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INTEROPERABILITY BETWEEN URBAN RAILWAYS – THE HIGHEST LEVEL OF INTERMODAL INTEGRATION

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Abstract: Nowadays the most often used concept in urban planning is the *integration*. The formerly strict borders within and between the heavy and light rail networks are disappearing. Many interoperable systems emerge to provide passengers with door-to-door services, knowing that seamless mobility is the key of attractive public transportation. This paper briefly introduces the current and planned integrated, interoperable urban rail systems, including the best practices: StadtBahn, S-Bahn, RER, Crossrail, Passante, Cercanias, the Karlsruhe model, and the Japanese-style “through operation”. Many examples prove that there are no unbridgeable barriers between railway types. The main focus of the paper is on interoperability between metro and railway lines. This is a cost-effective method of extending the urban rail network, and integrating the conventional suburban railways into the urban railway system. As a case study, the ambivalent railway development plans for Budapest are discussed.

Key words: Interoperability, Urban railway, Integration, Metro, Cross-city Tunnel

1. INTRODUCTION

During the second half of the 20th century, while being busy planning new metro lines, many cities have discovered the urban network of the national railways as unexploited corridors for urban transport. By today the suburban railway network is completely integrated to the urban network in many cities, however, there are still cities in which tracks are completely unutilised, or even seen as obstacles for urban development..

This practice may no longer be maintained. Most international organizations force integration in public transportation, as this is the only way to provide efficient and attractive public transportation. The alliance of European Metropolitan Transport Authorities (EMTA) states “Metropolitan areas usually have several public transport modes in operation (bus, tramway, metro, regional rail services, sometimes water services). … Integration of modes and of operators (physical integration of services, integration of fares and of information, etc.) is therefore a fundamental task of transport authorities so as to be able to offer travellers a seamless trip”. UITP also promotes the idea of integration: “Unlike motorized individual transport, which can be used from point of origin right through to destination without a single transfer, the available public transport services will often comprise several different legs of transport modes, between which a passenger is obliged to transfer in order to reach their destination. This is a systemic and, at the same time, competitive disadvantage compared to motorized individual transport if PT is unsuccessful in bringing about the greatest possible integration between its individual subsystems”.”[Only] *seamless* - and, therefore, unimpeded - service (…) is capable of competing with motorized individual transport” (Meyer, 2003).

This paper examines how far the authorities and engineers have gone in railway integration, especially in the field of the integration of the national railways into the urban transportation system. The focus is on the *physical integration of railways and metros*, as the author believes that the future of urban transport is based on the “seamless” integration of these classic and well-known types of railways. Tariff systems and other kinds of integration between other modes are out of the scope of this paper.

2. TYPES OF RAILWAYS

There are 3 basic types of railways from the point of view of integration. The borders between these types are not always clear, and basically there is at least one exception for each characteristic. Hence, each sentence in the following descriptions should have a word expressing uncertainty, such as basically, usually, or typically. For the sake of simplification these words are omitted.

2.1 National Railways

In this paper the term *national railways* is used for the heavy railway network, which was built for interurban, long distance purposes, no matter if it was/is operated by the national railway company or by private companies. The first „national railway" was opened in 1825 between Stockton and Darlington, followed by the boom of railway construction in the late 19th century, and a decline in the network length in the 20th century. National railway lines are originally not designed for intra-city travel, their alignment in the bigger cities serve the industrial rather than the residential areas. Comparing to urban railways, the maximum number of trains per hour is low; the smallest unit of time used in scheduling is 30 seconds or more, and the lines ar often used for freight transport. Locomotive traction is more widespread than multiple units, the radius of the curves are long, gradients are low, electrification – if exists – has high voltage. Stations are far from each other; trains have ineffective accelerating and braking characteristics. The operator is the national railway company or its successors; however, some lines had been built by private railways, which were later nationalized. National railways form a worldwide network, but interoperability is not always possible due to the different track gauge, electrification method, safety systems, regulatory differences, etc. There is a strong political will to promote interoperability, but the national railway companies are not motivated enough for introducing it.

In the developed world, most national railways are in crisis. Especially in Europe, national railway companies are seriously loss making, meaning a very heavy burden on the national budget. The share of the national railways in the market of non-individual travel is very low (less than 10%) and even decreasing. In Eastern Europe, this figure is higher (around 20%, depending on the country), however, also decreasing. Freight transport in Europe is in the black, just like in the U.S., however, unlike in America, where the importance of freight transport is high, in Europe the lossmaking passenger transport is in the focus of national railway companies. In Japan, the situation is reversed; there the freight services are unprofitable, so railway companies earn their living from the passenger services in the high population density areas.

More and more national railway companies discover that the breakthrough (or survival) point for them is the integration into the urban public transport system of big cities. Not only because urban areas are good venues to be in headlight enough to receive huge subsidies, but also because the non-blind railway managers know that „alongside with high-speed intercity services, good urban services are probably the only passenger lines that will survive the coming century" (Suga, 2000). It should be kept in mind in those developing countries, which are now busy planning and constructing classic rural railways.

2.2 Metro

Metro is the term used in this paper for underground railways, or subways in U.S., which serve the urban travel needs of cities. These railways have neither freight traffic, nor long distance services; run on separate right-of-way, underground, elevated or grade, and rarely cross the city borders. Municipality-owned or -supported companies operate the systems; projects are also financed partly by municipalities. Trains have very high frequency, 1 to 10 minutes, use high platforms and EMUs, with good acceleration and breaking characteristics. There are new metro technologies, which use special tracks, different from classic railways, (VAL, People Mover, monorail, etc.), these are out of the scope of this paper, as these cannot be physically integrated/connected with other railways.

The first metro line was opened in London in 1863, but the real boom of metro construction started in the early 20th century in today's developed countries. By the 21st century, most cities in the developed world have finished their trunk metro-systems, solving the capacity problems of urban public transportation, and now the focus is on the quality of the service, however, developing countries are busy constructing new metro lines to catch up with the massive travel demand and to promote huge housing developments.

