City Transport Company (DPMO, a.s.), Connex Morava, other bus companies and Czech Railways

(routes in the north of the region). The main railway station in Olomouc is situated 2.5 km away from the city centre (bus station another 500 m) and both are connected with the centre by tram and bus. Most passengers arriving in Olomouc by train or regional bus have to use city transport to get to the centre, hospital, shopping centres or schools (see Figure 1).

Other important regional centres are especially Prostějov and Přerov (both more than 47.000 inhabitants). They are the administrative, industrial and cultural centres of their area. Smaller and less important are Litovel, Šternberk and Uničov (about 10.000 inhabitants each).

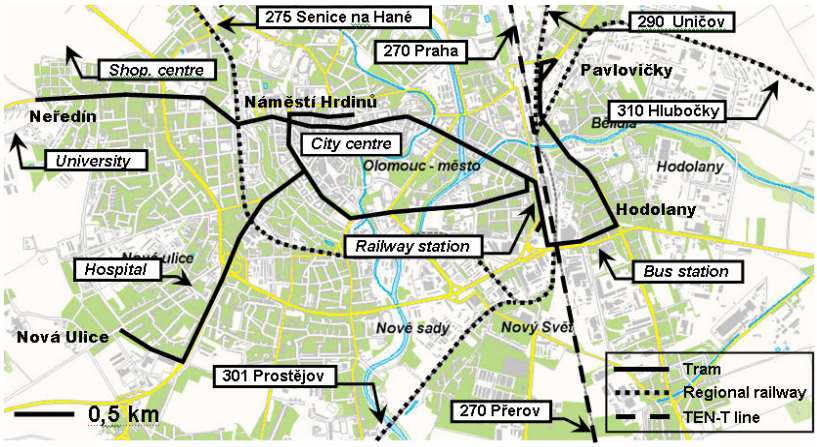

Fig. 1 *Railway and tram lines situation in Olomouc [1]*

3. Tram-Train system as a possible means of regional transport improvement

Tram-Train systems link urban tramway infrastructure with the regional heavy rail network around cities. The Tram-Train operation reverses the train to tram idea: direct access from the region to city centres by using light-rail vehicles [2]. The system could serve not only between region centre and his surrounding (most Tram-Train cases), but also between two big cities (Den Haag and Rotterdam) and between two states (Saarbrücken)

At present there are many different systems in operation in Europe. The differences are especially in power supply:

- single-system in Chemnitz (DC)
- Single-system in Aulnay-sous-Bois – Bondy (AC)
- Dual-Mode Electric/Electric in Karlsruhe, Kassel, and Saarbrücken (DC/AC)
- Dual-Mode Electric/Diesel (DC/diesel) in Kassel and Nordhausen
- Dual-Mode Electric/Electric (DC/metro) in Den Haag and Rotterdam

For example, following systems are in preparation – Mulhouse, Alicante. The Train-Tram system in Zwickau shows that trains can use tram tracks to get passengers into the city centre as well.

The city of Olomouc is well-suited with its transport and geographical circumstances for Tram-Train application:

- dense regional railway standard gauge network
- most of the routes connect Olomouc with important regional centres with minimal population of 10.000
- standard gauge tram system
- central bus and railway station distant from the city centre and from the other passenger objectives (hospital, shopping centre, university, offices)
- possible tram and train system infrastructure connection

4. Tram-Train route selection

The Tram-Train system could be theoretically applied onto all railway tracks in Olomouc and the surrounding area. The priority of this Paper was choosing one of the routes with the best track condition (low cost, regional benefit) as a pilot project. This has to be profitable, efficiently applied and should be a basis for other system development.

The basic tool for Pilot Route selection was an analysis of current conditions. The analysis was made for all railway routes from Olomouc to the surrounding region (see Table 1) and compared with bus connections (see Table 2).

Tab. 1 *Possible Tram-Train route characteristics*

Route	Stage Olomouc to *(end of the route)*	Length	Supply system	Number of tracks	Track Condition
275	Senice n. H. *(Prostějov)*	19 km	None	1	bad
290	Uničov *(Šumperk)*	29 km	None	1	bad
301	Prostějov *(Nezamyslice)*	20 km	3 kV DC	1	good
310	Hlubočky *(Krnov)*	15 km	None	1	bad

Tab. 2 *Connection and passenger density (bus and train comparison)*

Olomouc to	Connection density per day from/to Olomouc on usual work-day without interchange [3]		Average travel time in minutes [3]			Average passengers flow density by railway in one direction between Olomouc and first station in region/end-station in passengers per day [4]	Population of region excluding city of Olomouc [5]	Passenger flow increase in the case of Tram-Train system application
	railway	bus	railway	bus	car			
Senice na Hané	16/13	7/8	35	50	20	709/659	13.946	middle
Uničov	23/20	15/13	41	56	35	3134/1624	38.387	high
Prostějov	26/26	49/46	23	31	15	1620/1400	54.744	low
Hlubočky	21/21	18/17	30	25	20	2225/1600	10.416	middle

After analysis of current situation a SWOT analysis was undertaken for each railway route (see Table 3).

