Trolleybus intermodal Compendium

This compendium has been prepared by the authors
in the framework of the TROLLEY Project

CENTRAL EUROPE
COOPERATING FOR SUCCESS.

EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND

Trolleybus Intermodal Compendium

This compendium has been prepared by the authors
in the framework of the TROLLEY Project

The TROLLEY Project is implemented through the CENTRAL EUROPE Programme
co-financed by the ERDF (www.central2013.eu)

www.trolley-project.eu

CENTRAL EUROPE
COOPERATING FOR SUCCESS.
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Centrum dopravního výzkumu, v. v. i.

Divize rozvoje dopravy
Líšeňská 33a

636 00 BRNO

Magistrát města Brna

Odbor dopravy
Kounicova 67

671 07 BRNO

Authors:

Jan Spousta
Dr. Zoltán Ádám Németh
Dr. Marcin Wolek
Alexandra Weiß
David G. Chick

Photos by:

Jan Spousta
Dr. Michal Váňa
Jan Vašíček
Dr. Zoltán Ádám Németh
Dr. Marcin Wolek
Salzburg AG
Barnim Bus Company
SZKT

Layout:

Jan Vašíček

ISBN 978-80-86502-50-2

This compendium has been prepared by the authors in the framework of the TROLLEY project.

The TROLLEY project is implemented through the CENTRAL EUROPE Programme co financed by the ERDF

Promoting electric public transport

Trolley

Promoting electric public transport

Content

Introduction 6

1. Intermodal passenger transport........ 7

1.1. Integrated transport as main driver for intermodal passenger transport solutions 8
1.2. Current status of integrated transport systems – trolleybus role in scheme 9
1.2.1. Regional systems ("Verkhrsverbund") 9
1.2.2. Functions and benefits from the contractor's (public authority) view 10
1.2.3. Key quality requirements........ 10
1.2.4. Functions and benefits from the passenger's view 11
1.2.5. Functions and benefits from view of operator 11
1.2.6. Trolleybus as core/crucial mode........ 11
1.3. Quality of service as the crucial requirement for PT competitiveness........ 12
1.3.1. Information technology equipment 13
1.3.2. Automatic Vehicle Monitoring System (AVMS) 13
1.3.3. Travel information tools........ 14
1.3.4. Ticketing system........ 17
1.3.5. Passengers counting tools........ 18

2. Analysis of the trolleybus transport role and potential in the transport system - trolley system as the backbone of public transport, and as part of intermodal passenger transport solutions 19

2.1. Development of trolleybus transport mode 19
2.2. Trolleybus vehicle development........ 22
2.3. Legislative framework of trolleybus operation 26

3. Examples of specific modal interchanges in selected trolleybus networks 27

3.1. General principles........ 27
3.1.1. Accessibility of transport services, the impact of intermodality / multimodality on increasing the share of public transport in the modal split, the impact on passenger satisfaction........ 27
3.1.2. Other major benefits - the system's functionality, capacity, congestion reduction, use of public space, the impact on the quality of public space, increase of personal safety 27
3.1.3. The main user groups, intermodality influence on their attitudes........ 28
3.1.4. Costs of trolleybus line construction, operation, involvement of key actors in the process........ 29
3.2. Examples of specific modal interchanges in selected networks........ 31
3.2.1. Trolleybus extension projects in Brno 31
3.2.1.1. Brno-Starý Lískovec development project 31
3.2.1.2. Brno-Bystrc (ZOO) extension project 32
3.2.1.3. Integrated Mobility Centre in Brno 35
3.2.2. Intermodality in Szeged 37
3.2.2.1. Modal interchange Széchenyi tér 37
3.2.2.2. B+R Trolleybus intermodality in Szeged 39
3.2.3. Trolleybus projects in Salzburg........ 40
3.2.3.1. Intermodal interface Salzburg/Mülln........ 40
3.2.3.2. Stadtwerke Lehen 42
3.2.3.3. Mobility Management........ 42
3.2.4. Plan of intermodal integration node of Gdynia Karwiny 43
3.2.5. Hradec Králové Intermodal Transport Hub 45

4. Technical aspects of trolleybus as a key mode in intermodal passenger transport solutions 51

4.1. Common tram-trolleybus power supply 51
4.2. Common tram-trolleybus maintenance........ 54
4.3. Common tram-trolleybus corridors 56
4.4. Trolleybus & motorbus synergies........ 58

5. The potential of trolleybus mode in the E-mobility era........ 59

5.1. EU electromobility initiatives and projects........ 59
5.2. Trolleybus in the future 60
5.3. Trolleybus potential in the e-mobility concept 62

Introduction

The INTERREG Central Europe project TROLLEY – Promoting electric public transport - contributes to an improved accessibility of, and within, Central European cities, focusing on urban transport. By taking an integrated approach the project has one main aim: the promotion of trolleybuses as the cleanest and most economical transport mode for sustainable cities and regions in Central Europe.

The Central Europe project TROLLEY (www.trolley-project.eu) is one consortium of 7 European cities: Salzburg in Austria, Gdynia in Poland, Leipzig and Eberswalde in Germany, Brno in the Czech Republic, Szeged in Hungary and Parma in Italy. Horizontal support for research and communication tasks is given by the University of Gdansk, Poland, and the international action group to promote ebus systems with zero emission: trolley:motion.

The project TROLLEY promotes trolleybus systems as a ready-to-use, electric urban transport solution for European cities, because trolleybuses are efficient, sustainable, safe, and – taking into account external costs – much more competitive than diesel buses. The project directly responds to the fact that congestion and climate change come hand in hand with rising costs and that air and noise pollution are resulting in growing health costs. The Greater London Authority estimated that in 2008 there were 4267 deaths in London attributable to long-term exposure to small particles, partly resulting from road traffic pollution[1]. Trolleybus systems are assisting with the on-going transition from our current reliance on diesel-powered buses to highly efficient, green means of transportation.

Trolleybuses long were out of fashion, but the TROLLEY project is helping to show how these existing transit networks can play an integral role in providing green transport for well-planned cities of the future. Therefore, the TROLLEY project seeks to capitalise on existing trolleybus knowledge, which is truly rich in central Europe, where trolleybus systems are more widespread.

The following Trolleybus Intermodal Compendium presents the way trolleybus systems, as well working sustainable public transport systems, can face challenges like growing car ownership in Central Europe area cities, strong separation of transport modes, but growing mobility demands (in quantity and quality), and environmental pollution through increasing road traffic congestion. Intermodal passenger transport is a key element of sustainable mobility and allows for seamless travel of passengers, speeds up transfer times and provides a real alternative to personal motorized mobility. And trolleybus systems can provide the backbone of an integrated and seamless intermodal passenger transport network in urban areas.

The implementation of intermodal passenger transport is a more sustainable alternative to car transport and makes public transport more efficient ensuring seamless travel from A to B. However, there are preconditions to offer a seamless intermodal passenger transport, which are described in chapter 1 of this Compendium. Chapter 2 describes trolleybus development and the potential role of trolleybus systems in passenger intermodality solutions. The TROLLEY partners present their examples for passenger intermodality with trolleybuses in chapter 3. Chapter 4 shows technical aspects and synergies of the combined operation of a trolleybus and a tram network as key modes in intermodal passenger transport solutions. Chapter 5 provides an outlook on the future of trolleybus systems as the backbone of an intermodal electric mobility system for a smart city of the future.

---

1) The Mayor´s Draft Air Quality Strategy, http://www.london.gov.uk/priorities/environment/publications/the-mayors-draft-air-quality-strategy

1. Intermodal passenger transport

Mobility is a fundamental necessity of the 21st century living and brings access to primary services and leisure. But today, current patterns of provision and consumption of mobility are unsustainable and cities all over the world are facing challenges: they must drastically reduce their greenhouse gas emissions and congestion is approaching intolerable levels in many cities. Addressing the issue of climate change is a key topic for transport in particular. At present, CO_2 emissions from transport are growing despite improvements in technology and fuels mainly due to the sheer increase of the number of trips made. Therefore, one of the main priorities is the integration of different transport modes as a way to improve the overall efficiency of transport systems. And passenger intermodality integrates two or more transport modes on the same trip. The current challenge of intermodal passenger transport is to transfer the use of motorized vehicle towards the use of public transport and non-motorized modes. Thus, a comfortable and practicable connection offered in between the modes like bicycle, bus, tram, rail and walking is the pivot of intermodal transport, for example, to construct platforms, to integrate information systems and to install bike and ride options etc. And due to the guiding principle of sustainable public transport trolleybus systems offer a good starting point for sustainable intermodal transport passenger solutions, as trolleybuses - as a main public transport mode – provide a clean and efficient basis for mobility planners, which should integrate other modes (e.g. cycling) to ensure a seamless intermodal door-to-door transport chain in cities.

Passenger intermodality is not only a planning principle, but also a policy that aims to provide a passenger a seamless journey using different modes of transport in a combined trip chain. The European forum on intermodal passenger travel defines passenger intermodality as follows: “Intermodality can be seen as a characteristic of a transport system that allows at

Fig. 1 - Trams and trolleybuses are the core of Brno public transport

least two different modes to be used in an integrated manner in a door-to-door transport chain. The adjective intermodal can be used for a service, facility, consignment of journey, involving transference between different modes of transport. Moreover, intermodal travel necessarily involves transferring from one mode to another. This usually takes place at modal interchanges."[2]

However, the concept of passenger intermodality is an efficient and more sustainable alternative to car transport and mirrors the flexibility wished by passengers as a key concept for mobility in the 21st century. In order to face ever more complex mobility needs and to provide a complete mobility solution to their customers, public transport companies are providing an ever broader mix of mobility services by building new alliances with actors such as car- or bike-sharing operators, taxis, etc. helping to create a culture of more sustainable travel choices by citizens. This will transform public transport companies into true mobility providers while nowadays passengers not only consider the most economic transport mode in terms of monetary budget, but also seek the most effective mode or intermodal trip chain in terms of time budget, higher comfort and environmental friendliness. The effort to improve passenger intermodality involves many issues ranging from concrete services and implementation issues to (legal) framework conditions. Therefore, platform solutions are needed, representing a tool for stimulating interaction and debate among all combined mobility actors, including public transport operators and organising authorities.[3]

A main barrier to implement intermodal passenger transport solutions is the fragmented ownership of public transport.[4] Intermodal passenger transport can constitute trip chains, which create high demands on the interfaces and operational integration of the involved transport systems. Seamless intermodal passenger transport services need integration of public transport information, services, fares and ticketing as well as infrastructure provision and transport measures and land use planning policies. Therefore, Integration, thus, the extent to which different transport services are combined or contiguous in terms of ownership, operation or usability is a main precondition or driver respectively for intermodal passenger transport solutions. The concept of integrated transport therefore will be described in the following chapters.

1.1. Integrated transport as main driver for intermodal passenger transport solutions

The term 'integrated public passenger transport services' is defined by *the Regulation (EC) No. 1370/2007 on public passenger transport services*[5] as interconnected transport services within a determined geographical area with a single information service, ticketing scheme and timetable.

---

2) The European forum on intermodal passenger travel: PASSENGER INTERMODALITY FROM A TO Z: http://www.mobiel21.be/sites/default/files/publications/Brochure%20link%20kleiner.pdf
3) The Concept of Sustainable Development, http://www.uitp.org/Public-Transport/sustainabledevelopment, UITP Press Release (2010): Combined mobility, the freedom to move, http://www.uitp.org/news/pics/pdf/PR_CombinedMobility.pdf
4) John Preston: Integration for seamless transport. OECD Discussion Paper. 2012/01.
5) REGULATION (EC) No 1370/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70

The first urban public transport services were established by private entrepreneurs at the end of the 19th century. They were mostly horse- or electric-tram lines connecting the most important places in a city; their operators were awarded concessions to build and operate their line, separated from other PT services and in many cases technically incompatible. Municipal authorities had very limited control of their business. After a short period with increasing numbers of private operators in the territory, the municipalities recognized the unsustainability of such conditions and at the beginning of the 20th century implemented certain regulatory measures which targeted particularly technological standards (gauge, voltage), routeing and tariffs.

The next step was the takeover of private operators by municipalities and their merger into a single public company, in many cases incorporating also other public services (electricity, gas and water supply, waste collection, municipal roads) - such actions took place mostly in the 1920s. Such measures enabled the optimisation of the PT network and contributed also to the introduction of the trolleybus mode as a cheaper alternative serving the newly built districts or to replace the inefficient tram systems in medium size cities.

A new concept of public transport integration started to be implemented during the 1980s-1990s. The first feature of this higher level of integration was the incorporation of national rail services in the relevant area and their tariff and timetable unification with urban PT. The next step, implemented since the late 1990s, extended the integrated transport area to the entire conurbation (in some cases corresponding to its administrative structure, in others reflecting regional economic requirements). Practical experience showed that the effective transport system could not only integrate just different PT modes but needed to address the individual transport users as well by means of P+R, B+R and K+R facilities.

The highest PT integration level, applied nationwide, has been reached in Switzerland and the Netherlands. Further expansion of such integrated transport systems exceeding administrative regions can be expected thanks to the implementation of IT based ticketing systems enabling the objective re-distribution of fare revenues.

1.2. Current status of integrated transport systems – trolleybus role in scheme

1.2.1. Regional systems (“Verkhrsverbund”)

Public transport integration has been implemented in all TROLLEY partners’ cities even though the exact level differs city by city. Full integration on a regional basis is generally applied in Germany (except national express and IC/EC/ICE trains) and Austria (incl. express and IC/EC trains, but excl. Railjet). The Brno integrated system incorporates the entire South Moravian region and all PT services within (excl. IC/EC trains), though this is not common in other Czech regions – integrated transport systems are established in ca half of them and except Brno nowhere includes national express train services. The opposite situation is in the other TROLLEY project participating countries where systems integrate different urban PT modes only, irrespective of the operator, but generally do not incorporate national rail – one of the few exceptions being the “Trójmiasto” (Tri-City) region with trolleybus city Gdynia with extension to Sopot. As already stated, integrated transport systems are well developed in Switzerland and the Netherlands, where they incorporate all PT modes nationwide, while in France, Italy and Belgium railway services are generally excluded except for some specific urban rail lines (RER). A very low level of PT integration exists in the East European countries.

It is necessary to point out that the public tendering system and PT integration create one serious risk to trolleybus (or tram) operation – the risk of trolleybus service abandonment in favour of cheaper diesel or CNG bus services. This potential problem must be resolved at the initial stage of public call when the utilisation of existing infrastructure should become one of the indispensable conditions. Another option, commonly used in the Netherlands or France, is the tendering of operation (service) only while the vehicles and infrastructure (in the case of trams and trolleys) are owned by the public authority and the selected operator is obliged to use under given conditions.

1.2.2. Functions and benefits from the contractor's (public authority) view

The public contractor (regional and/or municipal authority) establishes an integrated transport system with the aim of providing PT service to all citizens in the relevant area in an efficient way and of reasonable quality. The system should integrate all PT means irrespective of their operator. An increasing number of operators is now being selected by public tenders with clear criteria targeting service quality requirements (certain ones are already set by legislation: accessibility for disabled users, passenger information systems, average and/or maximum age of vehicles). A well organised integrated transport system brings the benefits of effective management and control reflecting the needs of the public (represented by the authority) and transparent allocation of financial support/compensation.

1.2.3. Key quality requirements

area coverage:

- PT service provided for all residential districts and other important places
- distance to stations/stops and their accessibility
- direct links between major points and/or interchange points

level of service:

- time range of service
- coordinated timetables (intervals, guaranteed transfer) reflecting expectations and needs
- reasonable travel time
- capacity of vehicles
- services at terminals
- accessibility of services (vehicles, terminals, stops) for disabled users

mobility and quality indicators:

- travel time
- vehicles
- information system
- tariff structure and ticketing system
- punctuality and reliability
- traffic safety, customers´ security, cleanliness

1.2.4. Functions and benefits from the passenger's view

The passenger benefits from PT integration in many ways:

- broader service offer and better access to services
- simplified and unified ticketing
- customer information (pre-travel, en-route)
- modern vehicles complying with environmental standards
- service quality standards

1.2.5. Functions and benefits from view of operator

The operator selected by public tender is awarded a timely guaranteed contract with the public authority or system coordinator which enables the planning and organisation of all processes in an efficient way, fleet renewal, hire of drivers and other staff.

1.2.6. Trolleybus as core/crucial mode

Transport systems incorporating urban rail or other track bound modes (which is the case of the trolleybus) represent certain specifics, given by the fact that (in most cases) the infrastructure is owned by the PT service operator and its capacity does not allow the access of competitive service providers. While tram or urban rail is clearly considered as the core of a local transport system by the professionals as well as by the public, the trolleybus is often seen as just an electric bus. In order to benefit from the trolleybus advantages, the network should be organised with trolleybus routes as its core. One of the specific trolleybus features is the "visibility of network" urbanism phenomena which give to the citizen - potential customer clear indication of PT service availability. This positive customer feeling can be extended by the use of dual power trolleybuses which enable them to serve the core line (equipped with traction overhead) in the most environmentally friendly way and simultaneously provide direct connection to the suburban areas by means of their second power mode. This is not possible with any other urban public transport mode as trams or metro necessarily require feeder bus services in the outskirts while motorbuses generate their emissions throughout their entire journey.

1.3. Quality of service as the crucial requirement for PT competitiveness

The position of public transport in modal split has changed since the 1960s when it held an almost monopolistic position in urban mobility. PT is now facing strong competition from car transport and, in order to keep its competitiveness, must offer a comparable level of service at least in terms of reliability, travel time, comfort, and accessibility. These requirements are reflected by the new trend called “transport with high level of service” which is now being implemented all across Europe. This trend is particularly visible in the bus mode which suffered most and is now being restored under the brand names Buses with High Level of Service (BHLS), Bus Rapid Transit (BRT) or Metrobus[6]. They improve the network attractiveness with the addition of significant investment in system reliability, customer support and marketing. One of the greatest paradoxes of modern transport planning has been the excessive focus on very expensive projects of limited scope (although effective at their point of application) – particularly on construction of metro and light rail systems, while ignoring the degraded conditions for the vast majority of public transport customers. These are the result of poor urban structure and form, and greatly exacerbated by urban sprawl. This has contributed to the degradation of economic and financial conditions of public transport in the last four decades of the 20th century, with great loss from public to private forms of transport.