2.3 Tramway, Streetcar, Light Rail (LRT)

Light rail is the contemporary version of the tram, or streetcar in the U.S. The classic tram runs on street level, operates with short vehicles, not more than 3 of them may be coupled. (Unfortunately in Southern-East Asia the term „light rail" is often used also for some people mover and automated rail systems, causing confusion.) The word „light" refers to the lightness of the track and vehicles. The main technical characteristics distinguishing the tramway lines (either conventional or upgraded) from the heavy rail lines (national railways or metro) are in the shorter curve radius, steeper gradients, less or even no safety signalling built next to the tracks, and the often non-separate right-of-way.

The origin of light rail systems is the horse drawn urban rail, which used to be operating in the centre of the cities on street level. These lines were later electrified and operated as tramways (streetcars in the U.S.). The tramway construction was booming in the early 20th century, and the first lines were built to connect the isolated national railways termini establiched at the edge of the city centre, and also to serve the weekend leisure travel heading out of the city. Many lines were built also for commuting purposes to serve the newly built industrial and residential areas.

The capacity of tramways proved to be insufficient as the cities and the individual motorized transportation were growing, and many tramways were replaced by metro lines. Many cities have completely closed their formerly huge tramway network as the metro services were expanding.

Nowadays the renaissance of the tramway can be seen, in the form of, and under the name of light rail, however, the economic performance of the newly built LRT projects are not always a success story, especially in the U.S. One of the biggest disputes nowadays among urban transportation planners is about the advantages and disadvantages of LRT projects versus bus services. This is out of the scope of this paper, as the focus is on heavy railways.

2.4 The need for new railway solutions

The last 40 years of the 20th century brought the need for new kind of railways, as the travel needs, and also the motorization level has changed. While until the first half of the 20th century urbanization was the main trend, resulting in very densely inhabited cities, in the second half of the century *suburbanization* is the key trend. Residents leave the congested city centres and move to the suburbs into areas with much higher living standards and better environment. However, the jobs are still located in the city centre, so people have to commute back to the city on a daily basis. This resulted in a shift from concentrated urban passenger flows – which can be served by metro very well - into the more disperse and regional level travel demand.

The above-mentioned 3 basic railway types cannot meet the needs arising from suburbanization and regional commuting. The national railways cannot serve the sprawling urban areas well enough, because the lines have only few stations, trains are not frequent and reliable enough, and cannot carry the passengers directly into the city centre. Hence, the passengers have to transfer, mainly to metro (or tram or bus), and this is a major inconvenience. Extending the metro lines to the suburbs is very expensive, especially because metro lines cannot easily be built on the surface. The other problem is the capacity: metro is designed as an urban railway to carry huge amount of passengers, but huge amounts cannot be found in the suburbs far from the city centre. So most cities have unfinished metro lines, which will never be finished the way they were planned, and their temporary terminus will become a permanent one, forcing users to transfer every time. The construction of light rail is also expensive, and has low cruising speed, so LRT is not the best solution for regional commuting, either. To solve this problem, various intermediary, or middle-system railways emerged by now.

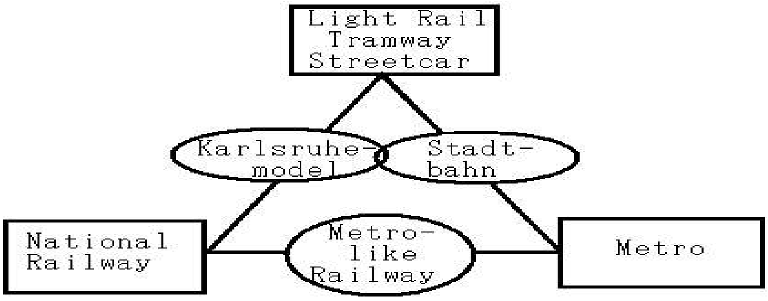

Figure 1: Basic Types of Railways and Middle System Railways

2.4.1 Stadtbahn

The Stadtbahn (literally "city rail") is a middle system between the tramway (light rail) and the metro. A German-originated urban rail system, unifying the advantages and not the disadvantages of tramways and metros. Traditional tramway lines have been being upgraded to Stadtbahn level since the 1970s, by building cross-city tunnels for the bundled tram lines, raising frequency and cruising speed, and providing better access to the city centre. Outside the city center trains still run mainly on the surface on separate right-of-way or in the axis of the roads, with many level crossings.

Figure 2: The Hanover Stadtbahn in the Cross-city Tunnel, and at its Entrance

Due to the underground stations in the city center, the system is often marked with the U letter referring „underground", though most of the tracks of the Stadtbahn system are on the surface. The Stadtbahn is a good solution only in cities having extensive urban rail (tram) network. In the process of upgrading tramways to Stadtbahn, the track gauge often has to be widened to standard 1435 mm and platforms to be raised. Hence, during the transition some sections are mixed gauged and some stations have both low and high platforms, or trains need to have special steps to allow boarding at both high and low platform stations and stops. Stadtbahn system is usually not interoperable with the national railway. When the underground section of a Stadtbahn system is designed so that it can be used by full metro trains later, it is often referred to as *premetro*.

2.4.2 The Karlsruhe model

The Karlsruhe RegioTram is a middle system between the tramway (light rail) and the national railways (DB), introduced in 1992. Dual voltage tram vehicles have been operating on national railways, stopping at additional stops along the suburban sections, offering more frequent services, and what is probably the most important, *connecting the suburbs directly with the city center, eliminating the transfers between the different modes*. The Karlsruhe system is also called Stadtbahn, however it represents not an urban (Stadt), but a regional level interoperability. The first interoperable line between Karlsruhe and Bretten is one of the most successful transportation projects in the 1990s, as the annual weekday ridership increased from half a million to more than 2 million between 1992 and 1993, after the introduction of the Stadtbahn services. (Voskuhl, 1995)

Figure 3: The Karlsruhe Stadtbahn at the Hall of the Main Railway Station next to an Intercity Train, and on the S5 Line, next to a Regional Service

2.4.3 Metro-like railways

These are middle systems between national railways and the metro. The best practices are known as S-Bahn, RER, Passante, Cercanias, and the “Japanese-style through operation”. Their common characteristics can be summarized as follows. These systems have evolved by *integrating the national railways into the urban system*. There are two main approaches to do so, the extending-out, and the cross-city tunnelling. When extending out, a formerly built *metro line is being extended using the national railway tracks*. Cross-city tunnelling means *connecting two suburban radial lines under the city center*. Both main approaches require compromises in solving the problems arising from the many technical and organizational differences, but it is worth making the efforts. Suburban railways can never be well integrated into the urban network if the suburban trains terminate at a hidden sidetrack at dirty railway termini located at the very edge of the downtown area. Suburban services have to operate right into the beating heart of the cities.