Tab. 3 *SWOT analysis*

Route	Olomouc to	Strengths	Weaknesses	Recommendation
275	Senice na Hané	• Traffic recovery in the agriculture west part of region • Tram system crossing near Olomouc city centre • The city quarter Hejčín, Řepčín and ironworks connected by tram • More connections per day by using trams with lower capacity • Flat land route	• Infrastructure costs • Small towns (Horka na Moravě and Senice na Hané with 2.000 inhabitants) • Route in bad condition • The consecutive heavy-rail service between Senice na Hané and Prostějov has to be operated • Ironworks employees reduced	This route should be converted to Tram-Train later, but only with low capacity diesel vehicle operation
290	Uničov	• Attractively connecting two regional cities Šternberk (13.967) and Uničov (12.385) with Olomouc • Planned track electrification before 2020 by Czech Railway • Stations situated in the centre of towns or villages • Simple connection to Tram system in Olomouc possible • Sufficient passing points • More connections per day by using trams with lower capacity and operational cost than heavy rail vehicles • Flat land route • Exclusive Tram-Train operation (passenger flow Olomouc – Šumperk should be transferred via Zábřeh na Moravě)	• Infrastructure costs • Direct connection between cities by road – road traffic is much faster at present • The consecutive heavy-rail service between Uničov and Šumperk has to operated	**Route with the best conditions to be a pilot Tram-Train project**
301	Prostějov	• Possible new tram system in Prostějov connecting main station with the city centre • New long-planned tram track connection of suburb Nové Sady with Olomouc centre • Track Olomouc – Prostějov already electrified • Flat land route	• New tram routes construction costs • Route sharing with heavy-rail • Single track • Both cities are individual centres - ,there is not much principal centre to region linking • Direct connection between cities by high-speed road – road traffic is much faster at present • Low population in area without Prostějov city	This route is more suitable for "S-Bahn" model application
310	Hlubočky	• Simple connection to Tram system in Olomouc – Pavlovičky (tram – railway crossing) • Industrial area in Hlubočky • Tourist area in Mariánské údolí	• Route in bad condition • Fewer passengers than on the route nr. 290 • Railway traffic Olomouc – Krnov – (Opava)	The Tram-Train application should be simple by using Diesel tram, but the route specification is not suitable for pilot route because of low passenger flow

5. Tram-Train system implementation

The implementation of a new Tram-Train system is very complex, as a range of diverse fields has to be considered. One of the main tasks is to adapt the model to the local conditions [2]. The Tram-Train system was recommended (see Table 3) for application on the railway route nr. 290 as a regional transport improvement possibility. For efficient application, regional transport increase and future investment return the line has to be useful. This section resolves the tram and rail system connection, terminal points, supply system and service level. The results will be used for construction cost calculations.

6. Connection between tram and railway system

In the basic research three variants of railway and tram system connection possibilities were compared. The Tram-Train makes use in the first variant of railway infrastructure to the railway station. The Tram-Train route is then connected to the tram system in the front of the station. This solution makes possible the use of railway and tram platforms (it brings easy interchange between tram and other trains), but has two disadvantages: the TEN-T conventional line crossing (it makes system dependent on railway service) and difficult line location because of lack of space in the station area. The second variant took account of a TEN-T conventional line bridge over. This variant brings the fastest Region – City connection, but is very expensive and doesn't allow the use of railway or tram platforms in the station area. The third variant links the parallel tram and train routes in Pavlovičky area.