There are several criteria, marked as KPI (key performance indicators), which classify the “high level transport system”. **Three fundamental indicators** can be considered as the most often strategic, that does not mean always systematically:

- punctuality / regularity,
- frequency,
- speed;

However in addition to these three fundamental ones, a number of other factors are also important and should be considered for building an attractive service, such as:

- schedule span / intermodality with the mobility network
- information / comfort
- safety / security
- accessibility

In case of those fundamental as well secondary indicators, which are seen as rather crucial by the public, trolleybuses have already proved their capability and advantages against other bus modes.

In order to reach the required service level and quality, the operator should have a detailed overview of the complete vehicle movement in the network while the passengers should be provided with information necessary for their mobility needs. This can be relatively easily achieved with trolleybuses, permanently linked to the overhead network, even though the latest ITS technologies enable similar feedback to be obtained from other bus (or any other) mode as well.

6) COST Action TU0603 Buses with high level of service - Final Report available at http://www.cost.eu/media/publications/12-08-Buses-with-High-Level-of-Service-Final-Report

1.3.1. Information technology equipment

Intelligent Transportation Systems (ITS) is an essential component in a BHLS system, including systems that enhance operations by improving operating efficiencies, increasing service reliability and reducing travel times. ITS in a well-designed BHLS vehicle can include:

- Automatic Vehicle Monitoring system (AVM) is a key system for monitoring and management of the services. It is based on determining the real-time location of each vehicle, which is equipped with the required hardware and software. The most popular technology currently used to determine location in an AVM system is the global positioning system (GPS).
- Transit signal priority, which can alter signal timing to give priority to public transport vehicles. This allows vehicles to improve schedule adherence, reliability, and speed.
- On-board passenger information usually includes information on the next stop, vehicle schedule, transfers and delays. This is accomplished using an automatic announcing system, consisting of dynamic message signs on-board the vehicle and an audible message of the same information being displayed. On-board passenger information can be utilized to display and announce advertisements, making it a potential source for additional revenue. Video displays on-board vehicles may provide entertainment (news and general information), thus giving attractiveness to the service
- On-board cameras, providing remote monitoring and recording of the passenger environment on vehicles. On-board cameras are a form of crime deterrence. Also, cameras can provide information on driver behaviour by recording drivers' actions. Further, camera images can be used to review the seconds just prior to an accident to determine fault and suspected offenders.
- A number of other tools can be linked to the in-vehicle or en-route ITS, e.g. collision warning system, precision docking system or automated passenger counters

During the last two decades, Intelligent Transportation Systems (ITS) have emerged with their own gleam in the world of transport and become firmly established. ITS involves the applied use of various engineering disciplines, enabling technologies and management strategies to facilitate modern transport operations and policy development. In this context ITS has had a significant impact in all the recent implementation and operation of BHLS systems/services.

1.3.2. Automatic Vehicle Monitoring System (AVMS)

The Automatic Vehicle Monitoring System is recognised as the indispensable key component for managing public transport operation, particularly BHLS; in fact most PT operators have already invested in this ITS element which increases PT efficiency and is capable of responding to disruptions and congestion and provide real time information to PT customers at all stops. The AVMS is becoming a standard and, in many cases, the equipment of vehicles with such a system is one of the tender conditions, namely in the integrated networks. AVMS should be installed for the overall PT network, not only for the core lines.

The 3 pillars of any Automatic Vehicle Monitoring System are:

- positioning and monitoring of all buses, which need to be supported by a minimum of Rights of Way and priority measures at junctions.
- communication function between the different sub-systems, e.g. vehicles, stops, control centre / depots / workshops.
- Operations Management Strategy, supported by real-time location and communication technologies, the effective analysis and presentation of the relevant information to the dispatchers, the capability of dispatchers to act on the service and/or to provide bus/line with specific commands/information.

The main AVMS task is to collect and monitor data about the performance of vehicles in service with 2 main objectives:

- to control, regulate and inform in real time, according to quality objectives.
- to analyse the data collected for quality control purposes, transport planning and asset management including performance of infrastructure (right of way and priority at traffic lights or other priority measures) or any other purposes necessary for redesigning services and timetable reliability based on current operational conditions. This mission is particularly crucial in the framework of interconnected networks where single disruptions are transferred into the entire system and degrade its quality performance. Long-term unresolved problems then lead to low customer satisfaction and loss of their trust.

Currently, the most common AVMS instruments are the GPS technologies which enable all vehicles in the PT system to integrate, irrespective their mode. This can be considered as a great step forward against the previous technologies based on detection of vehicle passage through fixed points – which used to be much easier to install on track-bound modes where such a point was represented by a detector installed on the rail or trolley wire.

1.3.3. Travel information tools

The TROLLEY project partners and other trolleybus operators have implemented many of the above listed ITS tools and applied them in their services. One of the most important measures, which attract the public to use public transport, is a good and reliable information system, covering the whole mobility process from travel planning up to the journey itself. Potential customers in most European countries can now choose among various options, which place the quality information system at the top of the selection criteria. The importance of passenger information has been recognised not only by the transport operators, but also by the European Commission and many national governments as well as regional and local transport authorities. They all introduced a set of information channels providing citizens with relevant information needed for their mobility planning. Up-to-date information systems are usually presented in the form of very sophisticated IT tools providing their users with a huge amount of data – which are not probably not necessary considering that the potential customer is asking for simple information about how and when to get from point A to B which are just a few miles distant. On the other hand, such simple answers should be very reliable otherwise the customer will lose his confidence in the whole system. It is also necessary to provide information to those customers who, for whatever reason, are unable to use the IT tools and are dependent on the advice given by the operator's staff.

The process can be divided into several sub-systems, which, nevertheless, should be given equal consideration:

- pre-travel information
- easy ticketing
- on-line information
- information and ticketing tools using modern technologies
- tools for customers without access to IT technologies

Pre-travel information

The increasing access to internet in the last decade of the 20th century created new challenges for customer information and service promotion tools. The first step became the publication of route timetables which was replaced by more customer friendly search engines providing detailed travel planning in a single operator's network. The next step was the introduction of multimodal systems covering a broader area and more – or all – operators in it. Nevertheless, such systems based on the voluntary involvement of transport operators showed their inefficiency and vulnerability and were replaced by region- or nation-wide information systems coordinated by the public body.

The Commission organised the first public survey "Smart Mobility Challenge on European multi-modal journey planners" in 2012[7]. The initiative aimed to promote the development of all-in-one journey planners, going beyond national borders and offering travel options combining different transport modes. In the category of 'operational journey planners' the two winners were Idos and Trenitalia, and in the category of 'innovative ideas' the winners were Penelope Ventures GmbH and SNCF. The Czech system **IDOS** is a door-to-door journey planner for the Czech Republic and Slovakia. It also provides other cross-border travel connections around Europe by bus and train. It has 66 million online views per month. With respect to the TROLLEY project, IDOS not only incorporates all transport modes but specifies the exact mode the customer should use – which might be a trolleybus, as shown in figure 2. Distinguishing between different bus modes is unique as shown in the ZVV Zurich journey planner where BHLS trolleybus route Nr. 31 is indicated in figure 3 as "Bus 31", not as trolleybus.

Different information means are used for providing information to customers who are unable to utilize the IT technologies. The most common form are information centres operated by transport operators or municipalities, usually located either at a PT terminal or at some central point of the city. One of the good practice examples is the Integrated Mobility Centre in Brno (Czech Republic) which has been one of the results of the Brno participation in the EU CIVITAS ELAN project. The central intersection in the city centre, where six tram and six trolleybus lines meet was chosen as the location for the Integrated Mobility Centre (IMP). The implementation of the measure started with the reconstruction of the area around Joštova Street. As part of the measure, real-time passenger information panels have been installed at Public Transport stops in the entire area and on the roof of the IMP itself. Also, touch-screen

7) *First Smart Mobility Challenge, http://europa.eu/rapid/press-release_IP-12-233_en.htm*

internet information terminals are available within the centre. Customers of the IMP can also purchase tickets by debit or credit cards. Detailed description of the Integrated Mobility Centre is available in section 3.2.1.3.

Fig. 2 - IDOS Journey Planner – trolley/EC train/trolley/motorbus trip Šlapanice (Brno) – Dubina (Pardubice)

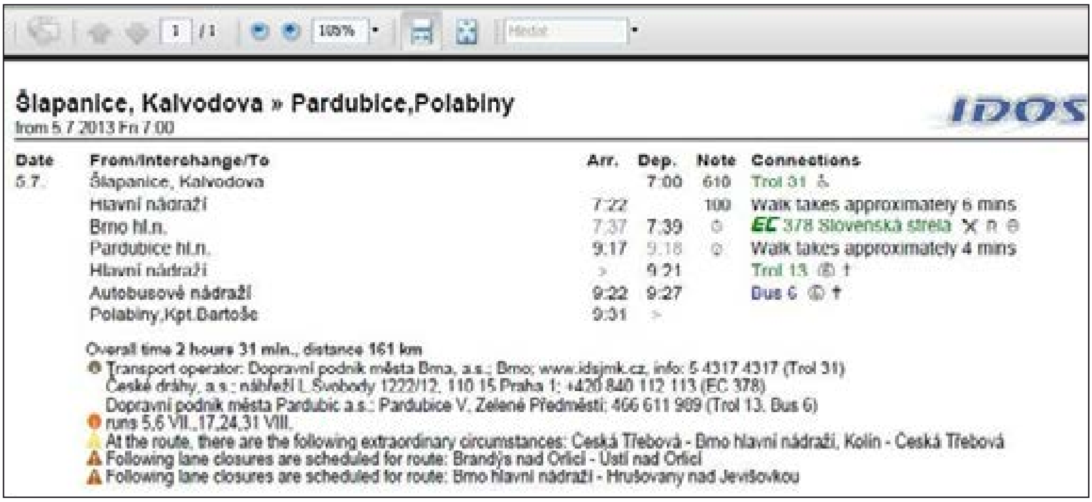
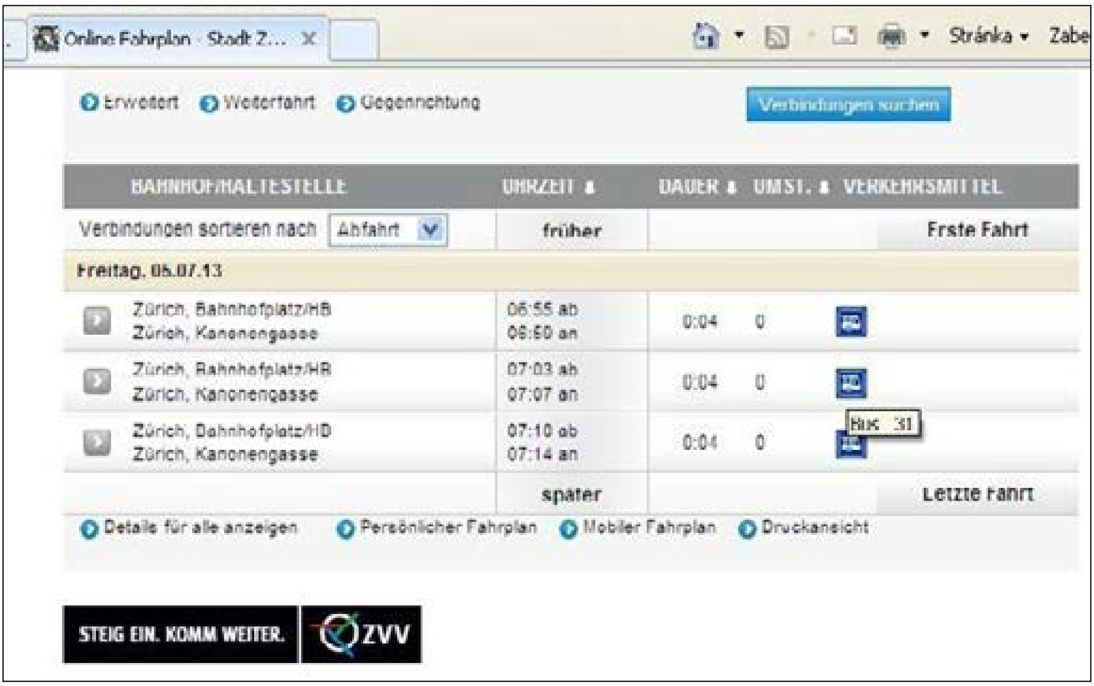


Fig. 3 - ZVV Journey planner – trolleybus route 31 indicated as "bus"



Dynamic on-line information

On-line information is becoming an important quality indicator. Most operators have installed panels indicating the next arrival or departure of each route, at least at the main interchanges or important stops. Data, collected from AVM system, are often used not only for these information panels but it is becoming very common that they are transmitted into on-line information accessible to smart phone users.

On-board passenger information usually includes information on the next stop, vehicle schedule, transfers and delays. This is accomplished by using an automatic announcing system, consisting of dynamic message signs on-board the vehicle and an audible message of the same information displayed.

1.3.4. Ticketing system

A uniform ticketing system is usually implemented for the whole PT network. Various solutions (e.g. contactless smart card) and different payment/selling device locations are observed. These should be divided into the purchase of a single trip ticket and of obtaining a travel pass and its recharging.

The most common ticketing system, applied by operators in the majority of European big cities, is purchase of tickets outside vehicles (before boarding) which is then validated inside the vehicle. Single trip (which could mean a trip with several interchanges between routes and/or PT modes) tickets are usually obtainable in ticketing machines available at all (or at least major) stops, while complementary selling points are newspaper kiosks, general shops, restaurants etc. In order to respond to all customers, ticket machines should be able to issue all types of short-term tickets (single trip, one- or more days, group-ticket) and accept all types of payments (cash-coins, banknotes, bank cards). Unfortunately, experience shows that this is still not the case as many machines do not accept banknotes or foreign bank cards, unlike petrol stations where the motorist can pay by any mean.

Some operators provide complementary ticket sale by the driver; an additional fee is usually charged for this service as the necessary time has a negative impact on timetable reliability. Passengers are obliged to validate the ticket inside the vehicle. Validity of such tickets can be restricted by time period (more common in urban service) or by distance (common in sub-urban and interurban services). However, even the paper ticket can be combined with e-ticketing by adding an electronic strip or chip; such tickets can be used for more trips and also support its utilisation for transport planning purposes.

The new ticketing technologies utilising IT tools are SMS tickets and e-tickets. The employment of the first one is increasing both in terms of operators offering such services and, thanks to the almost absolute saturation of citizens with mobile phones, number of users. SMS ticketing saves the customer´s time by obtaining a ticket at any time and any place while reducing the operator´s costs of ticket sales. Despite all the advantages, SMS ticketing is restricted to national phone numbers only and cannot be used by foreign tourists which are frequent PT users. This restraint can be eliminated by the use of smart phones which can act as “mobile wallets”.

Seasonal travel passes are the most common payment means for regular PT users. Different systems have been implemented: while there are still many cities or regions using the classic paper card complemented by paper coupon issued for a certain period (month, quarter or year), the new IT technologies are being brought into ticketing systems and the number of cities applying these systems is permanently growing. The common basis is a plastic chip or contact-less card to which the relevant applications are uploaded. It can be used not only for PT travel in a single or several zones in one or different PT networks but can serve as a credit for bike rental or car parking, but its use can be extended as a discount or customer´s card to non-mobility services (e.g. entrance fee to sporting and cultural events, restaurants).

Card employment might bring complementary benefits also to PT operators and organisers. The most typical example is traffic flows counting in PT systems where the obligatory passengers´ check-in and check-out is applied and the operator has exact knowledge of boarding, disembarking and transferring passengers at each stop and each route during the whole day. It gives also the overview on category of customers (students, full fare payers, pensioners) and their travel behaviour which enables better planning and organising of PT and response to customers´ needs.

Different methods of uploading of credit to the card are used. The most conventional one is payment at PT ticket office; the others exploit various modern IT technologies – the fare can be paid through internet banking and credit uploaded on the card through special machines installed at stops or inside vehicles or the whole ticketing tool (“card” plus “fare credit”) can be uploaded to a smart phone.

1.3.5. Passengers counting tools

Passenger counting tools are one of the benefits of the new technologies. Their aim is to provide the operator and transport authority with a detailed overview of patronage between different stations and facilitate the transport planning process.

The most efficient method is counting on the passengers´ check-in and check-out (or at least check-in) if such action is obligatory for all passengers. As described earlier, it brings exact knowledge of boarding, disembarking and transferring passengers at each stop and each route during the whole day per different group of ticket/travel pass holders.

Operators, who do not apply the check-in/check-out method, can equip their vehicles with several types of counting tools. Probably the most common is electronic counting of passengers passing through the doors in the relevant direction (in-out) which used to be applied at rail or metro stations where passengers are passing through some form of gate (turnstile) and now is being implemented directly into vehicle doors.

The other method of counting is floor weighting and measuring the axle load; such approximate data are considered as sufficient for basic transport planning. On the other hand, such equipment gives exact information on axle load to the driver which might be crucial in case of overloaded vehicles and their driving safety.

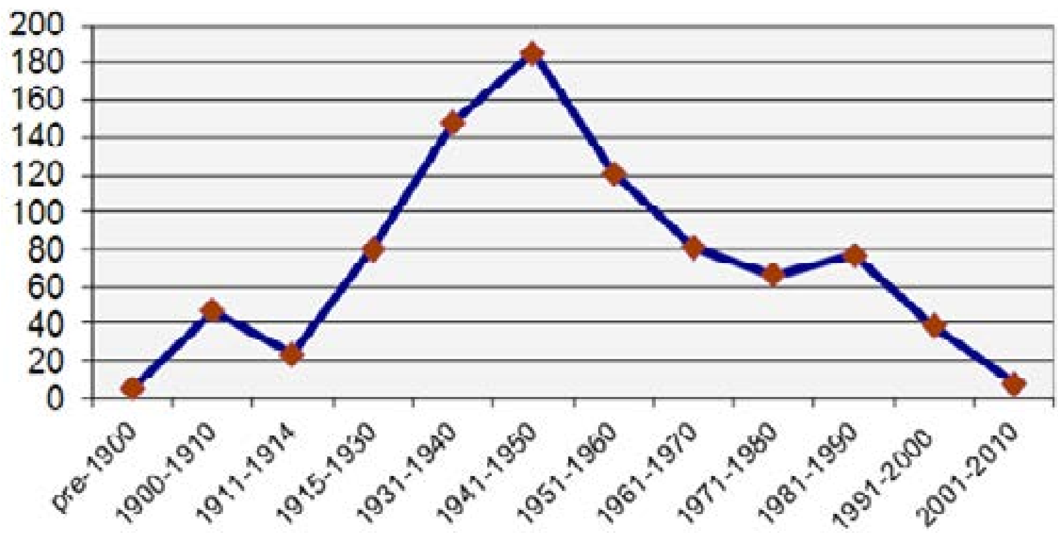
2. Analysis of the trolleybus transport role and potential in the transport system - trolley system as the backbone of public transport, and as part of intermodal passenger transport solutions

2.1. Development of trolleybus transport mode

The first trolleybus – a road vehicle powered by electrical energy supplied through two overhead wires - first appeared in Berlin in 1882, barely three years after the first electric tram, but it was not until the turn of the century that experimental installations gave way to permanent systems with regular public service. The first installations were built in Germany and France, followed soon by Italy and Austria-Hungary and somewhat later by the United Kingdom and the United States. Trolleybuses were seen as a cheaper alternative of a proven power source. A number of the first lines – at that time often called *"trackless"* or *"rail-less tram"* - complemented the already existing tram systems by providing transport services to districts inaccessible by rail while the others enabled the establishment of public transport in areas where the operations of rail-bound systems would be near the margin of profitability. However, a number of external factors such as poor roads combined with technical failures of vehicles led to a short life of most of those early systems. The remaining ones could not survive the disruptive effect of the First World War - out of 29 pre-War continental Europe systems, only 8 were still running after 1919, while in the U.K., 8 of the 10 systems launched before or during the War were active.