3 METRO-LIKE RAILWAY SYSTEMS IN THE WORLD

Trains on metro-like railways are usually EMUs, running frequently and directly into the city center, usually on lately built tunnels or quadrupled tracks, and serving more stations than the national railways. These systems are briefly introduced in the following sub-chapters.

3.1 Europe

In most European cities all the three basic types of railways can be found, and it made Europe the cradle of various integration solutions. There are no 2 cities with the same geographical, operational, organizational and network circumstances, so each city has unique solutions, however, some adaptable models can be found. The best-designed integrated tramway-based urban rail systems were built in Germany (Stadtbahn), however, in terms of railway-metro interoperability, the best practices can be found in Paris (RER), in Spanish and Italian cities (Cercanias and Passante), and in the cradle of the metro, London. Other good practices are also mentioned at the end of this chapter.

3.1.1 London – a little bit of everything

London is not just the birthplace of the metro, but also the first city in which metro services started to operate on national railway lines, when the services of Bakerloo line were extended from Queen’s Park to Willesden Junction from 10th May, 1915. Today – after few years of disruption – metro trains run even further, using their shoes on the third rail, while the Silverlink services (North London Railways, using former national railways tracks) utilize the catenary. The Richmond branch of the District line of the London Tube (metro) is also a joint operation with Silverlink services, the tracks between Gunnersbury and Richmond used to belong to the national railways.

The East London line, which can be considered as the oldest metro in the world, as it uses a tunnel built for pedestrians in 1843, will be extended on former national railway lines. The extensions are referred to as a “low-cost railway construction”, as these will use mainly existing, partly disused railways, which will be upgraded and converted into a metro-like service. The main goal is to improve interchange and congestion, and integrate the East London line with main line services. Based on the official homepage of the ELLP, the main objectives of the East London Line Project as presented in the ‘Statement of Case’ of 2000 are improving PT accessibility, reducing the need to interchange and thus providing some congestion relief to central London rail termini and on radial routes into central London, integrating main line rail services and the Underground, and making full use of the valuable but underused river crossing. (ELLP, 2000)

The biggest interoperable rail project in London, however, is the Crossrail. This will be a cross-city tunnel, which will connect the southern and northern suburban rail lines between Paddington and Liverpool Street. The trains capable of carrying more than 1000 passengers in the tunnel will have a frequency of 2 and a half minutes in the rush hour, hence Crossrail will be one of the busiest metro service in London, delivered in a heavy rail environment. It will be London’s RER, expected to open in 2012. The trains will have toilets; will run at 160 km/h on the surface and at 95 km/h in the tunnel. Platforms on the underground section would be 283 metres long and 5.5 metres wide, both values are the double of the typical London platform size. The entire route will use overhead electrification: wires will be built above some to-be-connected existing railways, which have third rail power supply.

The project caused serious debates about the alignment, and other related issues. There were fears that Crossrail would attract many passengers from partly parallel metro lines and it would harm the privatisation prospect of those lines. Due to the official homepage of Crossrail the project is expected by the Corporation of London to deliver an annual profit of 800 million pounds in 30 years. The benefit/cost ratio is calculated between 1.7 and 2.5, annual number of passengers is 187 million, and 600,000 on a weekday. Crossrail brings 15% increase in the seating capacity in Central London.

There is another big cross-city tunnel project in London, the Chelsea Hackney/Express Metro from Wimbledon to Epping and Woolwich, also known as the Chelney line, which would ease congestion on the Victoria line. The future of this metro project is uncertain, and might be replaced by a rail-based Crossrail 2 line, however, a study considers the original Chelney line project feasible only if Crossrail (1) is not built. (Rowland 2001) The London Underground proposed a cheaper route for the Chelney line, using not metro, but mainline loading gauge, fewer stops, and sharing tracks of North London metro line in a short section, but due to physical constraints at Piccadilly Circus, the traditional Tube-gauge is supported. The name of the line would be King's line.

Even the tramway has returned to the streets of South London as a light rail. The Croydon Tramlink network - built partly on old national railway alignments - was opened in 2000.

3.1.2 Paris – The RER

Paris is another city with very good solutions in the field of railway-metro integration. By the end of the 60’s Paris already had built a very extensive, but slow metro system in the core city, and the attention was turned to the direction of the suburbs and the speeding up of travel. This led to the construction of altogether 5 „RER” lines, with a huge, 7track underground transfer station at Chatelet. This Regional Express Network connects various suburban lines with the opposite side of the city through cross-city tunnels, similarly to the Japanese style through operation. The main concept is common, however, there are important differences in the operation circumstances of the lines.
Line A is a masterpiece of RER. It provides very fast access to the suburbs, with only five stops within Paris. Two of its branches out of Paris belongs to the national rail (SNCF) and tracks are shared with conventional suburban trains, however, the rest of Line A is operated by RATP, the company that is responsible for all other means of transport in Paris. Line B has

more stops in the city centre, travel speed is low, which is further decreased by the frequent delays. The southern part of the line belongs to the RATP; the northern one to SNCF, where some express RER services may use the long distance tracks. Line C has some under-utilised sections and its routing is not attractive. The line is SNCF-operated, and the tracks in most sections are used by conventional trains, too. Line D is sharing its tracks with other rail traffic, too (except for the underground section in central Paris) and even uses some section of RER B. In the outer sections some parts of the former railways that were integrated into the RER system were diverted to serve the residential areas better. Line E is designed to connect the l'Est and Saint Lazare railway termini under the ground. Currently only the eastern section is in operation, in most of its route sharing tracks with long-distance trains.