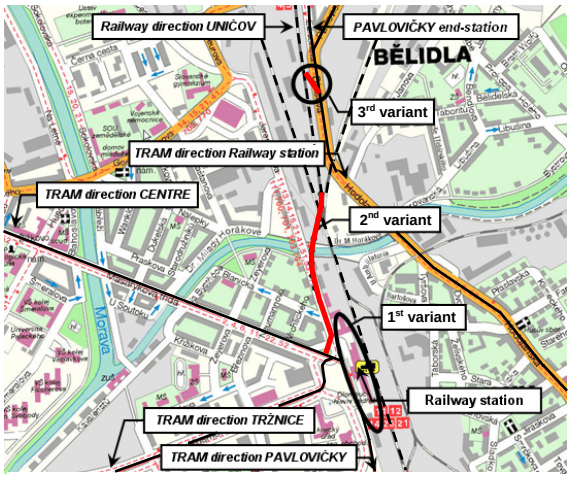

Fig. 2 *System connection variants [6]*

The most important selection criteria were: costs, building difficulty, construction and travel time. All variants are shown in Figure 2. After comparing all aspects the third variant was chosen. This variant has the lowest costs, realisation time and unlike the other variants provides a connection between the region and the central bus station. The travel time will increase by 6 minutes against other variants because of using the tram track Pavlovičky – Hodolany – Central railway station (see Figure 1). As a result, travel time will decrease compared to the current situation. The median passenger interchange time between train and tram is 9 minutes today (including walking, ticket purchase and waiting for the tram or train).

7. Terminal stations allocation

In Olomouc city centre two items have to be resolved: either terminate the Tram-Train system in the city centre, where a single interchange to other city transport lines is possible (here there could be cross-platform interchange, so that no passenger walk is necessary) or terminate the Tram-Train in the surrounding area (Nová Ulice – hospital, urban settlement, Neředín – cemetery, university collage, shopping centre). The termination variants on the other regional routes (especially 275 to Senice na Hané) were not considered because of high infrastructure cost.

To solve this problem SWOT analysis was used, too. After comparing all aspects, termination in the city centre was recommended, because:

- interchange available to all tram lines and most bus lines
- utilisation of hold yard on the Náměstí Hrdinů as an end station
- saving of at least one new tram-train vehicle in service (because of shorter line)

In the region there are only two possibilities to end the system according to population and passenger flows: Šternberk and Uničov. The terminal point in Šternberk will save the track modernisation cost (Šternberk – Uničov is another 12 km) and the number of vehicles, but passengers traveling from/to Olomouc to/from Uničov would have to change (at present all regional connections terminate in Uničov). The passenger flow between these cities is approximally half of the Olomouc – Šternberk flow, but this is still important. Bringing the Tram-Train system to Uničov will help serve all this area and bring better connections to Olomouc.

8. Supply system

The tram system in Olomouc is supplied by 600V DC and the regional track nr. 290 to Šumperk is non-electrified. The electrification of this track is planned before 2020 by Czech Railways. According to this plan the tram supply system (750V DC) would not be used, like in Chemnitz for Tram-Train. The other remaining variant (3 kV DC and Diesel Tram) have been compared with emphasis on costs, ecology and implementation difficulty. After good expeirence with Diesel Trams in Nordhausen and Kassel this system was recommended, because: no infrastracture cost, no implementation time required, ecological service with alternative fuel, in case of later electrification the rolling stock could possibly be used on other routes (to Senice na Hané, for example).

9. Service definition

The current passenger traffic between Olomouc and Uničov would be fully substituted by Tram-Train operation. The passenger traffic (Brno) – Olomouc – Uničov – Šumperk – (Jeseník) (two pairs of fast-train per day) should be operated faster by using routes nr. 290 to Zábřeh na Moravě and then nr. 291 to Šumperk. The regional heavy-rail traffic from Uničov to Šumperk remains with guaranteed interchange possibility to the Tram-Train system. The freight traffic (at present 3 pairs every day) will be operated at night (no track sharing with Tram-Train at the same time).

As a result the operation on the route Olomouc – Uničov should be a single mode (like in Chemnitz). It brings lower demands for vehicle safety construction, better conditions for time-table planning, no delay incurred by railway traffic and the use of low-floor rolling stock (railway platform rebuilding required).

10. Frequency, number of carriages

At present approximately every 55 minutes there is a railway connection between Olomouc and Uničov. Because of lower Tram-Train vehicle capacity and in order to provide attractive connections, a more frequent service would be operated. Due to half passenger flow density between Šternberk and Uničov the following frequency in the peak is recommended: Olomouc – Šternberk every forty minutes and Olomouc – Uničov every forty minutes which means Olomouc – Šternberk service every twenty minutes. The number of vehicles was calculated from the service scheme (see Figure 3), which was optimised to require the least number of vehicles and lowest circulation time. The system needs five vehicles (in total seven with two reserves).