During the 1920s, a need for tram renewal appeared throughout Europe, both in terms of fleet renewal as well as infrastructure upgrade and public transport services extension into new outlying districts. Trolleybuses undoubtedly proved their ability to supplant tramways in the PT core mode role – besides their lower investment costs they offered new quality

Chart 1 - Number of trolleybus systems opened in decade worldwide



and higher comfort compared to existing obsolete tramways and better performance and engine power against motorbuses. New trolleybuses, developed after the War, shifted from the trackless-tram look to the modern road vehicle design benefiting from the advantages of electric power.

Trolleybus operation boomed between the late 1930s and early 1950s when some 350 new trolleybus systems were inaugurated worldwide. WWII affected trolleybuses in a number of different ways. The fuel, steel and imported raw materials restrictions contributed to the introduction of trolleybuses in many European cities as they were less dependent on all these materials and war damage was easier to repair. A similar situation applied to the early post-WWII period when there was an urgent need to reinstall public transport services in damaged cities and the trolleybus, powered by local electric energy sources, became the unambiguous solution. This period also initiated trolleybus production; trolleybus manufacturers showed up in almost all European countries and the majority of those vehicles were specifically designed as trolleybuses, not as just an electrified bus.

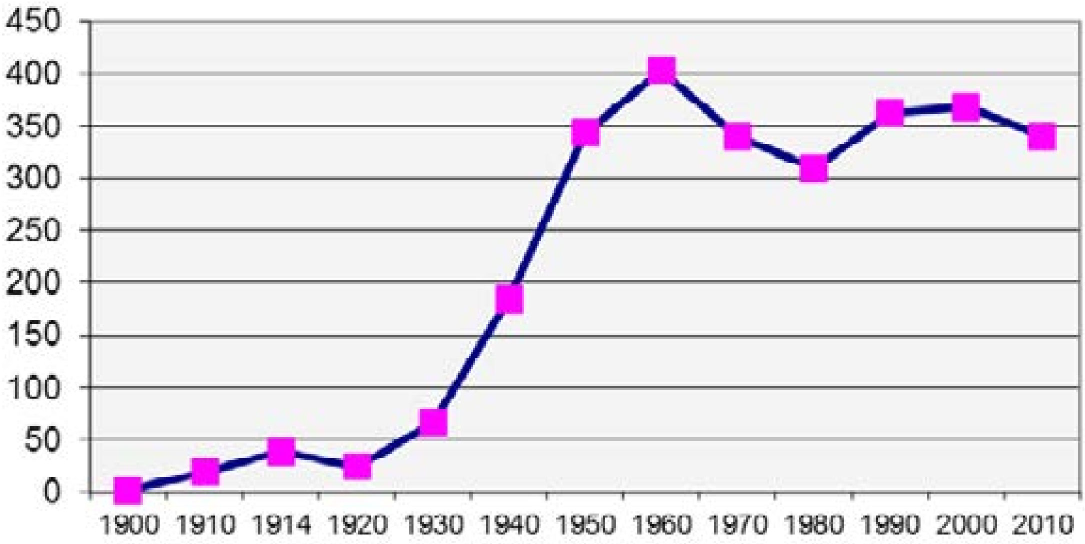
In the beginning of the 1960s, the role of trolleybuses in public transport policy started to change. New motorbus technologies eliminated their deficiencies against electric modes and bus expansion was supported also by extremely cheap fuel, liberated from the previous high excise duty. The economic pressure forced a reduction in the number of PT modes and as the need for trolleybus fleet and infrastructure renewal after 20 years of service emerged, trolleys were replaced by diesel traction in many places in Western Europe – until by the mid-1970s, trolleybuses had disappeared from e.g. Britain, Belgium, Denmark, Finland and Sweden while in other countries like France, West Germany, The Netherlands and Spain the number of systems decreased to just single numbers in service.

Fig. 4 - Number of trolleybus systems in TROLLEY partner countries + SK and CH

Region	current number of T-bus systems in service	maximum number of T-bus systems
World	340	400+
Austria	2	9
Czech Republic	13	14
Hungary	3	3
Germany	3	67
Italy	15	30
Poland	3	7
Slovakia	5	5
Switzerland	13	18

A similar approach started to be adopted in the cities of the communist part of Central Europe at the end of the 1960s where the number of systems dropped significantly as well. The reverse approach was recorded in the Soviet Union, where about half of the currently existing systems were opened during the 1960s-70s.

Chart 2 - Number of trolleybus systems in service in decade worldwide



The 1980s can be considered as trolleybus market stabilisation in the then Western Europe while there was another trolleybus boom in the Soviet Block. Several new systems were inaugurated in Czechoslovakia, Hungary, Poland and East Germany (DDR). In Bulgaria and Romania their number increased very significantly in those years.

After the revolutionary year 1989, trolleybuses started to face the competitive economic environment in the East European countries. Some systems were unable to cope with the new conditions and have been closed while quite a big proportion of networks has accepted the challenge and developed into modern transport systems meeting the up-to-date requirements of their customers. Major change occurred in East European vehicle production after 1990: production of special trolleybus design was replaced by the electrification of standardised bus bodies which had been the trend existing in West European countries and the U.S. since the 1970s.

Several new systems have been opened in the "old" EU Member States as well after 1990 – most of them in Italy, one in Sweden; special attention can be given to the optically guided system in Castellon (Spain) and partly rail guided line in the French city Nancy. On the other hand, some of the existing systems were abandoned in Austria, Belgium and even in Switzerland in recent years.

2.2. Trolleybus vehicle development

The first trolleybus appeared in 1882, when Werner von Siemens inaugurated two *"railless lines"* in Berlin on 29th April which opened for the public on 1st May 1882. This demonstration project was terminated after six weeks. Serious attempts to develop a reliable rail-less electric vehicle and use it in public transport started around the year 1900. The design of all the early road vehicles was rather similar, being reminiscent of their horse-drawn carriage origin while differing by their power source – steam, internal combustion engine, electricity. In the case of early trolleybuses, there were also differences in the method of power supply; though they all obtained energy from a pair of overhead wires, there were several different systems of collectors. The most effective system became the one developed by Max Schiemann using two poles mounted side by side roughly in the middle of the vehicle length, which later became the most common standard. Specific collection systems were developed for industrial lines application using electrically powered lorries. One of those industrial collection systems utilising pantographs instead poles is now being reinvented by Siemens´ "e-Highway of the Future" project.

Between 1910 and the early 1920s, trolleybus bodies were influenced by tramcar design, while since the mid-1920s trolley bodywork has had many similarities with contemporary motorbus design. Most of the early and post-Great War trolleys had two axles where the rearmost was the powered axle. The three-axle layout became very popular in the later period when the question of permitted axle load combined with increasing traffic demand became relevant.

In the 1930s, vehicle design developed according to local traditions. In the U.K. and most British colonies, three-axle double deckers became the trolleybus standard, the third axle permitting vehicles to be larger and therefore having a greater capacity, which was important as in the U.K. the trolleybus was mainly being used to replace busy tram lines at that time. In Continental Europe where axle load was limited, single deck three-axle vehicles were common in bigger cities while two-axle vehicles were sufficient for systems with smaller customer demand. The great need for the increasing number of cities which opened their systems in the pre-WWII period was met by a great number of manufacturers producing relatively small series of vehicles; beside production limits, there was also a strong protectionism in favour of local manufacturers, the only exceptions being the U.S., U.K. and Soviet makers who started mass production thanks to their broad market at that time.

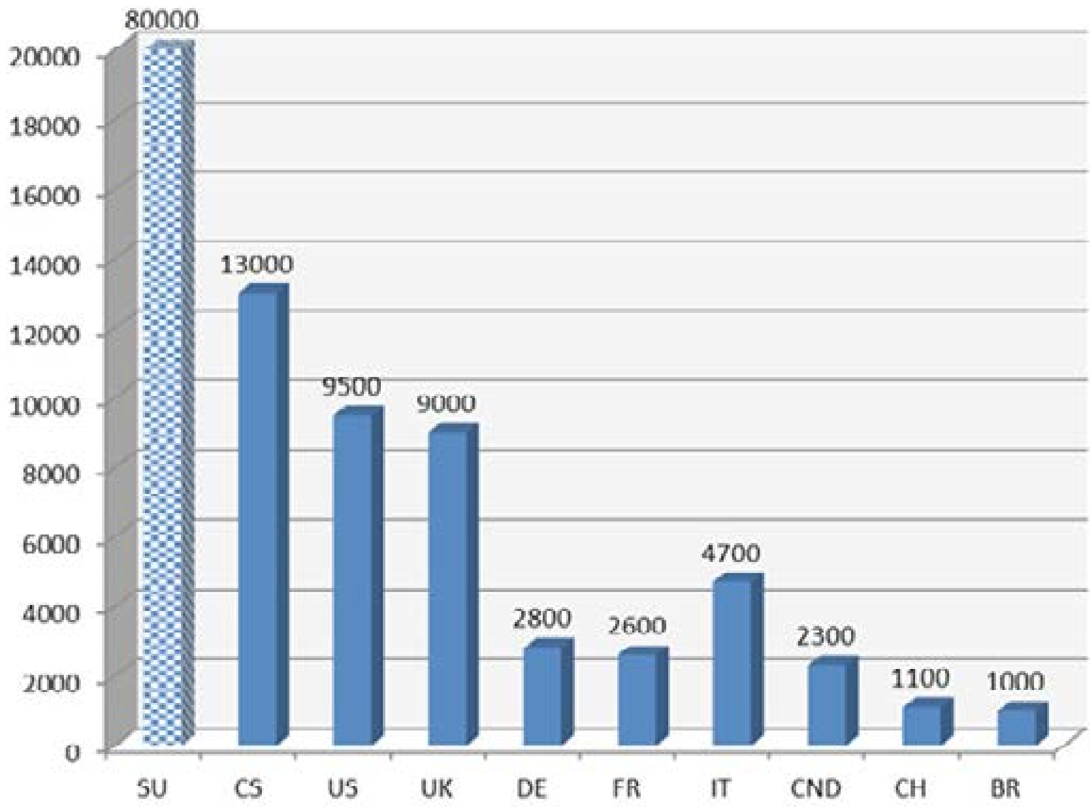
This changed rapidly after the outbreak of World WII. Only a few companies were designated for civil production and they had to behave in a very efficient way. This situation contributed to the "globalisation" of production at national level while the need for rational use of resources combined with the technical development transferred from military production led to very significant improvements in vehicle performance. The post-War era opened the market to more manufacturers, mostly with direct military production experience, which enabled further innovation of vehicles as well as manufacturing processes. The late 1940s and 1950s was the period when trolleys were prevailing technically over their tram and motorbus competitors.

The need for higher capacity was met by the use of trolleys with passenger trailers which became common in many countries, namely Germany (both BRD and DDR), Austria, Switzerland, Czechoslovakia and Poland. They had the advantage that they could be discarded at off-peak hours;, on the other hand, more powerful motors would be necessary for the hauling vehicle – but this requirement was not a problem as in some cases the three-axle vehicles were powered by an electric motor on both rear axles. The use of trailers declined in the 1960s as a result of legislative change, though they are still used in Switzerland (e.g. Lausanne operates low-floor trailers hauled by high floor buses).

The solution for coping with high customer demand was found in the articulated trolleybus. The first of these were developed in Italy at the end of the 1930s and, as a result of forced transfers between countries during the War and military reparations after WWII, they saw service in different European countries. A broader spread of the articulated design occurred only in the mid-1950s in West Germany; since the 1960s, a majority of German, Austrian and Swiss production has been artics.

While trolleybus production in Western Europe decreased during the 1960s due to the closure of many systems and loss of markets, the East European market experienced a boom. As a consequence of the planned economy system, only a few companies were designated for trolleybus production which rose to – by Western European standards – enormous figures (see chart 3).

Chart 3 - Trolleybus production per major manufacturing countries (data until 1995)



The 1970s brought improvements in vehicle design and equipment. New West European trolleybuses used motorbus bodies produced on a mass scale which increased their efficiency from the operators´ point of view. New technologies were implemented, for example the thyristor drive significantly reduced electrical energy consumption; this type of control system ruled for twenty years until being replaced by new electronic and IT control technologies. Other improvements (steering, suspension, air conditioning – commonly applied in motorbuses and trolleys) contributed to drivers´ and passengers´ comfort.

In the early 1990s, a new phenomenon in public transport – low floor accessible vehicles – was introduced. Vehicle accessibility and brand new interior design were among the crucial steps which contributed to the rediscovery of mass transport by the general public.

Fig. 5 - Low floor electric-diesel hybrid trolleybus in Hradec Králové

The changing economic conditions in Central European countries led to the adoption of the Western trend of chassis and body standardisation with motorbuses. There are still several specialist trolleybus makers in the former USSR incl. TROLZA/ZIU, the world's biggest manufacturer with total production reaching some 70 thousand trolleys.

On-going world globalisation has brought another new feature – new trolleybuses are no longer produced in just one country but they are assembled from components coming from several different countries and, in many cases, the country of vehicle (bus + chassis) origin does not correspond to the country where the entire trolleybus manufacturing process is completed by electrification.

Recent technical development has been reflected in trolleybus technology. Most new trolleybuses are capable of being driven independently of overhead by means of dual power (auxiliary or full power diesel engine) or hybrid power (surplus electrical energy generated during braking is stored in batteries or supercapacitors). Driving comfort is comparable to modern cars, and the passenger compartment is adjusted to the needs of all users. The new electronic control systems reduce fuel consumption and with the “at wheel” higher energy efficiency of the electric motor (35 %) against any mechanical transmission of internal combustion engine (25 %) make the trolleybus the most efficient and most environmentally-friendly high capacity road vehicle. Trolleybuses can carry the same passenger flows as trams if double articulated vehicles are used, as seen in several Swiss cities. The length of such vehicles (which are produced by several manufacturers in trolley-, diesel- and CNG-bus versions) is 24 metres, which is above the EU permitted maximum length of 18.75 m, however exemption for use on a specified route can be given by the municipality.

Several futuristic trolleybus designs have been produced in recent years. There are various reasons why; to distinguish trolleybuses from their diesel or gas powered competitors and diverse ways to make the public aware of the difference. Extraordinary design is one of the most effective ways with which to attract all citizens, not only PT users, immediately. The first such design was the Cristalis in Lyon prior to 2005, followed by the latest Solaris/Cegelec MetroStyle and VanHool/Kiepe EquiCity trolleys introduced in Salzburg and Parma in 2012, which have more of the streamlined appearance of modern trams than buses. The new Hess Swisstrolley4 deliveries to Limoge are also of a revised, more streamlined design.

Not only trolleybuses benefit from the latest technological developments; many competitive bus concepts using electricity as their energy source have emerged since 2000. The most widespread are hybrid buses, generating electrical power from diesel or gas fuel and supplying it to the electric motor (series hybrid) or parallel hybrid where the internal combustion engine and the electric motor are directly connected to the mechanical transmission. An important feature of the “hybrid” powertrain is surplus electric energy storage which distinguishes this concept from diesel-electric power which has been used on railways for many decades. Hybrid diesel or CNG buses save ca 15-20 % of fuel against conventional diesel buses in practical traffic conditions. Diesel-electric hybrid buses are in the range of most bus manufacturers.

A brand new hybrid solution has been developed by Solaris Bus for Barnim Bus GmbH, a member of the TROLLEY consortium; this trolleybus is fitted with lithium-ion batteries instead of an auxiliary diesel engine plus supercapacitors which makes it a fully electric vehicle supplied from three different sources.

Electric buses are considered to be the most promising concept for the future. It should be mentioned that electric vehicles powered by batteries had been developing simultaneously with internal combustion engine vehicles and trolleybuses since the beginning of the 20th century, but their development was interrupted in WWI; their further development was carried out only in laboratories and test circuits until the 1970s. The energy crises of the 1970s and 1980s brought a short-lived interest in electric cars, but it took two further decades until electric vehicles and particularly buses started to turn into a real alternative to combustion engines. The first widely used were electric minibuses with a capacity of around 20 passengers in the historic centres of Italian cities. The current leader in electric bus production is China, which produces a few hundreds of vehicles annually and exports them or at least presents their advantages to public authorities worldwide; European manufacturers are starting production of 10-metre and bigger electric buses as well and some of them have already entered regular service. Though electric buses with energy supplied from batteries are viable, they still suffer from expensive accumulators with a relatively short lifetime – they must be replaced every 4-5 years.

Several new hybrid concepts combining electricity collection from external fixed infrastructure like the trolleybus with in-vehicle energy storage (batteries or supercapacitors) have been developed recently. The most common option is collection from traction poles installed at most stops; another possibility is energy supply by means of induction plates at terminals.

“Tram sur pneu” - concepts mixing road vehicle and tram technologies were developed by Lohr and Bombardier. The “Translohr tram” is fully bound to a single rail and cannot drive as a road vehicle; the Bombardier vehicle in Nancy is bound to a single rail for most of its line, and otherwise operates as a trolleybus, while depot connection is carried out in diesel-bus mode. The Translohr system was built in several cities and currently is being supplied to Paris while the Bombardier TVR concept, which was more similar to the trolleybus, was implemented in two French cities only and its further development was stopped.