In other French cities, similar solutions in smaller scale exist. Line C of the Toulouse metro is a national railway line, integrated into the tariff system. Marseille has a tram (no. 68) in a cross-city tunnel, similar to Stadtbahn

3.2.3 Cercanias – the Spanish contribution to the future of railways

Madrid is famous for having built the most metro lines during the 1990s in Europe. However, its achievement in the field of railway integration, the upgrade of the suburban lines to metro level, and the building of cross-city railway tunnels, i.e. the creation of the Cercanias network is even more important.

"Use of the existing, mainline rail network in areas near large towns and cities has made the construction of large infrastructures unnecessary, with the corresponding savings in time and resources. It has only been necessary to complete specific stretches of railway with a view to expanding capacity and improving the functionality of existing services. The drawback with this approach, however, is in having to share the rail infrastructure." (Carrillo, 2003)

"The five key axes of Cercanias is the use of standard railway network as the starting point for metropolitan network, a radical approach, based on practical experience, to solving functional problems in the commuter train system, implementation of specific technologies in metropolitan transport that had been lacking in the traditional railway system, a strictly business-oriented approach to the management of the organization responsible for the transformation, and a design of and compliance with a stable economic framework for funding both the investment and operational aspects of the activity" (Carrillo, 2003). In practice these mean the upgrade of railway network, extending platforms, widening the loading gauge, building cross-city tunnels, and turning the system to a metro-like operation.

The Cercanias became a very important mode of transportation in other cities of Spain, too. In Barcelona, the Cercanias lines complement a very extensive metro network, offering further 4 cross-city lines. Some metro lines utilize the national railway alignments, too, running parallel to them (Line 1), and sometimes mixed with suburban trains (Line 6). In Valencia, the metro network is based on a 100 years old narrow gauge suburban railway network, which was upgraded to a network by the opening of a cross-city tunnel in 1988. The tunnel connects two lines in the north with one in the south. The national railway also plans to build a cross-city tunnel for the Cercanias services. Even Bilbao has its Cercanias system, which got a great upgrade when the northern Muskiz and Santrutzi line were re-connected with the southern Orduna line, by the rebuilding of the formerly existed connection. Hence, these lines are interoperable again, and provide a new cross-city route. Bilbao has other type of railway integration, too. Metro line 1 uses former national (Basque) railway alignment in its outer section, while in the city it runs in tunnel. Line 2 runs mainly parallel to a national railway line, however, it is sometimes diverted to serve the city centres.

3.2.4. Italy – The Passante

Most of the big Italian cities plans to build a cross-city tunnel for the national railways, to allow metro-like operation. Genova metro was built so that it can utilize some tunnels previously used by either trams or national railway. There are 2 very important suburban lines operated by FS (Italian Rail), which will be upgraded to metro standard by the end of the decade. In Milan there is a tram based, Stadtbahn-like metro system. The importance of physical integration is proved by the fact that those tramlines, which are not integrated into the metro, are close to closure. The first part of Milan's Passante (Italian name for a cross-city tunnel connecting formerly existing suburban railways and providing metro-like services) was opened in 1997. In Turin the national railways is building the Passante, which will be a north-south oriented cross-city tunnel, and trains will run through it in every 5 minutes from 2006. There will be another cross-city tunnel for light rail, being upgraded from Tram No. 4 as a Stadtbahn.

3.2.5. Germany – the home of S-Bahn and Stadtbahn

Berlin has two metro systems, the U-Bahn and the S-Bahn. While the U-Bahn can be considered as a classic metro, the S-Bahn system cannot deny its strong relation with the national railways, however, it is physically independent. The S-Bahn network is very similar to that of JR East in Tokyo: it offers a loop line and a diagonal line on the surface (mainly elevated), plus another diagonal line in tunnel. Much percent of the S-Bahn network was built parallel to the national railways, but the different power supply mode separates the two systems (S-Bahn uses third rail, like classic metros.)

The Hamburg S-Bahn is similar to the Berlin S-Bahn in being completely separated from the conventional national railway traffic; however, it often runs parallel to it. The system itself can be considered as another metro network besides the U-Bahn system. In the future the strict separation of S-Bahn and national railways will diminish, as there are plans to extend the network from Neugraben to the southeast using the DB (German Rail) tracks. As the Hamburg S-Bahn uses third rail supply, it would mean the employment of dual system trains, which can operate both from third rail and catenary.

Figure 4: S-Bahn in Berlin (Potsdam), and in Hamburg, beyond DB Tracks

In other big German cities, the S-Bahn shares track with regional services. Frankfurt has converted one cross-city tunnel originally built for trams into a metro tunnel in 1980. Ten years later a new cross-city tunnel was built, in which separate tracks are laid for S-Bahn services and U6-U7 metro lines. In Munich the cross-city tunnel for S-Bahn operation was opened in 1972. Trains run on the butterfly bow shaped network, and are operated by the national railway (DB), with a frequency of 2-3 minutes in peak hours. Just like on the S-Bahn in Copenhagen, the basic frequency of each branch is 20 minutes. Stuttgart has extensive, and almost completely upgraded and gauge-widened tram-based Stadtbahn system, complemented by a cross-city S-Bahn line, which cuts short the route from the western suburbs to the city centre. In the Ruhr-area, the densely populated, but independent cities are connected by criss-crossed S-Bahn services, sometimes diverted into tunnels to serve the city centres and residential areas better than the original national railway line does. There are S-Bahn services around almost all the German cities, but many of those operate only on DB lines.

3.2.6 Other good practices in Europe

In Amsterdam the metro often follows the national railways (NJ) alignment, however, there is no through operation. At some stations cross-platform transfers are provided.

Athens has built a metro and suburban lines for the 2004 Olympics, and these share tracks between Stavros and the airport.

Figure 5: New and Old Rolling Stock on Copenhagen S-Bane

Copenhagen built a very convenient, curved butterfly shaped urban-suburban railway system called S-Bane, based on the national railway lines, opening its first section in 1934. The boundled common section of all lines serve the city centre and the main railway station every 1-5 minutes, on partly elevated and underground tracks, laid parallel to but completely separated from the long distance tracks. The S-bane branches are served at least every 20 minutes. The system is so extensive and serves the city so well that the first section of the city's automatic metro project was opened only a few years ago, and is rather an urban development than a transportation project. The metro took over a short section from the S-bane alignment, which will be re-routed on an unused freight line.