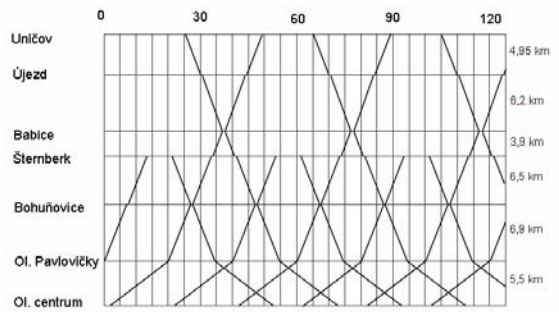

Fig. 3 *The service scheme*

11. Constructional measurement

In this chapter all necessary construction for TramTrain application is defined:

- Track reconstruction to increase maximum speed to 100 km.h-1
- Level crossing signalling installation: according to norm ČSN 736380 all crossings (even railway-forest road) have to be secured.
- Platforms: as in Saarbrücken the Tram-Train system in Olomouc should be fully accessible low-floor from the beginning. The use of platforms 350 mm high is recommended.
- Signalling (central control station in Olomouc main station, full interoperability provided by using ERTMS/ETCS)
- Stations and stops (quality access communication, P+R, B+R, barrier-free access, information boards with actual train position, timetables, ticket machines)

12. Technological-economical evaluation

Infrastructure cost

The route nr. 290 to Unicov is in a bad condition today and modernisation will certainly be required in the next few years for regional transport service security.

The Tram-Train construction cost has to be compared with modernisation cost, because the current service with modernized infrastructure, improved frequency and integration in the IDSOK could increase transport quality in region as well. Both of the costs were compared in Table 4.

Tab. 4 *Tram-Train construction and railway reconstruction costs [8]*

Construction	count, length	price per unit in thousands CZK	Tram-Train cost in thousands CZK	Railway cost in Czech crown [Kč]
Rails reconstruction	28 000 m	20/m	560,000	560,000
Station reconstrution	4 stations	20,000	80,000	80,000
Stop reconstrution	5 stops	2,000	10,000	10,000
New stop (Bohuňovice)	platform	1,500	1,500	None
New passing point (Babice)	2 railway switches	3,000/unit	6,000	none
	100 metres	20/m	2,000	
Physical connection between Tram and Railway systems	1 railway switch	3,000/unit	3,000	None
	3 tram switches	1,000/unit	3,000	
	tram cross	350/unit	350	
	rail 20 m	20/m	400	
End-station in the city centre	3 tram switches	1,000	3,000	None
Level-crossing signalling	20	7,000/unit	140,000	140,000
Station signalling	9	10,000	90,000	90,000
ECTS System – track equipment	28 000 m	1/m	50,400	None
ECTS System – vehicle equipment	7 vehicles	750/unit	5,250	None
Vehicles (not counted)	7	60,000/unit	420,000	Possible
Total cost exluding vehicles in million CZK			**954,900**	**880,000**
in million EUR			**34,100**	**31,450**

The Table 4 shows that there is minimal difference between modernisation cost required in the next few years and Tram-Train construction cost. The Tram-Train system as shown in other already operated cities has a big regional contribution compared to heavy-rail. The Tram-Train system in the Olomouc region would result in: direct connection between Olomouc centre and region, the increase of passenger flow between the region and Olomouc, the decrease of individual transport, new business and industrial areas in the region, better environment (less noise and pollution), modern stations and stops as new centres of villages or towns. As a result Tram-Train system will cost more than modernised regional heavy-rail, but it brings better potential for regional sustainability and transport quality at the same time**.**

Service cost and profit

Service costs will consist of traffic route charges, depot expenses, fuel, energy, staff salaries and vehicle maintenance.

Service profit will consist of fare and regional office subsidy. The effort of the Regional transport Company should be economically balanced. Company could have other income activities: freight traffic operation, advertising (on/in vehicles, at stations,

and on timetables), P+R and B+R service, bike hire office or regional travel agency (with Tram-Train use, of course). The firm cost and profit study would be elaborated in another paper.

13. Control management

After studying other Tram-Train system management options, the "Chemnitzer model" was recommended for system management in Olomouc. The Regional Railway Company will be the operator shared by three main operators in the region (see Figure 4). The Tram-Train system should be fully integrated into IDSOK.