2.3. Legislative framework of trolleybus operation

The existing EU and national legislation and standards review and responses to the survey, which was carried out in the TROLLEY project framework, indicate that the trolleybus has no clearly defined position. It is categorised as a “track-bound system” (though not “rail-bound”) in several countries and as such is subject to rail (or special “urban transport”) legislation. Even in countries where the trolleybus is considered more as a road mode and subject generally to the relevant road legislation, certain specific provisions are applied for trolleybuses while all other buses are regulated by the uniform rules.

Such an approach restricts the competitiveness of the trolleybus mode and influences the political decision making process against trolleybuses. The lack of harmonisation of trolleybus technical regulations on the EU level and particularly of the common type-approval decreases the competitiveness on the trolleybus market and is reflected in the low competitiveness of the trolleybus mode. Despite the manufacturing and market globalisation, which has already brought benefits to almost all industrial areas, trolleybuses – similar to trams and railways – are still governed by national legislation and standards, non-harmonised throughout the European Union. The European Commission has already recognised the negative impact of this lack of homogeneity as one of the crucial obstacles for further development of the common rail system and this unsatisfactory situation has been reflected in the Fourth Railway Package.

The results of surveys and their analyses indicate that it would be in the interest of further extension of trolleybus operation to set up preconditions for European harmonisations of national legislation and standards which has been already established in the field of road vehicles. The most important and most beneficial area subject to harmonisation would be the vehicle type approval process and its common recognition by all Member States.

Harmonisation of legislation would produce benefits in terms of decreased costs to manufacturers and operators, and therefore to those who pay these costs, whether they would be passengers or local authorities; it would also enable free movement between Member States of drivers and others with skills needed by trolleybus operators. It would also make for a new level playing field when assessing the merits of bus and trolleybus operation and therefore may have benefits in providing public transport with zero emissions in cities.

The potential follow-up project should target harmonisation as one of its main goals and dedicate appropriate time and work force to the preparation of the relevant work document. This recommendation therefore directly promotes the EU aims of facilitating the free movement of people, goods and services within the EU.

3. Examples of specific modal interchanges in selected trolleybus networks

3.1. General principles

3.1.1. Accessibility of transport services, the impact of intermodality / multimodality on increasing the share of public transport in the modal split, the impact on passenger satisfaction

Public transport started to facilitate mobility in the middle of the 19th century when steam railway networks crossed continents, linked hinterland with seas and oceans and connected villages with regional centres. Urban public transport had a similar impact on local mobility which enabled their urbanisation in the first half of the 20th century. Unfortunately, after recovery from WWII, many cities and urban agglomerations turned their back on public transport and placed cars and individual motorisation as their priority. Such an approach has shown its unsustainability and policy makers and transport professionals want more journeys to be made by sustainable transport: public transport, supported by cycling and walking. This is essential to the generally adopted goal of reducing carbon emissions from transport.

The positive impact of high level and high quality urban transport can be documented by Swiss and Austrian statistics. The PT modal share in their major cities is above one third, already higher than car users; if occasional PT users are included, the figure exceeds a half of local populations. The EU has recognised these achievements and set among the goals of its transport policy a major push towards multi-modal travel planning and integrated ticketing.

Trolleybuses comply with these policy goals and represent a less costly alternative to trams or light railways, but offering comparable performance. The higher investment costs of trolleybus against motorbus caused by necessary infrastructure and higher price of vehicles, forces careful network planning reflecting customers' long term demand and needs. Trolleybus lines cannot be built randomly; their system planning reflecting local spatial and transport needs enables their design as high capacity corridors equipped with ITS, traffic priority, accessible stops with passengers´ amenities, fully utilising the mode potential.

3.1.2. Other major benefits - the system's functionality, capacity, congestion reduction, use of public space, the impact on the quality of public space, increase of personal safety

Transport accounts for almost 20 per cent of greenhouse emissions worldwide. Cars and other internal combustion engined vehicles represent a major source of particulate pollution into the atmosphere at street level as well as producing high levels of "greenhouse" gases such as carbon dioxide. There is a need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change to an increase of 2°C. Overall, by 2050, the EU needs to reduce emissions by 80-95% below 1990 levels in order to reach this goal.

The European Commission has set a three-part strategy for transport in cities. A key part of the Transport 2050 strategy is to move towards the goal of phasing out conventionally fuelled cars in cities by 2050 – with a shift to electric cars, hydrogen cars, hybrid cars, to public transport, and to walking or cycling in cities. One of the crucial tasks is to halve the use of 'conventionally fuelled' cars in urban transport by 2030 and phase them out in cities by 2050.

Congestion costs Europe about 1% of gross domestic product (GDP) each year. Quality public transport is a tool to reduce urban road congestion without restraining mobility. Trolleybuses are one of the modes which can tackle both goals – environment and congestion – effectively. Dedicated trolleybus lanes which can be shared with motorbuses are more visible thanks to overhead than ordinary bus lane signed on street only. The need for high frequency and capacity guaranteeing service efficiency means that the number of trolleybuses justifies the lane and also psychologically prevents other drivers misusing it.

The impact of urban public transport on road safety is without doubt. Given by the vehicle design, buses provide higher protection to their occupants (driver and passengers) than passenger cars. The safety technical requirements are incorporated into EU (**Directive 2001/85**)[8] and UN/ECE (**Regulation No 107**) vehicle legislation; additional safety prescriptions for trolleybuses are set in Annex 12 of the UN/ECE Regulation No 107[9].

3.1.3. The main user groups, intermodality influence on their attitudes

Public transport used to be the predominant means of urban mobility and all big European cities were covered with tram or trolleybus networks. Increasing private motoring moved a whole generation of citizens away to cars and closed many electric transport systems. The current reinvention of trams opens up mass transport to new customers. They are called "light rail" in many cities which reflects the need to present them as something advanced compared to the old obsolete vehicles remembered by older generations of citizens. In the case of the trolleybus, the same perception can be seen: the old vehicles used by some Western cities are unattractive against modern low floor buses; citizens of the ex-communist region, who are excited by owning private cars only now, consider the trolleybus – and all public transport - as a relic of the previous period. The running and new systems should target their potential customers and react to their needs by network planning, vehicle comfort and attractive offers; in addition to these processes applied by all transport operators irrespective the mode, trolleybus operators should highlight their emission-free, low noise and smooth ride not only to the public but also present these arguments to the policy- and decision- makers in order to convince them of the benefits of the trolleybus. The main advantages of trolleybus systems are presented in TROLLEY's image campaign "ebus – the smart way!", which can be seen at www.trolley-project.eu.

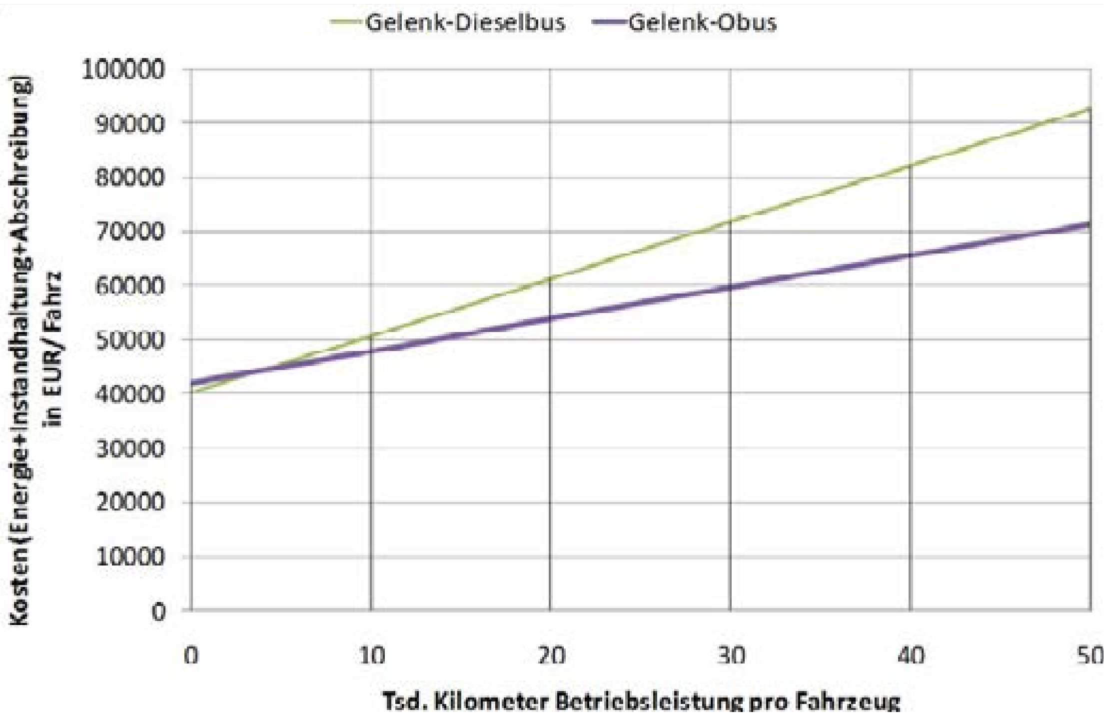
---

8) DIRECTIVE 2001/85/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 November 2001 relating to special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the driver's seat, and amending Directives 70/156/ EEC and 97/27/EC
9) Regulation No 107 of the Economic Commission for Europe of the United Nations (UN/ECE)— Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction

3.1.4. Costs of trolleybus line construction, operation, involvement of key actors in the process

Implementation of PT modes bound to an external energy source (trolleybus, tram, light rail) requires significantly higher initial investment than any independent traction mode. The same applies to investment in rolling stock, though this factor can be partly eliminated by the much longer lifetime of electric vehicles; however, the longevity effect should not be overestimated as such vehicles are seen by the public as old-fashioned and unattractive and induce additional maintenance costs to operator. In the past, it used to be quite common to modernise older trolleys by fitting a new body complying with an increased comfort demand. Nowadays, it is not the customers´ view only but also quality legislative requirements (accessibility for disabled users) and more efficient technology which influence operators´ decisions. One potential approach is the conversion of diesel buses with bodies matching current requirements into trolleybuses as applied in Gdynia and Szeged[10].

*Chart 4 - Break-even analysis for comparison of cost-effectiveness between diesel bus and trolleybus systems in Salzburg (based on operational kilometres) Source: TROLLEY project**

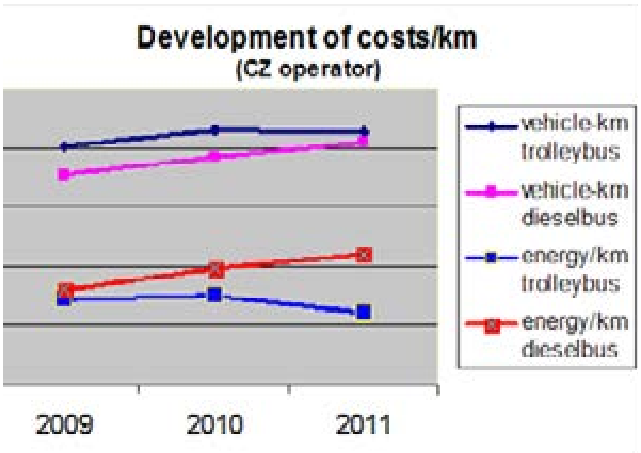


**) The break-even analysis is based on TROLLEY's "Transport Mode Efficiency Analysis Tool". More information can be found at: http://www.trolley-project.eu/index.php?id=44*

10) See also TROLLEY's handbook on "Conversion of a Diesel Engine Bus into a Trolleybus" available at: http://www.trolley-project.eu/fileadmin/user_upload/download/Conversion_of_a_diesel_engine_bus.pdf

On the other hand, trolleybuses with their lighter infrastructure are inherently cheaper to construct than equivalent light rail systems – while trolley infrastructure investment is in the € hundreds of thousands order of magnitude (without substation), a tram line costs ten million per kilometre. *[Trolleybus line Hroboňova - Pražská in Bratislava: € 2.361 million/4.15 km, tram line to Nové Sady under construction in Olomouc: € 12-15 million (estimate)/1.5 km]* The recent tram expansion in Western Europe might have a knock on effect for trolleybuses as well as much of the electrical equipment is the same and standardisation and mass production brings lower costs.

Chart 5 - Development of costs / km   Source: SDP CR



The operational costs of trolleybuses and their comparison with other road modes are dependent on several factors, which differ country by country very significantly and any common European formula can be hardly established. The main indicators influencing the operational efficiency of trolleybus mode are the energy consumption and energy price. The total costs incorporating the investments (CAPEX = Capital Expenditures) the cost of vehicle acquisition and infrastructure are higher than other modes because of initial investment. It is expressed in track and vehicle depreciation, which differ according to the relevant fiscal legislation in each country. However, if external costs of internal combustion and emissions generated in-situ are internalised, the total costs can be equalised. For example, for the TROLLEY partner city Salzburg, a break-even analysis regarding the cost-effectiveness of the trolleybus system shows that above approx. 40.000 operational kilometres (on the chosen line), the cost-effectiveness of the trolleybus is better compared to the cost-effectiveness of a (fictitious) diesel bus system for Salzburg (see chart 4). Another example is described for the TROLLEY partner city Eberswalde in the following chart 6.

The example shows that the trolleybus system is only 1 cent more expensive per scheduled kilometre compared to a (fictitious) diesel bus system in Eberswalde. But the underlying study also demonstrates that the trolleybus system saves 95% of CO_2 emissions (based on local green power mix for Barnim Bus Company) compared to a diesel bus system in Eberswalde.

“Fuel” costs (diesel oil vs. electricity) are favouring the trolleybus and oil and its taxation are permanently rising; CNG is cheaper than oil because its excise duty is in most countries lower but this is tending to harmonise with petrol and diesel taxes. Electricity price is rather stable or declining. The fuel costs calculations differ country by country because many EU Member States apply reduced (or partly refund) excise duty for public transport operators while use of electricity for public transport is exempted from environmental taxes because of its positive environmental impact. Traction and overhead maintenance are generating additional costs for trolleybus operation. According to a survey among Czech and Slovak operators, the labour costs of trolleybus maintenance are slightly higher as well because of the higher number of specialised staff.

Chart 6 - Comparison of trolleybus and diesel bus system for Eberswalde, Germany
Source: TROLLEY project

	Trolleybus	Diesel bus
Energy/fuel	264.000 €	442.600 €
Staff costs/driver	No difference	
Maintenance vehicle	80.000 €	72.000 €
Staff costs/garage	No difference	
Staff costs/cat.	126.000 €	---
Maintenance/cat.	19.000 €	---
Insurance vehicle	48.000 €	24.000 €
Investment/Recovery time	37.800 € 18 years	31.000 € 10 years
Difference	+5.200 €	
Difference/km	0,01 €	

The New Member States are eligible to use EU Structural Funds for funding their trolleybus projects. Many cities have benefited from this challenge and upgraded and renewed their fleets or extended their network. This Community support enables the improvement of public transport systems and keeps the positive modal split and operate trolleybuses as the environmentally most friendly mode.

3.2. Examples of specific modal interchanges in selected networks

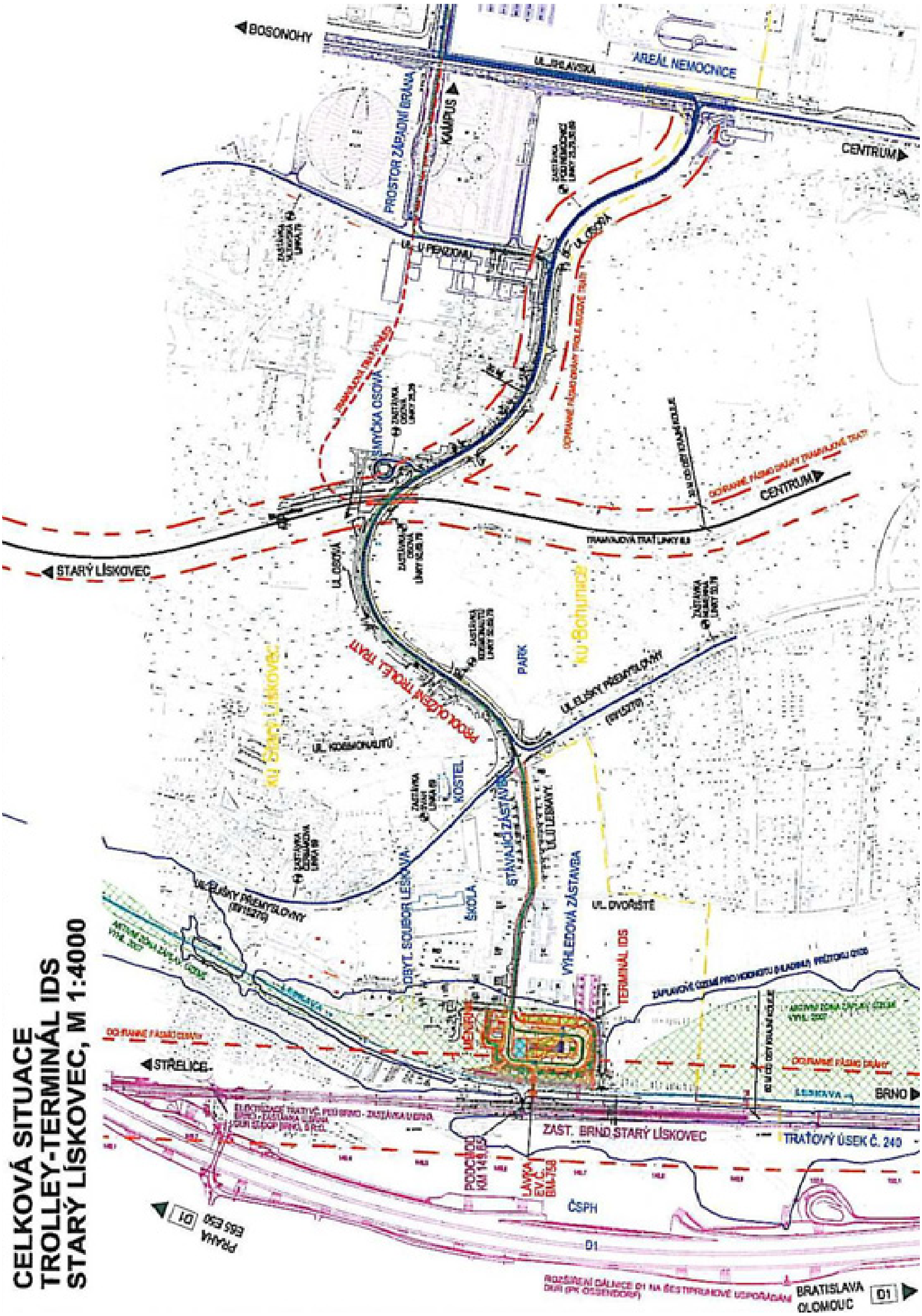
3.2.1. Trolleybus extension projects in Brno

Two projects for trolleybus network extension have been prepared in the framework of TROLLEY project in the City of Brno; they are both in the phase of building permit authorisation now. One of them is ca 1 km extension to Starý Lískovec in the southern edge of the city, the second one is a short 100 metres section improving the public transport access to the Zoological Garden in the north-western district Bystrc.