Istanbul has started to build its own cross-city tunnel for metro-like railway operation called „Marmaray", which is also a cross-Bosporus tunnel, linking Europe and Asia. As a connecting project, many national railway lines at both side of the tunnel will be upgraded for metro level. The upgrade means laying further tracks, building new stations, improving signalling, and raising speed to allow frequent metro-like operation.

Lisboa's special feature in the venue of railway interoperability is the urban-suburban line, which is operated by a private operator called Fertagus. The company won the tender and was granted a concession for suburban public passenger transport on the new North-South line, which connects Lisboa with the southern side of the Tagus River. The company pays usage fee to the REFER (Portuguese Rail) for the use of their infrastructure.

The Newcastle metro has many special features. From the point of railway integration, the most important is that most of the network was converted from former national railway (BR) lines. A 6 km long tunnel created a busy urban network out of the low demand or even abandoned railways. In some sections metro trains share tracks with local „heavy" trains.

Oslo railways have a very unique history. The Tunnelbane (metro) is a network of formerly existing suburban lines and a cross-city tunnel, which connects them. The tunnel was opened gradually, as the to-be-connected suburban lines had different technical characteristics, and these had to be more or less unified. Finally, since 1995 the system has been using trains capable of operating with both third rail and catenary power supply. On other lines the power supply was changed to third rail.

Warszawa was one of the first cities that built a cross-city railway tunnel. It was opened in 1925, runs in east-west direction, and used not only by the national railways, but also by an urban light rail line. It served the city so well, that the first real metro was opened only in the 1990s.

3.2 Asia

In most Asian cities the role of mass public transport is different from that of the developed countries. In big Asian cities mass crowds have to be transported, and huge land developments and housing projects have to be supported by mass transport projects. While cities like Tokyo and Singapore exercises restrictions on car ownership or use, and concentrate on transit projects, other cities favour car use, making the generalization difficult.

3.2.1 The Japanese-style model of metro-railway through operation

Tokyo is the best example in the world for both the interoperability of metro and suburban railways, and for the integration of the national railways into the urban transportation system.

The latter network, operated by JR East, the successor of the former Japanese National Railways in the Kanto area, provides the skeleton of Tokyo's transportation system, and JR trains carry more than 40% of the passengers in the Tokyo Area.

The 34.5 km long JR Yamanote loop service is a completely urban rail line, which encompasses the traditional core Tokyo, linking the main sub-centres of the megalopolis on the surface. In the first half of the 20^{th} century, only tramways were allowed within the loop, hence the private suburban railway companies built their termini at certain stations of this loop. As the population and congestion of the city grew, metro lines gradually replaced the tramways in the inner city. The construction of the first two*, conventional* metro lines brought serious congestion at the interchanges between suburban rail and metro. To cure this problem, since 1953 the subway policy has been promoting the "through operation" between suburban railways and metro lines. Since then, except for a new linear motor technology based metro loop line, all new metro projects have been built as cross-city tunnels allowing suburban trains run directly into the CBD, and metro trains operate on suburban railway lines, too, on a reciprocal basis. The metro lines are usually connected with the suburban railways few stops outwards from the inner terminal. Direct services from the metro usually operate as local services on the suburban line (most of them are private railways, but 3 JR lines are also involved in the system), while the express services use the traditional terminals adjacent to the JR Yamanote line.

Creating through-operation was difficult in many cases, as the technical characteristics of the to-be-connected lines were very different in terms of signalling, track-gauge, loading gauge, etc., and the metro tunnels had to be built wider because of the overhead catenary. However, direct connection to the city center is a very attractive service for commuters and contributes to the relatively good modal share of public transportation in Tokyo.

Other Japanese cities also took over the concept of through operation from Tokyo, but none of them used it as widely as the capital city. In Osaka, only 2 of the 8 metro lines allow the classic type of through operation. The eastern section of the Chuo line was built by Kintetsu railway, and the Sakaisuji metro line is connected with Hankyu Railway's Kyoto and Senri lines. The transfer point between the Kyoto line and the metro is Awaji station, which allows convenient cross platform transfer between trains running in the same direction.

Figure 6: Hankyu Awaji Station and the Keihan Metro on Surface in Otsu

Both the under-Osaka and under-Kyoto sections of the Keihan main line operates like a metro. From the point of view of interoperability, the smaller (and separated) part of the Keihan network has an even more unique feature. Kyoto's second metro line partly replaced the Keihan tramway line between Yamashina and Kyoto, however, the outer part of this tramway was converted to a metro-on-surface, and runs on the streets of Otsu city. By this solution, both Kyoto municipal Metro lines allow through operation (the Karasuma line is connected with Kintetsu Railways's Nara line at Takeda), and the city has even two private railways-operated metro-like lines, too.

In Kobe none of the two metro lines offer the typical Japanese through operation, however, there is a cross-city tunnel through the city center owned by Kobe Kosoku Railway, which connects the Hanshin Railway's Osaka-Kobe line with the Sanyo Railway's Kobe-Himeji line, allowing direct services on these private railways between Himeji and Osaka. Besides, Hankyu Railway's express services also use the eastern part of this tunnel and offer convenient cross-platform transfer between Hankyu and Sanyo trains.

In the Kansai area (the metropolitan area of Osaka, Kyoto, Kobe and Nara), and especially in the city of Osaka JR trains have less market share than in Tokyo. The JR Loop line does not serve the very center of Osaka, and on the inter-urban venue private railways are often more convenient for the passengers. JR was trying to bring closer its trains to the office area in southern Umeda by building a cross-city tunnel called the Tozai line, which helped to ease the congestion of the near Osaka (Umeda) station, too.
In Fukuoka, the Meinohama line of the metro is connected to the JR Chikuhi line, in Nagoya the Tsurumai line of the metro offers through operation at both ends with the private Meitetsu Railway.

Figure 7: A picture of the JR West Tozai Line, and a Meitetsu Train in the Nagoya Metro

Considering the very high-level physical integration between Japanese railway and metro operators, it is very surprising to see that the fare systems are not integrated. Connection tickets are available, but there are hardly any discounts. Hence, a short, 2 stations' trip made on a through train, if it uses two different railway company's lines, may cost double the price of a 10 km trip made on a single company's line.