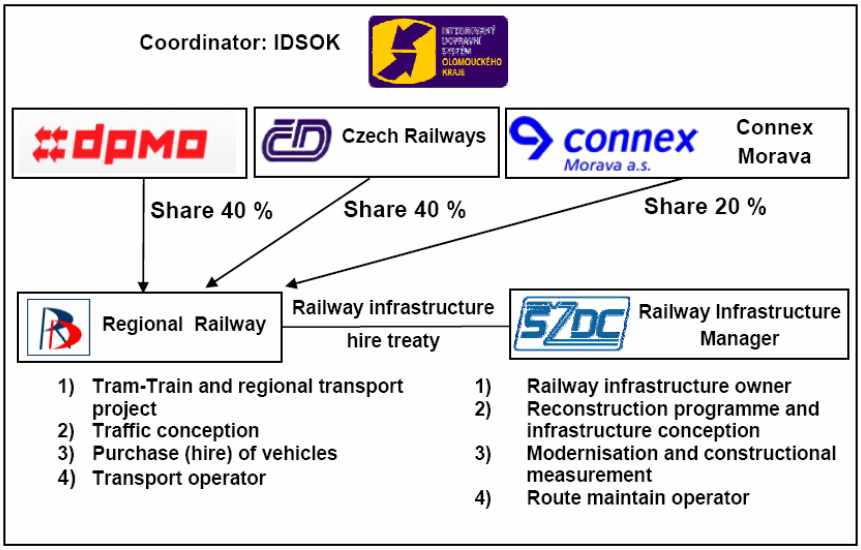

Fig. 4 *TramTrain system management [7]*

14. Recommendation

Realisation steps:

- Tram-Train system project preparation (including cost and profit study)
- Finance project
- Regional transport company establishment and its organisation structure
- Putting new vehicles out to tender
- Route reconstruction
- Operational organisation (train diagrams, staff requirements)
- Promotional Campaign
- Service introduction

Methods of finance

- state and regional subsidy
- long-term credit
- European Union support – there is possibility of using of Structural Funds in particular Operational Programmes Infrastructure. More information is available on the European Union Funds web sites [9].

15. Conclusion

This paper shows that the Olomouc region has good conditions for Tram-Train application as a tool for regional transport improvement. The pilot-route Olomouc – Uničov was chosen after regional railway current condition analysis. The cheapest, quickest but fully operational solution was proposed on this route. In the near future investment in the regional railway infrastructure will be necessary. This investment should be used for Tram-Train application. It brings higher construction cost, but better potential for regional sustainability and transport quality at the same time. The problematic of the Tram-Train application in Olomouc region was solved for the first time. The paper outlines the possibilities and first steps of successful application. The continuation in this problem area research is planned, especially with support of demand transport modeling software (Omnitrans).

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Resumé

THE TRAM-TRAIN SYSTEM APPLICATION IN OLOMOUC REGION

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Při analýze dopravních vztahů mezi městem Olomouc a obcemi regionu ležících na jednotlivých železničních tratích byla porovnána nabídka spojů, jejich četnost a doba jízdy v železniční a autobusové dopravě.

U železniční dopravy byly vyčísleny proudy cestujících mezi městem Olomouc a regionem pro jednotlivé tratě. Na základě velikosti přepravních proudů, stavu tratí a možností nárůstu cestujících byla vybrána železniční trať vhodná pro aplikaci systému Tram – Train.

Na vybrané železniční trati byla komplexně řešena podoba systému Tram – Train při snaze o minimalizaci časových a finančních nákladů pro realizaci. Na základě vyčíslených nákladů a přínosu oblasti bylo provedeno zdůvodnění možné realizace.

Summary

THE TRAM-TRAIN SYSTEM APPLICATION IN OLOMOUC REGION

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By analyzing the transport connections between Olomouc city and the villages situated in the region and along the line of the local railways, the offer of railway and regional bus connections, their frequency and journey time was compared.

For the railway services the flows of passengers between Olomouc and the region were evaluated for each route. On the basis of the strength of passenger flow, condition of track and possibility of passengers increasing in the future the route for application of the Tram – Train concept was chosen.

On this designated route the form of Tram–Train concept was found to have low financial and time expenditure for infrastructure construction. On the basis of an evaluation of the costs and the sustainability of the proposal within European Union guidelines, the realisation of a Tram-Train project appears justified.

Zusammenfassung

DIE TRAM-TRAIN SYSTEM VERWENDUNG IN DEM OLOMOUC KREIS

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Der Artikel beschreibt die Tram-Train System Verwendung im Olomouc Kreis. Das Angebot des gleichzeitiges Verkehrs (Regionaleisenbahn und Bus) war vergleicht. Der Fahrgästestrom war für die Eisenbahn abgeschätzt.

Nachdem, mit der Rücksicht auf Fahrgästestrom, Infrastrukturzustand und mögluche Fahrgätstesteigerung, der Koncept des Tram-Train systems für die Strecke war ausgewählt und gelöst .