3.2.1.1. Brno-Starý Lískovec development project

The proposed rail and public transport terminal Starý Lískovec is located on the southern edge of the city built-up area, ca 6 kilometres from Brno main station. The terminal construction

Fig. 6 - Brno – Lískovec terminal location



is linked to the Brno – Střelice rail line upgrade (installation of second track, electrification) and new station Starý Lískovec construction. The goal of this new development is to create intermodal interchange between rail, bus and trolleybus transport directly plus tram line within walking distance. The upgraded railway line will attract customers from the south-west suburbs of Brno and facilitate mobility to the neighbouring Bohunice hospital (main hospital in Brno) and student campus. The districts of Starý and Nový Lískovec and Bohunice represent population of ca 50 thousand inhabitants, while the university campus and hospital may attract up to 10-15 thousand employees and visitors per day. The Brno – Střelice line is the main rail access to Brno from the West and South-West, carrying currently up to 5000 passengers per day. Considering the fact that the train service on the upgraded line is proposed with a 15 minute peak frequency, a doubling of this traffic volume can be estimated with a high number of passengers terminating their rail journey at this new station and changing for trolleybus. Trolleybus routes will connect the new terminal via the Bohunice hospital and university campus with Mendlovo nám. (city centre hub) and tangent across the whole city to Lišeňská.

The new trolleybus extensions will be ca 1 km long, connected to the existing network close to the Osová street terminus. The new line will be partly (half of its length) placed in a newly built road infrastructure.

The following main principles have been taken into consideration in the planning process: preserving the existing and extension of pathways and reduction of negative impacts on the environment. Emphasis is put on ergonomics of structure and its fusion into surroundings.

The PT terminal includes a bus loop and car park linked by pedestrian bridge across the river Leskava with the railway section.

The area of the development site is 120 × 60 metres divided into two sections:

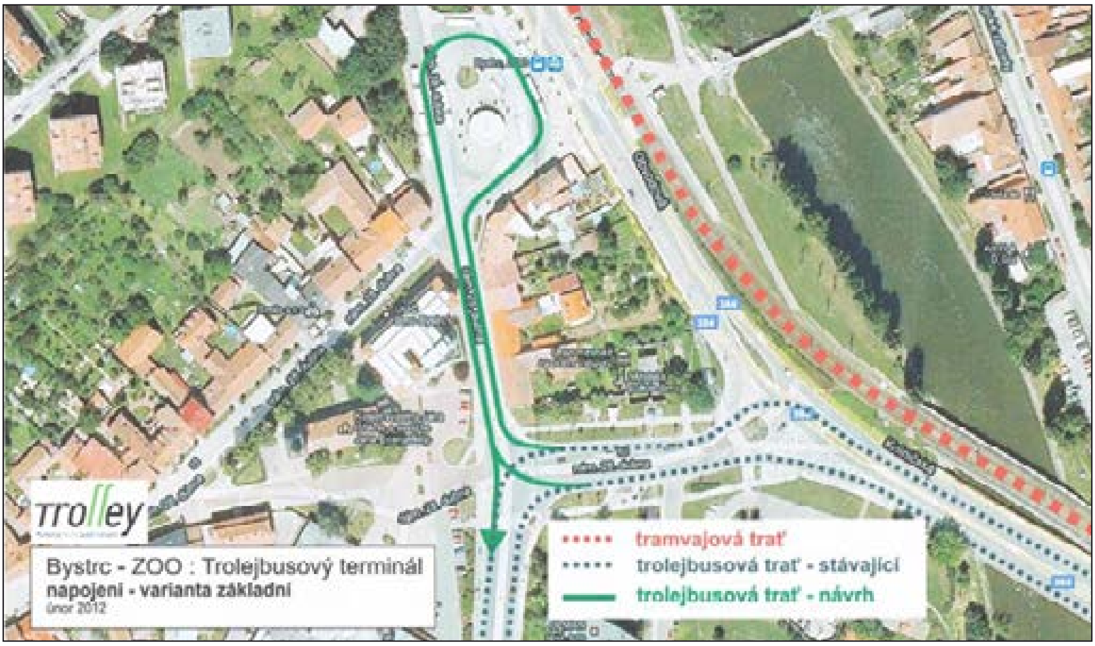
- PT terminus (one way loop with 2 disembarking stops, 7 bus parking places, 4 boarding platforms for regular routes + 1 platform for rail replacement services) with facilities for bus drivers and passenger shelters. All platforms and facilities will be accessible for disabled users.
- Car park for 25 cars; this site will be temporarily occupied by the mobile sub-station supplying the new trolleybus extension

The expected start of development is during 2013 and will take 2 building seasons.

3.2.1.2. Brno-Bystrc (ZOO) extension project

The aim of this project is to incorporate the trolleybus mode into the existing intermodal PT terminal Bystrc, ZOO. The stops of different bus routes are spread across the entire area which makes the transfer uncomfortable. This hub already serves as an interchange between city centre bound tram lines and motorbus and trolleybus lines providing local connections within the district and some tangential links passing round the centre. The trolleybus route Nr. 30 connects the Bystrc district along the north-western city centre border with the Královo Pole district, its rail station (on the main line to Havlíčkův Brod) and the newly developed technological park site. The motorbus route Nr. 50 creates the south-western tangent linking Bystrc with the Lískovec and Bohunice districts. The tram line location at the

Fig. 7 - Trolleybus extension Bystrc, ZOO in Brno



edge of Bystrc residential district (given by the river and layout of road network) does not allow direct access to tram services for the residents concerned and forces them to use one of the bus modes; however, the interchange points are spread into several locations so far, which has a negative impact on citizens´ perception of public transport.

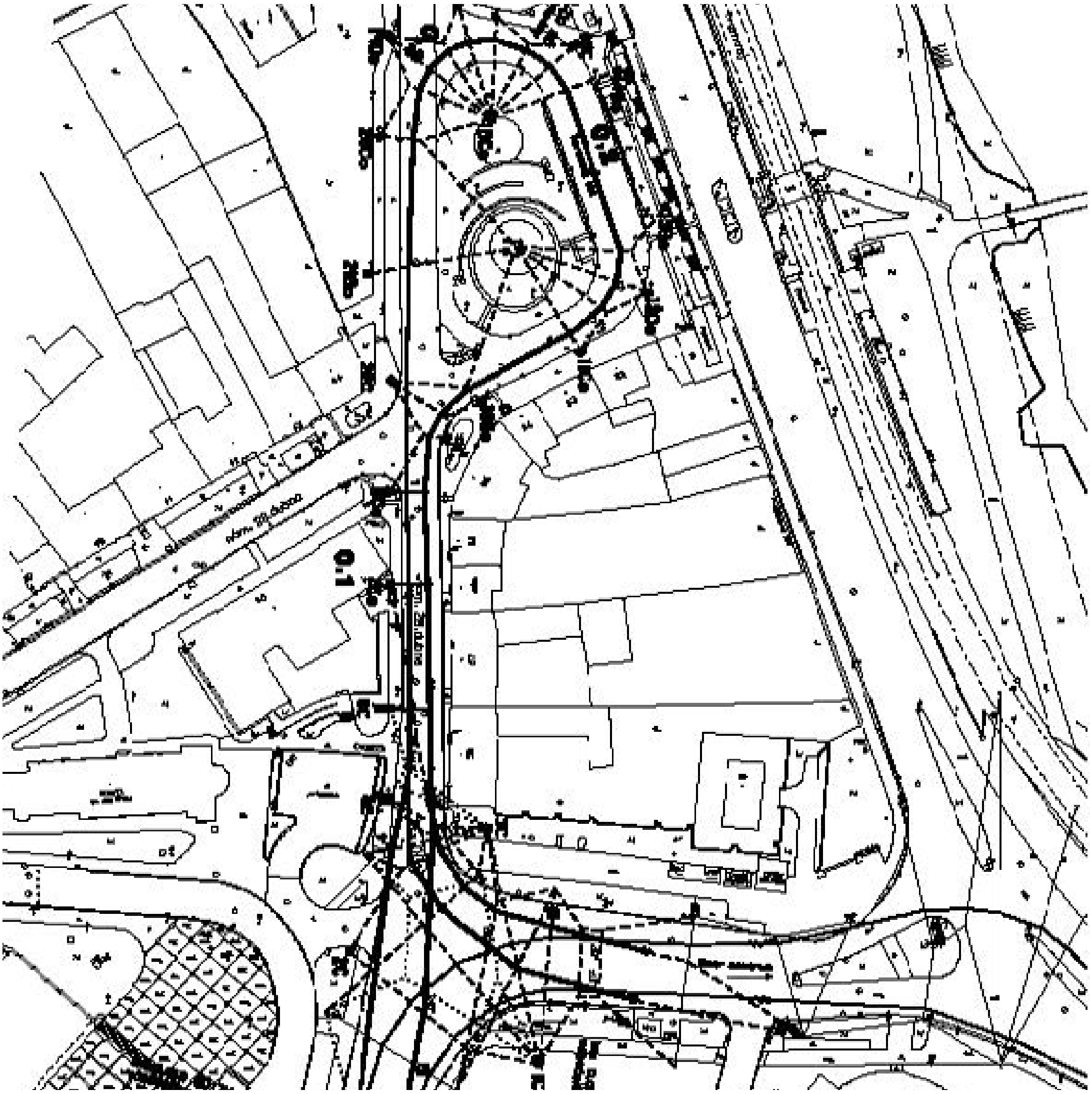
Naturally, another goal of this trolleybus extension will be to improve the PT access to the ZOO itself. The zoological garden is one of Brno's major cultural sites, attracting around 250 thousand visitors per year as well as providing educational activities for the young generation.

The centralisation of all transfer links covering all "road" modes (trams, trolleys, city buses, regional buses) into a single point equipped with all necessary background (shelters, benches, refreshment kiosk) will facilitate them and contribute to higher attractiveness of public transport.

The new trolleybus loop in the ZOO Terminal will be connected to the existing network by ca 100 metres long extension from the road junction Odbojářská x Náměstí 28. dubna along the western side of Náměstí 28. dubna to the area in front of the ZOO entrance gate. In order to enable services to all potential directions, 3 pairs of frogs, remote controlled from the approaching vehicles, will be installed at the Odbojářská x Náměstí 28. dubna junction. The type of adjacent buildings requires hanging the overhead on 21 steel poles with anti-corrosion protection placed in concrete foundations. Due to its short length, the extension does not require additional energy power source and will be supplied from the existing substation and grid.

The construction process will be divided into two phases – first positioning of poles followed by the installation of overhead itself as a second phase; the exact schedule should be concluded during 2013 depending on the approval process.

Fig. 8 - Overhead layout at ZOO terminal



3.2.1.3. Integrated Mobility Centre in Brno[11]

The city of Brno participated in project CIVITAS ELAN, the European project focused on innovative solutions in urban mobility. Within the CIVITAS ELAN project six measures were implemented in Brno in the years 2008 - 2012. One of them was the establishing of the Integrated Mobility Centre.

The main goal of this measure was the installation of the Integrated Mobility Centre (IMC) on the intersection of the Joštova and Česká Streets. This intersection is situated next to the historic centre of the city of Brno. This place is not only very valuable public space but

11) http://www.civitas.brno.cz/?q=eng

also one of the most important junction points of public transportation in the city. There is a transition point for six tram lines and six trolley bus lines. This place is the main meeting point in the city centre as well.

On this spot the IMC provides its clients with all kinds of targeted traffic information as well as tourist information on Brno and the South Moravian Region. The building was equipped with the necessary facilities for two officers and a sophisticated ticket vending machine offering not only single but also open and season tickets. The computer terminal installed in IMC displays topical information and news interesting for the citizens and visitors alike. It also provides Internet access for the visitors.

Apart from the building of IMC itself there are several other improvements of the public space made for construction in the framework of this measure. Real Time Passenger Information Panels suitable for this historic city centre were developed and then installed into the newly reconstructed Česká and Joštova interchange point (reconstruction was done outside the CIVITAS framework), new shelters were erected on the stops and the stops themselves were made more accessible for handicapped persons.

The measure “Integrated Mobility Centre” (IMC) was implemented by the City of Brno with the aim of providing all the necessary information regarding transportation and tourism in both Brno and the entire South Moravian Region. It is a reaction to the growing requirements of the passengers, an effort to make a public transportation (PT) more accessible and provide the right information in the right place and at the right time. Other than that, the Integrated Mobility Centre will serve as a support in further efforts of the City of Brno in the field of sustainable urban mobility. According to a first evaluation phase the IMC was visited by 9,320 clients from its opening in September 2011 till the end of August 2012.

Fig. 9 - Information Mobility Centre kiosk in Brno, Česká

3.2.2. Intermodality in Szeged

3.2.2.1. Modal interchange Széchenyi tér

Széchenyi tér is the central square of Szeged (number of residents: 170,000), which is also a major intermodal junction of the different public transport modes of Szeged: trams, trolleybuses and buses. In this area major business and public service institutions can be found such as the central post office, banks, municipality administration buildings, regional government buildings, courts, corporation offices as well as the central commercial area of Szeged.

The area has been partly restricted for individual traffic since the middle of the 1990s in order to prioritize public transport. The modal split of Szeged in 2009 was 22 % by car, 22% on foot, 46 % by public transport, and 9 % by bicycle. In recent years bicycle traffic further increased, which is demonstrated by the high use of the bicycle storage facilities. Three such bike storage facilities were built within a 50 m radius of this junction.

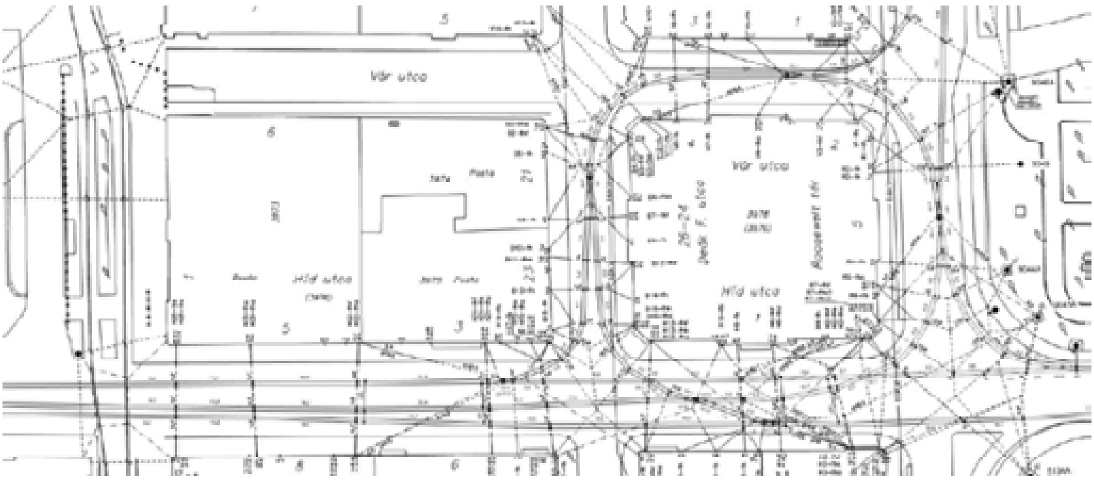
According to the 2012 survey of passengers, from the daily passenger load of approx. 198,000 voyages: 30 % chose trams, 24 % chose trolleybuses and 46 % chose buses. The busiest tram routes 1 and 2 meet at Széchenyi tér with trolleybus routes 5, 7, 9 and 19 as well as the bus routes 60, 60Y, 70, 71 and 72. Altogether the daily use of these stops is by 31,800 passengers, which means an approximate yearly use of the intermodal hub of around 10 million passengers.

Fig. 10 - Széchenyi tér - tram stop, trolleybus crossing and bike racks

In recent years this busy hub was reconstructed extensively from different EU-funds. The bus and trolleybus stop direction Újszeged was reconstructed from South Great Plain Regional Funds, using conventional layout in 2010. The tram stops and the tram tracks were reconstructed using Transport Operational Program (Cohesion Fund) in 2011. Here 30 cm high elevated platforms were used to give accessibility for disabled persons. The height of the platforms were in synch with the floor height of the new low-floor trams giving access for people in wheel-chairs without any external help.

The trolleybus stop at Híd utca and the overhead catenary of the trolleybus was reconstructed as a part of the Central Europe Trolley project in 2011 as a pilot action of demonstrating high speed trolleybus corridor elements. The stop was constructed with new elevated (20 cm high) platforms introducing special kerb elements to make the positioning of the trolleybuses easy. If a low-floor trolleybus uses its kneeling ability, a disabled person in a wheel-chair is able to access the trolleybus without help as well.

Fig. 11 - Overhead construction plan, showing the trolleybus layout at Híd utca area as well as the tram-trolleybus crossing at Széchenyi tér



Also thanks to the EU co-funded projects, all overhead elements of the trams and trolleybuses were refurbished in recent years, making it possible to cross in every direction at high speed, avoiding malfunctions and trolley derailments which often happened prior to the reconstruction. Six tram-trolleybus crossings, eight trolleybus switches and two trolleybus-trolleybus crossings were built in, all high-speed elements. In case of any disturbance in trolleybus traffic, the reconstructed overhead loop makes it possible to reorganize the trolleybus routes from every direction.

In the near future, traffic light influence will be introduced in order to enable the trams to cross the junction faster. All reconstructed stops obtained stylish stop signs which already have connection to the optical communication network of the public transport company SZKT. All these masts incorporate a place for digital information tables; furthermore a web-terminal was placed in the area for tourist information systems. These devices will be put in at the end of 2013.

3.2.2.2. B+R Trolleybus intermodality in Szeged

Modern trolleybuses are getting more flexible, thus becoming a possible solution for electromobility in public transport. Trolleybuses are the most environmentally friendly in terms of local pollution, noise and vibration emission, and can serve as a high passenger capacity route in a trolleybus corridor as well as a feeder route in a few km long overhead free mode in a low-density residential area. The combination of these features can create a combined network to support all capacity needs of especially mid-size cities.