Seoul, the Korean capital copied the Japanese model for some of its lines, but pure metro lines also exist. Some lines are operated by the national railway company, Line 1 connects Seoul with the neighbouring city, Inchon, parallel to the long distance tracks. A new cross-city tunnel is also planned for national railway use. In other Korean cities, metro lines are not interoperable with national railways.

3.2.2. The Indian model

In Indian cities the railway-metro interoperability is very simplified, the metro system is completely based on the national railway lines, integrating them into the urban system mainly by quadrupling the tracks and separating long-distance and local traffic. In Calcutta there is an extensive tramway network, however, the metro system under construction is the upgrade of the existing suburban lines of the national railways, including laying further tracks parallel with long distance lines. In Chennai the metro tracks are laid parallel, but usually separated from the national railway tracks, however, some lines offer rush hour metro service on the long distance tracks. There is a project for widening the gauge of the Beach-Tambaram metro line to allow through operations with other lines. It is not surprising that the national railway lines are physically integrated into the system, because both the Calcutta and Chennai metro lines are owned and operated by the Indian (national) Railways. The Delhi metro concept also includes the quadrupling projects parallel to the existing railways, but the metro has different routes from railways. Mumbai (Bombay) is served by extremely overcrowded urban-suburban railways, which sometimes use long distance tracks to ease congestion.

3.2.3 Other practices in Asia:

In Izmir (Turkey) some suburban national railway lines are being upgraded to metro standard.

Kuala Lumpur, the capital of Malaysia is unfortunately developing many incompatible railway systems, and do not utilize national railways for metro use, however, the express rail connection to the airport allows commuter transport, too. In Metro Manila the Philippine national railway is planning to build tracks through the centre of the city to make direct services possible. In Shanghai the Pearl line has been upgraded from a former ring railway, but the city's ambitious metro development plans do not contain other interoperable lines. In Hong Kong, the old national railway offers metro-like service and operates the newly built line to a remote but huge residential area, which has an own light rail network. In Taipei the northern section of the Danshui Line was built on former railway route. There is a cross-city tunnel for national railways; both long distance and local (EMU) trains use it.

Figure 8: Interior of a KCR train in Hong Kong, and an EMU in Taipei

3.3. North America

In North America the interoperability between metro and national railways is not a common experience. The biggest U.S. cities have already developed their definitely necessary metro lines; the others rely mainly on road transport. There can be seen a shift towards rail-based transportation, however, there are serious disputes about the expected economic performance of such systems, especially when the projected and the real results can be compared. The U.S. is more interested in the light rail projects than metros, however, U.S. cities – with very few exceptions – no longer have streetcars (trams), so the creation of a real network is difficult and expensive. Moreover, if the new rail-based systems do not form a network, they can be used only by the expense of many transfers, and at the age of integration and convenience-based transportation planning this is unfavourable. On the other hand, where there are already existing and unused or under-utilised rail infrastructure, the (re)opening of these lines for passenger transport is definitely positive. One good example for this is the Tri-Rail in Miami, Florida, however it is a heavy rail line.

Boston's metro network was created partly from former railway lines and tram tunnels, and even the expansion plans contain projects for converting, upgrading, or reopening former railway lines for metro operation. Most of these projects are related with the Blue Line. Another good American example for using the advantages of the three basic railway types can be found in Saint Louis, Missouri. The metro-like light rail utilizes a former railway infrastructure, including a tunnel, which had not been in use since the 70s. The planned extensions also follow the disused rail alignments. San Francisco is also worth mentioning, because of its Stadtbahn-like system called Muni, besides the famous streetcars and the full metro BART.

3.5 South-America

The concept of physical integration between national railway and metro is more popular is South America, probably because of the lack of financial resources comparing to North America. Buenos Aires metro is expanded based on the Japanese model. At Ferrocarril Urquiza a new link between Line B and the suburban railways will allow through operation between the two systems. Fortaleza (Brazil) is building its metro network completely based on the existing suburban rail lines. The lines will be diverted to serve the city center via a cross-city tunnel as frequent metro, and the outer sections of the lines will also be upgraded to metro standards. Medellin, Colombia's second biggest city also utilizes the national railway tracks, metro line A will be extended to Cisneros on the existing railway tracks. Recife's first metro line was built by laying new tracks along the national railway line, so the metro is mainly at ground level. The southern section of the metro is being built by upgrading the national railway service, and connecting it to the airport. Rio de Janeiro's metro was built as a light rail parallel to a suburban railway alignment, and is among the few premetros which had already been converted to full metro operation. Sao Paulo is also a very good example of smart urban railway planning. Several different companies have built the suburban commuter railways around the city, but the metro system turned them into a real urban network. The metro utilizes the suburban railway lines, which were upgraded to metro level, and linked together. On the busiest suburban lines additional tracks were built for the purposes of express metro operation.

3.6 Africa

There is a good example for railway-metro integration from Africa, too. Cairo's Metro Line 1 is a cross-city tunnel, connecting two suburban commuter lines, similarly to the Japanese model, however, the average distance between the stations in the underground section is relatively big, 1.5 kilometres is average.

4. BUDAPEST – CASE STUDY OF METRO LINE 4

The Hungarian capital was the first city on the European continent to open its metro, in 1896. After that 74 years had been spent until the next metro opening came to reality. During the following 20 years continuous metro construction was going on, but the collapse of the communist regime in 1990 brought severe financial and political conditions, so since then not even a meter of metro line was opened. In 2004 three metro lines are in operation, all meet in the city centre at Deak ter. Besides the hundred years old first line, there is 10 km long Line 2, which is an East-west oriented heavy metro with 11 stations, serving 2 main national railway termini, 2 suburban railway (HEV) termini, and the 18 km long Line 3, which is a North to Southeast heavy metro line with 20 stations, serving one national railway terminus and 2 railway stations. Budapest has 4 HEV lines, 2 of them feeding metro line 2, while the others can be reached only by trams and buses. HEV lines are different in characteristics, the Csepel and Szentendre lines are busy, operate with 5 minutes intervals within the city borders during rush hours, the Godollo line is less busy, and the Rackeve line has only few trains an hour, especially at their outer sections. Trains are 3 or 6 car EMUs, operating on separate right-of-way, but with many level crossings. There still is an extensive tramway network, a large and still frequently served bus network, and 12 trolleybus lines. The tramway line on the Great Boulevard carries ten thousand passengers during rush hour in each direction, with 54 meter long coupled sets, operating every 2-3 minutes. Tramways are conventional, cannot be considered as modern light rail. All of these modes are integrated into the tariff system, except the national railway and the suburban buses. The national railways (MAV) operate 11 suburban lines, but only 2 of them have periodic schedule (introduced in August 2004), the other lines are served with not more than 1 services in off-peak times, and 2 to 5 services in peak hours.

There are two more metro lines planned. Line 4 would be a southwest-northeast line, connecting the Kelenfold with the Keleti national railway station, or even further to the northeast. This lines has been planned for more than 30 years, and construction works have been „expected to start within 2 years" for three decades. The line is planned to be a conventional metro, without physical connection to the national railways. Line 5 had been planned as a half circular conventional metro, but the Development Plan of Budapest's Transportation System (DPBTS) approved in 2001 contains a reconsidered line. Instead of the conventional metro, the Plan proposes an interoperable line with the HEV lines, and also with the national railways Esztergom line. Technical characteristics are unclear, however, this is a major step toward a physically integrated railway system in Budapest. The shift from the conventional metro to the interoperable „regional express railway", or RER, is the biggest improvement of the DPBTS.

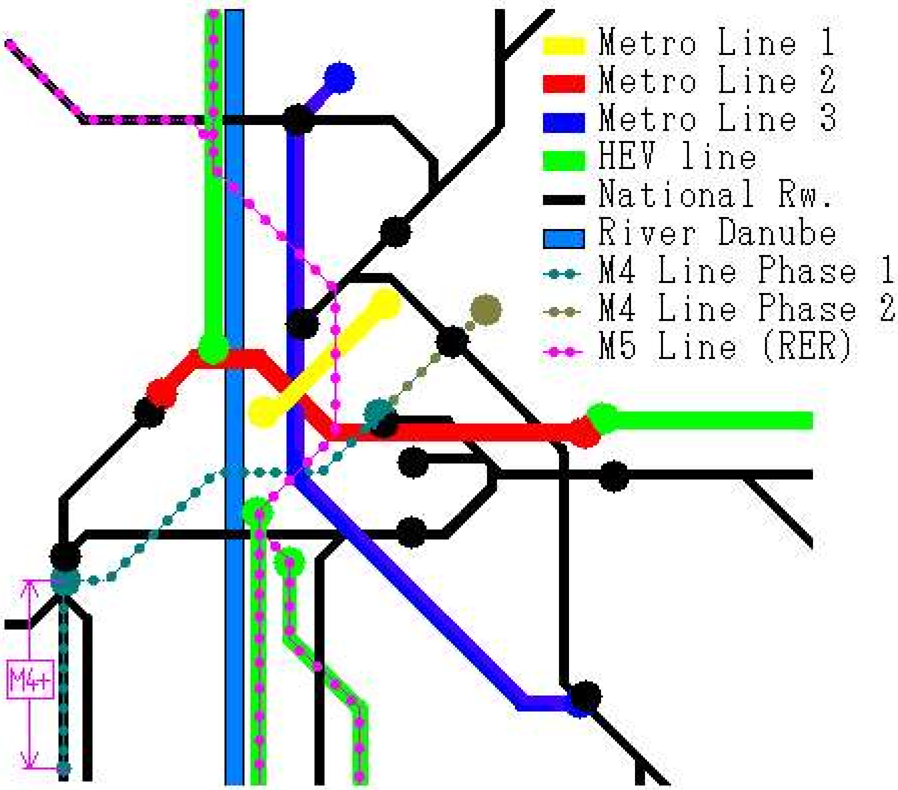

Figure 9: The stylized urban railway network in Budapest

The question is: if the current urban railway planning trends reached Budapest so that the metro line 5 is re-planned as a RER (and not as a metro), then line 4 is why not re-planned? The theoretical part of DPBTS explains it in the following way. The 2 main approaches for integrated network planning are "intermodality" and "interoperability". The intermodality approach keeps the various means of transport physically separated, and provides good interchanges between them; the interoperability-approach physically connects the systems. „The most convenient and attractive solution is the interoperability, however, considering the lack of financial resources in Budapest, network-planners have to plan intermodal interchanges instead". Hence, instead of the "better and more expensive" solution, the "cheaper and worse" one has to be chosen in Budapest. This strategy will have seriously damaging effects on the transportation of Budapest (Acs and Istvan, 2003). On the other hand, by reading carefully the DPBTS, it can be seen, that the above quoted approach is designed only to support the idea of conventional Metro 4. The other proposed projects (reconsidered Metro 5, East-West Stadtbahn, North-South tramway links, etc.) represent the approach of interoperability.

Only metro line 4 is the exception. This fully underground line will be built between two major railway stations, and as such, its alignment would be perfect for through operation for national railways. Unfortunately, the plans do not allow through operation, and propose a conventional metro line. For this reason, some individual, new generation urban planners formed the M4+ Team to promote the idea of the interoperable metro, but the efforts seem to have no results by now.

The basic idea was converting the planned metro line into a Japanese style, or RER-type metro allowing through operation with national railway trains. This idea was refused by many experts. The main reasons were the necessary wider cross-section of the tunnel (which means extra costs), and the need of re-routing because of the different curves and platform length required for an railway-based metro. The third reason of refusing the concept of interoperable line 4 was that the national railway services are so unreliable, that integrating them into the metro system would cause serious disruption. The final, and most „convincing" reason was, that construction of the metro 4 is the main priority of the city, which is "just about to start", so it is too late to reconsider the line (Csordas, 2002). These reasons seem to be weightless if one considers the data published in the same article. It ranks the extensions of the metro operation on railways in terms of cost-efficiency. Metro extensions along railways proposed in (Acs, 2000) have 86, 51, and 44 units of efficiency depending on the involved lines, while the basic metro project has only 11, in terms of spared-time per investment (Csordas, 2002).