An important quest of any public transport is to reach all areas of the city, and at least give residents the opportunity to reach the public transport within a short time. While on foot the conventional wisdom is to serve a residential area of around 500 m radius, it can be multiplied if there is a possibility of combining a bicycle ride with public transport. Especially at the outer termini of trolleybus routes there is a way to attract new customers with B+R parking areas. It is advisable to create the B+R station to have higher comfort level: e.g. with roofs for rain protection, lights, and security cameras.

In recent years, the number of electric bikes or electric mopeds has been increasing. An opportunity at trolleybus termini is the usage of the existing DC power feeder line, which was explicitly designed for high amperage (a typical trolleybus takes round 400-500 Amperes by accelerating). However the power lines are only used for relatively short times at their highest output. The termini of trolleybuses with B+R parking can also become future charging stations for electric bikes.

Fig. 12 - Bike and Ride terminal in Szeged

In the framework of "Reconstructing of Szeged Electric Public Transport" project, which was a 100M Euros investment from the municipality supported by EU Cohesion funds, eight such B+R facilities were built in the outer termini of Szeged trams and trolleybuses in 2012. One such facility is shown in the above picture. All B+R stations have the function to reach out for the neighbouring low density residential areas to attract more passengers for the trams and trolleybuses, which run significantly more frequently than the buses in the outskirts.

3.2.3. Trolleybus projects in Salzburg

3.2.3.1. Intermodal interface Salzburg/Mülln

With the removal of the suburban train in Salzburg and the erection of the stop "Salzburg Mülln-Old town", an important intermodal interface has been created. The interregional "S-railroad line 3" connects the Southern Tennengau district with the provincial capital Salzburg and the neighbouring communities Freilassing and Bad Reichenhall. It takes residents and employees, but also tourists from the surrounding countryside directly to Salzburg City Centre. In the year 2011, 3.6 million people used the connection running every half hour. This is an increase of 12 % within a year. Unfortunately, no exact passenger numbers for the stop Mülln-Old town are available.

Fig. 13 - Salzburg/Mülln trolley + S-Bahn interchange

Connected to the urban public transport net (seven trolleybus or bus lines altogether), this stop represents a trend-setting interface. The favourable location close to primary cycle track axes is an additional asset. Roofed bicycle parking spaces support intermodality.

The fact that the historic city centre is within walking distance facilitates the intermodal approach of this junction. The integration of a pedestrian bridge crossing the river Salzach makes this suburban train stop even more attractive. The scenic walking path along the riverside encourages not only tourists to reach the old town on foot.

Thanks to the electrification of a diesel bus line and opening of the new Trolleybus line 10, another step in the direction of eco-friendliness was made. Thus the connection of the Salzburg city library to the environmentally friendly trolley bus net could be realised. Line 10 runs to the Fair and Convention Centre and serves the reinforcement of the Park & Ride strategy in Salzburg primarily in the vacation season.

The intermodal interface Salzburg Mülln-Old town ties up important public utilities like the Salzburger Landeskliniken (medical clinic), the PMU Paracelsus Privatmedizinische Universität (University) as well as the new “Stadtwerke-Areal” (residential area and competence park).

Fig. 14 - Obus network linked to S-Bahn

3.2.3.2. Stadtwerke Lehen

With the redesign of the former “Stadtwerke-Areal”, a strong emphasis was put on the connection to the public traffic network. Due to its particular location next to the city centre, it is characterised by high-quality municipal functions. For the whole project, a strong significance was given to sustainability, e.g. energy efficiency, mixed use and public participation.

The “Stadtwerke-Areal” contains about 300 modern apartments, a students´ home, a nursery school etc. The competence park will be set in the second construction phase. It will house institutions with their main emphasis on medical research as well as the new headquarters of a Salzburg educational organisation.

The area is made accessible on all four sides by a trolleybus line with direct connection to the main station, the city centre or in the direction of the airport.

3.2.3.3. Mobility Management

A special welcome package, developed in cooperation with the VCÖ (Austrian traffic association) and Salzburger Verkehrsverbund (transport authority) should stimulate the new residents to reconsider their previous mobility habits. Information about schedules and rates should promote an environmentally friendly means of transportation choice.

Fig. 15 - Salzburg mobility concept

For residents, public employees and visitors to the restructured city area, this newly created interface is a perfect opportunity to reconsider their mobility habits and to change over to public transport. Departure monitors in the foyers of the university and the competence park shall give easy access to information.

In particular it was tried to demonstrate the high emphasis put on steering individual mobility towards public transport, walking and cycling.

This leads to considerable CO_2 savings because the share of individual car use in comparison with other living areas is expected to be significantly less.

3.2.4. Plan of intermodal integration node of Gdynia Karwiny

The district of Gdynia Karwiny (ca. 11 thous. inhabitants, 4,5 % of total population) is situated in the southern part of Gdynia, having connection with the central part of the city by one of the most important and heavily congested roads, Wielkopolska street. Wielkopolska street is also an important trolleybus corridor providing service on lines nr 23, 24, 27, 29 and 31 (to Sopot). Its extension also links Tricity Ringroad being today of strategic importance for the whole metropolitan area. It results in intense car flows on Wielkopolska street during working days.

Railway line nr 201 of regional importance runs in the vicinity of the area which crosses with Wielkopolska street. Currently, the nearest railway station, Gdynia Wielki Kack, is located away from the main pedestrian and road routes which results in low attractiveness of passenger railway transport for inhabitants of the Karwiny district. There are only 7 daily passenger train connections available.

The potential of the railway line will increase when the Pomeranian Metropolitan Railway project is completed in 2015. This project includes reconstruction, upgrading and construction of the railway infrastructure between Gdansk Wrzeszcz (located on one of the most important railway corridors in Poland) and Gdansk Osowa located on line nr 201. Part of this project is also the construction of a railway stop servicing Lech Walesa Airport in Gdansk (almost 2.9 mio. passengers in 2012). After completion of the Pomeranian Metropolitan Railway project, the importance of the regional railway line will increase. A new railway stop – Gdynia Karwiny, directly integrated with urban public transport in this part of Gdynia, is needed.

Gdynia City Council passed a spatial plan for this area (Fig. 16) in March 2012 in close cooperation with other stakeholders.

Completion of the Pomeranian Metropolitan Railway will have significant effects for Karwiny and neighbouring districts, such as:

- construction of new railway stop (Gdynia Karwiny) at crossing with Wielkopolska street;
- creation of direct railway link to centre of Gdansk, through Airport with Gdansk train stop;
- improvement of railway accessibility of Gdynia centre through increase in number of trains linking Gdynia Glowna (main railway station) and Karwiny;

- development of intermodal node of metropolitan importance for Karwiny and neighbouring districts (Park & Ride – capacity of 200 to 450 cars, depending on chosen option, Bike & Ride);
- improvement of the municipal public transport service because of creation of bus lanes on Wielkopolska street and providing convenient interchange between urban and regional trains and buses and trolleybuses.

There are two alternative projects for Gdynia Karwiny intermodal node, which will be constructed on existing railway line nr 201. One of them includes the construction of train platforms, three level parking with a capacity of 450 cars and convenient bus/trolleybus bays. Also, a section of Wielkopolska street bus lanes will be extended with potential for further development (Fig. 17).

Fig. 16 - Spatial plan for area of Gdynia Karwiny intermodal node. *Source: City of Gdynia*

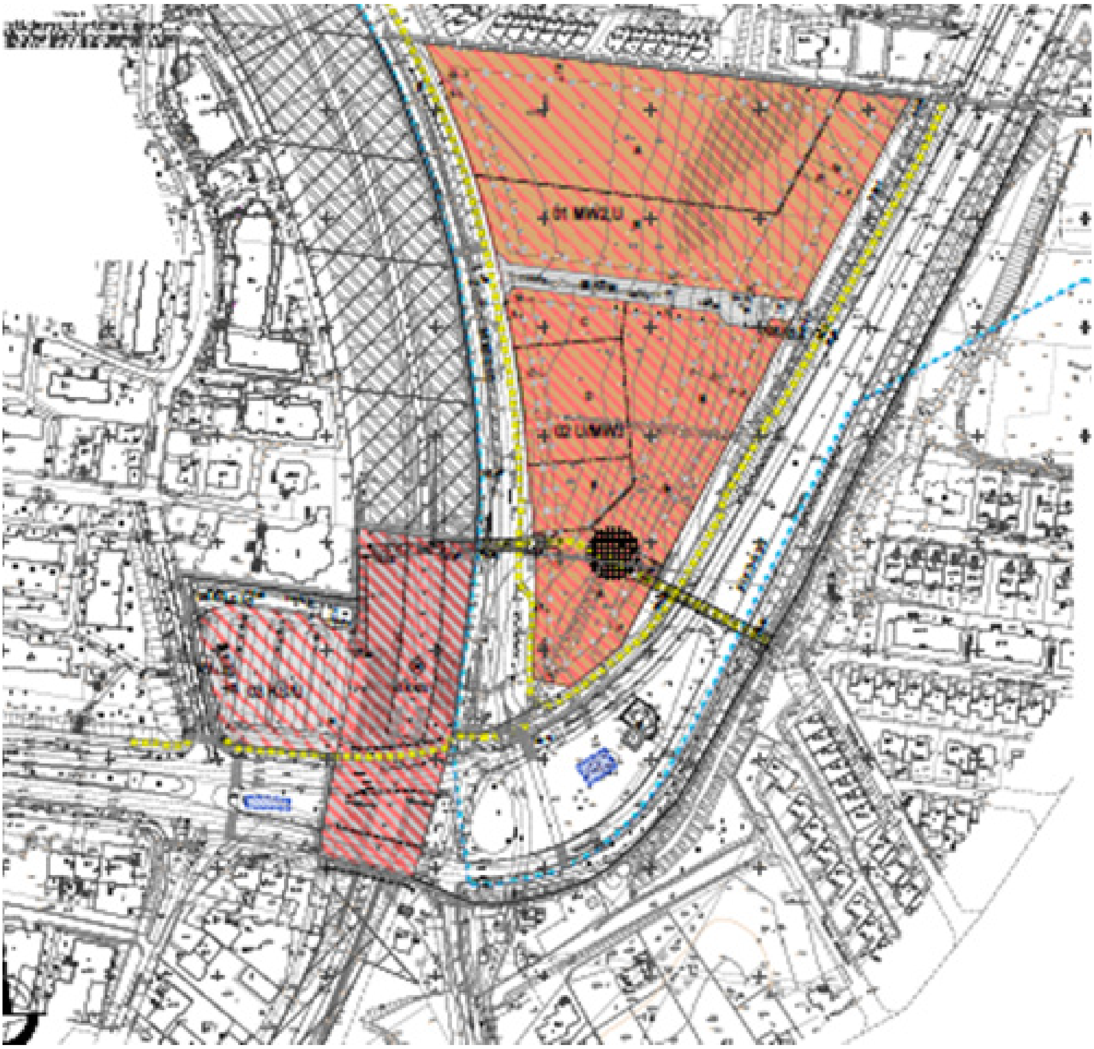
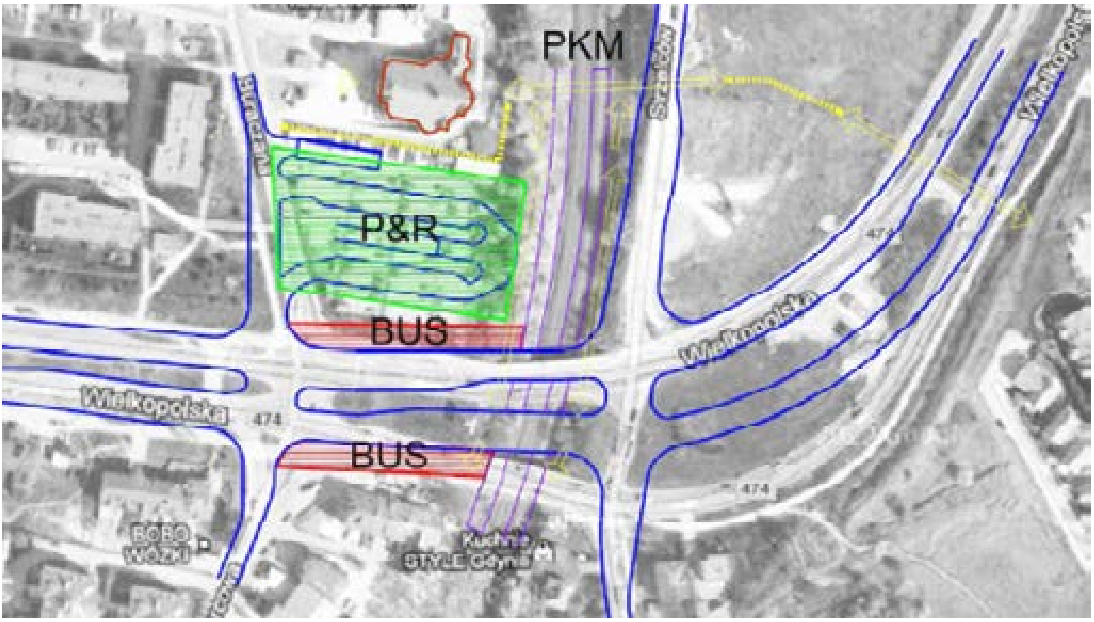


Fig. 17 - One of the options of construction of Gdynia Karwiny intermodal node Source: Typology of train stops of the Pomeranian Metropolitan Railway on the section between Gdynia Wielki Kack and Airport Gdynia – Kosakowo. Urban elaboration. BPBK S.A., Gdańsk 2012, p. 73 (courtesy of Bureau of Spatial Planning of Gdynia City)



The second option is the construction of a bus/trolleybus terminus instead of a part of the parking facility. It would provide more convenient interchange but would result in a significant decrease of parking capacity (only 200 cars) and shortening/reconstructing the routes of trolleybuses and buses.

Construction of intermodal node Gdynia Karwiny is predicted in 2015 as the Pomeranian Metropolitan Railway first stage is completed.

3.2.5. Hradec Králové Intermodal Transport Hub

Even though the City of Hradec Králové in the Czech Republic has not participated in the TROLLEY project, the Public Transport Terminal is one the European best examples of up to date transport hubs incorporating all major transport modes and – as it has been co-funded from the EU Funds – should be listed in this document.

The idea of the centralisation of bus services into a common terminal in order to avoid the existing fragmentation in several posts spread across the city dated from the 1960s. It was initiated by the need for a link between the expanding suburban bus networks and the already stabilised core rail network. Regional bus routes were diverted to the Hradec Králové Main Rail Station which was also one of the urban trolleybus and city bus network hubs. The concept of this bus station was far from the current standards – it consisted from the trolleybus loop and number of regional bus stops distributed across the whole space of

Fig. 18 - Bus stop in front of Hradec Králové railway station

Rieger Square (the square in front of the rail station building) while passenger facilities were available in the rail station only. Such a bus station coped neither with the increasing traffic nor road traffic safety requirements.

The public tender for the wide station area redesign was launched by the Hradec Králové City Council in 2000. The winning project, submitted by the Atelier of Design and Architecture Prague, represented the entire area regeneration into a multimodal transport hub incorporating the existing railway station and newly built bus station, serving both urban trolleybus and diesel-bus services, regional bus services (integrated into the Regional Transport System) and long distance bus/coach services (incl. international). The redevelopment project incorporated the public space of the Rieger Sq. and extended these public utilities to the area along the Nádražní street.

Construction of the public transport terminal in Hradec Králové was divided into two main parts:

- construction of the new terminal site (urban services terminal building, non-urban bus terminal building) including necessary supporting facilities (particularly bus parking, trolleybus traction overhead)
- complete redevelopment of the Rieger Square

The project funding was divided between two investors:

- Hradec Králové Transport Company, which became the terminal operator, funded the construction of the Terminal itself, the construction of traction overhead and bus parking
- The City of Hradec Králové funded reconstruction of the Nádražní street and most of the Rieger Sq. redevelopment.

The total price of the entire project was 500 million CZK (€ 20 mil) incl. 62 million CZK (€ 2.5 mil) co-funding by the EU Structural Funds for the terminal construction.

The new terminal consists of two separate buildings (halls) – a city public transport hall for trolleybus and bus services operated by the municipal Hradec Králové Transport Company and the other one serving regional and long distance bus and coach lines. The entire area is covered by a light membrane roof in the shape of a hot air balloon overlaying all passenger platforms.

The City Transport Hall includes a local transport centre incorporating an enquiry desk and ticket sales, ATM and public internet kiosk, waiting facilities (seating) and restrooms on the ground floor and restaurant on the first floor; the Regional and Long Distance Transport Hall has a similar layout, the main differences being more waiting space, left luggage boxes and more refreshment and catering options. Its transport centre provides tickets and information for regional and long distance bus routes. Terminal management is located on the top floor of the City Transport Hall in the "floating glass sphere". Each hall and its platforms are specifically distinguished by colours – red for urban services, blue for regional and long distance services; such colour marking has been traditionally used in Czechoslovak public transport since the fifties and is commonly recognised by the public.

Fig. 19 - PT Terminal Hradec Králové

The terminal site is equipped with an on-line information system providing passenger information on both local and long distance services. The information system is divided into three levels:

- overall level – indication of the next twelve departures of all public transport modes (urban, regional buses, rail) – these panels are installed inside each terminal hall. In addition to this pre-programmed information database, specific information can be added manually in case of traffic problems. The colour of letters corresponds to the above described colour scheme.
- particular mode level – indication of the next twelve departures of the relevant mode – these bigger panels are installed at the entry to and inside the relevant terminal hall
- platform level – indication of the next four departures from the particular platform

Timetables in hard copy (paper) format are displayed inside the terminal halls and at platforms as well indicating all departures of the particular route throughout the whole timetable validity.

Fig. 20 - PT Terminal Hradec Králové Interior

The adjacent area north of the terminal is used as short-term parking lots for both urban and regional buses. The whole development area is bounded in the north by a supermarket with a short-term car park.