This is not the only point where unexplainable events happened in connection with metro 4. There are 3 potential extensions for the basic project as conventional metro, and due to the manual published by the planners of the line; "all experts agree that" the western extension of the line has the highest priority (Gulyas et. al, 2000). In spite of that, politicians in 2003 decided to extend the line first to the northeast, which shows great amount of optimism, as the construction works have not started even on the first phase.

M4+Team still promotes the southwest bound extension of the metro operation on the national railway tracks. The plans were reconsidered to be more acceptable and to reduce criticized points, hoping that the decision makers understand that even if the metro line is extended on the railways, it will still provide everything that the original plan, plus many more. The plans for the original phase of metro 4 (in terms of alignment, cross-section, third rail power supply, etc) can be kept basically unchanged, only a slight modification is necessary to allow the construction of the physical connection towards the railway tracks. This change is necessary, because the original plan places the western terminus of the metro under the Kelenfold railway station, perpendicular to the tracks, making through operation completely impossible. This is the only thing that has to be changed to make M4+ feasible.

The final, or as it is often called, the minimum-version of M4+, i.e. the extension of metro operation on national railway tracks contains the followings. One of the 3 more-or-less parallel tracks between Budapest-Kelenfold and the city of Erd, currently catering both long-distance, suburban, and also freight traffic, should be taken from MAV and transferred to metro operation. MAV is able to operate on the remaining 2 tracks, especially because the metro takes over the local (suburban and intra-city) traffic, so MAV local services can be fastened, therefore the capacity of the line is raised, and suburbs beyond Erd can be reached faster. Metro, as a reliable service, can operate on the single track, with some stations allowing trains to cross, as the headway need not to be shorter than 10 minutes even in the rush hour. The third rail power supply can be built along the metro tracks; the alignment can completely be isolated from crossing traffic.

The plan of M4+ provides many advantages, without disadvantages. Without the construction of expensive underground alignment, the metro operation can be extended easily towards the suburbs, providing fast and convenient direct access to the city centre. The length of the original metro line can be more than doubled with only 10% cost increase. Further savings can be reached because the M4+ makes some other projects unnecessary, including the planned Fehervari ut branch of Metro 4, and the replacement of 50 buses. The extended metro would allow the construction of more P+R facilities, closer to the residential areas. The train depot could also be built outside of the city on less expensive land, and in better location from the operational point of view.

Even this minimal version plan had to face strict refusal from the planners of metro 4 and also from MAV planners, however, encouraging comments were received from individuals. The another popular interoperable alternative to Metro 4 called "AliGut" is also rejected by the officials. The AliGut would be a cross-city tunnel for the national railway, connecting the Kelenfold station with the Nyugati station under the CBD, and would allow not only suburban but also long-distancetrains (Perlaki, 2002). Complementing it, the Stadtbahn-like Karolina project would serve the residential areas in southern Budapest (Bodrog and Perlaki, 2005).

The metro 4 project is a pure political issue and hardly any expert dares to propose any changes which does not fit the actual political wind. So, it seems that even though all experts understand the need of physical integration of metro 4, it will be built as a completely incompatible line in Budapest.

5. CONCLUSION

Metro and suburban rail are perfect complementary systems to each other. Metro offers what railways are lacking (direct access to the city center), and railways offer what metros are lacking (high capacity tracks in the suburbs). Hence, integrated interoperable lines mean the most economical and most user-friendly answer for the challenge of suburbanization. Developed countries have already experienced that the problem is no longer the provision of adequate capacity, rather the attractive quality of public transport. The need for convenient, seamless transport will be stronger and stronger in a few decades even in the developing countries, so it is high time to reconsider mass transit projects to allow interoperability with the good old, and under-utilised railways.

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REFERENCES

Ács, B. 2000 Hogyan kepzelem a vasut jovojet? Palyazat. Paper Presentation held at MAV Pecsi Teruleti Igazgatosag, 7. September, 2000.

Ács, B., István Gy.: 2003 4-es metró plusz- Egy modern gyorsvasút megvalósulásának lehetősége Budapesten, Presentation held at Főmterv, Budapest, 28. January 2003.

Bodrog, Z., Perlaki A. 2005: Concept of a new tramway mainline in Budapest, **Városi Közlekedés (Urban Traffic)**, **Vol. 45, No. 2**, 97-99

Budapest Közlekedési Rendszerének Fejlesztési Terve 2001 (**Development Plan of Budapest's Transportation System**)

Carrillo, Abelardo 2003 Madrid Cercanias: A Railway Metamorphosis, **Public Transport International, Vol. 52, No. 2,** 16-17.

Csordás, M. 2002 Method for grading the traffic development projects in Budapest, **Városi Közlekedés (Urban Traffic)**, **Vol. 42, No. 6**, 321-328

Gulyas, L., Pinter L., Pozsgay L. 2000, Metro4 - **Osszefoglalo Ismertetes**, DBR metro Budapest

Karr, M. 1998 **Mehrsystemkonzepte der Schienenbahnen in Europa**, Institut für Straßen- und Eisenbahnwesen, Universität Karlsruhe (TH)

Meyer, Wolfgang 2003 Editorial, **Public Transport International, Vol. 52, No. 2,** 2.

Parlaki, Attila, 2002 Vasút a város alatt, www.aligut.ini.hu

Rowen, John Francis 2001: See How They Run – Transport Plans for the London Area, http://www.geocities.com/Athens/Acropolis/7069/tpftla.html

Schwandl, Robert 1999-2004 UrbanRail.net, , http://www.urbanrail.net/

Suga T., 2000 Editorial: Significance of competent urban railways, **Japan Railway and Transport Review, March 2000, No. 23**, 3.

Voskuhl, D.E.F. 1995, Viewpoint: Interlinking the region with its centre - The example of the Karlsruhe region in Germany, **Journal of Transport Geography, Vol 3, Issue 4**, 281-286

Official Homepages:
Crossrail UK: http://www.crossrail.co.uk/
The East London Line Project: http://www.ellp.co.uk/index.htm
European Metropolitan Transport Authorities: http://www.emta.com/
M4+ Team: www.metro4plusz.ini.hu
Metro4 Budapest: http://www.metro4.hu/
Transport for London – The Tube http://tube.tfl.gov.uk/