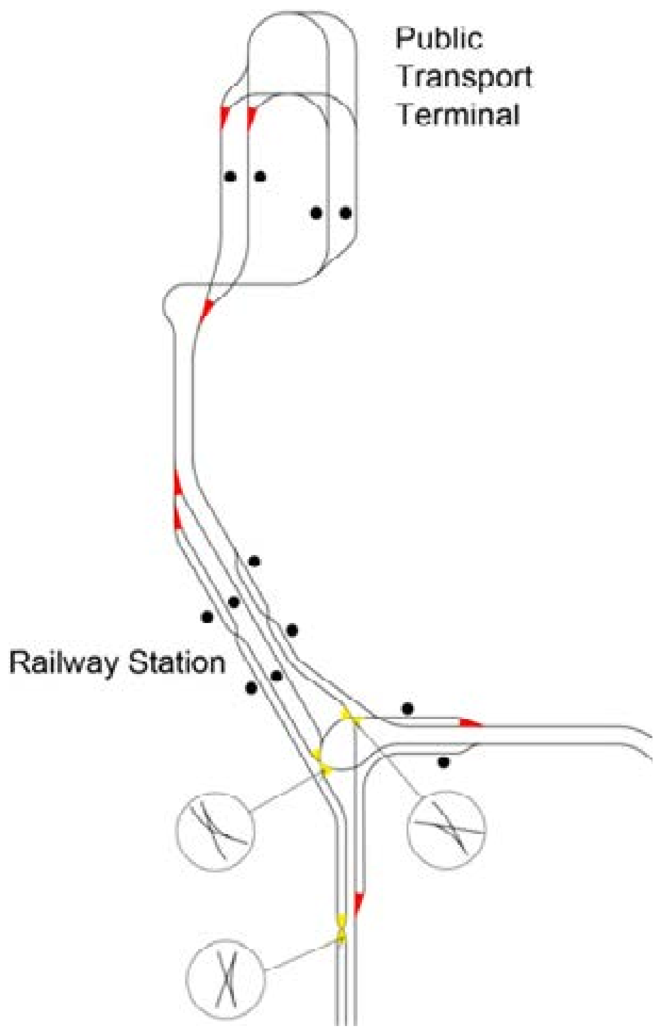
The PT Terminal was inaugurated on 5 July 2008 after two years of construction work. It serves 23 urban transport routes, 37 integrated regional bus routes, 50 long distance and 18 international routes with almost 3000 services per working day. The terminal handles 30-40 thousand passengers daily.

The second part of the project is the redevelopment of the public space of Rieger Square, ca 300 metres south of the new terminal. Its importance is given not only because of the main railway station, but also because of the city's biggest hotel, main post office and regional electricity provider´s headquarters. The square is also the starting point of S. K. Neumanna Street, the main shopping street of this city district where traffic calming measures (PT corridor, private cars access restrictions) have been applied.

The new layout of Rieger Sq. separates different road traffic flows (urban public transport, automobile traffic, cyclists) and facilitates pedestrian movement. The original broad surface area has been clearly divided into pedestrian space with bike racks, a straightened through road reserved for urban PT only with safety measures applied and public roads (access to and exit from car parks) moved away from the main pedestrian flows.

Two platforms with two stands each are available for the city centre bound services - the trolleybus and core bus routes pass along the first platform (closer to the rail station), the complementary routes using the distant platform; the terminal bound routes use the opposite platform with two stands. Shelters and information panels are installed at each of the six stands. Two stops (for each direction of trolleybus route Nr. 3 passing through Rieger Sq. but not going to the Terminal) are located at the end of S. K. Neumanna Street.

Fig. 21 - Traction overhead scheme



The square regeneration included also redesigning the pedestrian area in the middle of the square, particularly the installation of water fountains and new, specifically designed street lighting poles and traction overhead components.

Connecting passengers between the Rail Station and PT Terminal are offered free use of all passing trolleybus and city bus lines.

Fig. 22 - Traffic Statistics – PT Terminal

	Number of routes	Number of services (arr. + dep.) per Working day	Number of services (dep. only) per Working day
Trolleybuses	4	1008	489
City buses	19	1012	572
Regional bus (integrated)	37	554	278
Long distance bus (national)	50	248	177
International bus	18	*	*

* International bus routes operate irregularly (mostly 1-2x per week)

Fig. 23 - Traffic Statistics – Rail Station (Rieger Sq.)

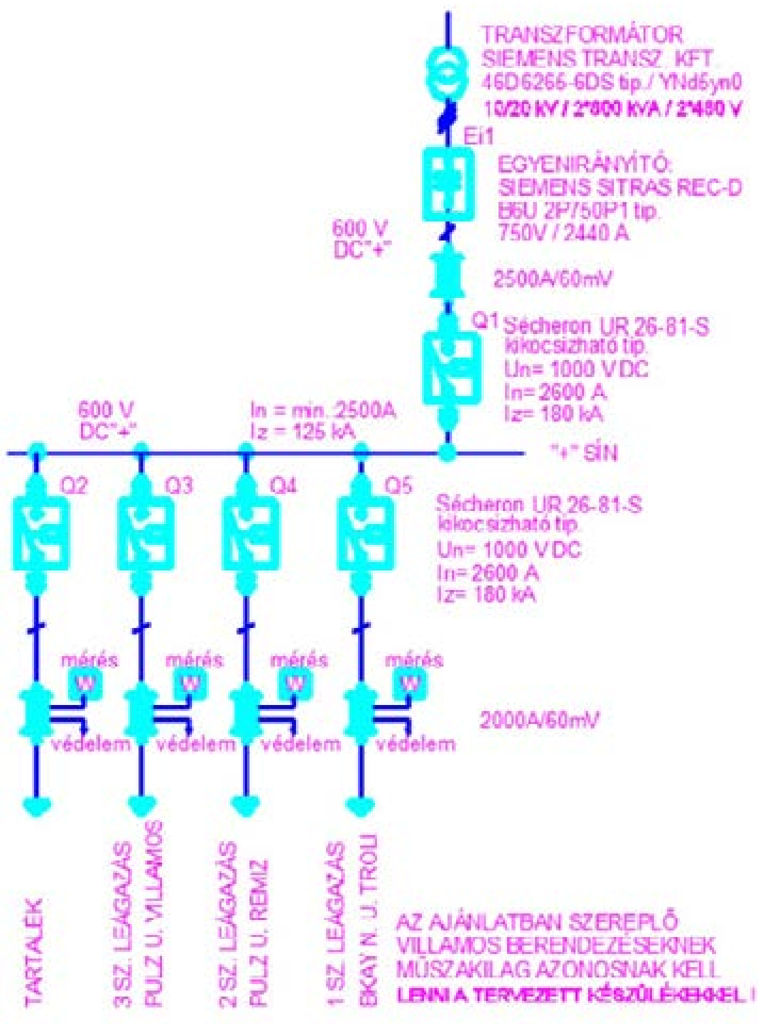
	Number of routes	Number of services – arrivals per Working day	Number of services -departures per Working day
Trolleybuses	5	1676	1676
City buses	24	1945	1945
Local trains	5	75	73
Regional Express trains	4	35	35
National Express trains	2	42	41

4. Technical aspects of trolleybus as a key mode in intermodal passenger transport solutions

4.1. Common tram-trolleybus power supply

The most obvious synergy of the two modes is the common tram-trolleybus power supply, which is an economical solution for the two electric modes. The most common urban voltage both for trams and trolleybuses is traditionally 600 V DC. Even newer serial hybrid buses have battery packs which produce between 400-600 V DC (e.g. Mercedes-Benz Citaro G prototypes), and both tram and trolleybus traction technology in their newest forms still rely on 400-600 V traction motors even in their most sophisticated form (see e.g. ZF's new wheel-hub motor drive solution for low floor hybrid buses).

Fig. 23 - Power supply scheme



Thus the power supply is common for common tram-trolleybus operators. Operators use common substations, which can feed both tram and trolleybus catenary.

An example is shown in the following figure, which shows the positive wiring of the 1500 kW output power substation in the Pulz utca depot of Szeged Transport Company.

One can notice the transformer and the rectifier in the top, which creates 600 V DC. There is a common “+” rail from which four branches start: 1. Bakay Nándor utca trolleybus section, 2. Pulz utca tram depot section, 3. Pulz utca tram network section, 4. reserve.

The positive feeder cables for the trolleybuses and trams are separate and diverge from this point. For safety reasons there is always high-power switch between the tram and trolleybus side in order to get a perfect insulation between the two operations in case of detecting a short-circuit in the tram or trolleybus network. The positive cables are regularly joined to the overhead wires of the trams and trolleybuses, the negative cables go partly to the trolleybus overhead wires, partly to the rails of the tram system. This makes the negative cable of the trolleybuses grounded.

A feature of this layout is that the current generated from a tram or trolleybus during braking can be fed to the common “+” rail, thus there is a possibility that a braking tram can feed an accelerating trolleybus and vice versa.

Fig. 24 - Overhead tram – trolleybus crossing

By operating a trolleybus network one needs to be aware, that if there are sub-stations in the trolleybus network that are solely used for trolleybuses, then it is likely that the "-" side of this network part is not grounded. One needs to have attention at the meeting of the grounded and the non-grounded network parts (at section insulators or e.g. at tram-trolleybus overhead crossings).

For tram and trolleybus overhead crossings one can use a wide selection of geometry of overhead materials from the manufacturers (e.g. Elektroline, Esko or Kummler & Matter). Different solutions are shown in the above figure (crossing of Rókusi körút and Csáky utca); these strain overhead elements provide smooth and fail-safe crossings with tram-pantograph and trolleybus current collectors.

Tram and trolleybus overhead wires can co-exist without any major trouble, and many overhead elements (e.g. span wires, contact wires, insulations, hangings, anchors, etc...) are common. Overhead maintenance crew for trams and trolleybuses are also common in Szeged Transport Company.

One of the crucial issues of vehicle movement in urban areas is the loss of energy due to relatively frequent braking. The braking energy generated by electrically powered motors can be recovered to the overhead network. This advantage has been limited by the fact that substations and overhead are divided into short sections; the recuperated energy can be utilised by vehicles located in the same section where generated while any surplus is lost again.

Recent technology development extends the energy efficiency options. One of the challenges is transfer of recuperated energy between different power sections and even between tram and trolleybus traction supplied from different substations. This energy transfer balances the energy losses in the range of magnitude of hundreds of kilowatts.

The second feature of this technology development is the storage of surplus energy by means of supercapacitors (supercondensators) installed in substations. Their application enables utilisation of tram and trolleybus regenerative capability and significantly reduce energy consumption.

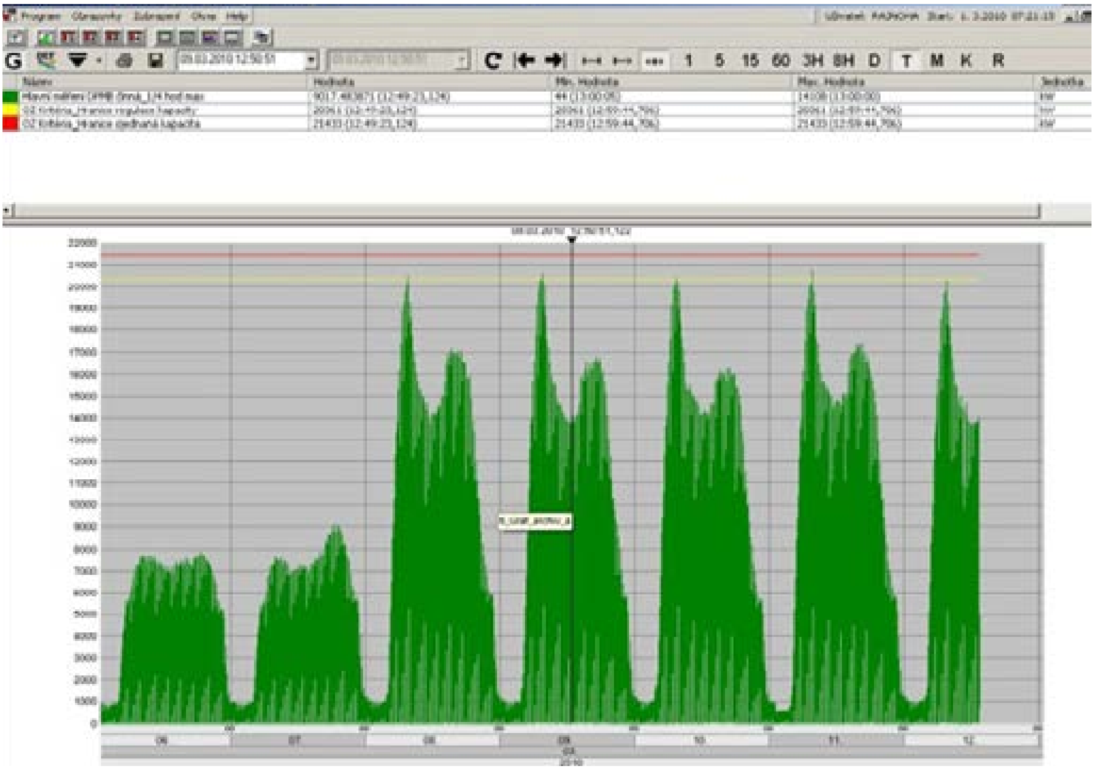
This new type of substation equipped with supercapacitors represents an efficient way of further tram and trolley technology development. Their incorporation in substations enables them to support an increased number of vehicles and several power supply sections, which makes this measure very effective. The system installation does not require road works (placing of additional cables underground). Very efficient results have been recognised with respect to the operational costs – beside 18 per cent energy consumption reduction by recuperation, additional savings of more than 20 per cent of energy may be achieved by intelligent power supply using energy accumulated in supercapacitors. This scheme has been applied in the tram and trolleybus system of the city of Plzeň (Czech Republic).

So far it is the very specific advantage of transport means connected to the power supply network, though it can be expected that this tool will be applied in buses and cars in the future. In fact, supercapacitor technology has already been used in hybrid trolleybuses for their operation outside the traction overhead.

Another employment of new technologies is the automatic remote control of heating systems in tram and trolleybus vehicles. This system enables control (switch-off/-on) remotely of in-vehicle heating following the actual electricity consumption in the network automatically. This measure reduces the impact of power peaks without negative effects on passengers comfort.

An in-vehicle heating remote control system has been applied in all Brno trams and trolleybuses since 2011 in the framework of the CIVITAS project; while the investment costs were € 60 000, the annual energy savings reached € 70 000 which means that all costs were saved in the first year of system operation. The customer survey carried out through questionnaire in the operator´s magazine showed that passengers did not recognise any difference in temperature and their satisfaction with in-vehicle comfort did not change.

Chart 7 - Brno power supply - Energy consumption in the morning peak



4.2. Common tram-trolleybus maintenance

There is a significant difference between bus and tram depots, although there are historic examples of common operations. For trolleybuses the daily maintenance cycles more resemble those of conventional buses. Maintenance operations however became very different in the two sides of Europe. In Western Europe there are more examples of operations without major workshop activities, but in the former socialist states' operators almost all have a developed workshop area for major overhauls of the vehicles. These activities can be merged for trams and trolleybuses. By the example of Szeged Transport Company: there is a separate electrical workshop, mechanical workshop and painting workshop and final assembly workshop which all work both on trams and trolleybuses. Below is a picture of the common tram-trolleybus mechanical workshop showing the frame of a Skoda trolleybus.

While the synergy between tram and trolleybus operation is evident particularly on the financial savings with smaller operators, common tram – trolleybus maintenance workshops are not as beneficial in the case of big operators. The Czech and Slovak experience (Brno, Bratislava with hundreds of trams and more than 100 trolleybuses each) keep heavy maintenance separated. Their needs requiring much higher capacity do not allow sharing the specialised staff in an efficient way nor to have facilities and equipment suitable for both rail bound and road vehicles. However, the range of common maintenance facilities varies by operator and depends on local conditions such as managerial and technical policies.

The synergic potential between two electric tractions maintenance used to be indisputable in case of previous generations of vehicles. The increasing use of sophisticated electronic components and units places additional demand on the skill of maintenance staff and the tools used in the processes. Such specialisation is in many cases explicitly required by the manufacturers and the warranty conditions. Even the experience of manufacturers producing both trams and trolleys shows that these vehicles are assembled on separated production lines using specialised workers.

Fig. 25 - Common tram-trolleybus mechanical workshop in Szeged

4.3. Common tram-trolleybus corridors

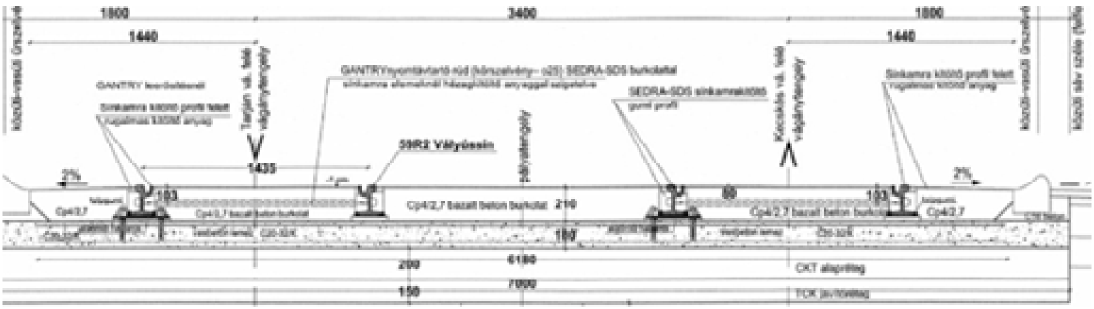
Many cities in Europe fight with the problems of the lack of space in their old city centres. The tram's major advantage thus became the possibility of a separate tram track which provides a visible high passenger capacity public transport corridor.

Often buses and hence trolleybuses use this opportunity: the surface of a tram-track is an ideal bus and trolleybus corridor: a common tram-bus-trolleybus lane – preferably with physical separation – can increase the speed of all traffic modes. It is an interesting psychology that the city's decision makers and inhabitants can also more easily accept a separate tram lane than a separate bus lane – the latter is often seen as only taking away space for cars, while a separate tram track is more associated with good public transport. Several common tram-bus lanes and also a tram-bus-trolleybus corridor have been installed in Szeged.

Fig. 26 - Tram-bus-trolleybus corridor in Szeged.

While in terms of traffic technology there are many advantages of these corridors: higher circulating speed, decreased accidents due to the physical separation, public transport advantage by traffic lights, etc, ..., in terms of track maintenance common tram-bus operation is a bigger challenge. One can observe increased wear of the common asphalt surface, which is caused mainly through an insufficient technical solution at the meeting of the asphalt and the rail. Since often the rails are in a rubber cover in order to decrease noise and vibration, one has to keep a groove between the asphalt and the rail. Asphalt itself does not hold itself for a long time without support from the side, thus often it starts to fail near the rails. In Szeged after 7 years of operation it became necessary to renew the asphalt cover due to intense bus usage. This was the case for several different type of asphalt built with different technologies and width.

Fig. 27 - Design of common tram-bus lane

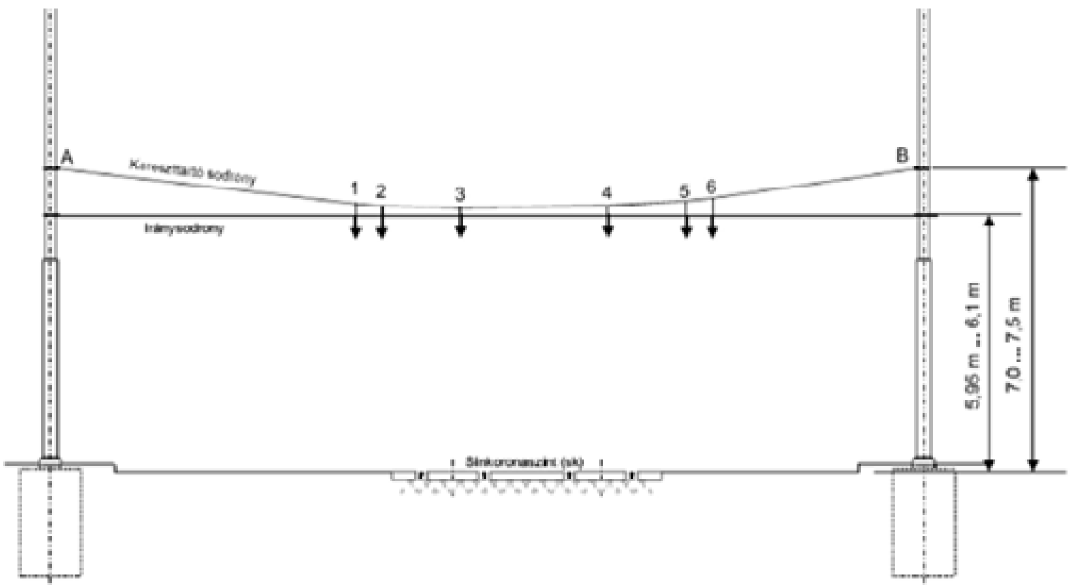


In the recently reconstructed common tram-bus-trolleybus tracks special basalt-concrete was used for preparing the road surface between the rails. Due to the recent increase of petroleum-product prices, using concrete also became cheaper. The obvious disadvantage however is the time the concrete needs in order to solidify, which is more than for asphalt.

The above figure shows the used cross section of the concrete covered section; notice the lack of asphalt at the top of the surface.

In terms of the overhead wires of the common tram-trolleybus lanes, due to the flexibility of the trolleybuses the overhead of the trolleybuses was placed slightly to the side of the corridor. This means also, that in case of any obstacle on the tram track the trolleybuses have the ability to use the side road surface as well, and by-pass the obstacle. It is advantageous to think about this also at tram stops; i.e. the trolleybuses should be able to get around the tram's loading island from the other side in case there is an obstacle or construction in the

Fig. 28 - Design of overhead above common lane



stop. For this purpose one should avoid having objects higher than 4 m in the stops (e.g. lampposts, trees, etc...). This of course is not necessary, if all trolleybuses have the ability to run without overhead wire for a short section.

4.4. Trolleybus & motorbus synergies

The trolleybus is considered as “some kind of bus” not only by the unconcerned public but also by many policy- and decision-makers, realising the overhead collectors as the only difference. Though there are many synergies between trolleybuses and other types of buses, they are diverse in a number of aspects. All types of buses use the same lanes; however trolleybuses and electric battery buses might have a bigger impact on road structure because of their higher axle load. Trolleybus drivers need special training in addition to other bus driving principles. Buses and trolleybuses are now based on the same body and chassis which facilitates their heavy overhaul and accident damage repairs. On the other hand, the daily maintenance and regular checks are so specific that overall the majority of work is done by specialists – the survey among Czech operators shows ca 25 % of common maintenance staff, 40 % of high voltage electro specialist and 35 % of diesel engine mechanical specialists working in common depots.

5. The potential of trolleybus mode in the E-mobility era

5.1. EU electromobility initiatives and projects

Increasing awareness on climate change, the scale of the challenges involved, and the pressing need to prepare for a post-petrol future have prompted most of the world's developed countries to step up the research, trialling and deployment of transport systems that use more energy-efficient and less petrol fuel-dependent vehicles. In response to the second objective on petrol dependency, electric power offers a potentially groundbreaking solution, provided that the production supply chain does not emit too much CO_2.

Electricity as an energy vector for vehicle propulsion offers the possibility to substitute oil with a wide diversity of primary energy sources. This could ensure security of energy supply and a broad use of renewable and carbon-free energy sources in the transport sector which could help the European Union targets on CO_2 emissions reduction.

Electric vehicle 'tank-to-wheels' efficiency is a factor of about 3 higher than internal combustion engine vehicles. Electric vehicles emit no tailpipe CO_2 and other pollutants such as NOx, NMHC and PM at the point of use. Electric vehicles provide quiet and smooth operation and consequently create less noise and vibration.

The policy related to battery-powered vehicles is mainly focused on technological optimisation and market development. Future challenges in this field include reliability and durability of batteries and super-capacitors, reducing battery weight and volume, safety, cost reduction, improved hybrid electric power-trains, charging infrastructure and plug-in solutions.

Electrification of transport (electromobility) will stay a priority in the upcoming Community Research Programme "Horizon 2020" or the new transnational cooperation programmes for 2014-2020. Electromobility also will be an essential part of the of the European Innovation Partnership (EIP) "Smart Cities & Communities"[12].

The EC Vice-President Siim Kallas, responsible for transport, said at the occasion of announcement of the cross-European electromobility initiative "Green eMotion"[13]: *"Transport is current 96 % dependent on oil for its energy needs. This is totally unsustainable. The Transport 2050 Roadmap aims to break transport's current oil dependency and allow mobility to grow. We can and we must do both. It can be win-win. But there are major challenges. Transport 2050 calls for a reduction of CO_2 from transport of at least 60 % by 2050. At the heart of this strategy is a major shift in cities to the electric vehicles away from cars with conventionally fuelled engines."*

On the climate change front, an electric vehicle powered by electricity from nuclear power or renewable sources like wind, hydroelectric or solar power would release no greenhouse gases while on the move. And even in regions and countries where much

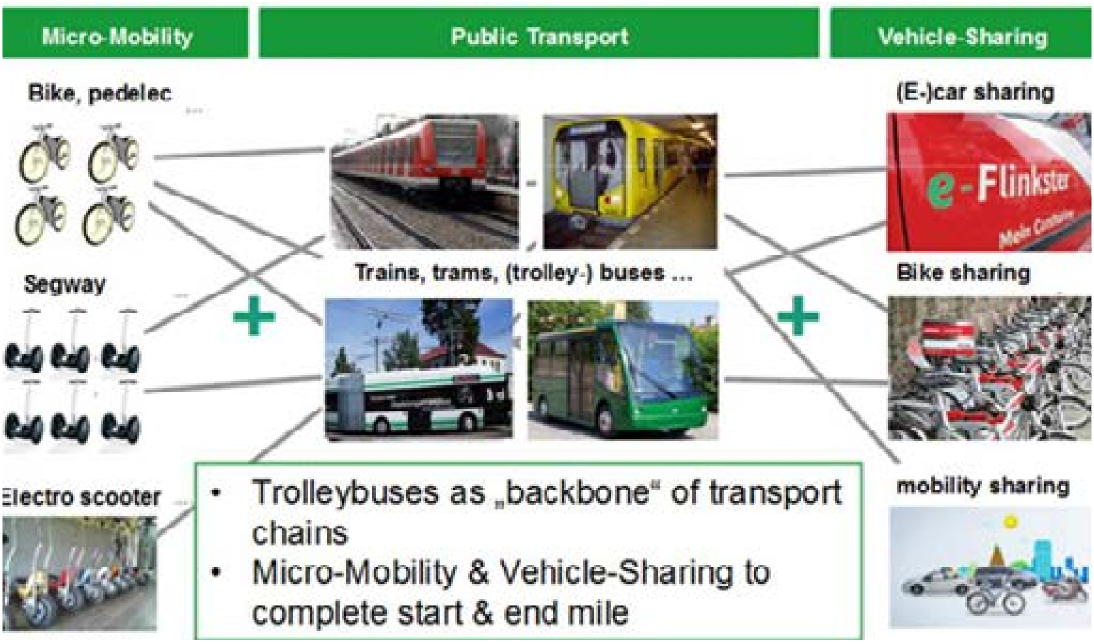
12) Smart cities and communities - Support for a better future, http://ec.europa.eu/eip/smartcities/index_en.htm

13) Commission makes €24.2 million available to the development of electromobility in Europe, http://ec.europa.eu/commission_2010-2014/kallas/headlines/news/2011/04/2011_04_01_electromobility_en.htm of the electricity comes from fossil-fuel burning power plants, electric vehicles are still less harmful to the environment than cars that burn fossil fuels directly in their engines. This is because power plants use energy more efficiently than ICEs (although some adjustment needs to be made for electricity lost during transmission along the wires from the power station to urban areas). This all means that electric vehicles can help to reduce Europe's greenhouse gas emissions and dependence on imported fossil fuels.

From the perspective trolleybus cities this "new" development is more a "back to the future!", as the trolleybus has already presented itself as fully developed, technically secure and economical electromobility system over the past decades. However, electromobility with trolleybuses incorporates number of elements, not just the electric drive train, which could facilitate and enhance the user experience and acceptance of electric vehicles by offering various ICT services for urban and inter-urban electro mobility in a smart city concept. Based on the trolleybus system as a backbone of an electric intermodal passenger transport chain, services for real time information on the charging infrastructure (for example using power-substations of trolleybus networks), pre-trip and on-trip planning and optimization based on the energy use as well as vehicle to grid connectivity could be offered. However, this would require new roles, markets and business models that facilitate the increased deployment of electromobility in public transport chains with "micro-mobility" and "vehicle sharing" concepts to complete the start and end mile of a door-to-door trip.

Fig. 29 - (Electric) intermodal passenger transport chains with trolleybuses

Source: Spath, IAO, 2011 (modified)



5.2. Trolleybus in the future

The above mentioned attention given to electromobility by the European Commission and other EU institutions is mainly focused on electric cars and only starts heading slowly towards the electrification of bus systems in Europe; however the trolleybus mode is hardly mentioned in any official document. And the research topics are primarily targeting research and development of new technologies, reliability and durability of batteries and super-capacitors, reducing battery weight and volume, safety, cost reduction, improved hybrid electric power-trains, charging infrastructure and plug-in solutions.

The advantage of trolleybus against those technologies is its reliability proved by already more than one hundred years of practical experience. And meanwhile the Commission has recognised that trolleybuses are still playing a crucial role in urban mobility and trolleybus systems can be an important "bridging technology" for smart electromobility of the future based on research topics like smart infrastructure concepts exploiting synergies between trolleybus/tram electrical infrastructure, smart grids and the wider urban electromobility infrastructure. Or testing advanced hybrid electric-electric drive train concepts combining wire-based and autonomous modes of operation (based on automatic wiring/ de-wiring technology). Thus, trolleybus systems, as backbone for urban mobility, could have an enabling role for electrified mobility in the future, based on their undoubtedly many benefits to the citizens:

- they are producing no local emissions, they generate less noise and less vibrations compared to motorbuses
- their engines consume no energy during stops
- their braking energy can be recuperated which saves around one quarter of energy consumption; this energy can be immediately used in the network or, in case of battery or supercapacitor hybrid buses, used for their recharging
- they have up to twice longer life-time cycle which makes them more efficient – it saves not only direct costs but also reduces environmental impact of their production and scrapping
- compared to trams, they are lighter and more flexible in traffic and easier and quicker to install

On the other hand, trolleybus as a mode needs to develop in order to be competitive to other mobility modes and attractive to its users in the future as well.

Their disadvantage of permanent connection to overhead wires has been already solved by means of hybrid or dual mode power - the second power source can be not only internal combustion engine, but battery or supercapacitors have been implemented by various operators. For example the trolleybus operator from Parma, Italy (TEP) purchased nine Van Hool ExquiCity 18 vehicles equipped with "supercaps" (Maxwell Double Layer HTM Power) to test a Kinetic Energy Recovery System (KERS). Or the replacement of the auxiliary diesel engine by a lithium-ion battery in Eberswalde (Germany, Barnim Bus Company). The system in Eberswalde is now featuring two fully electric drive systems. This Europe's first Trolley-Battery-Hybrid-Bus can receive power either via the catenary or the lithium-ion battery. On short distances the bus can additionally run on "supercaps" – the third electric drive system. Tests carried out in daily operation beginning of

2013 demonstrated that the distance of 4 kilometres can be driven in battery mode (without catenary-connection) and is ideal for an optimised life cycle of the lithium-ion battery on a total line length of 18 kilometres. The battery is charged while braking the trolleybus on the remaining line operation with catenary connection. By these technological innovations, trolleybuses can operate without wires for several miles more efficiently than with diesel power. However, for the future of partial catenary networks of trolleybus systems with combined overhead and inductive power supply permitting flexible and efficient operation in wired and autonomous mode a technology for an automatic wiring and de-wiring (while driving) still is needed. This would reduce infrastructure cost for expensive and visually intrusive crossings and would provide more flexible possibilities of route extensions in existing trolleybus networks.

Fig. 30 - A TROLLEY pilot investment: Europe's first Trolley-Battery-Hybrid-Bus in Eberswalde
Source: Barnim Bus Company

The up-to-date overhead components enable to keep the road traffic flow speed at road junctions which avoids the earlier problem of speed restrictions. Furthermore, the up-to-date collectors made of composite glass or carbon reinforced polyester with retraction systems enable to drive rather far from the overhead axis and cope with the road traffic. Thankful to these and in-vehicle new technologies, trolleys and their passengers are now much safer against electric shock even during severe weather conditions.

It can be expected that the future technology progress and development will concentrate on further efficiency and competitiveness improvement against other bus modes, e.g. vehicle weight reduction and particularly decrease of investment costs which is considered as the main obstacle and disadvantage.

5.3. Trolleybus potential in the e-mobility concept

As mentioned above trolleybuses are an important “bridging technology” towards electromobility solutions and trolleybus networks could become a backbone of future electric intermodal passenger transport chains. One of the crucial issues already recognised by e-mobility initiatives is the lack of (re-)charging points; this problem concerns both electric midi (battery) buses and electric cars or bikes. Trolleybus (or tram) networks can provide electric energy to them – it is relatively easy in case of battery or supercap buses operated by the same operator. There are already several such examples – electric buses are charged in trolleybus depots during parking (Ostrava, CZ) and from recharging points connected to catenary network at selected trolleybus or tram stop (Vienna, AT).

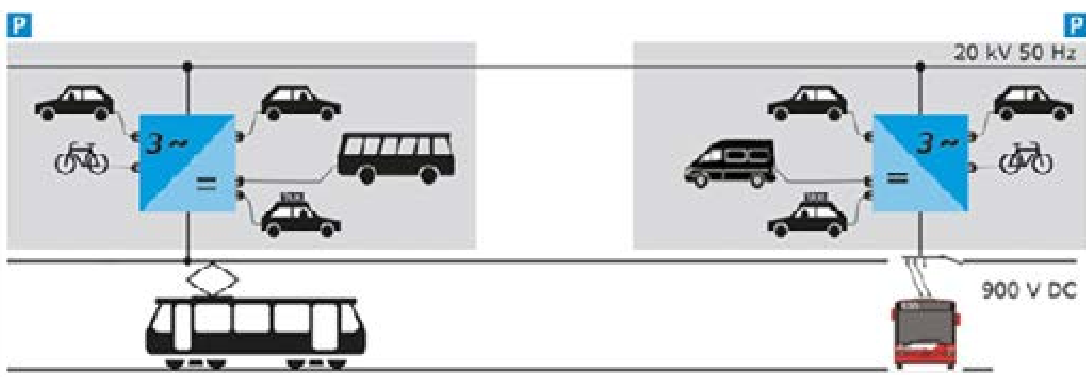
The same scheme could be applied to private electric cars; ideally during parking at P+R facilities where cars are standing for several hours. Public transport operators could become providers of universal mobility which could be beneficial not only for car users - private customers but also for PT operators. Their electricity consumption depends on traffic volumes which are significantly higher in the peak hours and sale of electricity to parking cars during off-peak period might balance this inequality. However, it is necessary to take into account the fact that PT catenary is, in many countries, classified as “dedicated electric appliance” (“specified electric appliance”) which prevent their use for other customers. Such restriction, which applies in certain countries, shows the need for the EU harmonisation of standards and is already the case of other modes where PT operators can sell fuel (diesel or CNG) to external users.

Together with an integrated energy management system implementing new ICT based interfaces (e.g. ICT for smart and more efficient energy management (smart grids), smart meter, real time information) between trolleybus and other electric mode’s (re)charging systems, the recuperation of braking energy and smart grid solutions the trolleybus system of the future could become an essential part of “smart city” concept.

Trolleybus networks also might support zero-emission city logistics concepts using trolleybus networks/technology as enabler for electrified city freight transport and the integration of zero-emission freight transporters into urban mobility systems. Even though trolleybuses are

Fig. 31 - Double use of power supply infrastructure of existing tram and trolleybus systems as loading stations for other e-vehicles (e-cars, e-bikes etc.)

Source: Müller-Hellmann, VDV-Förderkreis (modified)



generally seen as passenger transport mode, there are several examples of trolleybus lorries. Beside the current Siemens R&D project (Germany) for long distance freight distribution, electric trucks powered from overhead network are used in places requiring ignition-free environment (mines). The potentially most relevant and attractive application can be urban delivery services. Lorries can be supplied with electricity from overhead network where available and powered by batteries in streets not equipped with the overhead. Such scheme has been applied in the former U.S.S.R. since 1960s, though the "independent power" has been supplied from auxiliary diesel or petrol engine while the current electromobility technologies enable to use the battery power with battery recharging during the trolleybus drive mode. Such application could be the trolleybus contribution to the urban logistics which is another important EU transport policy topic.

This compendium has been prepared by the authors
in the framework of the TROLLEY Project

The TROLLEY Project is implemented through the CENTRAL EUROPE Programme
co-financed by the ERDF (www.central2013.eu)

www.trolley-project.eu

CENTRAL EUROPE
COOPERATING FOR SUCCESS.
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND