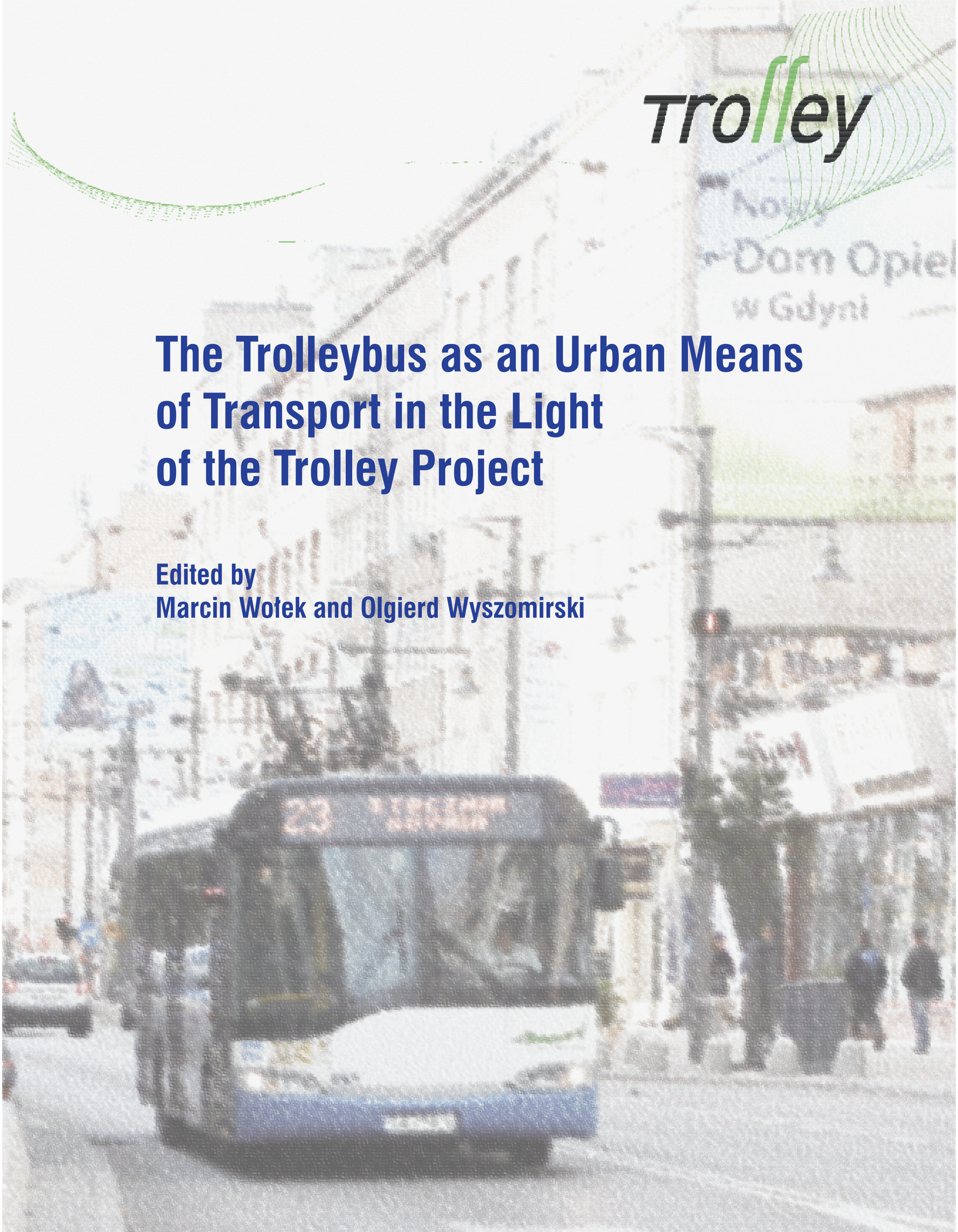

The Trolleybus as an Urban Means of Transport in the Light of the Trolley Project

Edited by
Marcin Wołek and Olgierd Wyszomirski

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Gdańsk 2013

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Introduction

The trolleybus, as a means of urban transport, has functioned since the 1880's reaching the peak of its development in the post World War 2 period. It then suffered a slump which came to an end in the 1970's, together with the Fuel Crisis, and is yet to regain the status it enjoyed during its heyday. Nevertheless, in many cities the trolleybus constitutes an vital part of transport services, whereas its development in the state, continent, and the entire world is also of importance as it influences the technical development and scale of production of rolling stock as well as power equipment. This, in turn, affects the pricing, costs, and, ultimately, economic efficiency in addition to the quality of trolleybus transportation. Thus, the promotion of this mode of transportation is not only necessary, but should also lead to its further development in those cities utilizing trolleybuses in addition to helping to facilitate the decision to introduce them to the cities, in which they are not present. In turn this would lead to a decrease in costs connected with the introduction of trolleybuses and influence the wider application of modern solutions in powering, exploitation and modernisation.

The Trolley project was brought to life in order to reach the aforementioned aims. Its task was to promote the trolleybus as an eco-friendly and economically effective mode of urban transport in the cities and regions of Central Europe. The project was realised as a part of the Central Europe Programme and partially funded by the European Regional Development Fund. Based on the extensive experience of nine partners from six countries of Central Europe, as well as on the organisation TrolleyMotion, it sought ways to develop the potential of the trolleybus, paying special attention to the increase in electromobility, which is one of the elements attesting to the realisation of sustainable development.

At the end of the Trolley project, the team of scholars and practitioners centred around the Department of Transportation Market at the University of Gdańsk (acting as the partner for the project) prepared a study entitled "The Trolleybus as an Urban Means of Transport in the Light of the Trolley Project" and published it in the form of an e-book. The aim of the study was to present the factors, scale of action, as well as the determinants of the development of trolleybus transport, with particular emphasis on the cities participating both directly and indirectly, through their transport companies, in the Trolley project. The study was organised according to the above aim.

The first part is dedicated to those factors which play a part in urban transport development within the European Union. It then focuses on the development and scope of utilization of the trolleybus transport within a city, particularly with regards to the cities involved in the Trolley project. The following part of the study discusses the technical and exploitation elements of trolleybus transport. The organisation and management of the trolleybus transport constitute the object of further deliberations, focusing especially, again, on those cities participating in the Trolley project.

Later on, the study takes a close look at the costs of trolleybus transport paying close attention to the cities participating in the Trolley project. It also presents a model view on the economical efficiency of the transport trolleybus research. The acquired method is then implemented in the estimation of the economical effectiveness of this mode of transport in the cities participating in the Trolley project.

The next part of the work presents the issues connected with the image of trolleybus transport shaped by marketing techniques – important considering the aim of the Trolley project. The final part of the work is dedicated to the directions and determinants of the development of trolleybus transport. It sets out to determine its potential role in the future, taking into consideration the cities participating in the Trolley project. Psychological factors were considered important amongst the determinants of the future development of the trolleybus transport.

The authors of this study do acknowledge the fact that it does not fully present the complexity of the issues connected with the functioning of trolleybus transport. The Trolley project was the first of its kind, fully dedicated to this mode of urban transport. During its realisation it became apparent that there is a significant need for the exchange of experiences and knowledge, which would sustain and serve the development of the trolleybus transport. The vast number of stakeholders (meaning the cities' authorities, organizers and operators of urban transportation, companies engaged in manufacturing and distribution of energy, manufacturers of rolling stock, non-governmental organizations as well as scientific communities) created a unique circle – a platform for the discussion and exchange of information – focused around trolleybus transport. Due to the technical advancement (especially in terms of storing energy) and the formation of ambitious aims for the municipal transport policy, a trolleybus is likely to become a strong element in urban transport concerned mainly with eco-friendliness and energy efficiency.

The experiences gathered as a part of the Trolley project became the starting point for other activities, which are currently realised in Gdynia as a part of the CIVITAS DYN@MO project. They include, among others, testing of new traction batteries, which enable trolleybuses to drive without the traction network.

The study was written by thirteen authors, the majority of them both scientists and practitioners who, through their professional activity, greatly influenced the development of trolleybus transport within Gdynia. They work for the trolleybus operator PKT Gdynia sp. z o.o., the Board of Public Transport in Gdynia as well as for the Metropolitan Transport Association of Gdansk Bay. The undertaking of this study has benefited greatly from the extraordinary involvement of Dr. Ernest Czermański, who, along with the editors, remained most active throughout the whole process. Significant input was also provided by Dr. Mikołaj Bartłomiejczyk from the Technical University of Gdansk, as well as Dr. Michał Wolański from the Warsaw School of Economics.

The research carried out as a part of the Trolley project constitutes the main source for the study. The Internet was also recognised as an important source of information, along with guides from within the industry and the Trolley project. The study also refers to publications and papers from industry conferences. Additionally, a survey was prepared for the purposes of the study and was completed by trolleybus transport companies participating in the Trolley project. Part of the book, concerning the functioning and development of the trolleybus transport in the cities taking part in the Trolley project, was written based on the findings of the aforementioned research.

The editors of the study would like to thank all participants of the Trolley project for their involvement in the preparation of the relevant data. They would also like to express their gratitude to the authors of the appropriate sections, whom in writing them have drawn upon all their knowledge and often passion for trolleybus transport, as was undoubtedly the case with Dr. M. Bartłomiejczyk, Dr. M. Wolański, M. Połom, M. Pudło and both editors of the study.

Words of appreciation are also due to the reviewer, Dr. hab. Tadeusz Dyr, Associate Professor of the University of Technology and Humanities in Radom. His valuable comments enriched the text and became and inspiration for further study in the field.

Dr. Marcin Wołek – the coordinator of the Trolley project at the University of Gdańsk
Prof. Dr. hab. Olgierd Wyszomirski – the head of the Department of Transportation Market at the University of Gdańsk.

Chapter 1. Conditions for the Development of Public Transport in the European Union

1.1. Transportation Problems and Challenges Faced by European Cities

One of the most important global trends is the dynamic growth of cities and the concentration of socio-economic functions in metropolitan areas. According to UN projections, world population will increase to 8.9 billion by the year 2050, two thirds of which will live in cities. By the year 2025, there will be only two European cities (Moscow and Paris) among the 30 most populous cities of the world. The average population of the thirty most populous cities of the world will have tripled between 1965 and 2025. However, the structure of urbanization shows important differences between cities of developed and developing countries (Table 1.1), which is related to the diversity of its structure.[1, 2]

In developed countries, the dynamic process of urbanization has abated, giving way to what one can may call "qualitative" urbanization, which manifests itself in institutional, spatial and economic aspects. The urban development of developing countries is focused in an entirely different direction. In this case the spatial aspect of urbanization is expressed in the uncontrolled growth of the area and the population of the city.

Before the Industrial Revolution the spatial structure of cities was determined by the needs of pedestrians. The Industrial Revolution, however, brought new impetus to their spatial development, as cities and settlements which already existed began expanding and exceeding their boundaries. They often developed around industrial plants, which due to their size were placed outside the existing city limits. P. George notes "the size and appearance of cities were changed as a result of the Industrial Revolution and the development of the capitalist economy in the nineteenth and early twentieth century." Residential areas were built

1 World Urbanization Prospects: The 2011 Revision. United Nations, Department of Economic and Social Affairs, Population Division, October 2012, CD-ROM Edition.

2 In 1965, the average population of each of the 30-most populated cities in the world amounted to 5.79 million, while the forecast for 2025 assumes that it will increase to 18.38 million. Own calculation based on World Urbanization Prospects: The 2011 Revision. United Nations, Department of Economic and Social Affairs, Population Division, October 2012, CD-ROM Edition.

Table 1.1. "Quantitative" and "Qualitative" Urbanization

Trait	Quantitative urbanization	Qualitative urbanization
Population growth	Dynamic	Stable
Technical infrastructure	Extensive use of infrastructure, infrastructure "deficit"	High amount of high quality infrastructure
Economic basis	Dynamically formed, does not require high qualifications, significant immigration potential	Developed and stable, established in both the national and international economic system, supported by 3rd and 4th sectors.
Potential for innovation	Low; at its base the economy is supported by the low cost of labour	High; high quality of workforce thanks to the availability of education and the innovative attitude of society
Local society	Lack of integration; the dynamic movement of people (residents)	Integrated; frequent dialog between the government and the citizen
Space	Low quality; the priority of ongoing activities over planning	High quality; the priority of planning over ongoing activities

Source: own work based on: M. Wołek: Marketing in shaping of the competitive advantage of the city. Study based on the example of Gdynia. Typescript, Sopot 2005

near factories as a result of the lack of an efficient public transport system, which led to the chaotic development of the city. The excessive concentration of different functions and their migration intensified the presence of negative external effects. Only the emergence of urban transport (in the first half of the nineteenth century) has enabled a more efficient use of urban space and its further development. This was confirmed in the dispersion of the city structure and its further spatial expansion. "With transport more readily available, homes no longer had to be cramped within a narrow circle around the industrial centre, any more than did workshops". This process has been enhanced by the development of motorization, which led to the emergence of the phenomenon of "urban sprawl".[34]

The thesis of the leading role of cities in the modern European economy needs no justification. "In many respects the European Union can be seen as a Union of cities, as approximately 1600 urban areas with more than 50 000 inhabitants are defined as functional urban areas". Economic social and political functions are centred in European cities and determine the current role of Europe in the global economy. A well functioning city requires an efficient transport system, ensuring its internal and external accessibility. This book, however, is concerned only with its internal availability.[5]

The transport system of a city is formed by the interaction between public transport and privately owned vehicles. The framework for these relationships is established through transport policy, the long-term goal of which should be to reduce the need for transport, whilst in

[3] P. George: Miasto. PWN, Warszawa 1956, p. 16.

[4] C. Clark: Transport breaker or maker of the cities. "Town Planning Review" 1958 no 2, pp. 237–250 [after:] Urban Transport. Ed. P. Rietveld, K. Button, P. Nijkamp. Edward Elgar, Cheltenham 2003, p. 512.

[5] Ensuring quality of life in Europe's cities and towns. Tackling the environmental challenges driven by European and global change. "EEA Report" 2009 no 5, p. 10.

the short-term, to rationalize the structure of the modal split and the formation of behaviour appropriate to the balancing of transport.[6]

The relationship between the city and transport is complex and bi-directional. The presence of externalities adds complication and difficulty in quantifying the problem. An efficient transport system is a prerequisite for the economic development of a city and its region, as well as one of the most important factors determining the quality of life in the city.

Challenges for European cities due to bi-directional relations between urban space and the transport activity can be summarized in the following points:

- Demographic; particularly the issue of population ageing and changes in the population of urban centres. „The major demographic impact upon land use in many cities has thus come not from the growth of population, but rather from its restructuring. It is mainly the social and age changes of past generation". As a result, the number of households with fewer people is growing, which is accompanied by an increase in demand for housing and transport services. According to demographic projections for the EU, the percentage of people aged 65 years and older in the general population of the EU in 2020 will reach 24%, and in 2050, as much as 29% compared to the current 17%. The ageing of the European population (the increase in the percentage of older people in the population and the lengthening of the average life span) brings huge challenges for urban mobility planning, focused on improving the availability of services, ease of use (fleet, infrastructure, passenger information and customer service) and the creation of new business models taking into account the lower level of mobility, as well as the lower purchasing power of those who are no longer economically active.[7, 8]
- Economic; the complexity of which is reflected in the first instance by the expenditure incurred for the development and maintenance of the transport system, and in the second instance the fact that transport is an important factor affecting the economic competitiveness of the area. The transport sector is also a major employer creating stable jobs due the mandatory nature of the provision of a number of transport services.

An important aspect that lies somewhere between spatial and economic issues is the impact of transport on urban property values, reflected in the increase in their value thanks to improved transport accessibility. An example is the increase in the value of property located near the newly launched metro line in Warsaw (Poland), and in Washington, DC (USA), where "cheap, good-quality metro service increased the willingness of people to pay for land parcels near metro stations".[9]

- Spatial; for which the relationship between the city and the privately owned vehicle becomes crucial to the process of shaping the spatial structure of cities, especially in the last few years. The European urban space, having been focused on the needs of drivers, has been transformed in a way, which hinders rapid change in its function. The importance of spatial development in shaping the transport market is highlighted by T. Litman, who

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[6] Transport miejski. Ekonomika i organizacja. Red. O. Wyszomirski. Published by Gdansk University 2008.

[7] P. Kivell: Land and the City. Routledge, London 1993, p. 88.

[8] Based on Eurostat and EUROPOP 2008.

[9] K. Button: Transport Economics. 3rd edition. Edward Elgar, Cheltenham – Northampton, 2010, p. 73.

writes „transportation market distortions include various types of underpricing of motorized travel, planning practices that favour automobile travel over other modes, and land use development practices that create automobile-dependent communities"[10]. The relation between transport and spatial planning is also touched upon by K. Small and E.T. Verhoef: „transportation potentially affects the nature of the urban area itself. If transportation were costless[11], participants in an economy would have no economic reason to locate close to one another". The mutual relations of spatial development, spatial planning and transport can be reduced to the so-called. „5D", i.e. „Density, Diversity, Design, Distance (to public transport) and Destination Accessibility.[12]

In theory, one can distinguish two extreme models of the relation between urban space and transport, namely:[13]

- „Compact City"; characterized by the high availability of the internal labour market, education and others, at the expense of limiting the space for low-intensity residential building development.
- „Sprawling City"; where people have a lot of space to live, but as a consequence they must take longer trips, which means higher costs and time spent on travel.

In practice, cities incorporate the two models in various proportions. Sustainable cities will seek to incorporate the compact city model. It should be noted that various districts of the city could show significant differences in incorporating the described urban models. Central districts are usually characterized by more intense development density and greater availability of public transport, while peripheral areas are characterized by lower development density, lower diversity of functions and lower levels of supply of public transport services. In view of the above, it seems reasonable to introduce a definition of a sustainable city, which operates in a manner that guarantees all citizens the opportunity to meet their needs and improve their quality of life without compromising the environment and creating a hazard for other people, now or in the future.[14]

- Environmental; manifest themselves primarily by the impact on the environment. External costs are difficult to measure and to direct assign to the polluter in the traditional economic calculation. Air pollution, traffic accidents, noise and vibration, landscape transformation, climate change and transport congestion are the most important categories of external costs borne by the public as a result of urban transport operations. Each means of transport in urban areas is characterized by a different level of impact on the environment.

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[10] T. Litman: Transportation Market Distortions. "Berkeley Planning Journal" 2006 Vol. 19, p. 19.

[11] K. Small, E.T. Verhoef: The economics of urban transportation. Routledge, London, New York 2007, p. 2.

[12] R. Cervero, O. Sarmiento, E. Jacoby, L. Gomez, A. Neiman: Influences of built environments on walking and cycling: lessons from Bogota. "International Journal of Sustainable Transportation" 2009 nr 3(4), p. 209.

[13] Cities at crossroads: Unlocking the Potential for Green Urban Transport. World Bank and Asian Development Bank 2012, p. 35.

[14] Girardet H.: Creating Sustainable Cities. "Schumacher Briefings" No 2. Green Books, Totnes 2003, p. 13.

Borderline environmental and spatial aspects include the land consumption of urban transport infrastructure. Scarcity of land and the variety of stakeholders (i.e. car-drivers, pedestrians, public-transport operators) create a state of permanent conflict. The low efficiency of a passenger vehicle, with the average number of passengers not exceeding two, contrasts with the potential of public transport. In addition, the energy efficiency of a passenger car compared to public transport is much lower, especially during peak hours.

- Social – in which the availability of transport services determines the possibility of taking advantage of public goods. „Transportation policy is inevitably social policy, with specific winners and losers in any transportation investment decision. Projects to benefit higher-income motorists may harm lower-income pedestrians, whereas other investments may significantly expand mobility and job opportunities for those too young, old or disable to drive". The role of transport in the fight against social exclusion manifests itself in offering services that are affordable, available and accessible, defining what is an acceptable minimum basic mobility / access provision.[15, 16]

Depending on the local and national conditions, the above factors determine European cities' varying degrees of attractiveness for investors and developers.

The strong market position of public transport, especially electrified public transport (trams and trolleybuses) is a characteristic element of the supply side of urban transport markets in the cities of Central and Eastern Europe, as shown in Table 1.2. The condition for maintaining a relatively high share of public transport in the modal split is to raise the quality of services and to deepen public transport's integration with private modes of transport, such as cars and bicycles.[17]

Table 1.2. The Characteristics of the Modal Split in the Cities of Central-Eastern and Western Europe

Cities of Central-Eastern Europe	Cities of Western Europe
Higher share of public transport	Lower share of public transport
Lower share of bicycle transport	Higher share of bicycle transport
High or average dynamics of individual transport development	Low dynamism of private transport development

Source: own study.

Maintaining a high share of public transport in the cities of Central and Eastern Europe is a major challenge in the case of the dynamic development of private passenger transport and the ongoing transformation of urban space, the major impetus for the development appeared only recently (it is related to the transformation of the political system and the membership in the EU).

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[15] J. Tumlin: Sustainable Transportation Planning. Tools for Creating Vibrant, Healthy ad Resilient Communities. John Wiley & Sons, Hoboken, New Jersey 2012, p. 4.

[16] Social exclusion and the provision of public transport. Main report. Department for Transport, London, p. 5.

[17] Hebel K., Wołek M.: Perspektywy rozwoju komunikacji tramwajowej w polskich miastach. „Transport i Komunikacja" 2010 no 1, p. 18.

Recent recommendations for cities include the leading strategy to reduce the negative impact of transport on urban areas. It consists of the following components:[18]

- Avoid;
- Shift;
- Improve.

The Avoid strategy includes activities aimed at decreasing the number of vehicle kilometres by Transport Demand Management, land use planning, Information and Communication Technologies (ICT), localized production and shorter supply chains.

The Shift strategy focuses on activities aimed at shifting from private vehicles to non-motorized transport and public transport.

The Improve strategy includes activities aimed at improving existing vehicles, like the downscaling of vehicle engine size, increased penetration of electric vehicles and carbon-neutral liquid fuels as well as the implementation of Intelligent Transport Systems (ITS).

The multifaceted relationship of urban transport and space is one of the most important determinants of the development of European cities. Shaping its availability on the basis of full economic calculation takes into account the occupancy of land and the loss/benefit recognized as a result of transport by the general public, should be an important prerequisite for strategic investment, organizer/management decisions.

1.2. The European Union Public Transport Policy

Transport policy must serve the general interest and should be a part of wider socio-economic policy, integrated at different territorial levels. Formation of a suitable transport policy, in an age which seeks complex solutions, requires taking into consideration a broader context and referring to other sector policies (i.e. social, energy, environmental, and economic policies).

Climate policy has gained special recognition within a European context becoming one of the most important factors determining the development of transport in the EU. Its aim is to radically reduce carbon dioxide emissions. The transportation sector was singled out as an area, which has the potential to achieve this by the year 2020. The vast concentration of settlements, as well as the varied forms of activities which take place within cities, constitutes a direct reason why the relocation of population in the urbanised areas of the European Union generates approximately 40% of the CO_2 emissions resulting from road transportation.[19] The

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[18] Green Economy Report. Transport, Investing in Energy and Resource Efficiency. UNEP 2011.

[19] Preparation of a green paper on urban transport: Report on urban transport in Europe. Prepared for the European Commission, Directorate General for Energy and Transport. Final version. MVV Consulting, Tractebel Suez Engineering, 2007, p. 2 for Keep Europe moving – Sustainable mobility for our continent. Mid-term review of the European Commission's 2001 Transport White Paper. Communication From the Commission to the Council and the European Parliament. Brussels, 22.06.2006,

entire transportation sector is strongly dependant on petroleum and its derivatives, generating 2/3 of the general demand for this resource in the European Union.[20]

The Strong dependency of the transportation sector on liquid fuel is rooted in the relative easiness with which petroleum is transported and processed; its low cost in the 1980's and 1990's; as well as the long-standing tradition and potential of the fuel trade and the transport policy of carriers providing their services on various markets of the transportation branches. Alternative power sources for vehicles require the construction of new, and the development of the existing infrastructure intended for processing and providing power, as well as the creation of a suitable demand, which would justify the large investment in the building of an alternative vehicle power system, competitive to liquid mineral fuels. Unification of the power infrastructure poses a serious challenge. Its varied nature, however, should not become an obstacle for the popularisation of electric vehicles.

During the last two decades, the transport policy of the European Union was dominated by the paradigm of branch shift.[21] In relation to transportation services within cities it includes actions aimed at decreasing the share of the role of cars in the transportation task division, whilst at the same time increasing the role of mass transportation, bikes and pedestrian movement. It aims not to restrict mobility, but to transform it by shifting its focus onto more sustainable trip planning within urbanised areas. Strong dependency on private passenger vehicles results in:

- "Climate change – rising transport – related carbon driven by oil dependence and climate change impacts.
- Environment and health – resulting in poorer air quality, congestion and health effects.
- Economic – rising fuel and congestion costs, wasted time and resources[22]".

The above cannot be resolved by a transport policy based on 'shift' paradigm. In addition to the above arguments, it is necessary to add that the introduction of electricity powered passenger vehicles will not entirely solve the congestion issue present in the urbanised areas of Europe.

European transport policy regarding urbanised areas should be, therefore, examined in the light of a wider background of sustainable development issues. In the Commission's announcement "A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development" congestion has already been acknowledged as one of "the main threats to sustainable development".[23] The same announcement included the proposal of 'decoupling'.

COM(2006) 314 final, p. 14.

[20] EU Transport in figures. European Commission, Luxembourg 2011.

[21] E. Załoga: Trendy w transporcie lądowym Unii Europejskiej [Trends in Overland Transportation within the European Union]. Rozprawy i Studia T. 873. Published by The University of Szczecin, Szczecin 2013, p. 112 and next.

[22] D. Lam, P. Head: Sustainable Urban Mobility. [In:] Energy, Transport and the Environment. Addressing the Sustainable Mobility Paradigm. Ed. O. Inderwildi, D. King. Springer–Verlag, London 2012, p. 360.

[23] A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. Communication From The Commission. Brussels, 15.5.2001 COM(2001) 264 final, p. 4.

Its aim is to "decouple transport growth significantly from growth in Gross Domestic Product in order to reduce congestion and other negative side-effects of transport".[24]

The evolution of the approach presented by the European Commission towards the issue of shaping mobility in recent years is presented in Fig. 1.1.

The White Book "European Transport Policy for 2010: Time to Decide" outlined ambitious challenges for the European transportation sector. Those referring to urban mobility were mostly not realised, reductions in CO2 emissions as well as the reduction in the role of passenger vehicles in urbanised areas among others.[25]

The document entitled "Keep Europe Moving" (2006) constituted an overview of those effects of the transport policy achieved to date. It also aimed at incorporating changes of a strategic nature; such as the expansion of the European Union, the acceleration of the processes of globalisation, the improvement of international cooperation in the scope of climate change as well as rising petrol and energy costs.

On the acceptation of The Green Paper: "Towards a New Culture in Urban Mobility" in 2007, the European Commission opened up a new discussion which resulted in the publication of "Action Plan on Urban Mobility" in 2009. The Green Paper emphasised the fact that although urban mobility has a local character, the result of a lack of action within this sphere may have a European, or even global, nature. Transport problems pointed out in The Green Paper were:[26]

- Congestion,
- Negative effect on the natural environment – air pollution, high CO2 emissions, noise pollution, energy consumption,
- Limitations in accessibility, especially for the elderly, disabled, parents with children,
- Road traffic safety, safety on board public transportation vehicles and at stops.

„Action Plan on Urban Mobility[27]" contained twenty measures, which focused on urban mobility and transport matters. In this document, the central role for the sustainable urban mobility plan has been outlined. The document presented a proposed action plan, which would support urban mobility according to the rules of sustainable development. It included a group of initiatives presented in Table 1.3. The focusing of the proposed actions on the plans of sustainable, urban mobility development, constituted a breakthrough.

In its communication entitled "A Sustainable Future for Transport", published in 2009, the European Commission acknowledge the need to define a general mobility strategy which would constitute an important element for the future White Book for transportation. The document draws attention to the need for the separation of economic growth and growth in the emission of greenhouse gases.

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24 Ibidem, p. 12.

25 W. Rydzkowski: Trolleybus and Sustainable Transport Policy [Trolejbus a zrównoważona polityka transportowa]. A lecture given during a conference entitled "Trolleybus in a Modern City" [Trolejbus w nowoczesnym mieście]. Gdynia 21–22.03. 2013

26 Green Paper: Towards a New Culture in Urban Mobility. European Commission, COM (2007) 551 final, Brussels 2007, p. 2.

27 Action Plan on Urban Mobility. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. Brussels, 30.9.2009 COM(2009) 490.

Table 1.3. Initiatives Anticipated Within "Action Plan on Urban Mobility"

Theme 1: Promoting Integrated Policies	Theme 2: Focusing on Citizens	Theme 3 – Making Urban Transport Green	Theme 4-Strengthening Funding
Accelerating the take-up of sustainable urban mobility plans	Platform on passenger rights in urban public transport	Research and demonstration projects for lower and zero emission vehicles	Optimising existing funding sources
Sustainable urban mobility development and regional policy	Improving accessibility for persons with reduced mobility	Internet guide on clean and energy-efficient vehicles	Analysing the needs for future funding
Transport for healthy urban environments	Improving travel information	Study on urban aspects of the internalisation of external costs	
	Access to green zones	Information exchange on urban pricing schemes	
	Campaigns on sustainable mobility behaviour		
	Energy-efficient driving as part of driving education		

Source: own analysis on the basis of "Action Plan on Urban Mobility" *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. Brussels, 30.9.2009, COM(2009) 490.*

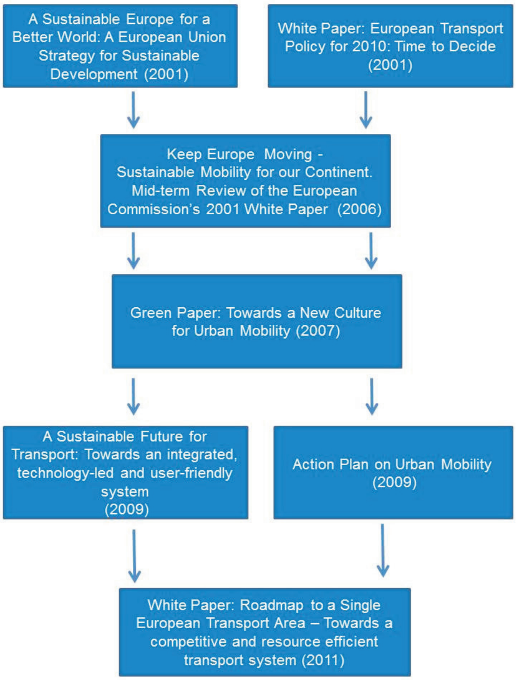

Fig. 1.1. The Most Important Documents of the European Commission Regarding Urban Mobility Published Between 2001 and 2011
Source: Own analysis.

Despite some progress in the introduction of the transport policy the remaining major challenges posed to the European transport sector are:

- Competitive pressure resulting from ongoing economic globalisation processes,
- The strong dependency of the European Union member states on petroleum and its derivatives (currently, the sector is dependent upon oil-based fuels and responsible for about 67% of the total oil demand in the EU),[28]
- The increase in congestion within the cities
- The imbalance of infrastructure in the expanded EU

The issues regarding urban transportation were emphasised in the White Paper entitled "Roadmap to a Single European Transport Area...", which postulates the need for integration of, among others, spacial planning, pricing systems, efficient public transportation services, and the infrastructure for non-motorised means of transportation within urban mobility planning.

The central aims of European transport policy, namely the reduction of CO2 emissions and the freeing of the transportation sector from petroleum, constitutes only a partial answer to the urgent issue of high volume traffic in the cities resulting in traffic congestion (the White Paper states that it "is vital not to restrict mobility").[29][30]

The two aims which refer directly to urban transport are the reduction of emissions resulting from it, as well as logistics through radical changes in vehicle powering solutions from 2030 and the introduction of the European system of information, management and payment within multimodal transportation, which will play a significant role in the unification of the urban transportation system with that of long-distance transportation (Table 1.4).

A review of activities aimed at the reduction of the negative influence of the transportation sector on the natural environment undertaken by cities, prepared in 2009 (revised two years later) by the German GIZ Institute, points out that one of the most important components of such activities is the improvement of the quality of the public transport, understood in its complexity together with limitations for the users of passenger vehicles of varied scope and affliction. Equally important are the actions supporting bicycle transportation and pedestrian movement as well as limitations on mobility resulting from integrated spacial planning.[31]

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[28] Kiel J., Maurer H., Fermi F., Fiorello D., Krail M.: Future challenges for European transport policy – Assessment of the implications of future challenges for transport policy. Deliverable D3.1 of ASSIST – Assessing the social and economic impacts of past and future sustainable transport policy in Europe. Project co-funded by European Commission 7th RTD Programme. Fraunhofer-ISI, Karlsruhe 2013, p. 13.

[29] M. Wołek: Sustainable Urban Mobility Plan As An Instrument Of Urban Transport Policy [Plan zrównoważonej mobilności miejskiej jako instrument miejskiej polityki transportowej]. Paper presented on the conference 10th Scientific and Technical Conference, Transportation Systems – Theory and Practice, Gliwice 2013.

[30] The White Paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM(2011) 144, Brussels 2011, p. 6.

[31] A. Wagner, P. Schaltenberg, J. Gomez Vilchez: Urban Transport and Climate Change Action Plans. An Overview. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by Federal Ministry for Economic Cooperation and Development, Eschborn 2011.

Table 1.4. The Aims of European Transport Politics and the Implications for Public Transport Within Cities

Goals of EU transport policy	Impact for public transport sector
1. Low emission urban transport and logistics	Strong
2. Low-carbon fuels in aviation and maritime transport	n/a
3. Freight, modal shift from road transport	n/a
4. EU-wide high-speed rail network	n/a
5. Multimodal TEN-T core network	n/a
6. Long-term comprehensive network	n/a
7. Traffic-management systems in all modes	Strong
8. Multimodal transport information	Strong
9. Close to zero fatalities in all modes	Moderate
10. Towards 'user pays' and 'polluter pays'	Moderate

Source: own analysis on the basis of the White Paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM(2011) 144, Bruksela 2011, s. 6.

Electric traction has proved a long-standing, effective solution in urban transportation. It demonstrates technical advancement, whilst remaining highly receptive to innovation. It is characterised by a variety of practised solutions and the possibility of utilisation in nearly every city facility (underground, urban train, tram, trolleybus, electrobus and partially hybrid buses). Emissions depend on the type of the energy produced. In the case of some cities the percentage of renewable energy in electric traction exceeds 90% (among others, trolleybus transport in Salzburg, Austria, and Eberswalde and Solingen, Germany). What makes electricity so appealing is its universality – it can be produced practically from all primary energy sources. In the coming years, thanks to electric traction, public transportation will become superior to privately owned passenger vehicles due to its strong ecological advantage. Electric traction constitutes a fundament for the possibility of the realisation of the aims of European transport policy; a substantial decrease in the greenhouse gas emissions related to transport.

1.3. The TROLLEY Project as a Partnership for the Development of Sustainable Public Transport

The TROLLEY project was implemented under the Operational Programme of Central Europe; a European Union program aimed at supporting transnational co-operation between the countries of this part of Europe in order to increase innovation, accessibility, the state of the environment, the competitiveness and attractiveness of particular cities and regions. Activities related to such countries as Poland, the Czech Republic, Slovakia, Austria, Hungary, Slovenia and partially Germany, Italy and western Ukraine. The programme budget for 2007–2013 amounted to EUR 298 million, and the financing of eligible project costs ranged from 75% (for the so called "old EU member states") through 85% ("new EU member States") to 90% (Ukraine).

The priorities of the Programme in the years 2007–2013 were:[32]

- driving innovation in a defined area;
- improving internal and external accessibility of Central Europe;
- responsible use of natural resources;
- improving the competitiveness and attractiveness of cities and regions.

The TROLLEY project was implemented in the framework of the Central Europe programme. The activities were related to the Priority of "Improving the internal and external accessibility of Central Europe". It gained support for projects aimed at reducing the negative impact of transport on the environment, promoting sustainable mobility, increasing safety awareness and contributing to a higher quality of living.

The aim of the TROLLEY project was promoting trolleybuses as the cleanest and most economical mode of transport for cities and regions of Central Europe. Based on their experience, nine TROLLEY partners from six Central European countries – Barnimer Busgesselschaft from Eberswalde and Leipziger Verkehrsbetriebe (Niemcy), Salzburg AG (Austria), Gdynia and The Univeristy of Gdańsk (Poland), SZKT Szeged (Hungary), Brno (Czech Republic) and TEP S.p.A. from Parma (Italy) together with TROLLEYMOTION organization – searched for a way in which to unlock the potential of trolleybus transport in order to convert the transport system from oil-dependant to electricity-based. This partnership involved approximately 25% of all trolleybuses and 30% of all trolleybus lines operating in Central Europe. The structure of the partnership of the TROLLEY project is presented in Figure 1.2. It is worth noting that more than half of the partners are operators of public transport.

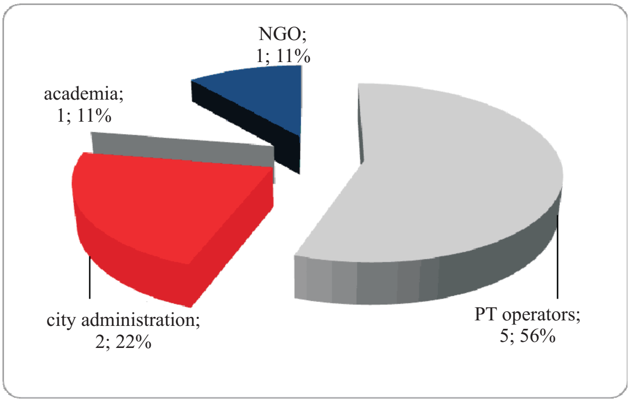

Fig. 1.2. The structure of the Partnership of the TROLLEY Project
Source: own work based on the application of TROLLEY project.

The TROLLEY project started in February 2010 and lasted until March 2013. It was the biggest project of the European Commission "INTERREG Central Europe", with a budget

[32] http://www.central2013.eu/about-central/priorities/?L=se%25, 4.02.2013

of EUR 4.2 million, of which EUR 3.2 million was contributed by the European Regional Development Fund (ERDF).

The Project Coordinator was Salzburg AG (Austria). It main aims were as follows:

- the development of operating strategies, which may be feasibly implemented in other cities operating trolleybuses;
- the development of innovative methods of promoting trolleybus transport, depicting it as an environmentally friendly form of transport;
- the revitalization and improvement of the image of trolleybus transport in Central Europe.

The structure of the project was adopted with these aims in mind. It included three main initiatives:

- optimizing energy consumption;
- increasing the reliability and efficiency of trolleybus transport;
- improving the image of trolleybus transport.

The structure of theTROLLEY project is presented in Figure 1.3.

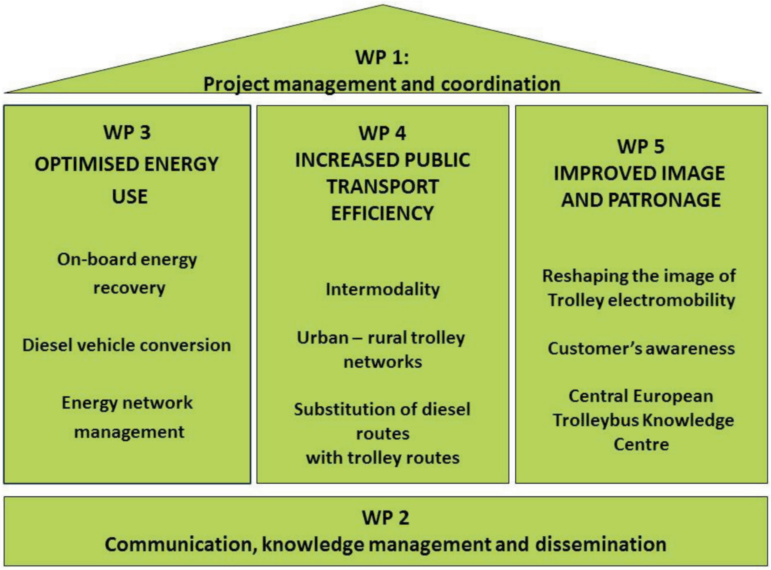

Fig. 1.3. The Structure of the TROLLEY Project
Source: own work based on the application of TROLLEY project.

The third initiative contained a number of measures aimed at reducing the energy consumption in trolleybus transport, both for the fleet and the overhead network. One of the key products included in this the package was a manual on the conversion of diesel buses into trolleybuses.

The initiative designed to increase the efficiency and reliability of trolleybus transport included activities aimed at increasing trolleybus transport integration with other means of transport, inducing the development of trolleybus transport in non-urban areas, and in some cases exploring the possibility of trolleybuses replacing regular buses.

The final initiative included promotional activities and the use of instruments of marketing research. These activities were particularly focused on shaping the image of trolleybus transport, increasing awareness of trolleybus transport and its advantages and the establishment of the Central European Trolleybus Knowledge Centre. The European Trolleybus Day, which was initiated in 2010, is an interesting example of an activity included in this work package. It is addressed to a wide audience and celebrated by an increasing number of cities, including those that were not partners in the project (e.g. Tychy and Lublin, Poland in 2013). Promotional activities carried out under this project are further described in chapter 8.3.

The second initiative involved horizontal action, including issues of promotion and dissemination of information about the project, and, more broadly, about trolleybus transport. The main target groups were citizens of the Project's partner cities, policy makers, representatives of manufacturers of the fleet and electrical equipment and other trolleybus operators in Europe. An interesting manifestation of the activities of this work package was the development of e-learning modules corresponding to major thematic issues of the TROLLEY project.

Chapter 2. Development and The Scope of Trolleybus Transport Operations in Europe

2.1. Stages of Development of the Trolleybus as a Mode of Urban Public Transport in the City

In the early nineteenth century urban transport comprised of pedestrians and draft animals. Cities were filled with horse-drawn carriages. The first Stephenson railway was built in 1985. This invention disseminated in subsequent decades, and cities began to operate city railways, either pulled by horses or powered by steam engine. The first electric tram was built by Siemens in Berlin in 1881. The inventor presented the first rail-free electric vehicle powered by an overhead wire in 1886. This vehicle may be considered a prototype of the trolleybus. However, in the eve of World War I, the dominant role in urban transport was played by electric trams.

The first trolleybuses with roller collectors of the Lloyd system, powered by two overhead wires suspended one above the other, were launched at the beginning of the twentieth century. Trolleybuses were often complementary to the existing tram network. The drawback was the need to switch the trolley collectors in order for vehicles to overtake each other. The systems were technically imperfect and rarely continued to operate after World War I.

From the beginning of the twentieth century motorization began to play a bigger role. Petrol powered vehicles were however slow, inefficient and not very durable. They originally had wooden wheels with a steel ring. In order to improve comfort, cast rubber padding was soon introduced. Driven on stone roads, these cars turned out to be far less comfortable than trams, which run on smooth rails. Nevertheless, tram rail systems required maintenance and huge investments in order to keep pace with the expansion of cities.

In the meantime, the first trolleybus systems powered with two parallel overhead wires were built. They used roller collectors; nevertheless this feature did not work efficiently with the overhead wire due to a small contact area between the roller and the wire. Due to the lack of rails, the vehicle concept was accepted in some British cities, where such systems were introduced and called rail-less trams.

The interwar period and the twenties witnessed significant technical progress in the automotive and road industry. The invention of asphalt roads enabled the smooth travel of rail-independent vehicles and improved their operating speed while reducing shocks, damage to vehicle bodies and operating costs. At the same time, pneumatic tires were added to heavy vehicles.

The smooth asphalt surface and the pneumatic wheel are inventions, which together with the development of car design, have created the potential to build the modern trolleybus. The introduction of the new trolley collector with a long area of contact with the wire was the basis for the construction of an efficient means of transport, more economical than buses, and independent of rails.

The thirties were the heyday of the development of the trolleybus. In London, where it fulfilled a special role, the local public transport authority, facing the need to overhaul and expand both the worn out tracks and the large but obsolete rolling stock, decided to introduce trolleybuses. While using the existing overhead wire infrastructure, trolleybuses ensured greater comfort and more dynamic transport which increased the operation speed. Comfort was ensured by pneumatic wheels – at that time a novelty – and smooth, powerful acceleration, made possible by the use of a powerful motor driving the pneumatic wheels which ensured very good traction. As a result, in the years 1934–1940 two thirds of London's tram system was converted to a trolleybus system, which resulted in the world's largest fleet of over 1700 vehicles.

Other British cities soon followed suit. Trolleybus systems were also developing intensely in Germany and Italy. The Soviet Union developed its own trolleybus designs replacing pre-war designed trams which were removed from the centers of many cities.

Trolleybuses also played a role in Germany's wartime economy, with both German cities and cities occupied by Germany introduced trolleybus transport in order to save fuel. Many of these systems were still operated after World War II.

After the war many Western Europe countries significantly increased their level of motorization, the car becoming a desirable status symbol and a synonym for prosperity. Transport companies noted yearly declines in both traffic and revenue. In the '50s trolleybus transport was still being developed with more capacious bodies and powerful motors being introduced.

With each passing year, however, it became clear that the downward trend towards public transport was permanent. The dangers associated with the excessive development of individual transport – pollution, congestion, lack of parking space and the associated loss of time for society and the economy – were not yet considered.

Lorries and buses with diesel engines were also being developed at this time. Underfloor and later rear engines were introduced with the power and efficiency of the being engine increased, and automatic gearboxes were installed. Fuel was relatively inexpensive, while maintaining the trolleybus infrastructure was relatively expensive. Despite the fact that the number of conductors was reduced, trolleybus operating costs were still high. Nevertheless, with the development of cities, it was necessary to decide whether or not to expand the tram and trolleybus network. Many cities, influenced by the development of the automotive industry, suspended trolleybus lines and shut down electric transport systems.

At this time in socialist countries a car was a luxury. Car ownership was extremely rare – as little as a few cars per 1000 inhabitants. However, trolleybuses were being developed their design initially based on designs from World War II until new vehicles were eventually developed. In the USSR trolleybuses proved their superiority over buses equipped with inefficient petrol engines. Soviet trolleybuses were put into service in a number of cities associated with the Soviet bloc.

In the United States, renowned for huge tram systems at the beginning of the twentieth century, public transport began to favor buses following the war. Owning and running one's own car became an integral part of life, and public transport was considered obsolete and gradually relegated to a marginal level. Significant urban rail systems were only kept in the largest metropolitan areas.

The fuel crisis in 1974 and the increasing cost of fuel changed the falling trend. It soon became obvious that oil is by no means the ideal fuel. This period also saw a rise in public awareness of environmental issues and of the dangers of air pollution. A number of cities reduced expansive development of road infrastructure and began analyzing alternatives to individual transport. Trolleybus transport was one of the considered modes of transport. The vehicles were equipped with new and more cost-effective drive control systems – thyristor, then transistor, and finally inverter with AC motors. The development of the trolleybus was hindered by the need to develop its infrastructure from scratch. However, due to the oil crisis trolleybus transport was developed in France and in many cities across Western Europe with the existing systems maintained and the trolley bus fleet modernized.

In the meantime, the Soviet Union continued its uninterrupted development of trolleybus transport. Nevertheless, associated countries were influenced by western tendencies – many trolleybus systems in Poland and in Prague were shut down. However, this trend was reversed in the late '70s and trolleybus transport was developed in new cities.

With the advent of the '90s's, the ecological trend intensified. In addition, low-floor trolleybuses were introduced. It helped increase the quality of trolleybus transport in many cities. In Central Europe, after the change of regime in former Soviet states, trolleybus transport began to be restored. Fleet renewal was associated with improved quality of service and was often an opportunity for the introduction of new technologies – batteries, super capacitors or auxiliary combustion engines.

In Western Europe, in cities where trolleybus transport was preserved, the fleet was renewed and given traffic privileges. As of the year 2000 Swiss cities began to introduce bi-articulated low-floor trolleybuses, with similar capacity to trams that do not require the construction of expensive tracks. Trolleybuses became useful in the promotion of public transport. Many cities call for the introduction of reduced or zero emission zones, for which trolleybuses are a perfect solution. At the same time, trolleybuses are popular due to the trend towards the development of hybrid and electric vehicles, which are considered the future of urban transport.

2.2. Trolleybus Transport in Europe

Trolleybus transport in Europe has gone through periods of varied popularity. However, despite the liquidation of a number of trolleybus systems in the world in the 1960s the ratio of systems within individual countries remains very similar. During the first half of the '60s the largest trolleybus system was operated in London and Great Britain could have been considered "a trolleybus promised land". It was the country with the highest share of trolleybus transport within its public transport system. Besides Great Britain, trolleybuses were also popular in Switzerland, the Soviet Union and the socialist countries of Central and Eastern Europe. This fact was largely magnified by the underdevelopment of the automotive industry within the Eastern Bloc.

With the end of a period of development for trolleybus transport systems in the mid-twentieth century, came a wave of liquidation in many European countries. This negative trend began in Britain – not only the home of the largest number of trolley bus systems, but also the main producers of trolleybus vehicles and equipment related to the construction of both overhead and power systems – before spreading to other European countries.. It should be noted that the decision to withdraw trolleybus systems from British cities was neither taken for economic reasons, nor was it a result of environmental concerns. The substitution of electric modes of transport with buses powered by combustion engines was rather political in nature.

The situation changed considerably following the global oil crisis in the late '60s and '70s. Once again attention was redirected towards electric modes of transportation, including trolleybuses. In Europe a number of new trolleybus systems were established, while the existing systems were expanded and modernized. However, trolleybus transport was not reintroduced in Great Britain and (with the exception of some cities) in Germany which had previously operated almost 100 systems.

In the '90s trolleybus transport was hindered by the difficult economic situation found in many countries as a result of the economic transformation (systemic), particularly in the former Soviet Union and Central Europe. As a result, some systems did not withstand financial distress, underinvestment, and the degradation of their fleet and infrastructure. There was a noticeable opposing trend against trolleybus transport (inherently more expensive to build and to operate) in favor of bus transport, preferred for its somewhat lower operating cost, whilst environmental concerns were sidelined. These actions led to the closure of almost 30 European trolleybus systems by 2012 (including that of the Russian Federation with its Asian territories), from 266 systems which were operated in the 1990s. The dynamics of the change in the number of operated trolleybus systems from 1990s to 2012 is shown in Fig. 2.1. However, a number of new systems were built at this time – mainly in Italy, but also in Sweden, Spain, Slovakia and the Czech Republic.

By the end of the first decade of the 21st century there was an increase in environmental awareness with local authorities (as well as within the population), which again resulted in a shift towards electric modes of transport, including trolleybuses. This effort was strengthened by the cohesion policy of the European Union becoming the main source of modernization and development of trolleybus transport in the countries of Central and Eastern Europe. It should be noted that among the 21 trolleybus systems decommissioned in Europe during the last two decades of the twentieth century, the area which bared relation to the phenomenon was made up only of post-socialistic countries whose economies were in transition. A apparent "renaissance" of trolleybus transport was reflected in the commissioning of several spectacular investments, the most important being the trolleybus network in Rome, which was launched on 23 March 2005, trolleybuses returning to the streets of the Italian capital after 32 years of absence. Aside from Rome, over the last two decades trolleybus transport was introduced in Landskrona (Sweden), Genoa, Lecce, Bari and Bologna (Italy), Castellón (Spain), Târgu Jiu, Baia Mare, Piatra-Neamt, Ploieşti (Romania), Kosice and Zilina (Slovakia), Ceske Budejovice (Czech Republic) and Kerch (Ukraine). The distribution of trolleybus systems in Europe at the turn of the 20th and 21st centuries is illustrated by Fig. 2.2.

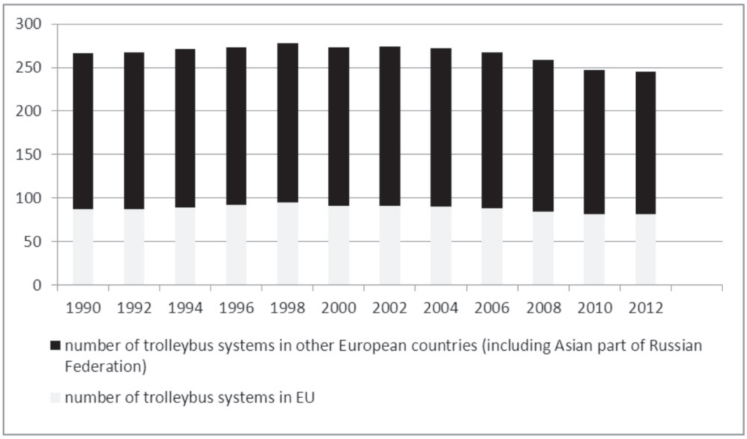

Fig. 2.1. Number of active trolleybus systems in European countries between the 1990s and 2012
Source: own work.

Besides the construction of entirely new trolleybus transport systems one can observe the development of existing networks reflected by an increase in the length of routes and replacement of trolleybus fleets, which although somewhat stalling in the last two-three years of economic crisis, has always benefited from support by the EU Structural Funds and specific measures, such as the preparation of Ukraine to host the UEFA European football Championship in 2012. A very important role in shaping the transport policy of European countries is played by the European Union which allows the execution of projects such as the development of trolleybus transport through various funding mechanisms for environmental investment and innovation. In Central and Eastern Europe, where nine countries (the Czech Republic, Slovakia, Hungary, Bulgaria, Romania, Lithuania, Latvia, Poland and Estonia) of the former socialist bloc have joined the European Union and thus adopted its structures, have become an area of intensified investment in trolleybus transport in recent years. Each of these states had previously operated trolleybus transport systems before joining the EU and thanks to EU support funds, have now modernized and expanded this type of transport. These countries have experienced greater investment in trolleybus transport since 2004 than over the previous 30 years. Particularly noteworthy projects are the expansion of the trolleybus system in Gdynia (Poland), Lublin (Poland), Plzeň (Czech Republic) and Szeged (Hungary), which resulted in a more prominent role for trolleybus transport within the transport system as a whole within these cities. Many other cities in the region, including Ostrava, Opava, Teplice, Zlin, Ceske Budejovice, Marianske Lazne, Zilina, Presov, Debrecen, Budapest, Cluj Napoca, Baia Mare, Vilnius, and Tallinn have modernized their routes and a significant part of their fleet.

Fig. 2.2. Distribution of trolleybus systems in Europe excluding the Russian Federation.
Source: own work.

Among 49 European countries 18 do not have a single city operating trolleybus transport. These include Great Britain, Denmark, Ireland and Finland, the remaining countries being small states, in most of which trolleybus transport has never been in operation. It should be noted within these countries research is being conducted on the feasibility of employing this type of transport, e.g. Helsinki and Leeds.

As a result of the processes discussed above, trolleybus transport did not regain the level of popularity it enjoyed before the decline of the 1960s in some Northern and West European countries. Switzerland and (to a lesser extent) Italy have resisted the trend of replacing trolleybuses with buses. In most Swiss trolleybus systems investments are being made that give a positive outlook on their future.

The largest number of trolleybus networks in Europe can be found within the Russian Federation (taking into account the whole territory of the country), Ukraine, Italy, Bulgaria, Switzerland, Czech Republic and Romania. Other countries operate only a few systems at most. Within Europe, trolleybus networks have never existed in Albania, Montenegro, Finland, Ireland, Iceland, Macedonia, Slovenia and Cyprus, and in small countries such as Andorra, Liechtenstein, Malta and Monaco. Analyzing the number of existing trolleybus networks in Europe throughout history, the number of decommissioned systems exceeds that of existing systems.

In Europe, activities were undertaken to modernize trolleybus transport in order to make it more effective. Given their dependence on the traction power supply, new solutions are being researched to make trolleybuses more flexible. Technological advancement now allows for alternative ways to power the trolleybus drive with either combustion units serving as a generator, a large capacity battery or super capacitor. It was the high maintenance cost of buses kept for the eventuality of a power failure, broken overhead wires or in the event of serious long-term repair or roadworks that influenced operators to aim at improving the operation of trolleybuses. Trolleybuses remaining in the depot were financially deficient, and buses operating on trolleybus lines increased the costs associated with trolleybuses. In the 1980s the first trolleybus lines with alternative power sources appeared with vehicles equipped with fuel driven generators and the first traction batteries. Such trolleybuses began to be used on a broader scale at the beginning of the 21st century. Outside of the cities of Western Europe, (particularly Switzerland and Italy where they were already in operation) the first Central European low-floor trolleybus, the Škoda 21TrACI was introduced. It was equipped with a diesel engine with a capacity of 100kW, which acted as a generator to power the trolleybus electric drive. The original purpose for the vehicle was line No.1 in the Czech town of Hradec Králové, where the final section was to service a street not fitted with an overhead wire network. The brand new trolleybus has replaced the makeshift solution used for several years in the form of the high-floor Škoda 14Tr with a trailer equipped with an internal combustion unit. Škoda 21TrACI trolleybuses were also delivered to Plzeň. Similar solutions are used by all manufacturers of low-floor trolleybuses in the European Union and Switzerland. Vehicles, on request, may be equipped with combustion powered generators (Fig. 2.3) by such manufacturers as Solaris, Škoda, Viseon, HESS, Van Hool.

Fig. 2.3. Combustion unit ready for installation in an articulated Breda MenariniBus trolleybus bound for Rome, with an electric motor by Škoda Electric in 2011
Photo Marcin Połom.

The combustion generator is the first and also the most popular of the solutions to diversify the power source. The popularity of this solution is mainly due to the ease with which it can be fitted in a trolleybus (the module's producer provides a complete, pre-assembled kit to be installed in the vehicle) and the availability of technology. Traction batteries are a second alternative power source, however, they are for now less popular and less likely to be seen in regular operation. This is caused by the underdevelopment of this technology and until recently, its high purchase cost. The interest in traction batteries has increased significantly over the last five years, mainly due to the development of modern technology, the introduction of new solutions in serial production and a decrease in costs. Rome, Budapest, Landskrona and Gdynia are considered pioneers of this solution.

The biggest advantage of traction batteries over combustion generators is their lack of emissions. A traction battery equipped trolleybus remains a fully electric vehicle, which is very important for those companies exclusively operating electric vehicles. Using combustion generators is burdensome in depots, which are not adapted to maintaining combustion vehicles. This is not a problem in the case of traction batteries, nevertheless, they are disadvantaged by their limited range. A trolleybus can only operate along a specified section of a route, whilst dependent on the battery's capacity. The battery capacity has an effect on its weight, a battery the size of a 100kW combustion generator allowing for a distance of 3 to 7 km depending on the technology used. In the case of battery operation in an emergency situation (temporary closure of a short section of the route) or linearly when handling a short distance, such as free range, the battery capacity currently available should be regarded as sufficient. Taking into consideration the fact that the battery (Fig. 2.4) can be recharged during

Fig. 2.4. Two modules of nickel-cadmium batteries built into a Solaris Trollino 12M trolleybus in Gdynia in 2009 r.
Photo Mikołaj Bartłomiejczyk.

regular operation, the disadvantage associated with the short range capacity is not that troublesome. Besides the aspects of battery capacity and weight, their life is also very important.

The last group of solutions are energy storing super capacitors – the least popular, however, also in use for the shortest period of time. Due to the novelty of the technology and its relatively scarcer availability with respect to the earlier discussed power supplies, there is very little experience with this solution. Currently used super capacitors for traction batteries have a much lower energy capacity, but other than when acting as an alternative source of power they really affect the efficiency of the electricity consumption of a trolleybus. Thanks to their rapid discharge and recharge, they are used in the current operating cycle, and allow improved traction e.g. during voltage drops in the overhead network. The speed at which they are able to recharge is important when recuperative (regenerative) braking occurs and there is no power receiver on the same stretch of the grid. In this case, the trolleybus accumulates the energy in super capacitors rather than wasting it on a braking resistor. This solution will surely be developed as standard and reinforce the competitiveness of vehicles using electricity. There is currently an attempt to connect super capacitors with traction batteries (Ostrava, Tallin) or a combustion generator (Eberswalde, Parma, Milan) in a single drive unit. The question remains as to whether super capacitors will be more effective when mounted on the side of the power supply (power substation) or on the receiver side (trolleybus).

Table 2.1. An example of using an auxiliary power source in regular trolleybus operation

Country	City	An example of using auxiliary power source in regular operation
Czech Republic	Hradec Králové	The use of a diesel-powered trolleybus when operating trolley line 1 from the Central Station to Kluk, where the last section of the route is traveled with the help of a combustion unit.
	Mariánské Lazně	Traction battery powered trolleybus is not used in regular traffic, trolleybuses with internal combustion power generators are operated on lines 6 and 7, and travel short sections which do not have overhead wires.
	Opava	Using a combustion power generator on line 221, Bílovecká – Kylešovice Škola section and Divadlo – Vrchní – Ratibořská section.
	Plzeň	Combustion generator powered trolleybuses are operated on sections of lines 12 and 13 which do not have overhead wires.
Spain	Castellón	In 2008 a small trolleybus network was built, expansion of which was began in 2010. Trolleybuses are equipped with combustion powered generators, which are used to turn around on a currently extended route.
Slovakia	Bratislava	Articulated trolleybuses on Line 33 are powered from the overhead wire, but the line itself is not connected to the rest of the network. Therefore, the trolleybuses use the generator in order to reach the line and to return to the depot.
Sweden	Landskrona	The small trolleybus network operates 4 trolleybuses, which link the railway station with the city center. They vehicles use the alternative power source in order to reach the area of operation and to return to the depot. 3 of the vehicles use traction batteries and the fourth uses a combustion power generator.
Hungary	Debrecen	Line 3E uses combustion power generators exclusively.
Italy	Rome	Line 90 operated by Ganz Solaris Trollino 18 trolleybuses use the traction battery each time the vehicles pass through the old city.

Source: own work.

Table 2.2. European trolleybus transport systems using alternative power sources in operated vehicles.

Nr	Country	City	Traction batteries	Super capacitors	Combustion power generator
1.	Austria	Linz			X
2.		Salzburg			X
3.	Bulgaria	Sofia			X
4.	Czech Republic	Hradec Králové			X
5.		Mariánské Lazně	X		X
6.		Opava			X
7.		Ostrava		X	X
8.		Plzeň			X
9.		Zlín			X
10.	Estonia	Tallin		X	
11.	Greece	Athens			X
12.	The Netherlands	Arnhem			X
13.	France	Limoges			X
14.		Lyon			X
15.		Nancy			X
16.		St. Etienne			X
17.	Spain	Castellon			X
18.	Lithuania	Kaunas		X	
19.	Latvia	Riga			X
20.	Germany	Eberswalde		X	X
21.		Esslingen			X
22.		Solingen			X
23.	Norway	Bergen			X
24.	Poland	Gdynia	X		
25.		Tychy	X		
26.	Portugal	Coimbra			X
27.	Romania	Timişoara			X
28.	Slovakia	Bratislava			X

29.	Switzerland	Bern			X
30.		Biel			X
31.		Fribourg			X
32.		Genève			X
33.		La Chaux-de-Fonds	X		
34.		Lausanne			X
35.		Luzern			X
36.		Montreux-Vevey			X
37.		Neuchatel			X
38.		Schaffhausen			X
39.		St. Gallen			X
40.		Winthertur			X
41.		Zürich			X
42.	Sweden	Landskrona	X		X
43.	Hungary	Budapest	X		
44.		Debrecen			X
45.		Szeged	X		
46.	Italy	Bologna			X
47.		Genoa			X
48.		Lecce			X
49.		Milan		X	X
50.		Modena			X
51.		Naples			X
52.		Parma		X	X
53.		Rome	X		
54.		San Remo			X

Source: own work.

Fig. 2.5. Solaris Trollino 12M in Gdynia (Poland), taking a detour through a street without the overhead wire in 2012.
Photo K. Grzonka.

Of all the trolleybus networks in Europe, 54 are experienced in using alternative power sources in emergencies or regular operation (Table 2.1, 2.2; Fig. 2.5). Most systems operating trolleybuses equipped with additional power supply operate in Switzerland – 13 cities, in Italy – 9 cities and the Czech Republic – 6 cities. The combustion generator is the dominant alternative power supply and is used in 46 cities. As a result of limited availability, there is far less experiences with other alternative power sources: the traction battery is used in 8 cities and super capacitors are used in 7 cities. Many cities which commission new vehicles plan to equip them with alternative power sources, hence the total amount of experience in this field will be gradually on the rise.

From the beginning of the 1960s trolleybus transport began to gain popularity all over the world, with the development of existing networks and the productive building of new ones. In the '70s the wave of decommissioning of trolleybus transport in the UK, France and Germany also caused non-European countries like the USA to lose interest.

After 1970, as a result of the global oil crisis, the growth of the national income of many countries and the new credit policy of banks, the pace of trolleybus network development accelerated. Between 1970 and 19'90s the majority of new trolleybuses were manufactured in Europe, the Asian part of the USSR and other countries of that region. In particular, many new systems were set up in China and North Korea (about 30 in total). The oldest active trolleybus line can be found in Shanghai, China and has operated continuously from 1914, today running about 300 vehicles. As of 2009 its trolleybuses began to use a separate lane.. The world's largest trolleybus network can be found in Moscow, the total length of its routes reaching 600 km, although during its heyday it reached 1300 km. The fleet includes 1300 trolleybuses, operating on 100 lines. The longest trolleybus line was built in 1959 on the Crimean peninsula. Its length is 86,7 km, linking Simferopol and the Black Sea resorts (Alushta, Yalta).

At the end of 2012 trolleybus transport operated outside of Europe in more than 100 cities, of which 6 systems were in North America, 11 in South America, one in Australia and the remaining systems in Asian countries and the Asian part of the Russian Federation.

A key operating element of trolleybus transport is its characteristic fleet. In the case of European cities, the number of producers is fixed, and most cities use the same types of Solaris, Škoda, Van Hool, Breda, VISEON or Irisbus vehicles. Non-European systems use different trolleybuses, usually dedicated to particular cities, often uncharacteristic. It is worth mentioning some of the existing non-standard systems, such as Quito (Ecuador), where trolleybuses are operated on dedicated lanes equipped with high platforms appropriate to the vehicle's floor.

2.3. Trolleybus Transport in Cities Participating in the Trolley Project

Four of the Trolley project participants have operated trolleybus transport since the 1940s. One of the participants – since the 1950s and a further participant – since the 1970s (Table 2.3).

Table 2.3. Trolleybus transport launch dates in the cities participating in the Trolley project

City	Year	Day and month
Salzburg	1940	01.10
Eberswalde	1940	03.11.
Gdynia	1943	18.09
Brno	1949	30.07
Parma	1953	25.10
Szeged	1979	29.04

Source: own work based on data received from companies operating trolleybuses in the above cities.

In Salzburg trolleybuses replaced trams. The first stage of development of trolleybus transport in the city took place from 1940 to 1949, by the end of which 4 trolleybus lines were operated on routes with a length of 16.8 km, using 26 one-piece (non-articulated) trolleybuses performing 1.482 million vehicle-kilometers annually. The first trolleybuses in operation were 10 MAN/Schumann MPE I from 1940 onwards. In 1941 4 Vetra CS 60 joined the fleet, but they were decommissioned 2 years later. In 1942 10 MAN/Schumann MPE II also joined the fleet and in 1948 – a MAN Gräf & Stift EO I.[1]

The second stage of development of trolleybus transport in Salzburg ended in 1978, when 6 routes were operated with a total length of 29.9 km. The fleet of 54 vehicles performed 3.078 M km annually. At the turn of the 1960s trolleybuses introduced during the first stage of development were still operated, together with 4 MAN Gräf & Stift from the years 1954–56 and 3 Uerdingen/Henschel from 1956. New vehicles were also purchased and putting them into operation became the next step in the development of trolleybus transport in Salzburg:

- first 5 articulated Henschel trolleybuses in 1961;
- 32 articulated Gräf & Stift trolleybuses from 1961–1976;
- 23 non-articulated Gräf & Stift from 1971–1975;

The third stage of development of trolleybus transport in Salzburg ended in 1988, when 9 lines were operated on routes 44.5 km in length. The fleet of 73 vehicles performed 4.161 million kms annually. The following new vehicles were introduced:

- 45 articulated Gräf & Stift trolleybuses from 1979–1980;
- 6 non-articulated Gräf & Stift trolleybuses in 1986;

The fourth stage of trolleybus transport development in Salzburg ended in 2003, when 8 lines (one less) were operated on routes with a combined length of 52.6 km (8 km longer). The fleet of 74 vehicles performed 4.197 million km annually. The following new vehicles were introduced in this stage:

- 2 articulated Gräf & Stift trolleybuses in 1989;
- 8 non-articulated Steyer trolleybuses from 1989–1990s;
- 24 articulated Gräf & Stift trolleybuses from 1987–1994;
- 32 articulated, low floor Gräf & Stift / MAN trolleybuses from 1994–1997;

[1] G. Mackinger, Der Obus in Salzburg, Verlag Kennig, Nordhorn 2005, p. 21 and further.

- 32 articulated low-floor Van Hool trolleybuses (half of which were equipped with an auxiliary combustion engine) from 1995–2005, i.e. exceeding the aforementioned stage by 2 years.

The next stage of development of trolleybus transport in Salzburg ended in 2007. That year 8 trolleybus lines were in operation, but the combined length of the routes was increased to 62.1 km. The fleet of 81 vehicles performed 4.633 million km annually. 6 articulated, low-floor Van Hool trolleybuses joined the fleet since 1995. At this stage trolleybus lines started to substitute bus lines.

The sixth stage of development of trolleybus transport in Salzburg ended in 2009, when the number of lines was increased to once again total 9, the combined length of the routes reaching 63.5 km. The new trolleybus line substituted a bus line and was serviced by a fleet made up of 86 vehicles, including the first three articulated Solaris Trollino 18 with an auxiliary combustion engine. 15 such trolleybuses were brought to Salzburg between 2009 and 2010.

There were 9 trolleybus lines in Salzburg in 2011 operating on routes of 64 km, the combined length of the lines totaling 191.6 km. The fleet included 94 vehicles (not counting antique vehicles) with 70 low-floor (74%) and 30 with auxiliary drive equipped vehicles (32%). The average vehicle was 8 years old. These trolleybuses serviced a total of 5.271 million vehicle-kilometers, which is the most in the history of Salzburg, carrying 40 M passengers

In 2012 Salzburg launched two additional trolleybus lines, increasing their number to 12. 10 new vehicles were put into operation. These are low-floor articulated Solaris vehicles with a new body style reminiscent of modern trams or subway cars, hence the name Metrostyle.

Just like in Salzburg in Eberswalde trolleybuses replaced trams, initially using the existing tram network drawing the electrical current via a single pole. These were MAN type MPE I. Later, after adding a second pole, Škoda 9 Tr were used. In the 1990s, the first low floor Gräf & Stift NGE 152 trolleybuses were introduced, however, by the year 2010 they began to be substituted by Solaris Trollino 18. There were no changes in the number of lines and the length of the routes throughout this period.

In 2001 Eberswalde operated 2 trolleybus lines of 37.2 km in length. The length of the routes was 16 km. The company's fleet included 13 articulated vehicles, out of which 9 were equipped with an auxiliary engine. The trolleybuses have travelled a distance of 755 thousand vehicle-kilometers, carrying 2.8 million passengers. In 2012 the last 3 Graf & Stift NGE 152 trolleybuses were replaced by Solaris Trollino 18 vehicles, Since then, all vehicles in this city have been equipped with auxiliary drives.

Trolleybus transport in Gdynia was launched with a single line serviced by 10 new Henschel vehicles which were adapted in order to tow trailers. During the first few years, the fleet was complemented by the use of JATB 2, Alfa Romeo and FIAT Breda and FIAT Tollero vehicles. Subsequent additions were Henschel trolleybuses and Büssing buses converted to trolleybuses. In 1949 13 new Vetra trolleybuses were added to the fleet. In 1957, which marked the end of the first stage of development, 5 lines were operated with the combined length of the routes being 30.5 kms and the 32 strong fleet travelling 2.2 million vehicle-kilometers.

The next stage during the years 1958–70, was a period of growth for Gdynia's trolleybus transport. From 1958 onwards 41 Škoda 8 Tr were added to the fleet, along with the introduction of 79 Škoda 9 Tr from 1962, including 7 used vehicles introduced in 1973. By the end of this stage of development, 97 trolleybuses, made up exclusively of Škoda 8 Tr (26 units) and Škoda 9 Tr (71 units) were in operation. These trolleybuses operated on 10 lines with the combined length of the routes being 33.5 km performed 5.1 million vehicle-kilometers.

The next period, during the years 1971–79, was a period of decline. The number of lines was reduced to 3, the length of the routes to 23 km, the number of units to 43 and the number of vehicle-kilometers to 2.27 million. From 1975 Soviet ZiU 9 trolleybuses were introduced to the fleet with 103 such vehicles brought to Gdynia from 1982 onwards. In 1976 the local public transport authority began to retrofit Jelcz Berliet buses with trolleybus drives and equipment, adding 22 such vehicles to the fleet starting in 1982.

The next stage for trolleybus transport in Gdynia was a period of revitalization which spanned the years 1981–97. During this time the total length of the routes was increased to 35.9 km, the longest since its beginning. The number of lines was increased to 8, the length to 79 km, and the number of vehicle-kilometers to 4.1 million. In 1987 new Jelcz 110 MTE and 120 MTE vehicles became part of the fleet, with 85 units purchased from the year 2000 onwards, In addition to these vehicles, 10 articulated trolleybuses, conversions of used Ikarus 280 buses, were added. These were the first articulated trolleybuses in Gdynia's trolleybus transport, the very first unit of which was introduced in the 1990s, the last of which was decommissioned in the year 2000.

The year 1998 was the beginning of a new stage in Gdynia's trolleybus transport, as it began to operate completely independently from bus transport. This stage, which lasted until the year 2004, did not see any change in the length of the routes – 36.3 km in 2004 – nor in the number of vehicles in service – a total of 75 in 2005. The number of vehicle-kilometers also remained stagnant at 4.1. However, the number of lines increased to 11, which means that increasing the directness of the routes, was undertaken at the cost of decreasing the average frequency on particular lines. More innovative was the addition of the first low-floor Jelcz 121E trolleybus in 1999. A further addition during the years 2003–2004 was made up of 6 low-floor Solaris Trollino 12 trolleybuses.

The final stage of development of trolleybus transport in Gdynia began in 2005. At this stage, a spatial expansion of the trolleybus network was conducted within the framework of two projects supported by a dominant share of funds from the European Union. By the end of 2012 the entire fleet was entirely upgraded to low-floor, non-articulated vehicles. New Solaris Trollino 12 trolleybuses (50 units by 2001) and rebuilt Mercedes O405 and O530 (30 units by 2004) were added to the fleet.

Gdynia operated 12 trolleybus lines with the combined length of routes amounting to 44 km in 2011. The trolleybus transport operator owned 85 vehicles, including 76 low-floor, all of them non-articulated. The average vehicle was 9 years old. 32 vehicles were equipped with an auxiliary drive in the form of traction batteries. The maximum number of trolleybuses in simultaneous operation was 72, performing a total of 5 million vehicle-kilometers and carrying 22.7 million passengers.

In 2012, a 13th 'historic' line – to be operated with antique trolleybuses – was launched (1957 Saurer, 1975 Škoda 9 Tr and a 1994 Jelcz 120MT). This line operates only on Sundays and holidays from May to October.

The first trolleybuses in Brno were 15 Škoda 6 Tr units, operated until the mid 1960s. They were joined in 1953 by 16 Škoda 7 Tr units – later withdrawn together with Škoda 6 Tr units in the 1960s. In the years 1957–60 the number of trolleybuses in Brno was increased to 11 Škoda

8 Tr. In the years 1963–1981 a total of 121 Škoda 9 Tr units were purchased. The last of these Škodas was decommissioned in 1996.

The first Škoda 14 Tr trolleybuses were brought to Brno in 1982. By the year 1995 there were 123 trolleybuses of such type. The first articulated trolleybuses were brought to Brno in the 1990s. 8 new vehicles of such design were purchased in the years 1990–91 and 5 used ones in 2011. Low floor trolleybuses began to operate in Brno in 1999. In the years 1999 and 2002 a total of 43 non articulated, low-floor Škoda 21 Tr were purchased. In the years 2003–2004 a total of 8 articulated, low-floor Škoda 22 Tr were purchased. Since 2007 Brno has also had low-floor 25 Tr Irisbus vehicles in service.

Following its development, the trolleybus network in became one of the largest networks in the Czech Republic. In the year 2011, 54 km of routes were operated by 13 lines with a combined length of 108 km. The company's fleet included 147 units with an average age of 15, none equipped with an auxiliary drive, including:

- 25 articulated (17%) and 122 non-articulated;
- 64 low-floor (44%) and 83 high-floor.

In 2011 a total of 6.2 M vehicle-kilometers were serviced on all lines, carrying 42.7 million passengers.

Trolleybuses in Parma began their operation on 3 lines, and just like in Salzburg and Eberswalde, they replaced trams. The first trolleybuses were 16 Fiat 2401 Cansa units, on 3 lines with routes measuring 13.3 km in length. In the years 1959–64 the number of trolleybuses increased to 20 with the introduction of 4 Fiat 2411 Cansa vehicles. In 1968 with an unchanged number of lines and trolleybuses in the inventory, the route of one trolleybus line was extended, thereby increasing the total length of the routes to 14.1 km. Four years later in 1972, trolleybus transport in Parma suffered a decline resulting in trolleybuses being replaced on one of the three operating lines. The length of trolleybus routes did not change and the company kept their 20 vehicles.

During the 1980s a period of development took place. The process of exchanging the fleet to new vehicles began in 1981. The first purchases were 10 Menarini Monocar 201 units. They were joined by another 10 units of the same brand five years later – this time type 201/2. In 1987 one of the operating lines was extended without lengthening the trolleybus routes. Two years later one of the bus lines was transformed into a trolleybus line. As a result, in 1989, 20 trolleybuses operated on 3 lines with routes totaling 14.1 km. 10 years later another bus line was converted into a trolleybus line extending the length of the route to 18.6 km and increasing the number of vehicles to 34, with the introduction of the first 14 low-floor trolleybuses Autodromo BusOtto, equipped auxiliary combustion drives.

In 2011 Parma had 4 trolleybus lines with a combined length of 27.5 km and routes of 18.6 km. The trolleybus operator had 29 Menarini Moncar 201 and 201/2 and Autodromo BusOtto units, including 14 low-floor trolleybuses (48%). None of the vehicles were articulated and the average vehicle was 21 years old. A total of 0.599 million vehicle-kilometers were serviced, carrying 7.1 million passengers. 2012 was marked by the introduction of nine low-floor articulate Van Hool ExquiCity trolleybuses with a modernly designed body similar to that of a tram.

The first trolleybus line in Szeged substituted a tram line, which was shut down 10 years earlier. The first stage of development of trolleybus transport in the city took place from 1979 to 1985 when the trolleybus network expanded by substituting bus lines. In 1985 6 trolleybus lines were operated with a combined length of 22.8 km. The fleet included 47 non-articulated ZIU 9 and 4 articulated Ikarus 280 T units.[2]

The next stage of development of trolleybus transport in Szeged came to a close in 1996. It was marked by a decline, the number of lines being reduced to 3 and the length of the routes decreasing by 1/3 to 18 km. By the end of the stage 40 trolleybuses were operated, including the units purchased in the years 1991–94:

- 11 articulated Škoda 15 Tr and 1 non-articulated Škoda 14 Tr;
- 6 articulated Ikarus 280 T.

The next stage of development of trolleybus transport led to the addition of 1 new line (now 4) in 2004 and the lengthening of the routes to 22.4 km. The number of vehicles remained unchanged at 40 units, the fleet still including ZIU 9, Ikarus 280 T, Škoda 15 Tr and Škoda 14 Tr units.

The last stage of trolleybus transport in Szeged was crucial to its modernization and innovation. As a result, in 2011 5 lines were operated on routes of 30.4 km. 44 trolleybuses serviced a total of 1.862 million vehicle-kilometers, carrying 12.926 million passengers. The following trolleybuses were added to the fleet at that time:

- 8 used articulated Škoda 15 Tr units;
- 4 modernized articulated Škoda 15 Tr units;
- 6 low-floor, non-articulated, modernized Škoda 21 Tr units;
- 5 low-floor Mercedes Citaro O530 obtained by converting used buses;
- the first articulated low-floor Škoda 22 Tr.;
- the first articulated low-floor Auto Rad Controlled.

By the end of this stage 23 (52%) of the units were articulated, while 14 (32%) were low-floor. None of the trolleybuses was equipped with an auxiliary drive, whilst the average vehicle was 17 years old.

During the following year the number of units in Szeged rose to 53, with 29 articulated (55%) and 37 low-floor (70%) units.

The basic operational data of trolleybus transport in 2011 for cities participating in the Trolley project is presented in Table 2.4. The data shows that among the participants:

- the longest trolleybus network was in Salzburg, the shortest – in Eberswalde; the largest number of trolleybus lines were operated in Brno, the smallest in Eberswalde;
- the largest fleet was in Brno, the smallest in Eberswalde;
- the youngest fleet was operated in Eberswalde, the oldest in Parma;
- Salzburg and Eberswalde exclusively operate articulated trolleybuses, while Gdynia's and Parma's fleets were exclusively made up of non-articulated units.

[2] A.Z. Nemeth: The trolleybus system of Szeged, [In:] Determinants of Functioning of Trolleybus Transport in Selected Cities of the European Union, edited by M. Bartłomiejczyk, M. Połom, Bernardinium, Pelplin 2011, p. 52.

Table 2.4. The basic operation data of trolleybus transport in 2011 in cities participating in Trolley project

Ordinal	Parameter	City					
		Salzburg	Eberswalde	Gdynia	Brno	Parma	Szeged
1.	Route length [km]	64	16	44	54	18,6	30,4
2.	Line length [km]	191,6	37,2	152	108	27,5	no data
3.	Number of lines	9	2	12	13	4	5
4.	Number of vehicles in fleet	94	13	85	147	29	44
5.	Average vehicle age	8	2	8,9	14,7	20,9	16,6
6.	Number of articulated vehicles	94	13	0	25	0	23
7.	Number of low-floor vehicles	70	13	76	64	14	14
8.	Number of vehicles with an auxiliary drive	30	9	32	0	14	0
9.	Total vehicle-kilometers in a year [mln]	5,271	0,755	4,964	6,2	0,599	1,862
10.	Number of passengers in a year [mln]	40,0	2,8	22,7	42,7	7,1	12,9

Source: own work based on data received from companies operating trolleybuses in the above cities.

- in Eberswalde all vehicles were low-floor, while the least units of this kind could be found in Szeged;
- most vehicles in Eberswalde were equipped with auxiliary drives, while in Brno and Szeged there were no such units;
- the greatest volume of service was performed by trolleybuses in Brno, the least in Parma;
- the most passengers were carried in Brno, the least in Eberswalde.

Chapter 3. Factors Determining Demand for Trolleybus Services

3.1. Characteristic Features of Demand in Public Transport

Transportation needs defined as "the willingness, need or demand of an individual or a specific group to put into operation a means of transportation from one place to another"[1] constitutes the original source of demand for public transport services. Therefore, transportation needs, which are fulfilled in urban areas belong to those needs triggered by the secondary aims mechanism.

Transportation needs in urban areas have specific features[2]:

- concentration within a limited area which produces a low, average transport distance;
- common occurrence;
- inconsistent occurrence;
- mass occurrence.

Transportation needs, the fulfillment of which is related to covering distance, are of a secondary nature with respect to primary needs. Therefore, the diverse character of transportation needs is reflected in the classifications used, of which the following two are the most relevant:

- transportation aim;
- movement sources impact.

The transportation aim, seen as a classification criterion for transportation needs, is significant as it determines, to a large extent, the frequency and time of travel and even the choice of means of transport. According to transportation aim criterion, transportation needs in urban areas can be divided into more general or detailed groups. The most general classification takes account of the following transportation aims:[3]

- professional;
- accommodation and living;
- leisure and entertainment;
- other.

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[1] Z. Pawlicka, Przewozy pasażerskie, WKiŁ, Warszawa 1978, p. 14.

[2] O. Wyszomirski, Ekonomika komunikacji miejskiej, Uniwersytetu Gdański, Gdańsk 1986, p. 30.

[3] A. Zalewski, Problemy oceny efektywności rozwoju miejskich systemów transportowych, SGPiS, Warszawa 1981, p. 24–25.

Transportation needs resulting from professional aims are characterized by their strong concentration in time, stable spatial organization and the highest frequency and regularity. Transportation needs connected with accommodation and living, leisure and entertainment as well as other aims are far less regular, spatially disorganized and less frequent.

According to the movement sources impact, transportation needs can be divided as follows [4]:

- obligatory;
- somewhat necessary;
- optional;
- incidental.

Obligatory transportation needs are those which when fulfilled condition the life of a human being. Therefore, both obligatory needs and those which are somewhat necessary are a regular occurrence. Obligatory needs create the necessity of everyday relocations during school and work days, within established hours and distances (work, school). Needs which are somewhat necessary require regular commuting, however not necessarily on a daily basis, made at random hours and in various directions e.g. work-related travels. However, they are not dependent on working hours, business trips and purchase-related travels.

Optional transportation needs are all other transportation needs, where the fulfillment of such needs is contingent on individual decisions taken by passengers. Optional and incidental needs arise spontaneously. Optional needs relate to shopping, leisure and entertainment, culture and socializing. Incidental needs are related to maintaining one's health and resolving official matters.

The possibility of transforming transportation needs into demand is conditioned by the ability to tailor the public transport services offer to those needs. Due to the fact that in practice not all transportation needs (both in quantitative and qualitative repects) are fulfilled by the public transport services offer, the need has arisen to distinguish between potential demand and effective demand for public transport services. Effective demand is that which is present on the market, and measured by the volume of transport services delivered by means of public transport vehicles. Potential demand reflects those transportation needs that were not fulfilled by a specific public transport offer. Therefore, this may be shown using a simple equation:

$$PP = Pp + Pe$$

where:
PP – transportation needs
Pp – potential demand
Pe – effective demand

It should be noted that even in a hypothetical situation where public transport within urban areas is monopolized, not all transportation needs would become effective demand. Disregarding factors related to specific microeconomic mechanisms (the consequence of the

4 M. Madeyski, E. Lisowska, Badania analityczne transportu samochodowego, WKiŁ, Warszawa 1970, p. 109.

monopolistic tendencies of companies on the market) the main reason for the absence of a desired balance between transportation needs and effective demand is the impossibility of tailoring the transport offer to the individual transportation needs of a single resident due to both the number and individual nature of such needs.

In order to identify the causes of disproportions between transportation needs and demand, as well as to specify the extent of those differences along with their origin, a thorough marketing survey on transportation needs, demand, behavior and the preferences of residents should be carried out.

Transportation behavior can be defined as a set of actions and activities that aim to fulfill transportation needs. The decision-making process, which predates and determines these actions and activities, should also be considered an integral element of this behavior[5].

The following factors impact on the actions of consumer (and thus potential passengers):

- marketing-related, that is related to the intentional action of a seller aimed at inducing a purchaser to buy specifics goods or services, in case of transport behavior this would be, for example, the impact of transport organizers and carriers;
- related to economic, technical, political and cultural aspects;
- internal factors specified as the characteristics of a purchaser[6]:
  - cultural;
  - social;
  - personal;
  - psychological.

Each disclosed transportation need entails specific requirements as to the manner of fulfilling the need. Those requirements are known as transport requirements.

The number and type of transport requirements are virtually unlimited and are subject to regular changes. They depend, to a large extent, on current transportation conditions, possession or non-possession of a vehicle social status and lifestyle.

The most important and most frequent transport requirements are[7]:

- time of travel;
- travel conditions;
- travel costs;
- travel safety.

Factors that determine the time of public transport service, and which, at the same time, are detailed requirements raised with respect to public transport, are[8]:

- velocity determining the time of travel;
- frequency, punctuality and reliability specifying the waiting time;
- location determining the walking distance;

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[5] S. Gajewski, Zachowanie się konsumenta a współczesny marketing, Uniwersytet Łódzki, Łódź 1994, p. 9.

[6] B. Żurawik, W. Żurawik, Zarządzanie marketingowe, T. 1.,Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 1993, p. 117.

[7] M. Ciesielski, J. Długosz, Z. Gługiewicz, O. Wyszomirski, Gospodarowanie w transporcie miejskim, Akademia Ekonomiczna w Poznaniu, Poznań 1992., p. 54.

[8] Ibidem, s. 54.

- directness – whether transport is direct or requires the passenger to change bus/trolleybus.

There is a number of factors that influence travel-friendly conditions and travel comfort. In general terms, the demand for comfort is raised with respect to the whole travel process.

Taking account of all travel phases, the following are considered elements of the demand for comfort [9]:

- simplicity of a tariff scheme;
- free access to purchase a ticket;
- clear information on timetables and directions/routs;
- convenient access to bus/trolleybus stops (the number of pedestrians crossings, tunnels, changing pavement profiles);
- clear timetables;
- the clear labeling of vehicles;
- convenient get-on and get-off
- service quality;
- clear labeling of bus/trolleybus stops and marking directions.

Cost seen as a transport requirement is unambiguous and measurable. It serves to minimize fees for transport services.

Safety refers to both traffic accidents and the threat to personal safety at buss/trolleybus stops and in vehicles.

In the opinion of public transport passengers, transport requirements vary in significance. In order to prioritize transport requirements, empirical research is carried out among transport users.

Demand response to changes in factors that influence demand is measured with an economic indicator known as demand elasticity.

Demand elasticity is defined as the ratio of a relative (percentage) change in quantity demand to a relative (percentage) change in demand determinants [10].

The price elasticity of demand is almost always a negative value, which results from the fact that along with a price increase, demand decreases and vice versa. If the elasticity coefficient is below –1, the demand is elastic – it responds more than proportionately to price changes. If elasticity equals –1, the demand is proportionate, but if elasticity ranges between 0 and –1, then the demand is inelastic – it responds to price changes less than proportionately. Price changes of goods characterized by high demand elasticity trigger mainly substitution effects.

Demand elasticity coefficient is not usually stable. In most cases, demand elasticity increases along with price rises. In the lower part of a demand curve it can be inelastic, whereas in the upper part elastic. Sometimes, however, elastic or inelastic can refer to demand for a

[9] Gospodarowanie w komunikacji miejskiej. Ed. by O. Wyszomirski, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2002, p. 69.

[10] D.R. Kamerschen, R.B. McKenzie, C. Nardinelli, Ekonomia. Fundacja Gospodarcza NSZZ „Solidarność", Gdańsk 1991, p. 474.

specific good in general – that is to the whole demand function, even though, as mentioned before, the elasticity for particular parts of a demand curve would be different[11].

The shape of a universal curve of demand for passenger transport services in cities is yet to be established. It is commonly believed that price elasticity of demand in transport is relatively low. It is estimated that in economically well-developed countries the price elasticity of demand for public transport services equals –0,4 and taxi services –0,3[12].

The data demonstrates that demand elasticity in public transport ranges between –0,2 and –0,5 within a short period of time (one year) and between –0,6 and –0,9 in a longer period (5–10 years) – table 3.1.[13] Demand elasticity should be measured taking into account factors characteristic for public transport within a specific area. American research indicates that in the process of demand elasticity analysis the following diverse factors should be considered, e.g.:[14]

- the possibility of using a passenger car (elasticity of persons who cannot use a passenger car is lower than in case of persons with a car);
- time of travel (elasticity during peak hours is about two times higher than during off-peak hours).

Table 3.1. Recommended indicators of demand elasticity for public transport services

Demand change due to	Market segment	Price elasticity value	
		In a short time horizon	In a long time horizon
Change of ticket prices	In total	from –0,2 to –0,5	from –0,6 to –0,9
Change of ticket prices	Peak hours	from –0,15 to –0,3	from –0,4 to –0,6
Change of ticket prices	Off-peak hours	from –0,3 to –0,6	from –0,8 to –1,0
Change of ticket prices	Sub-urban travels	from –0,3 to –0,6	from –0,8 to –1,0
Number of services	total	from 0,5 to 0,7	from 0,7 to 1,1
Car operating costs	total	from –0,05 to –0,15	from –0,2 to –0,4

Source: T. Litman: Transit price elasticities and cross-elasticities. "Journal of Public Transportation" 2004, Vol. 7, No. 2, p. 53.

Apart from changes in prices, there are also other factors that exert a significant impact on the demand for public transport; income and preferences of passengers as well as public transport efficiency which is determined by the pace of fulfilling other transport requirements, excluding price. Consequently, it is also possible to measure the demand response to changes in those factors by establishing appropriate demand elasticities.

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11 M. Ciesielski, J. Długosz, Z. Gługiewicz, O. Wyszomirski, op. cit., p. 71.

12 Ibidem, p. 71.

13 T. Litman, Transit price elasticities and cross-elasticities. "Journal of Public Transportation" 2004, Vol. 7, No. 2, p. 52.

14 Ibidem.

3.2. The Potential of Trolleybuses to Fulfill Transportation Needs

The recognized potential of trolleybuses to fulfill transportation needs is twofold: quantitative and qualitative.

In the quantitative aspect, the potential of trolleybuses to fulfill transportation needs depends on:

- technical features of trolleybus as a means of transport;
- volume of transportation needs;
- spatial diversity of transportation needs.

The main technical feature of a trolleybus that determines the use of this means of transport in providing services in urban areas is its transport capacity. The transport capacity of trolleybuses is defined as the maximum number of passengers that can be transported in a given direction within 1 hour. To present it as a mathematical formula, it is the product of the vehicles capacity (a unit transport capacity) and the maximum number of vehicles that can be used in a given direction.

Nowadays the most common trolleybuses in manufacture are standard (non-articulated), articulated and related (e.g., double-articulated) models. Since the current trolleybus manufacturing process is based on construction solutions applied with respect to buses, trolleybus parameters are the same as the ones used with for buses.

The number of standing places and seats in a trolleybus is derived from the vehicle parameters (length and width) and specific technical solutions applied at constructing the vehicle (e.g. the length of low floor, location of installing an engine and drive units etc.). The length of non-articulated trolleybuses is usually 12 m, articulated 18 m and double-articulated 24 m respectively, whereas the width is equal to approximately 2,5 m. Apart from the parameters and technical conditions mentioned above, the number of standing places and seats as well as mutual proportions depend on the preferences of the purchaser of a given model of a vehicle. In the case of non-articulated trolleybuses the number of standing places and seats is usually 30–35 and 65–70 respectively, in articulated trolleybuses 40 and 110 and in double-articulated trolleybuses 60 and 140 respectively. It is worth mentioning here that the maximum number of standing places, i.e. 4 for 1 square meter, regarded as a norm, should not be considered a mandatory figure in all conditions, including peak hours. It is preferences and expectations of passengers in a given city and not rigid norms of vehicle manufacturers that should be a decisive factor in the establishment of acceptable terms of travel at specific times of the day.

The maximum number of vehicles that could be used in a given direction is obviously contingent on financial capacity. Since public transport requires funding, there exists a number of consequent limitations. From a technical point of view, limitations in using a specific number of vehicles in a given direction stem from roads parameters, traffic as well as the scope of privileges for public transport vehicles in road traffic.

Fig. 3.1. Double-articulated trolleybus – HessB25U (megatrolley)
Photo M. Połom.

Table 3.2 presents the transport capacity of various public transport means in comparison with a passenger car.

Table 3.2. Transport capacity of various public transport means

Type of a vehicle	Number of passengers per 1 hour in a given direction	Multiply of transport capacity with respect to passenger car
Passenger car	3 500	1,0
Non-articulated bus/trolleybus	7 000	2,0
Articulated trolleybus/buss	10 500	3,0
Tram	15 000	4,3
Metro/urban railway	50 000	14,3

Source: own-study.

Specific functional features of trolleybuses determine their suitability to provide services within specified areas. Engine gradability predestines this means of transport to deliver transport services within areas of varied topography. The noiseless operation of vehicles and environmentally friendly impact provide a good premise for using trolleybus services in subdistricts and residential areas. The possibility of using traction batteries in a limited scope (without the necessity to use the overhead and power system) constitutes a good argument in favor of using trolleybus services in urban conservation areas, where standard solutions dictating the construction of overhead power systems would spoil the aesthetic value of historical development. The greater dynamics of trolleybuses, when compared to buses, supports the use of these vehicles in traffic congested areas, where their ability to easily merge into the flow of traffic has an influence on the capacity of the transport system in general.

However, the main limitations in using trolleybuses for fulfilling transportation needs in terms of quantity, apart from their technical and functional properties, are costs:

- infrastructure costs;
- trolleybus purchasing costs;
- operating costs;
- external costs.

The cost of trolleybus infrastructure and its operation (and also modernization) is a factor determining the decision of municipal authorities to use buss services which do not require additional costs connected with infrastructure elements, even though the two means of transport are comparable in terms of transport capacity.

The cost of purchasing trolleybuses exceeds the cost of purchasing buses. The fundamental economic factor determining the price ratio of trolleybuses and buses which, to an extent, are based on the same construction solutions, is lower demand for them.. From the research and development stage to activities promoting trolleybuses, the substantially lower number of vehicles sold in comparison with buses, gives rise to the higher cost of trolleybuses. This is despite the fact that the process of manufacturing trolleybuses is based on the same production lines as in the case of buses as well as on the results of research carried out previously with respect to the manufacturing of buses.

The operating costs of trolleybuses vary in different cities and they are determined mostly by the cost of electrical power and employees' remuneration.

The final economic factor presented above that could determine the use of trolleybus services in cities, are external costs which, if calculated in a reasonable and precise manner, could counterbalance the low opinion resulting from the costs of purchasing trolleybuses, as well as infrastructure costs.

In terms of quality, the following factors provide good arguments in favor of using trolleybuses to fulfill transportation needs:

- the possibility of fulfilling transportation needs using trolleybus services, including opinions on trolleybus services expressed by residents;
- the determination of public authorities to implement a transport policy on sustainable development;
- the environmental consciousness of residents and the belief that environmental issues are of crucial importance to quality of life in a city.

The technical similarities of trolleybuses and buses in the scope of fulfilling transportation needs are not conclusive when it comes to their comparable ability to fulfill transportation needs in terms of the quality of services provided. As the survey carried out in Gdynia shows (Fig. 3.2), residents expressed different opinions about the two means of public transport, considering various transportation requirements and the modernization stage of both road tractions (electric and combustion power).

Prior to the modernization of the trolleybus fleet and overhead power system, residents of Gdynia considered trolleybuses to be slower, less comfortable, less aesthetic and less punctual in comparison with buses. Consequently, residents, having the opportunity to use both trolleybuses and buses on the same route, would choose to travel by bus even at the expense of time. This situation was reflected in the research results – such transport behavior was declared by 67% of respondents.

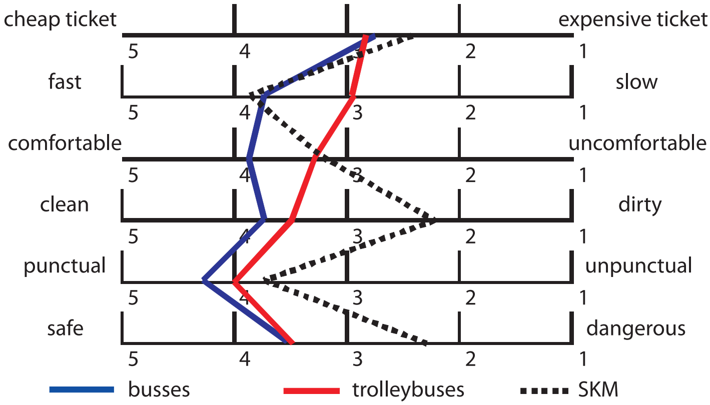

Fig. 3.2. Semantic profiles of buss, trolleybus and local rapid railway (SKM) services in Gdynia in 1998
Source: Preferences and transport behaviors of Gdynia residents in 1998. ZKM survey report. Gdynia 1999.

As a result social support for developing trolleybus lines in cities was relatively low: 28% of residents wanted to replace trolleybus lines with bus lines and 43% were in favor of keeping proportions in services provided by trolleybuses and buses (at that time those proportions, measured with vehicle-kilometers, equaled 23% and 77% respectively). Upon completion of the modernization of the overhead power system and replacement of the trolleybus fleet with modern, low-flow vehicles, the number of respondents in favor of replacing trolleybuses lines with bus lines decreased to the level of 9% whereas an increase from 11% to 18% was observed with respect to replacing bus lines with trolleybus lines and developing new trolleybus lines (despite an increase from 23 to 30% in the total share of trolleybuses in transport services).

The positive attitude of residents towards trolleybuses is a crucial factor that is taken into account by local authorities in the process of taking political decisions. Environmental arguments may prove insufficient in relation to the negative attitude of residents in general towards trolleybuses which result from the relatively low quality of services offered by this means of public transport. This issue is presented in detail in the next sub-chapter.

Other social and political factors influencing the development of trolleybus transport may be:

- perceiving trolleybuses as an element which makes up a city image;
- the reluctance of public authorities to introduce substantial changes to the transport system of the city.

3.3. The Attitudes of Residents Towards Trolleybus Transport

The decision-making process as to developing and modernizing trolleybus transport should be based on economic performance and find strong political support. In democratic countries the opinion of residents, as voters, exerts a significant impact on the final decisions taken by various political authorities. It can be assumed that communities with trolleybus transport in place express positive opinions as to the plans and activities which aim at further developing of this means of transport. In order to verify this assumption, a survey within the framework of the TROLLEY project was carried out with the aim of specifying the attitude of residents of partner cities towards trolleybus transport.

One of the aim of the survey formed within the framework of the TROLLEY project was to learn the opinions of passengers on the municipal transportation on the future governmental actions in regards to the trolleybus network. Four main theses were formulated and proposed (including two alternative ones, suggesting the substitution of trolleybus lines with bus lines and vice versa) as well as an option allowing the respondent to declare a lack of opinion. This question along with answers categories has for many years been an element of a survey questionnaire used for measuring the preferences and transport behavior of Gdynia residents, carried out by the Board of Public Transport (ZKM) in Gdynia.

The results for six individual cities are presented below. They are accompanied by aggregated results that allow conclusions to be drawn for the entire group of respondents.

Data was gathered by way of a direct survey carried out with passengers traveling by trolleybus lines in cities with respect to which standardized questionnaires in multiple languages were prepared. The method has been selected due to the greater scope of control over data acquisition, flexibility, as well as low time consumption. The project survey was carried out in September 2010 in Gdynia with a view to verifying survey instrument effectiveness. Research was conducted in autumn 2010.

Due to legal and formal limitations (personal data protection), a random sampling method could not be employed in this case. Non-random sampling is possible in the case of a preliminary survey. Quality tests are, in general, of introductory nature, and aim at presenting unstructured and initial observations concerning a given issue, based on a relatively small sample[15]. Sampling process scheme is presented on Fig. 3.3.

A total of 1070 respondents from 6 cities took part in the survey. As the number of the samples in individual cities varies substantially, one has to be cautious when interpreting the indicators for chosen groups (i.e., sex, age, etc.) defined for the cities altogether. The existing diversification will not be solely a consequence of the diversification of the surveyed factors, but also of the number of the respondents in each city.

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[15] M. Mazzocchi: Statistics for Marketing and Customer Research. SAGE, London 2008, p. 124

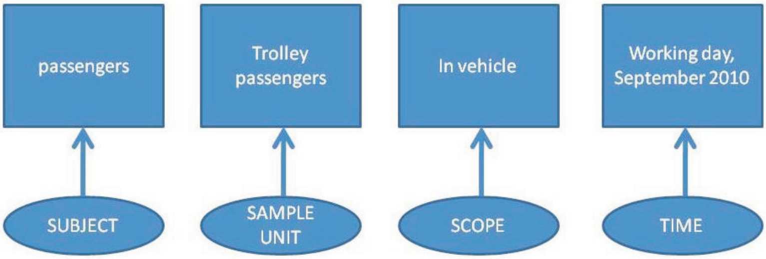

Fig. 3.3. Process of sample preparation
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011

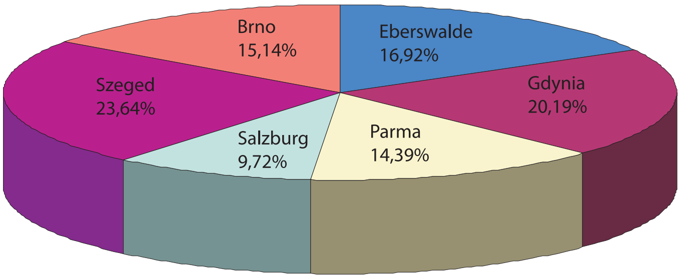

Figure 3.4. Structure of the number of respondents in the surveyed cities.
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011

Table 3.3 presents collective data facilitating the comparative analysis of the opinions of respondents opinions in particular cities in which the survey was carried out. The similarity in opinions concerning the replacement of buses with trolleybuses and vice-versa in Gdynia and Parma is notable[16].

7% of the respondents in Brno (Czech Rep.) wish to substitute bus lines with trolleybus lines. One in four respondents is expecting the opposite – substituting trolleybuses with buses. This may result from the fact that public transport in Brno consists of trolleybuses, buses and trams which cover the city with a dense network. Maintaining the current proportion between trolleybus and bus lines is supported by 16% of respondents. Its worth noticing that 40% of respondents want to see new trolleybus lines. Respondents in Brno expressed very strong opinions on the subject.

[16] M. Wołek: Stosunek mieszkańców do trolejbusów jako czynnik społeczny determinujący rozwój komunikacji trolejbusowej – analiza wybranych miast Europy Środkowo-Wschodniej w ramach projektu TROLLEY [In:] Funkcjonowanie i rozwój transportu. Pod red. W. Rydzkowskiego „Zeszyty Naukowe Uniwersytetu Gdańskiego. Ekonomika Transportu Lądowego" Nr 41. Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2011, s. 105–117.

Tab. 3.3. Future steps taken by authorities with respect to trolleybuses services – the opinions of resident in the surveyed cities

	Brno	Eberswalde	Gdynia	Parma	Salzburg	Szeged
Substitute bus lines with trolleybus lines	17%	41%	16%	20%	34%	26%
Substitute trolleybus lines with bus lines	27%	1%	12%	16%	3%	6%
Keep the bus to trolleybus ratio the same	16%	27%	39%	25%	14%	25%
Create more trolleybus lines	40%	25%	26%	23%	41%	31%
No opinion	0%	6%	7%	16%	8%	12%

Source: own-study based on marketing survey conducted within TROLLEY Project, September–October 2010

41% of the respondents in Eberswalde wish to substitute bus lines for trolleybus lines. This result is the highest among the opinions from the other surveyed and analyzed cities. Only 1% of the respondents is awaiting the opposite, that is, to substitute trolleybus lines with bus lines. A quarter of respondents wish to maintain the existing proportion in the division of the transportation tasks between the modes of transport analyzed. A comparable result was reached in the case of supporters of the development of the trolleybus network. Only 6% of respondents in Eberswalde did not hold their own opinion on the issue.

The majority of respondents in Gdynia feel that the bus to trolleybus ratio should not change. Over ¼ of the passengers is in favor of creating new trolleybus lines. 16% of the respondents want the current bus lines to be replaced with trolleybus lines, whilst 12% of the respondents expect actions to the contrary. It is interesting to notice a slight advantage in terms of the supporters of the trolleybus transportation over those of buses. 7% of the respondents in Gdynia did not hold their own opinion on the issue.

1 in 5 respondents in Parma is in favor of bus lines being replaced by trolleybus lines, whilst 1 in 6 for trolleybus lines to be replaced with bus lines. Opinions of the respondents on maintaining current proportions between the trolleybus and bus lines are distributed evenly (25% of the respondents). This is also the case, when it comes to the number of those in favor of developing new trolleybus lines. As many as 16% of the respondents in Parma did not hold their own opinion on the issue.

A definite majority of the respondents in Salzburg support the development of the trolleybus network (41%, the highest result among the surveyed cities) as well as the replacement of the existing bus lines with trolleybus lines (every third respondent). Only 14% of the respondents are in favor of maintaining the status quo, that is sustaining the current balance in the division of transportation tasks between bus lines and trolleybus lines. Also notable is the very low proportion of respondents (3%) in favor of trolleybus lines being replaced by bus lines. 8% of the respondents in Salzburg did not hold their own opinion on the issue regarding the future actions of the local governments in regards to the trolleybus network.

Almost a third of respondents (31%) in Szeged expect the new trolleybus lines to be created. A quarter of the surveyed passengers wants the existing bus lines to be replaced with trolleybus lines, whilst only 6% of the respondents hold expectations to the contrary. 25% of respondents do not want to upset the balance of between bus and trolley services. 12% of respondents in Szeged did not hold their own opinion on the issue regarding the future actions of the local government in regards to the trolleybus network.

When analyzing the data presented in Tab. 1 it has to be taken into account that the structure of the opinions expressed by respondents in Szeged is the most similar to the aggregated data. More than a quarter of the general number of respondents from the six surveyed and analyzed cities expect buses to be replaced by trolleybuses. Meanwhile, those in favor of replacing trolleybus lines with bus lines (only 7%) constitute a significantly lower group of respondents. A similar share (27%) is held by respondents in favor of maintaining the existing balance between trolleybus and bus lines. The number of the respondents in favor of the development of new trolleybus lines is slightly higher (29%). 1 in 10 respondents does not hold their own opinion on the issue[17].

The research conducted indicates that passengers using public transport hold significantly diverse attitudes in relation to the future steps to be taken by local authorities with respect to trolleybus transport. In German-speaking cities where ecological issues are of utmost importance, high expectations were observed with respect to the development of trolleybus transport as well as the replacement of bus lines with trolleybus lines. 41% of passengers in Salzburg (Austria) expect new trolleybus lines to be opened (similarly in Brno – 40%) and 34% want bus lines to be replaced with trolleybus lines. The number of respondents preferring the replacement of bus lines with trolleybus lines in Eberswalde (Germany) equaled 41%[18].

In future, as a result of the implementation of innovative technological solutions, the number of residents in favor of trolleybuses as the main means of public transport may see further increase.

3.4. The Segmentation of Trolleybus Transport Passengers

The selection of a target market is one of the most important strategic decisions for a company. The choice of a specific target market carries a number of economic, localization, environmental and social consequences. The process of selecting the target market is divided into the following stages[19]:

- specification of the needs, requirements and features of purchasers present on a given market;
- analysis of the similarities and differences among purchasers;
- determination of market segments;

[17] K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 “Local Trolley Guides”. Final Report. TROLLEY Project, April 2011.

[18] M. Wołek: Stosunek..., op. cit., p. 105–117.

[19] L. Garbarski, I. Rutkowski, W. Wrzosek: Marketing. Punkt zwrotny nowoczesnej firmy. Wyd. PWE, Warszawa 2000, p. 182.

- selection of market segment(s).

Segmentation is the process of dividing the market into relatively homogeneous groups of potential consumers based on a set of criteria related to a purchaser or to a product offered.

A properly segmented market should be measurable, substantial (that is – to guarantee the size appropriate to conduct a given business activity), accessible differentiable and actionable (susceptible) to marketing instruments[20].

In the process of market segmentation it is vital to establish criteria for such segmentation and assess the attractiveness of markets from the point of view of an entity that conducts such an assessment. The selection of segments with respect to which a further marketing activity will be carried out is known as positioning.

The assessment of the attractiveness of segmented markets may be carried out based on the following criteria [21]:

- growth rate;
- accessible size of segment (ie, this can come down to calculating total revenues generated in a segment within a given time period and deducting the revenue a company could not generate due to the volume of investments made);
- potential gains.

The functioning of the public transport market depends on a number of non-economic factors like politics, social and environmental issues. Market stakeholders, to a large extent, also represent public sector. Should this be the case, the assessment of the attractiveness of segment(s) may be based on criteria other than those presented in the first part of this sub-chapter.

According to D. Mercer "in the commercial world, the ultimate objective is to make a profit (…), but in the public sector greater efficiency may be the justification for such concentration[22].

The premise for segmentation in public transport should be the following:

- increased relevance of public transport in the modal split of a city/area by tailoring the marketing strategy to a specific group of addressees;
- increase in self-financing of the public transport system;
- social activation of a specific group of residents;
- growing importance of a specific public transport sub-system (e.g. due to its environmental advantages).

Market segmentation issues may be substantially influenced by the type of contract binding an operator and an entity contracting public transport services. In the case of a gross contract, the entity interested in market segmentation will be the public transport organizer. The remuneration due to the operator is the payment for effecting transportation, regardless of the number of passengers. Ticket sales revenues determine those of the organizer of transport. Payment to an operator for providing transport services is most often based on calculating

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20 Ph. Kotler, K.L. Keller: Marketing Management, Prentice Hall, 14th edition, 2011, p. 228.

21 M. McDonald, I. Dunbar: Segmentacja rynku. Przebieg procesu i wykorzystanie wyników. Oficyna Wydawnicza, Kraków 2003.

22 D. Mercer: Marketing, Blackwell Business, Cambridge 1992, p. 258.

the cost of vehicle-kilometers, and along with the term of a contract, is subject to changes, be it transportation velocity, power or fuel prices.

In the case of a net cost contract, revenue and cost-related risks are transferred to an entity providing transportation. Since the operator accepts higher business risks in a net contract he demands more influence than in a gross contract. Revenues from ticket sales determine those of the operator. Revenue-related risk may be subject to modifications depending on revenues generated on sales, which may encourage the operator to take measures aimed at increasing quality and effectiveness. Depending on detailed terms and arrangements, the operator may have a significant impact on shaping service parameters such as frequency (at constant volume of transport services during the term of a contract) or tariff change. In this case, segmentation will become a significant element of the operator's actions in the public transport market.

Incentive contracts are a synthesis of the two former contracts. Part of the compensation paid to the operator is contingent on the entire volume of transport services (as in the case of gross cost contract) and the other part depends on the number of passengers transported. Should that be the case, the operator may feel encouraged to effect market segmentation in order to increase the relevant parameters of contract performance, for which the operator may be entitled to a bonus payment (e.g. increase in the number of passengers, higher customer satisfaction ratio, etc…).

In terms of incentive mechanisms the operator fundamentally receives a bonus payment for exceeding a determined quality level. This, however, requires an efficient marketing information system to be in place (organizer and operator), which assesses customer satisfaction at different levels and on a regular basis.

Segmentation may be based on purchaser-related criteria or product-related criteria. In the first case, we speak of demographic, economic, social and psychographic criteria. Carrying out segmentation based on demographic and economic criteria is relatively simple and as a rule does not require a marketing survey to be conducted.

Product-related segmentation is especially useful in public transport. "This is frequently the next step taken once agencies have exhausted the possibilities of segmenting by demographics and/or geodemographics. In the transit industry, segmenting based on product usage is synonymous with segmenting based on ridership – notably frequency of ridership[23]". The advantage of such an approach is its use of quantitative data which is relatively easy to gather (e.g. the number of travels in given categories) as well as its practical suitability in the formulation of even short-term strategies and action plans.

A very important segmentation criterion in the process of establishing tariff policy in public transport is the household income[24]. S. Cole, in turn, stresses strong correlations between market segmentation (and characteristic features of particular segments) and various elasticity categories. "In earlier studies it was clear that the passenger market in urban areas is one

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[23] R. Ellmore-Yalch: A Handbook: Using Market Segmentation to Increase Transit Ridership. A Management Guide. "Transit Comparative Research Program", Report no 36.Transportation Research Board. National Research Council. National Academy Press, Washington D.C. 1998, p. III.

[24] E. Cascetta: Transportation Systems Analysis. Models and Applications. Second Edition. Springer, New York, Dordrecht, Heidelberg, London 2009, p. 17.

market with segments between which customers will move. Their actions are determined by price elasticities, fare structure changes, service elasticities and income elasticity"[25].

In order to support this view, S. Cole presented in detail the U-18 segment, which is characterized by the absence of demand elasticity (as a rule, transport costs are covered by schools, public institutions and parents). Moreover, this segment can be characterized by other parameters on non-school days (weekends and holidays), which makes it possible to apply a flexible tariff and ticket solutions in order to increase the number of transports services rendered on such days.

In the everyday functioning of the public transport market, both segmentation criteria groups are used – those based on a customer and product profile (or related issue). In such a case, the following aspects are considered[26]:

- place of living;
- place of work/school/universities,
- social and professional status;
- car ownership;
- the manner in which demand for public transport is put into place;
- tariff basis for public transport services;
- type of ticket.

Specific segmentation criteria related to trolleybus transport might include:

- the comparison of trolleybuses to other means of public transport;
- attitude towards environmental issues;
- attitude towards quality of life in a broad sense.

Based on the analysis carried out for Gdynia within the framework of the TROLLEY project, two target groups for activities promoting trolleybus transport were defined. The following criteria were considered:

- social and professional status;
- sex;
- age;
- opinions about trolleybus transport.

The two groups are[27]:

young people (combined segments of 16–20 and 21–30 years old), among which trolleybus transport has the best image. These are either students or those who have joined the labor market recently. seniors – segment of 61+. This is a segment in which the image of trolleybus transport is weaker. However, it seems that it could be radically changed if only the crucial elements of the image (punctuality, speed, cleanness) could be improved. It should be noted that this process is considered long-term.

[25] S. Cole: Applied Transport Economics. Policy, management & Decision Making. 3rd Edition. Kogan Page, London and Sterling 2005, p. 52.

[26] O. Wyszomirski, K. Grzelec: Badania marketingowe w komunikacji miejskiej. Izba Gospodarcza Komunikacji Miejskiej, Warszawa 1998, p. 14.

[27] Developing a positive image of trolley communication among selected groups of inhabitants of Gdynia (low-cost actions). Prepared by AMBER Consult for City of Gdynia in the framework of TROLLEY Project, Gdynia 2012.

The analysis of factors which have an influence on the image of trolleybus transport in Gdynia was presented in Table 3.4.

Table 3.4. Analysis of factors influencing the image of trolleybus transport in Gdynia among defined target groups

Target group	Size of target group	Leading theme for utilization	Postulates	Areas requiring improvement
Young people	45 102	Ecological aspects. Transport behavior is becoming multimodal	directness, frequency, punctuality,	safety, cleanness, punctuality, comfort
Seniors	39 093	Quality of life	directness, punctuality, availability	comfort, safety

Source: self-study based on Preferences and behavior patterns of the inhabitants of Gdynia in 2010, The Marketing Survey Report of Urban Transport Management, April 2009, p. 24. Developing a positive image of trolley communication among selected groups of inhabitants of Gdynia (low-cost actions). Prepared by AMBER Consult for City of Gdynia in the framework of TROLLEY Project, Gdynia 2012.

Young people make up one of the most difficult groups to reach, due to their averse attitude towards the media or intensive advertising.

The element common to both target groups is perception of the trolleybus as a slow and unfashionable means of public transport. This element should diminish over time. As a means of transport, the trolleybus should be treated as an independent brand which requires that its key attributes be specified. The attributes of the brand can be found by referring to the assumptions of passengers in the defined target groups.

Chapter 4. Technical, Operational and Economic Characteristics of Trolleybus Transport

4.1. Trolleybus Fleet Characteristics

Trolleybuses are driven by electric traction motors, which have different characteristics than those of the internal combustion engines used in buses. The main feature of an electric motor is its high torque and the possibility to adjust its speed over a wide range. Hence the reason trolleybuses are not equipped with a gearbox and the motor is directly connected to the driving axle via a Cardan shaft. The high torque is also advantageous in hilly areas where trolleybuses achieve significantly better operating parameters than buses.

An important feature of the trolleybus is its ability to use its traction engine for braking, meaning mechanical brakes are used minimally. The possibility of using the electric drive to brake arises from the reversible nature of each electric machine: during braking the electric motor acts as a generator and converts the vehicle's kinetic energy into electricity. The energy created can be dissipated with braking resistors or returned to the overhead wire and used by other vehicles. This so called recuperative braking allows for recovery of the energy that would be lost in a braking system as used in buses.

One can distinguish three main generations of traction motors currently in operation:

1) DC traction motor with resistor speed control,
2) DC traction motor with pulse speed control,
3) AC (induction) traction motor

The first generation of traction motors was either series wound or compound wound (series and shunt). The use of a compound wound motor is characteristic for trolleybuses. This is the result of driving trolleybuses with only one engine, which hinders the possibility of shaping the characteristics and increases energy consumption because of the impossibility of series/parallel switching of traction motors. A compound wound motor has a wider range of regulation than a series wound motor. An example of this generation is Polish Jelcz pr 110 E with a type DK210 compound wound traction engine with 110 kW power. In first generation motors the voltage powering the traction motor controls the vehicle's speed. The voltage is adjusted with resistors, which results in significant losses of 20–40%.

The second generation trolleybuses are equipped with a series wound DC traction motor. Analogous to the first generation, the speed is regulated by the traction motor's voltage, however in this case the voltage is modulated without losses with a pulse-width modulating circuit known as a chopper. An additional advantage of this solution is the easy implementation of regenerative braking. It consists in returning power to the traction grid during braking. The switching devices are based either on SCR thyristors, GTO or IGBT transistors. This solution is used in the Solaris Trollino 12 T, equipped with a DK210 series wound traction motor and a transistor based pulse switch manufactured by the Electro-technical Institute in Warsaw.

Virtually all currently produced trolleybuses are equipped with third-generation drive systems. Their drive unit is an AC traction motor. It is powered from the overhead wire through an inverter converting DC into AC. The purpose of the inverter is to control the motor's speed using voltage and frequency modulation of the output current. The IGBT inverter equipped traction motor's power is between 165–250 kW. There are four and six pole induction cage motors. Due to the small size and low weight, four-pole motors are the most common and are equipped in most currently manufactured trolleybuses. However, the advantage of six-pole engines, a direct result of lower rated speed, is the possibility of equipping a trolleybus with a standard bus rear axle with a 5:1–6:1 gear ratio.

Electrical apparatus, in contrast to the bus's internal combustion drive, is characterized by a modular design, which allows for an arrangement, which is much less restrictive to passenger space. Examples of a trolleybus interior arrangement are shown on Fig. 4.1. The main elements of the drive, the traction motor and the auxiliary combustion generator were placed in the center of the vehicle, which enabled the a rear part of the bus to be completely low-floor. Moreover, it made it possible to greatly increase the trolleybus interior capacity by avoiding the installation of the so-called „drive tower", typical of low-floor buses.

The traction motor can be placed in the rear of the vehicle, as with buses. An alternative, increasingly common solution is to put the traction motor between the first and second axis of the vehicle, a special motor chamber above which passengers seats are placed (Fig. 4.2, 4.3). This solution allows a more even distribution of axle loads in the vehicle.

Fig. 4.1. Spacious interior design (Solaris Trollino 18, Salzburg, Austria)
Photo M. Bartłomiejczyk.

Alternative solutions should also be mentioned. These include the use of the portal axle with integrated electric motors in the hubs (Fig. 4.4, 4.5). This solution allows for a very wide passage at the back of the bus when accompanied by supersingle tires. Among others, this solution is used in Irisbus Cristalis, and the prototype Trolza with a ZF AVE 130 axle.

Fig. 4.2. Traction motor chamber placed between the axles, covered with passenger seats (Solaris Trollino 15)
Photo M. Bartłomiejczyk.

Fig. 4.3. The interior of the traction motor chamber placed between the vehicle's axles(Solaris Trollino 15)
Photo M. Bartłomiejczyk.

The enclosure box with an inverter, a choke, an input filter, an immediate switch and a converter is located on the roof, just like the resistor box. The chassis only holds the motor, the compressor and pneumatics. This arrangement is dictated by the need to maximize the low-floor area inside the trolleybus. Fig. 4.6 shows examples of roof enclosures holding electrical installations.

Fig. 4.4. The back part of Cristalis trolleybuses, equipped with AC induction (asynchronous) motors in the hubs – note the wide passage for passengers
Photo M. Bartłomiejczyk.

Fig. 4.5. The back part Neoplan trolleybuses, equipped with DC traction engines in the hubs – note the wide passage for passengers.
Photo M. Bartłomiejczyk.

Power is transferred via an insulated, single stage shaft to the hypoid portal axle with a conical main gear and cylindrical reduction gears in the hubs. The wheel and axle are usually comparable to those of buses.

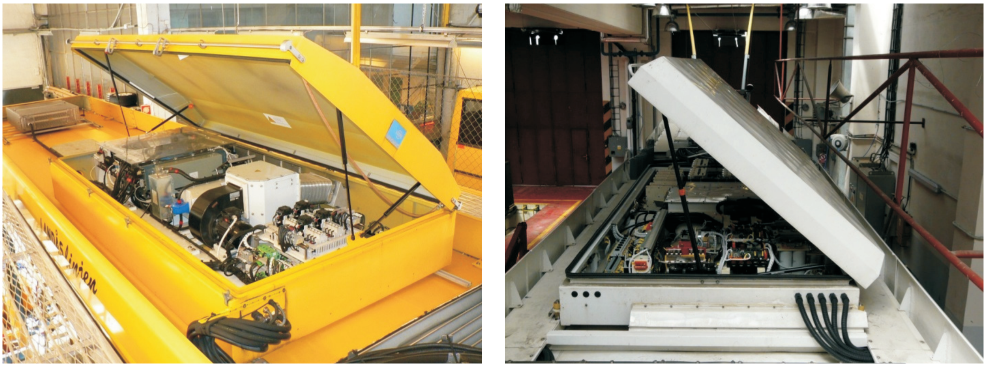

Fig. 4.6. Roof enclosures holding electrical installations
Photo M. Bartłomiejczyk.

Due to the same supply voltage and similar power, manufacturers seek to unify tram and trolleybus drives. The main difference between the tram and trolleybus drives is the number of motors, but this does not lead to other major differences in the structure of the electric drive system.

A second, more important feature distinguishing a trolleybus fleet from rail rolling stock is a two-stage isolation of the 600 V electric system. Train carriages are connected to the rails by metal wheels, all conductive elements available to passengers are galvanically connected to one pole of the power supply. Damage to the insulation of the 600 V system and a rupture to the vehicle's body will cause a short-circuit in the overhead wire 600 V system – the point of failure – the vehicle body – rails, creating the short-circuit current triggering overcurrent protection, which shuts off the power to the damaged vehicle. A trolleybus vehicles body is isolated from the power supply, so a short-circuit between the 600 V electrical system and the bodywork does not trigger overcurrent protection, so there is a risk of creating a dangerous electric potential. For this reason, the trolleybus overhead wire with the electric potential of 600 V, analogously to IEC Protection Class II appliances, is equipped with double isolation. As a safety precaution, trolleybuses are equipped with systems of continuous 600 V circuit insulation monitoring and detectors of dangerous electrical potential on the body.

Another difference between rail vehicles and trolleybuses are the types of auxiliary equipment used. As trolleybuses are built using the bodies of buses, they are equipped with the same auxiliary equipment as buses, namely:

- the pneumatic system for brakes, suspension (ECAS leveling system) and door mechanisms,
- the hydraulic system for power steering.

As was already mentioned, a major difference is equipping trolleybuses with an autonomous driving system i.e. a system without the need for an overhead wire.

It is worth mentioning, that the overhead wire is characterized by momentary changes of polarity. For that reason, the trolleybus electrical apparatus must be adopted in order to work with different polarities.

Fig. 4.7 shows an example of a modern trolleybus-wiring diagram. The electrical traction system voltage 600V is marked in red and the separated 600 V voltage is marked in blue.

A trolleybus is powered by an overhead wire with the help of trolley poles. Due to the possibility of changes in the polarity there is a voltage reverser (NP) installed, which can be a bridge rectifier, a contactor or a transistor. An AC traction motor ST is powered by a traction inverter FT. Auxiliary drives are also AC powered: compressor motor SS, hydraulics pump motor SP and ventilation motor SW. Auxiliary AC motors and other auxiliary 24V circuits OP are powered by static converters PP from the separated 600V voltage from a separating converter PS. The auxiliary 24V circuit voltage also powers the separating static PF 24V/24V of the traction inverter steering circuits. The 600 V – separated circuit is used due to the requirement of a two-stage insulation of the electrical installation under the overhead wire potential. For powering the vehicle when there is no voltage in the overhead wire, an emergency drive module is used (e.g. traction batteries, combustion driven generator). OG means heating, and RH breaking resistor.

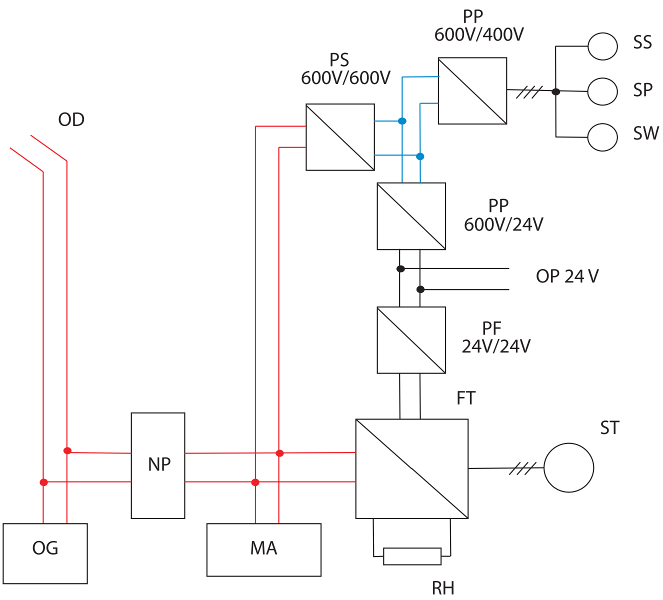

Fig. 4.7. An example of an electrical structure diagram of a trolleybus with AC traction motor
Source: own work.

4.2. Trolleybus infrastructure characteristics

The infrastructure necessary for the operation of trolleybus transport includes power supply facilities and equipment and technical facilities (depots) for fleet maintenance. The purpose of the infrastructure is to provide electricity to the vehicles through the overhead wire.

The overhead wire system is powered by traction substations with 660 V voltage. Depots serve as maintenance centers and garages.

Trolleybuses do not run on rails, so the trolleybus traction system works as the source of power and the traction return system. The traction system is divided into sections of power, which are supplied from the traction substations. This structure allows the decommissioning of a portion of the power supply system while leaving the rest operational. An example schematic of a traction substation's area of powering is shown in Fig. 4.8. The traction system is divided into sections with section isolators placed on both overhead wires. The sections are powered using bipolar power supplies, usually subterranean cables 625 mm^2 made of aluminum.

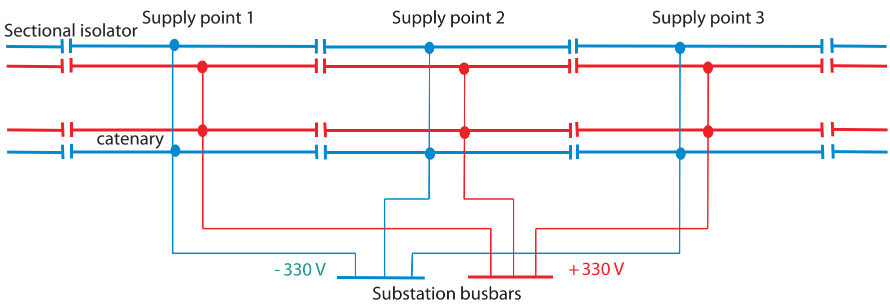

Fig. 4.8. The structure of traction power supply system
Source: own work.

The most common and the safest way to power trolleybus systems is an isolated system, in which the two poles of power are completely isolated from earth (IT systems). During normal operation, due to the symmetry of the supply, voltage distribution is symmetrical on both poles: the positive line voltage is +330 V and the negative is –330 V (power system with rated voltage of 660 V). In the event of damage to the insulation of one of the poles there will be a dispersed current flow towards ground, which is schematically shown on Fig. 4.9. Such a situation may arise in a case where the overhead wire is broken or there is an insulation breakdown in the electrical system of a trolleybus and may pose a potential threat to users. The current will flow from the positive bus bar of the substation, through the power supply, traction wire, the place of damage to the insulation, ground, leakage resistance, traction wire's negative pole $\boldsymbol{R}_{-}$ and the negative power supply to the negative traction substation. Due to the much higher resistance $\boldsymbol{R}_{-}$ from other elements of the circuit, we can assume that the amp value of the earth fault will be equal to the ratio of the power resistance to $\boldsymbol{R}_{-}$ resistance. Taking into consideration that the insulation resistance is between 10–500 kΩ, one can assume that the amp value of the earth fault will be between **1–60 MA**. In comparison, in the case of a tram the amp value of the earth fault could reach 10A, – which is over 100 times greater.. It must, therefore, be concluded that from the point of view of safety from electric shock trolleybus transport is much safer than the tram, as there is much smaller risk of bystanders getting an electric shock coming into contact with an electric wire lying on the ground after it is broken.

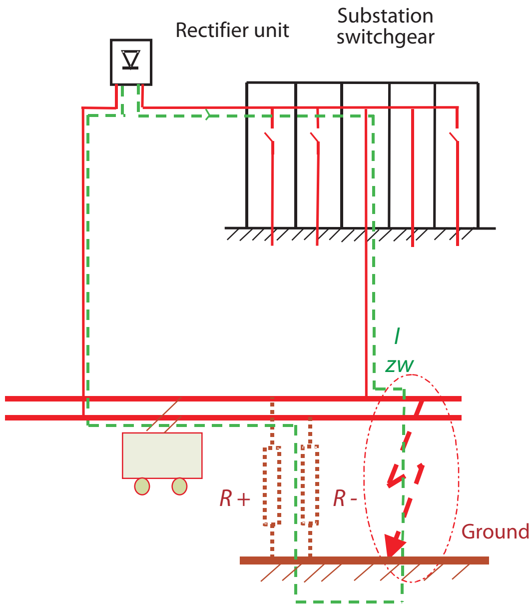

Fig. 4.9. Damage to the insulation in the trolleybus power supply system
Source: own work.

From the point of view of the power structure, there are two ways to deploy traction substations:

- centralized supply system
- decentralized supply system

The centralized supply system has its roots in early urban electric traction, when the first tram networks were supplied from one central power plant (mostly steam, sometimes water). As time passed, tram networks (and later trolleybus networks) developed and in order to increase the supply power, power supply rectifier units were introduced (initially they were rotary converters and later mercury arc rectifiers) supplied from the municipal mains power and thus power plants evolved into substations. Next newly built tram (trolleybus) lines were supplied from the central substation by increasingly longer power supplies.

A characteristic of the centralized power supply (Fig. 4.10) is the existence of large substations (powering even 20–40 power supplies), covering a large area of power with points of supply often very far from the substation. Their length reaches sometimes 5 km and their cross section areas 2000 mm^2. Substations operating in the centralized system must supply

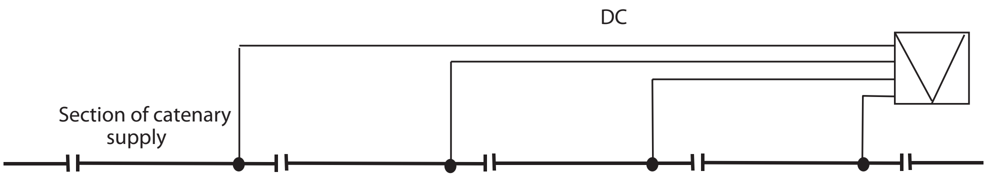

Fig. 4.10. The scheme of centralized supply system

uninterrupted power and thus are powered by two lines from the mains and have at least two rectifier sets. The central power networks used unilateral traction wire. Centralized power is common in Central Europe: in Poland, Czech Republic, Slovakia and Hungary.

A decentralized system is a more modern way of powering a trolleybus traction system (Fig. 4.11). It was created thanks to the rise of prefabricated, maintenance-free, small-scale substations. In this arrangement, power substations are densely spaced (every 1–3 km), located in the immediate vicinity of the overhead wire power points. Substations have one rectifier group (they have 1–3 power supplies), they are often supplied with only one MV line (6–35 kV). Damage to the rectifier unit or the supply line turns off the entire substation, so reserves are provided by using the power supply from neighboring substations by combining the power sections of the overhead line. Increasingly, bilateral power is also used. Decentralized systems are used in Western Europe (Austria, Switzerland, Germany).

The main advantage of the decentralized system of overhead wire power is that less electricity is lost in the power supplies and a lower voltage drop in the DC grid. In addition, operational practice shows that power cables are the most prone to damage of all power system components. This is because cables run through a dense urban underground infrastructure, which causes frequent cable damage during construction works. Also of importance is the fact that smaller volume substations can be located in other public buildings and, as a result, have less of an impact on the architecture of urban areas.

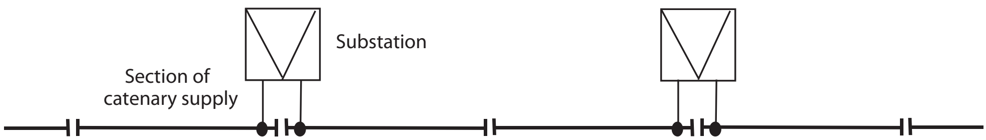

Fig. 4.11. An example of a decentralized apply system
Source: own work.

In many cases, existing power systems are being strengthened through the implementation of two-point power to the traction wire (Fig. 4.12), which is a modification to the bilateral system. This solution is commonly used in the Czech Republic.

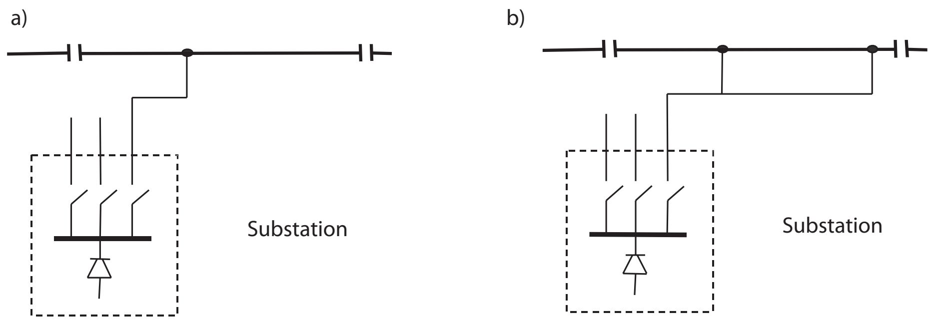

Fig. 4.12. One point (a) and two point (b) supply of section
Source: own work.

Traction substations convert the alternating current drawn from the power grid to DC power for trolleybus traction. The supply voltage of the substation tends to differ: in Poland it is 10–20 kV, in the Czech Republic 6–35 kV, Slovakia 22 kV, Hungary 10 kV and 20 kV. In Austria, Sweden, the Ukraine and Lithuania, all substations are powered with 10 kV voltage.

A traction substation consists of three main parts:

- power switchgear (medium-voltage switchgear), which divides electricity for each rectifier unit,
- rectifier groups consisting of a transformer and rectifier, which convert the alternating current electrical energy drawn from the grid to DC energy,
- DC current switchgear, which channels the energy supply into individual sections of the overhead line.

An example of a simplified diagram of trolleybus traction substation is shown in Fig. 4.13. This is a single-unit substation used in a decentralized power system. The rectifier unit is powered by 15 kV of alternating current from the public grid by the main switch and meter used for settlement bills with the power company. The transformer voltage is lowered from 15 kV to 525 V, then the voltage is rectified, resulting in 660 V direct current. In the DC distribution unit the electricity is distributed to individual sections of the power supply. Each section of the power supply is equipped with a linking – protection circuit, that allows the power for

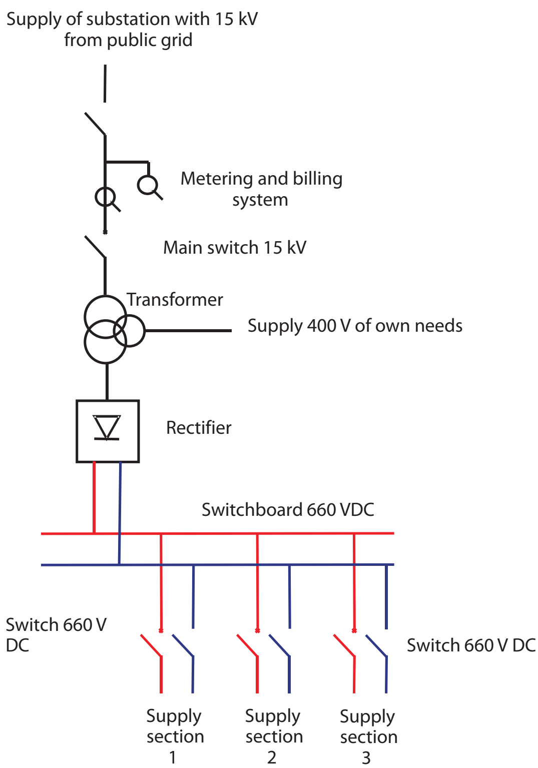

Fig. 4.13. The scheme of trolleybus substation with one recifier
Source: own work.

individual sections to be turned off. Frequently the positive power section is equipped with a high-speed switch breaker, which protects against short-circuit and overload, and the negative pole uses only a standard disconnector switch. It is possible to install switches on both power poles or bipolar high-speed switches, however for economic reasons this is rarely done.

Substation equipment such as control systems, lighting and heating is powered by an additional 400 V coil of the traction transformer.

Fig. 4.14 shows an example of a trolleybus substation interior. On the left: the medium-voltage switchgear, on the right: the DC switchgear and at the rear: the rectifier unit.

Fig. 4.15 shows two examples of small volume trolleybus traction substations. In many situations it is necessary for the traction to be incorporated into the existing architecture. Examples of such solutions are presented in Fig. 16, which displays photos of a substation stylized as a historical building and a subterranean substation

Fig. 4.14. Interior of a single unit traction substation (Gdynia, Poland)
Photo M. Bartłomiejczyk.

Fig. 4.15. Examples of single unit traction substations (Brno, Czech Republic and Gdynia, Poland)
Photo M. Bartłomiejczyk.

Fig. 16. Adopting traction substations to local architecture: a substation stylized as a historic building and a subterranean substation (Gandawa, Belgium and Brno, Czech Republic)
Photo M. Bartłomiejczyk.

Depots are an essential element of the trolleybus transport system. Their primary role is that of a technical facility for vehicles. However, more specifically the role of trolleybus depots can be divided into the following categories:

- Vehicle maintenance – overhauls, repair, inspection,
- Vehicle storage,
- facilities for other technical services (e.g. substation and wire network maintenance),
- administrative – the seat of the operating company.

The task set out in groups 3 and 4 are not directly related to the maintenance of the trolleybus fleet, and therefore, will not be mentioned later in this paper. It should be noted that in many cases the seat of technical services related to the maintenance of overhead wires and substations is located outside the depot, for example, on one of the substations.

Activities related to the maintenance of vehicles consists of:

- daily maintenance,
- technical maintenance,
- medium repairs,
- main repairs.

Daily maintenance activities include the servicing of the basic mechanical parts of a trolleybus: braking, steering and the insulation of the high-voltage installation. This usually takes around 10 minutes. Technical maintenance includes activities connected with the routine servicing of individual elements of the vehicle, its scope and frequency determined by the vehicle's manufacturer. Technical maintenance includes checking the condition of the traction and the auxiliary motors, insulators, poles and ropes, electrical installation, coatings, information stickers, inner and outer shell, seats, doors, windows, mirrors, steering system, suspension, wheels and tires, braking system, body and chassis, v-belts. The electrical system is cleaned, the level of oil in the gearbox is checked and mechanical components are lubricated. In addition periodic checks are performed on the tension of pole collectors, worn contacts are exchanged, pantograph rods are cleaned, the state of the roof, doors and floor covers is checked, the grill is checked for wear or repaired, the rear axle and drive shafts are inspected, wheels and brake drums are removed, the thickness of brake linings are checked. Performing medium, minor and major repairs and their scope depend on the company's fleet strategy. They usually include the exchange of corroded mechanical elements, the shell and the grill.

The garage in which daily and technical maintenance is performed should be equipped similarly to bus depots, that is with inspection pits, vehicle lifts, etc. The main difference is the need for an equipment maintenance area with platforms providing access to electrical equipment located on the roof (Fig. 4.17). It is also important to equip depots with the devices necessary to operate the electrical equipment, e.g. a blower to dry traction motors. The number of pits (stands) of daily and technical maintenance depends on the number of vehicles in the fleet. For a small depot it is sufficient to use one position for technical and one for daily maintenance (it is not advisable to perform those two activities at one station). It is recommended that pit maintenance be undertaken in the form of a drive-through. Blind channels are not recommended due to the need to withdraw the vehicle each time it is repaired.

Fig. 4.17. Trolleybus maintenance hall with balconies (Brno, Czech Republic)
Photo M. Bartłomiejczyk.

Fig. 4.18. Designated trolleybus garage pits in a bus depot (Landskrona, Sweden)
Photo M. Bartłomiejczyk.

Large depots may have up to 4 daily maintenance pits and 4 technical maintenance pits. The type of vehicle service stations depends on the conditions of a particular depot location. In a case where both a minimal number of trolleybuses and also a much larger fleet are operated it is possible to dedicate to them two maintenance pits (Fig. 4.18, 4.19).

Fig. 4.19. Designated trolleybus part of a bus depot (Bergen, Norway)
Photo M. Bartłomiejczyk.

In addition to vehicle maintenance pits, depots should also be equipped with other technical facilities, the number and type of which depends on the characteristics of the fleet. In the case of large depots the following elements can be distinguished

- electro-technical workshop,
- electronics workshop,
- mechanics workshop,
- pneumatics workshop,
- sheet-metal workshop,
- woodworking workshop,
- paint workshop,
- battery workshop,
- tire workshop,
- warehouse, tool storage.

Another key part of the depot is parking for the trolleybuses. This can be either outdoors, partially covered or fully covered parking (Fig 4.20). Roofed parking protects vehicles from the impact of weather conditions, reduces the rate of corrosion and most importantly, prevents moisture from entering the electrical system when the vehicles remain stationary at night. An important issue is the installation of the overhead wire within the trolleybus depot. Trolleybus depots are usually equipped with electric traction, yet with the proliferation of trolleybuses fitted with an auxiliary power source, it is not uncommon to build depots without electric traction (Fig. 4.18) or only partially equipped with it. The overhead wire in the depot is supplied at nominal voltage (600 or 750 V), but for safety reasons reduced (80–200 V) overhead line voltage is used in vehicle servicing areas.

In cases where space is limited two level depots are built. An example of this is the Komín depot in Brno (Czech Republic). The lower level is equipped with inspection pits, while the higher level serves as parking (Fig. 4.20).

Fig. 4.20. Partially roofed parking spaces for trolleybuses (Gdynia, Poland) and fully roofed (Brno, Czech Republic)
Photo M. Bartłomiejczyk.

Fig. 4.21. Two-level Komín depot in Brno (Czech Republic)
Photo M. Bartłomiejczyk.

Just like other public transport depots, trolleybus depots are equipped with vehicle washing stations. They can be built outside or inside the depot (Fig. 4.22). The washing stations are built similarly to bus washing stations, but because the pole collectors are placed on the vehicle's roof, no elements of the washing station can be placed over the vehicle's roof. Hence the reason washing stations for trolleybuses are not built in form of a gate, but rather as two parts. As a safety precaution the overhead wire's voltage is lowered to 80V in the area of the washing station. Some washing stations do not have an overhead wire at all and vehicles need to use their auxiliary drive to pass through them.

Fig. 4.22. Inside (Pardubice, Czech Republic) and outside (Coimbra, Portugal) trolleybus washing station
Photo M. Bartłomiejczyk.

4.3. Transport Capacity and Performance in Trolleybus Transportation

The supply of transport services as well as the volume of its consumption can be described by many measures. Transport capacity and performance constitute the two most important.

Transport capacity incorporates the total amount of service supply offered by a company in a given period, with the use of certain resources and within a frame of a particular public transport network.. Transport capacity is measured in:

- vehicle kilometres (vkm),
- seat kilometres (skm).

The transport capacity expressed in vehicle kilometres does not take into account the amount of seats available in each of the utilized vehicles. It, therefore, does not represent the actual transport capacity with regards to the passengers carried by the service operator. Due to the fact, however, that the majority of routes are serviced by vehicles of which the capacity is not fully utilised, the number of seats is not the main criterion used in order to determine the transport capacity. It is rather described by the number of vehicles operating on a given line or network together with the frequency of departures. Moreover, the standard number of passengers (both sitting and standing) does not constitute the maximum number of passengers which should be carried at a single time on a trolleybus. It depends on the space utilisation norms accepted by the manufacturer of the vehicle, which are measured by the number of passengers within an area of $1m^2$. Whilst the saturation on board, commonly accepted by the passengers amounts to 4 passengers per $1m^2$, in reality the most frequently encountered saturation allows for 6,7 passengers per $1m^2$[1].

In calculating the transport capacity (measured in seat kilometres) the number of seats provided for the passengers on each vehicle is included. The measure of transport capacity expressed in seat kilometres is used especially to establish the point of saturation of transport capacity. It can also be put to use in supply scope planning, especially during line planning which includes time factor (meaning the frequency of departures in a day together with the days of the week).

Most commonly, the transport capacity is set for one hour. It then stands for the maximum number of passengers for a given vehicle, which can be carried by it, from one transportation point on a particular route or line to another, in an hour. It is expressed by the following formula[2]:

$$Z_h\ [pax] = Q_p \times W$$

where:

Z_h – stands for the transport capacity of the operator, measured in the number of passengers carried per hour,

Q_p – stands for the capacity of the vehicle measures in the number of seats provided for passengers,

[1] *Transport miejski. Ekonomika i organizacja [Urban Transport, Economy and Organisation]*, ed. O. Wyszomirski, Wydawnictwo UG, Gdańsk 2008, p. 83.

[2] Ibidem, p. 84.

W – stands for the top number of vehicles which can depart from a given transportation point in an hour and travel in the same direction.

The transport performance understood in a more narrow manner is a type of exploitation work which constitutes a product of the number of vehicles of the entire company, together with the distance travelled in a given period, where the vehicle kilometre constitutes the measurement unit. The exploitation work measured annually, most commonly serves as a means for the verification of the volume of supply which the operator was said to deliver in the given period, as contracted by the local government, as well as serving as the basis of future volume planning.

The transport performance understood in a broader manner is expressed by the product of the total number of passengers who were carried in a given period by all the vehicles owned by the operator, as well as by an average distance travelled by each of the passengers, where the passenger kilometre constitutes the measurement unit. It is expressed by the following formula:

$$P_p\ [paxkm] = \Sigma Pax \times L_{śr}$$

where:

P_p – stands for the transport performance measured in passenger kilometres,
ΣPax – stands for the total number of passengers carried in a given period,
$L_{śr}$ – stands for the approximate distance travelled by one passenger in the given period.

At present, the methods used in registering passengers on the vehicles are not sufficient enough to know beyond all reasonable doubt how far each passenger has travelled. Therefore, in order to facilitate calculations, the most commonly applied method involves the application of an approximate distance travelled by one passenger in a given period. The methods of establishing the average distance vary between public transport companies. Sometimes it is based on the results of measurements concerning the trip of a sample of passengers using electronic cards/tickets, who log onto the system upon entering a bus and log out as they step off the vehicle. The most common error connected with this method concerns the passengers who forget to log off the system. It also does not take into account passengers who are using traditional or periodical tickets, who are not required, or not prompted, to log on to such a system. The system used in Amsterdam can serve as an example of an efficient measurement system. It is based on electronic readers, which take note of each person getting on a bus/a tram/underground/city train, and which register each electronic ticket user. The readers scan such tickets remotely, noting when their owner got on and off a vehicle.(24-hour, a set number of days, monthly). In such a case, the analysis of the flow of the passengers may be detailed.

Another, completely different method used to establish the average travel distance of each passenger, is based on surveys conducted by the employees/contracted employees working for the carrier, who randomly select a passenger and ask them where they started their journey and when they intend to finish it. Even a large sample of answers does not guarantee, however, a high measurement of accuracy. The method has been, nevertheless, employed for many years. Currently, electronic measurement tools, used to measure the effective demand, are becoming more significant and they should dictate the path of development in public transport.

The way of establishing the volume of the effective demand contributes to the achievement of a few aims. Firstly, the demand constitutes a value which can be compared to the level of transport performance (in vkm) which is feasible to carry out. The relationship constitutes an indicator of the level to which the vehicles are filled (utilisation of the transport capacity) in a public transport company, which can be described by the formula presented below:

$$\alpha = \frac{Pp\ [paxkm]}{Zp\ [mkm]}$$

After the expansion of the formula we obtain the following:

$$\Sigma Pax \times L_{śr} / \Sigma Q_p \times \Sigma L$$

The indicator is within range <0; 1>. The average daily value of the indicator is between 30,0% and 35,0%. During the peak hours it reaches 50%. In practice it states that in order to perform one passenger kilometre within urban transport the carrier supplies 2 seat kilometres.

The quotient of the transport performance (in passenger kilometres) and transport capacity (in seat kilometres) allows for an evaluation of the level of utilisation of the carrier's transport capacity. It provides a dynamic indicator which constantly fluctuates in time both in the daily, weekly and annual perspective.

The main influence on the supply of transport services provided in a given time belongs to the company itself, which through the use of many tools and methods can affect the generating of the aforementioned service. As a whole, they constitute external factors shaping the volume of the supply of transport services.

Those factors, examined with reference to the company utilising trolleybuses, can be named as follows:

- Factors concerning the size of the given company:
  - the amount of manufacturing workers, including the drivers and technicians maintaining the rolling stock and the network;
  - the amount of traffic management employees.
- Factors concerning the quality of work and company's code of conduct:
  - experience of the manufacturing workers;
  - skills of the management;
  - analytical and monitoring skills of the traffic supervisors;
  - ability to create timetables;
  - health and safety, as well as quality procedures;
  - strategy and policy of development;
  - financial credibility of the company;
  - social responsibility;
  - ecological responsibility.
- Factors connected with the quantity of the rolling stock:
  - the number of trolleybuses on route;
  - the number of substitute trolleybuses;

– the number of technical vehicles;
– the number of support vehicles.

- Factors connected with the quality of the rolling stock:
  – number of passenger seats;
  – average age;
  – technical condition and the level of wear;
  – efficiency class / emission;
  – annual average mileage.
- Factors concerning the given company's economics:
  – company prime costs (fixed, variable);
  – external service costs, outsourcing;
  – the infrastructure maintenance and modernisation costs;
  – forecasted and ongoing investments in infrastructure;
  – accounting liquidity,;
  – tariff system;
  – controlling;
  – reimbursement system for the public transport services;
  – collection system of the amounts due;
  – cooperation with the management of the public transport / local government unit.
- Factors connected with passenger service:
  – fare system;
  – availability of fares (ticket machines, retail sales, driver sales, e-commerce, mobile device purchases);
  – information.

Each operator, including trolleybus operators, acting as an economic subject, despite being self-sufficient and their financial and organisational independence, is influenced by various external factors shaping the volume of transport services offered. Those factors may demonstrate a varied level of impact on the supply. The impact may be both positive and negative. They may be completely independent or manifest as a result of the intended activity of external subjects. Alternatively, they may result from negligence of the aforementioned subjects.

In general the external factors influencing the volume of transport services supply are described as factors remaining outside the company, which cannot control them in any way.

These factors can be identified as follows:

- Macroeconomic[3] – resulting from the economic globalisation and state economy:
  – The amount and dynamics of the state's GDP;
  – The income structure of the GDP;
  – The scope and structure of international trade;
  – The investment level and structure;
  – The amount of state residents;
  – The level of consumption (both current and future);

[3] Mindur M., *Transport Europa – Azja [Transport Europe – Asia]*, Wydawnictwo Naukowe Instytutu Technologii Eksploatacji – PIB, Warszawa–Radom 2009, p. 163.

  - The changes in localisation, manufacturing and settlement;
  - The changes in localisation, manufacturing and settlement;
  - The accessibility of transport for travellers within a city (train, ferry, and air links as well as of long-distance coaches).
- Local – rooted in the city and its vicinity (other administrative districts):
  - The population;
  - The population structure (education, age, economically productive age, etc.);
  - The amount and dynamics of the GDP;
  - The income structure of the GDP;
  - The economic profile;
  - The public transport policy (tools);
  - The motorist indicator;
  - The branch structure of work and school routes;
  - The competitiveness of private mass transportation;
  - The level of development and integration of public transport within a city and region, together with the relationship with local public transport networks;
  - The number of job positions;
  - The number of people employed;
  - The number of schools and universities;
  - The number of places in schools and universities;
  - The number of people in education;
  - The tourism in the city and region.
- Microeconomic – resulting from the particular characteristics of the public transport business in a given city/region:
  - The internal competition in transportation branches;
  - The size and structure of the complementary elements of the urban transport system;
  - The size and structure of the substitution elements of the urban transport system;
  - The technical and exploitation specificity of the particular means of public transport;
  - The reimbursement system of public transport services.
- Social – resulting from the current needs of the local community concerned with public transport; meaning all the market demands of the consumers:
  - The operational and seasonal demand structure;
  - The transport demands.
- Infrastructural – depending on the condition of the transport infrastructure which is being used by the operator in order to fulfil their transportation tasks:
  - The condition and technical characteristic of the transport infrastructure within a city and region;
  - The infrastructure traffic capacity;
  - The urban and regional development programmes for transport infrastructure.
- Legal – resulting from legal acts on all levels – EU, state law, and local law established by local government units:
  - The EU legislation regarding environmental protection (fumes emissions, external costs, etc.);
  - The state legislation regarding environmental protection;

- The working law regulations, especially those regarding acceptable working patterns for drivers;
- The local legislation regarding city and regional planning and land development planning;
- The local strategies regarding the development of public transport together with all documents concerning the matter;
- The local legal acts regarding the tariffs and methods of accounting the free and discounted fares.

Chapter 5. Organization and Management of Trolleybus Transport

5.1. Models of Organization and Management of Trolleybus Transport

Urban public transport is a matter of public service. This requires public authorities to introduce specific regulations for this branch of the transport industry. Depending on the scope of the regulation, one can distinguish the following models:
- deregulated,
- regulated.

In the deregulated model of urban public transport the role of public authorities is reduced to the minimum needed to provide the standard of transport service required by residents. The transport is in fact regulated, but only to a small extent.

In the regulated transport model, public authorities have a substantial influence on the functioning of urban public transport. In order to provide the highest possible standard of service in public transport, public authorities greatly influence the way it is shaped.

The main difference between the two regulation models mentioned above concerns the service suppliers' freedom of:
- access to the market,
- determining the quantity and quality of services offered,
- pricing,
- development of information and promotional media.

In the deregulated model of urban public transport services can be provided by any operator meeting the technical and technological requirements arising from specific provisions relating to public transport. Freedom of access can also affect the infrastructure necessary for the provision of transport, particularly of all stops, interchanges, parking sites and systems used to provide vehicles with electricity. It is necessary, therefore, to define the principles governing the use of this infrastructure.

In the regulated model of urban public transport access is only given to operators who are owned by the city or hired by the city to implement transport services in this city (or part of the city), or to fulfill specific tasks within the service.

In the deregulated model of urban public transport the operator bears all market risk associated with basic decisions on how to provide services to achieve the desired profitability. While providing commercial services, the operator can flexibly adapt them to the needs of the market, deliberately choosing the most profitable areas of the market and customer groups. In certain situations, the operator can also employ the cross-subsidization of services i.e. cover the deficit caused by unprofitable routes or lines with income gained by other profitable routes or lines. The operator will do so if, thanks to an extended range encompassing both profitable and non-profitable services, the demand for services will rise enough to provide more profit than a smaller range, which only includes profitable services. The rational action of the operator is thus dependent on the correct assessment of the demand for transport services in urban areas, both present and future. This assessment has a bearing on the operator's whole strategy including the scale of services, investments, renovation and introduced innovations.

In the regulated model of urban public transport the market risk is usually born by public authorities, which regulate the functioning of the market. Nevertheless, it is possible to agree a contract in which such risk is ceded to the operator. Public authorities specify the services in terms of quantity and quality. It is also possible for the operator or operators employed by the city to determine the scope and level of services themselves. In both cases, the planned offer must be accepted by public authorities, particularly in terms of the possibility of it being subsidized by the city's budget.

In the deregulated model of urban public transport, the operator has the right to independently set prices for transport services. In the regulated model of urban public transport prices are adopted by public authorities and, therefore, are official in character.

The scope of information and promotion activities in the deregulated model of urban public transport depends solely on the creativity of the operator. However, in the regulated model the information and promotional message is the responsibility of the organizer of transport.

The diversity of access of operators to the market determines the competition among the suppliers. An inherent trait of the deregulated model of public transport is its instigation of competition. The regulated model of transport may be based on one operator's monopoly or on competition between operators.

Taking into account the criterion of supplier competition in the regulated model the following solutions can be distinguished:

- a city-owned monopoly on transport services operating continuously thorughout the urban area;
- a monopoly of a single operator, hired to handle the transport of the city for a specified time period after winning a tender;
- the competitive co-existence of operators who have won tenders to operate separate parts of the city's transport network.

Basic organization and management models of urban public transport are presented in fig. 5.1.

Each of the solutions in the regulated model of urban public transport requires a different way of organizing and managing the city's transport. In the case of the monopoly of a city-owned operator, the basic scope of organization and management activities can be performed by the operator itself, whereas in the case of a monopoly of an operator, hired to handle the transport of the city for a specified time period, there is the possibility that of a wide range of organization and management activities can be undertaken both by public authorities and the operator. Competition of operators on the market requires the majority of organization and management activities to be performed by public authorities.

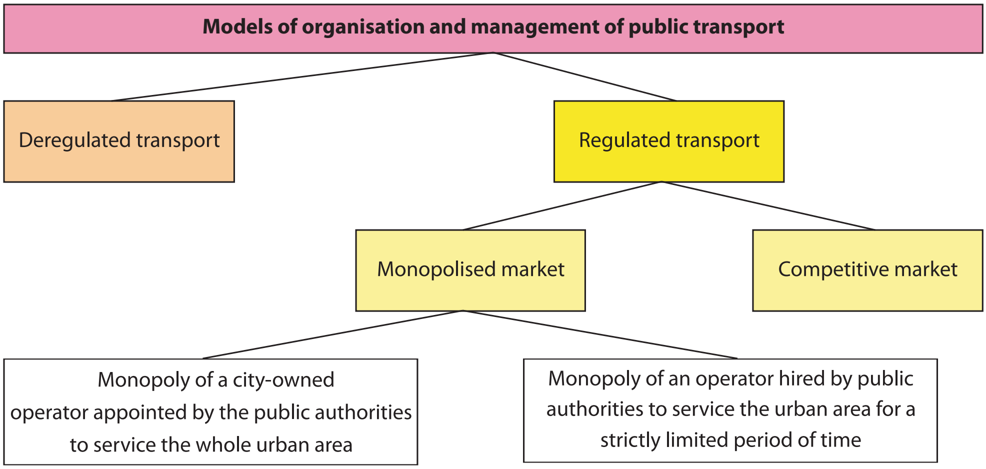

Fig. 5.1. Organization and management models of urban public transport
Source: own work.

The commitment of public authorities to the organization and management of transport services requires the appointment or employment of a specialized organization and management unit.

The fulfillment of organizational and management activities mainly by the operator is only possible when public authorities entrust all transport services to their own operator. This operator plays the role of monopolist on the market, free from competitive pressure, which in turn can cause:

- the failure to verify the effectiveness of the transport business by means of competition;
- the need for a grant to cover part of the costs exceeding the revenue from ticket sales;
- the propensity to plan the transport offer based primarily on the ease and convenience of its implementation;
- an absence of evidence prompting the conduction of market research on a wide scale;
- a lack of strong incentives for the implementation of the transport service at a level high in both quantity and quality.

The elimination of a monopoly of an operator entrusted with the city transport service requires the formation of an independent organizer of public transport, which will take on organization and management activities. Taking over this activity in part or in whole permits the implementation of a regulated model of urban public transport.

In the regulated model of urban transport it is possible for an operator to monopolize transport services for a specified period of time. This task is put up for tender by public authorities. This solutions enables:

- a periodic verification of the transport business by the market;
- the limitation of the competition to large operators who are able to operate transport services throughout the whole city;

- a need to specify the quantitative and qualitative parameters of the transport service in the contract forming the basis of the operator's transport activity;
- the determination of the level of subsidies rendered to public transport service via a tender;
- a decrease in the dependence of the transport offer on those resources at the disposal of the operator;
- a presentation of evidence prompting the conduction of a wider scope of market research;
- a presence of strong incentives for the implementation of the transport service at a level high in both quantity and quality.

In order to create conditions for the operator to operate efficiently, the contract has to be signed for a period long enough to allow for the depreciation of the assets involved. The scale of the project covered by the contract can effectively reduce competition to a small group of large operators who are prepared to take on city transport service in its entirety. A major problem that may arise is the lack of stable conditions of employment for basic professional groups, due to the threat of losing the entire market by the operator. In addition, this model requires the adoption of certain infrastructure solutions, particularly those parts of the infrastructure with a very long service life. Therefore, public authorities, who introduce this model should:

- remain the owners of infrastructure and fleet;
- guarantee stable employment conditions to the basic groups of urban public transport employees by requiring the operator to adopt specific formal and legal obligations in the scope of their employment continuity;
- limit the duration of the contract to 5–6 years (as a result of the newly created conditions);
- precisely define the scope of duties of the operator;
- motivate the selected operator through appropriate incentives to provide efficient transport services, as well as sharing the commercial risk.

In the regulated transport model it is also possible to introduce competition to the market. Controlled by public authorities, the public transport authority must in this case play the key role in organizing public transport. This results in the following:

- a periodic verification of the transport business by the market;
- the possibility of providing integrated transport services by a few operators of various scales and forms of ownership;
- operating an integrated transport system despite the presence of many competing operators on the market;
- the possibility of influencing competition between operators for the proper development of the transport service;
- the precise specification of the quantitative and qualitative parameters of the transport service in contracts forming the basis of the operators' transport activity;
- the payment of operators for provided services in the form of a single payment, not divided into revenue from ticket sales and public subsidies;
- the strong focus of the offer on the needs of passengers, not on the operators supply capacity;
- the presence of incentives to conduct a wider scope of market research;
- strong incentives for the implementation of the transport service at a level high in both quantity and quality.

In the case of a monopoly, where the operator is contracted by public authorities, and competition on the market, public transport services may be provided by operators with different forms of ownership. In the model involving a monopoly, the operator may act as publicly-owned or privately-owned. Meanwhile, in terms of competition on the market, a situation may arise in which the services will be provided by:

- a single public operator,
- a single private operator,
- two or more public operators,
- two or more private operators,
- two or more operators with different forms of ownership.

In the competitive market model the implication is that it is theoretically possible to achieve at a given period of time a monopoly in transport activity by a single operator. The condition for such a monopoly is the winning of tenders for all parts of the transportation network by a single operator.

The models presented above are universal in character, which means that they can be adopted by an operator of either buses, trolleybuses or trams exclusively, or by one who operates more than one mode of transport. The specificity of trolleybus transport, however, limits the practical applicability of the presented models.

5.2. Applicability of Different Models of Organization and Management to Trolleybus Transport

The main feature of trolleybus transport is the strong connection of the vehicles to technical infrastructure, which determines the range and efficiency of the transport.

The inclusion of this feature is essential in assessing the applicability of different models of organization and management to operate trolleybus transport. The deregulated model of urban public transport is not applicable to trolleybus transport. It is difficult to expect that in a competitive market a trolleybus operator will be able to effectively compete with bus operators. This is why in reality a trolleybus operator may only operate within the regulated transport model, either the one assuming a single operator monopoly, or competition between operators on the market. In each of the two models, a distinction can be made between two options in which trolleybus transport can be operated. Basic models of organization and management of trolleybus transport are presented in fig. 5.2.

While analyzing the applicability of each model of organization and management to trolleybus transport, it is important to notice that in all of these models the operator can provide services with both buses and trolleybuses In such cases, the possibility of the interference of competitive processes in options 3 and 4 must be taken into account. Operating both trolleybuses and buses in a single organizational structure may hinder the efficient functioning of trolleybus transport as buses may become favored over trolleybuses for operational and economic reasons.

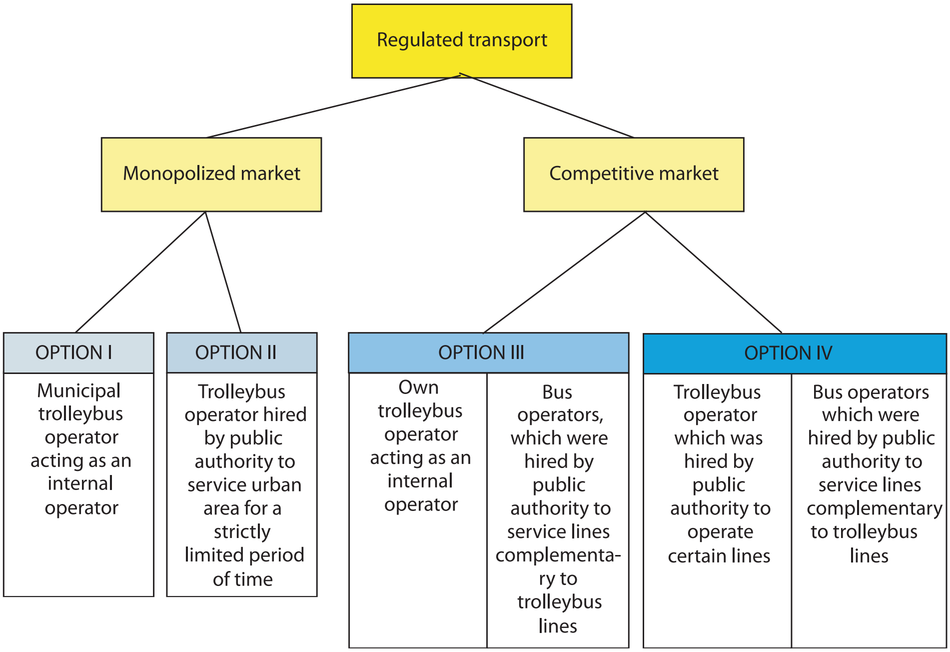

Fig. 5.2. Basic models of organization and management of trolleybus transport
Source: own work

The model assuming monopolized market can be divided into two variants. In the first option, the municipal trolleybus operator, acting as an internal operator, is the only entity rendering transport services as a result of the direct delegation of service delivery. This variant may occur in small cities with a well developed trolleybus infrastructure, making it possible to satisfy all citizens' needs for public transport. It is very important for the operator to be prepared to use trolleybuses with two kinds of power, i.e. those, who can use a specialized battery or an auxiliary combustion engine other than the main electric engine powered by the overhead wire. This enables the use of trolleybus transport in those areas of the city in which the installation of overhead wires is impossible, due to technical, economic or social reasons.

In the second option, the city puts up for tender the provision of trolleybus services for a specified period of time. This option makes it possible to use specific conditions stating that the trolleybus infrastructure remains the property of the city and either:

- the city handles the infrastructure's maintenance, while the operator uses the city owned trolleybuses, or
- the city handles the infrastructure's maintenance, while the operator uses its own trolleybuses, or
- the operator handles the infrastructure's maintenance and uses city owned trolleybuses, or
- the operator handles the infrastructure's maintenance and uses its own trolleybuses.

Having taken into consideration the above solutions, it should be recommended that the city takes responsible for the maintenance of the infrastructure, while the operator provides transport services using its own trolleybus fleet. The duration of the contract should in this case correspond with the depreciation time of the vehicles. One benefit of this approach is its assurance of the good order of the infrastructure for a longer time than the duration of a contract. Transferring the responsibility for the maintenance of infrastructure to private operators can lead to its degradation, especially if the operator does not obtain satisfactory profits from transport operations, or for other reasons is interested in prolonging its contract. In addition, the operator in service for a specific duration may not be interested in upgrading the trolleybus infrastructure or in introducing technical and technological innovations.

In the model assuming the monopoly of a trolleybus operator in urban public transport it is presumed that the transport infrastructure does not in any way constrain its ability to fulfill the transport needs of residents. However, in the competitive market model the trolleybus operator does not participate in the competitive struggle with other providers of transport services. The importance of trolleybus services, expressed by their share of the total vehicle-kilometers of urban public transport, can be varied. The trolleybus lines can, therefore, be considered as main, equivalent or complementary. In certain sections trolleybus and bus lines may be substituted, particularly on the main traffic arteries, nevertheless there should be no duplication of lines of various modes of public transport. These modes should work together to achieve synergy and optimize the use of public funds to subsidize the operation of the urban public transport system.

Analogously to the model assuming a monopoly, a model in which there is a competitive market can also have two options for public trolleybus transport. In one of them a trolleybus operator is entrusted with providing transport services, in the second one, an operator is chosen via tender to execute the contract for a specified duration. In the second scenario, it is possible to use analogous solutions for trolleybus transport to those described when referring to the model which assumes the monopoly of a trolleybus operator contracted by the city.

In the model assuming a monopoly on services, the organization can be handled by an organizer acting on behalf of public authorities or an operator handling both the organization and rendering of transport services. However, in the competitive model it is necessary to create a specialized public transport authority charged with the planning, organization and control of the operation of urban public transport.

When comparing the monopoly and the competitive models, the latter, in which trolleybuses are operated with other modes of transport, particularly buses, should be considered more applicable from the point of view of the current state of technical and technological development of urban public transport.

5.3. Organization and Management of Trolleybus Transport in Cities Participating in the Trolley Project

The cities participating in the Trolley project have adopted various solutions for the organization and management of trolleybus transport.

In Salzburg, trolleybuses are part of a public transport system which has been integrated by a transport association called Salzburger Verkehrsverbund GmbH. This association operates in the form of a limited liability company, which is 100% owned by Salzburg land, covering an area of 7,156 km inhabited by approx. 530,000. residents.

The main tasks of Salzburger Verkehrsverbund GmbH are:

- the planning of the development of local and regional lines and networks of public transport;
- the coordination of transport services provided to passengers by local and regional public transport;
- the monitoring of the quality of local and regional public transport;
- to provide information on the functioning of local and regional public transport;
- to ensure the possibility of purchasing integrated tickets for local and regional transport.

Trolleybuses in Salzburg are operated by Salzburger Lokalbahnen company as a part of an integrated transport system. In addition to trolleybuses this company also operates the local railway. The trolleybuses are branded Obus SLB, while the local railway is branded SLB Salzburger Lokalbahnen. SLB belongs to Salzburg AG, a municipal holding, whose activities encompass the following areas:

- energy (electricity, gas, water and heating);
- telecommunications (cable television, internet, telephony, business solutions);
- transport (public transport, suburban rail, FestungsBahn, Schaffsbergbahn, MonchsbergAufzug, tourism)

The holding was set up in 2000 through a merger of companies operating on the market of municipal services in Salzburg. Its shareholders are the Salzburger land, the city of Salzburg and Energie AG Oberösterreich, Service- und Beteiligungsverwaltungs-GmbH, whose majority shareholder is the land of Upper Austria.

Buses in Salzburg are operated by a separate, privately owned company. They are powered either by diesel fuel or compressed natural gas (CNG). The transport association ensures the integration of trolleybuses, buses and railway.

The timetables for trolleybuses in Salzburg are prepared by Salzburger Lokalbahnen Obus SLB. The vehicles are operated seven days a week, all year round.

In the year 2011 8 out of 9 trolleybus lines were operated 7 days a week. The maximum number of vehicles in operation was 86. The structure of vehicle-kilometers performed during individual days was as follows:

- workday: 16,350;
- Saturday: 14,123;
- Sunday and holiday: 9,557.

The transport offer for Saturdays and Sundays in respect to weekdays was equal to 86% and 58% respectively. Operating speeds for weekdays, Saturdays and Sundays were equal to 16.32 km/h, 17.59 km/h and 18.38 km/h. Trolleybuses used separate lanes with a combined length of 8.9 km.

In the year 2011 trolleybuses enjoyed a dominant share in the public transport market, thus ensuring their role as the main mode of urban public transport in Salzburg.

In Eberswalde trolleybuses are a part of the Berlin and Brandenburg transport system integrated by a transport association named Verkehrsverbund Berlin-Brandenburg (VBB). This association integrates public transport operators from Berlin and Brandenburg and 18 cities of Brandenburg, including Eberswalde, which has a 1,85% share in the association.

Verkehrsverbund Berlin-Brandenburg was formed in 1996. It covers an area of 30,367 sq. km inhabited by 6 million residents. Since 1999 a standard fare has been used throughout the whole area of the association. The operators participating in the association operate the following lines:

- 43 regional railway lines;
- 16 S-Bahn lines in Berlin;
- 9 metro lines in Berlin;
- 41 tram lines (26 in Berlin, 15 in Brandenburg);
- 949 bus lines (204 in Berlin, 745 in Brandenburg);
- 2 trolleybus lines (in Eberswalde);
- 7 ferry lines (6 in Berlin, 1 in Brandenburg).

In Eberswalde, the trolleybus operation company, Barnimer Busgessellschaft (BBG) GmbH, is a publicly owned limited liability company. The company operates buses and trolleybuses and is trademarked Barnimer Busgesellschaft.

Eberswalde timetables are prepared by BBG GmbH and accepted by the association. The vehicles are operated seven days a week, all year round on both lines.

The structure of vehicle-kilometers performed during individual days was as follows:

- workday: 2,523;
- Saturday: 1,055;
- Sunday / holiday: 1,018.

The transport offer in respect to weekdays was equal to 42% and 40% respectively. Operating speeds for weekdays and the two other days of the week were equal to 16.04 and 17.52 km/h. Trolleybuses did not have any separate lanes in Eberswalde in 2011. Their market share was 11.7% of the vehicle-kilometers operated by BBG.

In Gdynia, trolleybuses are a part of a public transport system organized by Zarząd Komunikacji Miejskiej w Gdyni (ZKM) and integrated by Metropolitalny Związek Komunikacyjny Zatoki Gdańskiej (MZKZG). ZKM is a budgetary unit of Gdynia municipality and organizes local public transport services in 7 municipalities (Gdynia, Rumia, Sopot, Żukowo, Kosakowo, Szemud and Wejherowo). The main tasks of this entity are as follows:

- planning lines and networks of public transport;
- contracting operators to service individual transport lines;
- conducting the sale and collection of revenue from tickets for local transport services;
- maintaining stops for local transport;
- providing information on the functioning of local transport;
- ensuring the quality of transport services through a system of monitoring, regulation and vehicle movement control;

MZKZG is a transport association of 14 municipalities forming the Metropolitan Area of Gdańsk Bay, with the two biggest cities being Gdańsk and Gdynia. This association is a legal entity. Its main tasks are as follows:

- to ensure the integrated operation of public transport including buses, trams, trolleybuses, local railway (SKM), and to a limited extent regional railway (PR) and ferries throughout the metropolitan area;

- sales and collection of revenue from metropolitan tickets valid in all modes of transport integrated by the association with the exception of ferries;
- providing information on the functioning of transport within the metropolitan area;
- promoting local urban public transport services.

Trolleybuses in Gdynia are operated by Przedsiębiorstwo Komunikacji Trolejbusowej Sp. z o.o. (PKT). The company has been operating since 1998, when it was separated from the structures of a bus-trolleybus company. It is 100% owned by the municipality of Gdynia. In the year 2011 it was one of seven operators contracted by ZKM. Other operators only use buses. Two of them are 100% owned by the municipality of Gdynia, the remaining five are privately owned.

Timetables for trolleybuses are prepared by ZKM and PKT executes them as apart of its contract with ZKM, which entrusts PKT with the obligations of an operator. Trolleybus transport operates all year round, 7 days a week. In the year 2011 8 out of 12 lines were operated 7 days a week. The maximum number of vehicles in operation was 72 and the number of vehicle-kilometers performed during individual days was as follows:

- weekday: 13,601;
- Saturday: 11,244;
- Sunday / holiday: 8,353.

The transport offer for Saturdays and Sundays in respect to weekdays was equal to 83% and 61% respectively. The offer distribution between different types of days of the week was similar to that of Salzburg.

Operating speeds for weekdays, Saturdays and Sundays were equal to 15.39 km/h, 15.47 km/h and 15.57 km/h. The relatively low operating speeds are a result of deliberate longer stops aimed to compensate possible delays caused by traffic congestion and for meal and rest breaks for drivers. In 2011 there were no bus lanes for trolleybuses (this is still the case), which is a further cause of such low operating speeds. The share of trolleybuses in local public transport in Gdynia is equal to 26%.

In Brno, trolleybuses are part of a public transport system integrated within the South Moravian Region. The regional organizer of transport in this area is KORDIS JMK (Integrovaný dopravní system Jihomoravského kraje). Trolleybuses in Brno are operated by Dopravní Podnik Města Brna (Brno City Transport Company), a joint stock company owned by the public. Its network of lines includes trams, trolleybuses, buses and ferries on Lake Brno. Trolleybuses have no separate organizational structure as in Gdynia or as is partially the case in Salzburg.

In 2011 all trolleybus lines in Brno were operated all year round, seven days a week. The maximum number of vehicles in operation was 120, including 20 articulated trolleybuses. The number of vehicle-kilometers performed during individual days was as follows:

- weekday: 21,500;
- Saturday: 9,100;
- Sunday / holiday: 9,300.

The transport offer for Saturdays and Sundays in respect to weekdays was equal to 42% and 43% respectively, clearly different from Salzburg and Gdynia, but similar to that of Eberswalde. Operating speeds for weekdays and Saturdays were equal to 13.76 km/h and 13.23 km/h. Trolleybuses used separate lanes with a combined length of 1.4 km. The share of trolleybus services in the public transport market in Brno was equal to 16% of the vehicle-kilometers.

In Parma trolleybuses are operated as part of the public transport system organized by Parma city and municipality in the Emilia-Romagna region by Società per la mobilità e il trasporto pubblico (SMTP). The main tasks of this organization focus on planning the development of transport infrastructure, as well as raising funds for investment. It also plans and promotes the public transport service in Parma and integrates it with privately owned passenger vehicles. The management of the public transport network is undertaken by outsourcing companies.

Parma trolleybus are operated by a public transport company, Transportii pubblici Parma (TEP) – the organizational and legal form of a joint stock company owned by the public. In addition to trolleybuses, the company also owns 345 buses, including 90 powered by compressed natural gas (CNG). The trolleybuses are thus operated as part of a single organizational structure with buses. In 2011 their share in the public transport market was less than 8.5% of the company's fleet.

The timetables for trolleybuses are prepared by TEP. Trolleybuses are not operated seven days a week. In July and August the trolleybus transport is suspended and substituted by buses. This is also the case when maintenance work is performed on the roads and the trolleybus infrastructure. From September to June, trolleybuses in Parma are operated on weekdays and Saturdays, but not on Sundays. In the year 2011 trolleybuses serviced 3,699 vehicle-kilometers each and every weekday and Saturday, with an operating speed of 15.05 km/h. The maximum number of vehicles in movement was 21. The vehicles did not use separate lanes, although they did have a single street in the city center free from all other traffic. The share of trolleybus services in the public transport market in Parma was equal to 4.4% of vehicle-kilometers.

In Szeged trolleybuses are operated as part of a public transport system integrated by the public transport authority, whose main task is to collect revenue from ticket sales. Local transport services in Szeged are performed by two companies, namely:

- Szegedi Közlekedési Társaság (SZKT), operating trams and trolleybuses;
- Tisza Volán (TV), operating buses.

SZKT is of municipal ownership and TV is owned by the state. Trolleybuses in Szeged are operated together with trams and separately from buses.

Timetables for trolleybuses in Szeged are prepared by the company which operates the vehicles and accepted by the public transport authority. Trolleybus transport is operated all year round, 7 days a week. In the year 2011 4 out of 5 lines were operated 7 days a week. The maximum number of vehicles in operation was 30, including 20 articulated trolleybuses. During weekdays, Saturdays and Sundays the trolleybuses serviced 6,644, 3,888, 3,888 vehicle-kilometers respectively. The supply of trolleybus services was thus the same during Saturdays and Sundays and equal to 69% of the supply on weekdays. The operating speed on weekdays was equal to 15.8 km/h. The combined length of the lanes was 2.9 km. The share of trolleybus services in the public transport market in Szeged was 17.9% of the vehicle-kilometers.

The basic data relating to the organization and management of trolleybus transport in cities participating in the Trolley project is presented in Table 5.1.

From the data in Table 1 relating to the cities participating in the Trolley project, it can be concluded that in the year 2011:

- in all the cities except Parma trolleybuses were operated throughout the year;
- only in Brno and Eberswalde were all trolleybus lines operated every day of the week;

- in each city the number of vehicles in operation was between 11 and 120;
- only in Eberswalde and Brno was the number of vehicle-kilometers on Saturdays and Sundays was decreased by more than 50%. In Parma the number did not decrease at all on Saturdays, yet all services ceased to operate on Sundays and holidays.
- the operating speed on weekdays was between 14 and 16 km/h, while on Saturdays and Sundays it was between 13 and 18 km/h.

Table 5.1. Organization of the service of trolleybus transport in 2011 in cities participating in the Trolley project

Ordinal	Parameter	City					
		Salzburg	Eberswalde	Gdynia	Brno	Parma	Szeged
1.	Period of Operation	Whole year	Whole year	Whole year	Whole year	10 months	Whole year
2.	Number of Lines	9	2	12	13	4	5
3.	Number of lines operated all year	8	2	8	13	0	4
4.	Maximum number of operated vehicles	86	11	72	120	21	30
5.	Maximum number of operated articulated vehicles	86	11	0	20	0	20
6.	Amount of vehicle-kilometers – Weekdays	16,350	2,523	13,601	21,500	3,699	5,664
7.	Amount of vehicle-kilometers – Saturdays Operating speed – Weekdays	14,123	1,055	11,244	9,100	3,699	3,888
8.	Amount of vehicle-kilometers – Sundays	9,557	1,018	8,353	9,300	0	3,888
9.	Operating speed – Weekdays	16.32	16.04	15.39	13.76	15.05	15.8
10.	Operating speed – Saturdays	17.59	17.52	15.47	13.23	15.05	16.0
11.	Operating speed – Sundays	18.38	17.52	15.57	13.23	–	16.0

Source: own work based on data received from companies operating trolleybuses in the above cities.

Chapter 6. The Costs of Trolleybus Transport

6.1. The Systematization of Prime Costs in Trolleybus Transport

The general costs of each transportation company, including urban transport companies, consist of the total costs incurred in order to provide a given service, expressed in a monetary form, and accounted for in a given period of time.

The classification of such costs is carried out in cross sections corresponding with various types of useful information concerning their extent, structure and dynamics.

The costs of an urban transport company can be grouped in the following way:

a) According to types of activity:
- The costs of the basic activity: exclusively the costs of the activity which constitutes the reason for the company's existence (i.e. providing a transport service for passengers);
- The costs of complimentary activities – isolated in cases where the subject is in charge of facilities that fulfil activities complimentary to the basic activity (i.e. maintenance facilities, boiler houses, social complexes, workforce hotels);
- The costs of administration and management – supporting and maintaining the management, training and administrative positions;

b) According to the level of complexity:
- Prime costs – there is no possibility to divide them into components (i.e. depreciation deductions, salaries),
- Joint costs – groups of prime costs (i.e. costs of maintenance, departments);

c) Costs according to type:
- Utilization of material and energy, including fuels and industrial gases,
- Outsourced services,
- Taxes and fees including: – excise duty,
- Salaries,
- National insurance and other benefits,
- Depreciation,
- Remaining costs according to type (business travel; car allowance; accommodation, fairs, exhibitions, advertising allowances; content and personal insurance; gratuities);[1]

[1] In compliance with the Polish Accounting Act, 29 September 1994, – legislation in force as at 1/01/2011 (Dz. U. z 2009 r. nr 152 poz. 1223). The above order is considered a basic requirement for the companies to produce a profit and loss account in an annual financial report.

d) According to the level of fluctuation in the incurred costs:
- Overhead costs – their nature is fixed and independent of the manufacturing process of commodities or services. They include the depreciation of fixed assets (real estates, means of transport, other fixed assets, intangible and legal assets) as well as taxes and fees (insurance, tenancy costs, rent),
- Variable costs – increasing and decreasing in proportion to the production volume. Part of the costs is proportional to the number of carried passengers or cargo (i.e. costs of the passenger service, re-loading), and part is directly dependant on the distance travelled, meaning the volume of travelled kilometres (i.e. fuel costs). Variable costs include:
  - Utilization of supplies and energy (electrical and thermal),
  - Utilization of propellants,
  - Utilization of the tyres,
  - Utilization of other materials,
  - Outsourced services (transportation, maintenance, communal, IT, telecommunication, other),
  - Salaries and surcharges (drivers, helpers, technical workers, management and administration),
  - Business trips,
  - Training;

e) According to the way the cost is generated:
- Direct costs – concerning the calculation units established for accounting (i.e. vehicle kilometre, vehicle hour),
- Indirect costs – concerning a single, type-identified transportation service. They are accounted for in a conventional manner, usually as a surcharge on the direct costs. The direct costs are usually understood as department and general costs (companywide).

f) According to the company's function (the reason for incurring a cost):
- Maintenance costs,
- Service generation costs (concerning traffic management and carriage services),
- Management costs,

g) According to the company's organisational structure (source):
- Basic departmental costs,
- Complimentary departmental costs,
- Management costs,
- Service sale costs.

The classifications given above outline where costs are incurred and the relationship between them in a given period. Depending on the need of the company's activity analysis, a specific classification is chosen. For research purposes they can be classified according to their nature, function and [economic] calculation. The following should be considered as the basis for the account:
- The total prime costs according to their type;
- The total prime costs according to their [economic] calculation;
- The total prime costs according to their function;
- The individual prime costs;

- The fragmentary prime costs.[2]

The costs incurred by the carriage organisers and carriers in urban transport are considered to be prime costs, where:

$$K_w = K_m + A_m + K_p + K_f$$

K_w – stands for prime costs [koszty własne]
K_m – stands for supply costs [koszty materiałowe]
A_m – stands for depreciation [amortyzacja] (calculated from the initial value of the non-current assets)
K_p – stands for the labour costs [koszt pracy]
K_f – stands for financing costs [koszty finansowe]

In the breakdown of costs according to type, the account for total prime costs is aimed at grouping the costs in tangible, non-tangible and financing contexts. It includes the following groups of costs:

a) Depreciation,
b) Utilization of supplies and energy,
c) Outsourced services,
d) Salaries,
e) National insurance and other benefits,
f) Taxes and fees,
g) Other types of costs, such as business travel, property insurance.

In the above arrangement points a–b are treated as tangible costs, point d as non-tangible costs, and points c, e, f, and g as financing costs. The arrangement does not allow for an analysis of the relationship between the costs and their source or the stages of the transport process. This requires that an account of the total costs in their functional context is created, dividing the costs according to their source as follows:

a) Costs of the basic activity including: utilisation of direct supplies, salaries of workers directly involved in the manufacturing process, outsourced services, outsourced processing, preparation of new services,
b) Department costs – indirect costs of manufacturing incurred by the departments concerned with basic production, depreciation and maintenance costs of the equipment, internal transport, utilized tools, light, heating and cleanliness of the department,
c) Management costs – salaries of the board and managers, costs of the business trips, connectivity, office, expense account, advertising, taxes and fees, warehouse and laboratory maintenance, company cars expenses,
d) Purchase costs – costs of supplies,
e) Sales costs – concerning services on sale and including i.e. advertising costs,
f) Complimentary activities costs – costs of the maintenance workshops, boiler houses, as well as living and social units.

[2] *Transport*. Ed. by W. Rydzkowski, K. Wojewódzka Król, Wydawnictwo Naukowe PWN, Warszawa 2007, p. 346.

In the profit and loss account, by function of gross expenditure the costs are grouped in a way which enables the calculation of individual costs of the enterprise. The costs are divided into groups incorporating the following:

- Direct costs:
  - Direct supplies,
  - Depreciation of transport costs,
  - Direct salaries,
  - Other direct costs.
- Indirect costs:
  - Departments,
  - Companywide,
- Sales of transport services.

The companies of urban transport are interested mainly in the calculation of individual costs. The account of individual prime costs in transport is governed mainly by the ways in which transport service prices are being shaped. In the account of the individual prime costs the components of the costs are gathered in groups of direct and indirect costs.

In the case of trolleybus transport, in a situation where the carrier manages the technical infrastructure required to perform the service, prime costs include the costs of maintenance, servicing and renovation of this infrastructure. The infrastructure costs are fixed costs, which depend marginally on the volume of transportation tasks.

The correct functioning of urban transport in a situation where the functions of the organiser and carrier are divided into two entities, requires certain types of settlements between the commissioner (local government or its organisational unit) and the operator (carrier). The choice of suitable settlement units, which would constitute appropriate means of conveying the costs, is necessary. In urban transport the vehicle kilometre constitutes the most commonly applied unit. There are also other units such as vehicle hour, vehicle or route.

A vehicle kilometre constitutes a unit which stands for the distance travelled by a vehicle in a given time.

A vehicle hour constitutes a unit which measures the time of engagement of vehicles fulfilling a given task (i.e. exploitation work). It is calculated as the difference between the time the activity ended and the time it commenced. This measure is used mainly in exploitation data in passenger transport, but seldom in economic accounts. It is also applied during planning (especially in the division of services). Currently the vehicle hour unit is not employed on a larger scale in settlements between the carriers and the commissioners of a given transportation task. It can be used as a complimentary measure, i.e. in settling the ineffective working hours of a vehicle.

Assuming the vehicle kilometre is a basic cost calculation unit in urban transport, then the variable costs can conventionally include the costs dependable on the number of performed vehicle kilometres. Similarly the fixed costs can include the costs dependable on the number of performed vehicle hours, the number of utilized rolling stock and the length of routes:[3]

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[3] *Transport miejski…*, p. 133.

Therefore:

a) The variable costs per 1 vehicle kilometre can be expressed by a following formula[4]:

$$k_z = k_{mp} + k_o + k_{rt},$$

where:

k_{mp} – stands for the costs of propellants, oils, grease and solar energy used for traction purposes,
k_o – stand for tyres,
k_{rt} – stands for the repairs carried out due to utilisation, as well as the refurbishing of the rolling stock, tracks and network,

b) The overhead costs dependant on the number of vehicle hours performed can be expressed by the following formula:

$$k_{sg} = k_{vr} + k_{mr} + k_{ow} + k_{oz},$$

where:

k_{vr} – stands for salaries, national insurance, and uniforms for the vehicle crews,
k_{mr} – stands for the supplies related to transport services (excluding tyres and propellants),
k_{ow} – stands for the departmental traffic costs,
k_{oz}, – stands for the surcharge on department-wide costs.

c) The overhead costs per 1 vehicle:

$$k_{sp} = k_{aw} + k_{pw},$$

where:

k_{aw} – stands for the depreciation of the rolling stock,
k_{pw}, – *stands for the servicing of the rolling stock.*

d) The overhead costs per 1 kilometre of the route:

$$k_{ss} = k_{al} + k_{pl},$$

where:

k_{al} – stands for the depreciation of tracks and network,
k_{pl} – stands for the maintenance of the tracks and network.

The above division of costs enables the introduction of the following formulas:

a) The formula for the gross prime costs in urban transport[5]:

$$K_c = W_{km} k_z + W_g k_{sg} + W_e k_{sp} + L_t k_{ss},$$

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4 The formula should incorporate depreciation of the rolling stock if it is calculated using the mileage method,

5 *Transport* miejski…, p. 134.

where:

W_{km} – stands for the number of vehicle kilometres performed,
W_g – stands for the number of vehicle hours performed,
W_e – stands for the number of vehicles in the inventory,
L_t– – stands for the length of the exploited routes.

b) The formula for the unit cost in urban transport:[6]

$$K_{wkm} = \frac{K_c}{K_{km}}$$

6.2. External costs of transport

An analysis of the profitability of the operation and development of trolleybus transport must take into account its external costs and compare them to the external costs of alternative transport services, for example buses.

The external costs of transportation are costs or part costs that are not born by the operators involved in transport production, though they, the operators, are responsible for creating them. The community as a whole bears the burden of these costs, although they are essentially incurred at a more local level.

In recent years, the European Commission has placed great emphasis on the necessity for external costs to be taken into consideration as part of the transport operation costs account and profitability of investment.

The most commonly used methods in the valuation of external costs include:[7]

the damage valuation method;

- the avoided cost method; estimates the cost of the measures to be taken to reduce the external costs to a socially acceptable level;
- the replacement market method: an attempt to assess changes in the value of the goods subjected to the negative impact of transport;
- the willingness to pay method; consists of assessing the amounts which people who are inconvenienced by public transport would be willing to pay in order to resolve the problem;
- the compensation method: determines the acceptable level of financial compensation for the damage caused by transport;
- the method of evaluating the physical processes and their valuation: consists of estimating the physical changes occurring in the environment under the influence of transport and then determining their effects in terms of value.

6 *Ibidem*.

7 S. Puławska, *op. cit.*, s. 48–49.

The diversity of methodological approaches to the issue of the valuation of external costs has prompted the European Commission to support activities to develop a manual on means of evaluating external costs in the transport sector. In 2007 the book titled "Handbook on estimation of external costs in the transport sector. Produced within the study Internalization Measures and Policies for All External Costs of Transport"[8] was published. At the same time the European Commission published a consultation paper" Preparation of an Impact Assessment on the Internalization of External Costs Consultation Document", in which methods for estimating costs were published. The methods presented were met with both positive appraisal[9] and critical assessment[10].

The manual distinguishes the following categories of external costs:

- congestion;
- accidents;
- air pollution;
- noise;
- climate change;
- other (e.g. related to landscape transformation, water pollution).

Directive 2009/33/EC of the European Parliament and of the Council of Europe of 23 April 2009 on the promotion of clean and energy efficient road transport vehicles, requires entities and certain operators to take into account the power factor, the environmental impact during the whole life of the vehicle, including energy consumption, CO_2 and some other pollutant emissions when purchasing road transport vehicles,in order to promote and stimulate the market for energy-efficient, clean vehicles.

In assessing the impact of electrically powered transport, the method by which the energy is produced is important. To characterize the production of electricity, the structure of electricity production in selected EU countries has been shown in Table 6.1. This allows the presentation of the current values (at a national level) of the share of carbon free energy sources in total electricity production. This data was used in Chapter 7, in which, due to the absence of local data on the structure of electricity production, average values for the country have been used for the purpose of analyzing the effectiveness of the trolleybus system.

In the model comparing external trolleybus and bus costs, the structure of electricity production should be taken into account. German studies conducted by the VDV[11] provide justification for this procedure. They compared the various public means of transportation in terms of external costs during a full, seventeen-year life cycle, with the structure of electricity production also being taken into account. It was trolleybuses using electricity from fully renewable sources which were compared most favorably.

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[8] *Handbook on estimation of external costs in the transport sector. Produced within the study Internalisation Measures and Policies for All external Cost of Transport*. Delft 2008. Ver. 1.1.

[9] *Results of the Consultation on the Internalization od External Costs* (TREN.A2/EMD (2007)).

[10] *External Costs in the Transport Sector – A Critical Review of the EC-Internalisation – Policy*. Institute for Transport Economics at the University of Cologne. May 2008.

[11] R. Pütz: *Quo Vadis Linienbus-Elektromobilität? Paper presented on the conference* „New Horizons for Urban Traffic", Luzerna, November–December 2010.

Table 6.1. Structure of electricity generation by fuel in selected EU countries (in %)

Type of fuel	Country							EU27
	Austria	Czech Rep.	Germany	Hungary	Italy	Poland	Sweden	
Total electricity prod.	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Solid fuel	6,8	54,8	41,8	16,5	13,1	86,6	1,2	24,7
Petroleum products	1,8	0,2	1,3	1,3	7,1	1,8	1,2	2,5
Gases	22,6	4,7	15,4	31,2	52,1	4,1	2,5	23,5
Nuclear	.	32,5	22,3	42,2	.	.	38,8	27,3
Renewables:	67,9	7,5	17,5	8,0	26,5	7,2	55,3	20,9
Hydro	58,5	3,9	4,3	0,5	18,0	2,2	44,7	11,8
Wind	2,9	0,3	6,0	1,3	3,0	1,0	2,3	4,4
Solar	0,1	0,7	1,8	0,0	0,6	.	0,0	0,7
Biomass / bio-wastes	6,4	2,5	5,4	6,1	3,1	3,9	8,2	3,6
Geothermal	0,0	.	0,0	.	1,7	.	.	0,1
Others	0,7	0,0	1,4	0,5	0,9	0,1	0,8	0,8

Source: based on Energy. Country factsheet, Brussels, 2012, V.1.3.

The currently observed dynamic development of power systems, including the favorable forecasts for electric batteries, constitutes the aspect most difficult to grasp in this analysis. The cost of the production of such batteries should drop by around 60% by 2020.

Among the currently available commercial and technical means of transport, electric public transportation is potentially the least harmful to the environment. This determines the level of external costs generated by the transport.

Analyzing the impact of trolleybus transport on the environment in the city, the local structure of electricity used by this means of transport should be considered. This factor has been taken into account whilst building the efficiency model, in Chapter 7. Its importance lies in the way in which electricity is obtained. In the case of coal energy, which is the basis of energy for trolleybus transport, only the consequence of the transfer of CO_2 emissions from a city, to the area where the coal power plant is located needs to be taken into account. In this case, even the most technically equipped trolley system does not meet the requirements for full cleanliness since it generates CO_2. Nevertheless, it does so outside the city, and its advantage over the bus system is smaller in terms of emissions. However, in a case where electricity is derived entirely from carbon free sources (hydropower, wind, solar) the trolleybus system has a strong advantage over buses, as it emits practically no CO_2. It should be added that nuclear power, in addition to not being a renewable energy source, is not seen as a non-emission source, as it generates other substances, of which radioactive waste has the most harmful effect

Among the trolley bus systems in cities participating in the project, only Trolley Salzburg and Eberswalde can prove the non-emission origin of the electricity used in urban transport. It is in the countries of Central and Eastern Europe, where the share of non-emission energy is less than 15%, that the structure of electricity production has to undergo the most extensive changes.

6.3. Trolleybus Transport Costs in the Cities Participating in the Trolley Project

This part of the analysis includes the costs of trolleybus transport in selected partner cities participating in theTrolley project, i.e. Salzburg, Parma, Gdynia, Szeged, and Eberswald.

Despite the efforts that had been made to unify the various elements of the analysis of the selected cities, a full comparability of results was not presented. To a large extent, this is due to the different accounting systems in individual partner countries. Also important are the individual economic and financial solutions applied in different transport companies and their activity profile. To some extent, the local and national transport policy on the electric drive can be decisive. Finally, the reason for the differences is the varying structures of the public transport systems in the cities analyzed. In all cities buses powered by internal combustion engines are operated, and additionally, in Gdynia and Parma, there are gas-powered buses. Trams are operated in Szeged.

Data collected during the project on the costs incurred by public transport companies in the twin cities had to be limited to the direct fixed and variable costs of the means of transport in question. The aim of the analysis is to compare the operation costs of different means of transport in the urban transport system, which differ in terms of their drive(motor), and energy sources, and therefore the costs of purchase, maintenance and amortization. Other costs, such as indirect factory overhead and departmental costs are similar for all means of transport, regardless of the type of drive. Therefore there is no need for them to be presented.

In analyzing the above, the following methodology has been adopted:

- Firstly, the calculation of the direct costs of trolleybus transport has been presented.
- The direct costs for bus transport has then also been provided (where this was possible due to the availability of data).
- Followed by the generic structure as the direct costs of trolleybus transport (in one case, a bus) on the basis of the actual book values, taking into account the wear and tear of fixed assets.

The comparative analysis presented sometimes provides divergent data. This is due to the use of two methodologies. The first is based on the use of the actual costs for the accounting year 2011, calculated for 1 vehicle-km (VKT). The second takes the value of amortization of a new vehicle at the prices of 2012.

Calculation of the unit cost of the bus and trolleybus transport in Salzburg is shown in Tables 6.2 and 6.3.

Table 6.2. Calculation of the unit cost of trolleybus transport in Salzburg in 2011

Lp.	Cost items	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE (ROUTE-DEPENDENT)		–	2,514	–
1.	Electricity:	PLN/VKT	–	0,714	–
1.1.	– the price of 1 kWh (net)	PLN	0,28	–	–
1.2.	– standard energy consumption per 1 km	kWh/1 km	2,55	–	–
1.3.	– overhead costs of energy consumption	%	0	–	–
2.	Service and repair:	PLN/VKT	–	1,80	–
2.1.	– the cost determined by the status quo	PLN	105.882,35	–	–
II.	DIRECT COSTS VARY ACCORDING TO TIME (TIME-DEPENDENT)				93,235
3.	Amortization/ depreciation:	PLN/hour	–	–	39,305
3.1.	– the price of a new vehicle	PLN	3.400.000,00	–	–
3.2.	– the amount of annual capital allowance D(9(depreciation)	PLN	136.000	–	–
3.3.	– annual working time of the vehicle	hour	3.460	–	–
4.	Drivers' salary and overheads:	PLN/hour	–	–	53,93
4.1.	– monthly salaries	PLN	7.121,16	–	–
4.2.	– adjustment due to holidays and sick leave	%	0	–	–
4.3.	– the amount of salary overheads	%	21,4	–	–

Source: Own calculations based on accounting data Salzburg AG.

Table 6.3. Calculation of the unit cost of bus transport in Salzburg in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	3,598	–
1.	Fuel and oil:	PLN/VKT	–	2,398	–
1.1.	– the price of 1 liter of fuel (net)	PLN	4,36	–	–
1.2.	– standard fuel consumption per 100 km	1/100 km	55,0	–	–
1.3.	– overhead costs of oil consumption	%	0	–	–
2.	Service and repair:	PLN/VKT	–	1,20	–
2.1.	– the cost determined by the status quo	PLN	247.058,70	–	–
II.	DIRECT COSTS VARY ACCORDING TO TIME (TIME-DEPENDENT)				78,015
3.	Amortization:	PLN/hour	–	–	24,085

3.1.	– the price of a new vehicle	PLN	1.000.000,00	–	–
3.2.	– the amount of annual capital allowance	PLN	83.333,34	–	–
3.3.	– annual working time of the vehicle	hour	3.460	–	–
4.	Drivers' payment and overheads:	PLN/hour	–	–	53,93
4.1.	– monthly salaries	zł	7.121,16	–	–
4.2.	– adjustment due to holidays and sick leaves	%	0	–	–
4.3.	– the amount of salary overheads	%	21,4	–	–

Source: Own calculations based on accounting data Salzburg AG.

In regards to Salzburg, the comparison of direct costs which vary according to the route falls in favor of trolleybus transport. There is a slight difference of 0.48 PLN (0.12 EUR), in the cost of of 1 vehicle-km (VKT), thanks to the low cost of electricity. Moreover, there is a great margin of susceptibility to changes in the cost of this energy, that is an incredible 171%. It means that an increase in electricity prices at this growth rate, whilst diesel fuel prices remain stagnant, still equates to lower direct costs associated with the movement of the vehicle. When taking into account the amortization costs charged for 1 vehicle-km, it suggests that the operating costs of are lower. This is due to the substantially higher purchase prices of new trolley buses in relation to those of new combustion-powered buses.

In terms of the costs connected with trolleybus transport, the most important item is that of the drivers' salary. (Table 6.4).

Table 6.4. Generic structure of the direct costs of 1 vehicle-km trolleybus transport in Salzburg

Type of cost share	share[%]	value[PLN]
Energy costs	7,42	0,714
Maintenance costs	18,70	1,80
Driver's salary	32,94	3,17
Network maintenance costs	16,92	1,629
Amortization	24,02	2,312
Total	100,0	9,625

Source: Own calculations based on accounting data, Salzburg AG.

Vehicle maintenance is the third largest cost item. A slightly smaller share is taken up by maintenance costs (including substations), with power consumption being the least costly.

The total direct cost of 1 vehicle-km of a trolleybus calculated for Salzburg AG is 9.63 PLN (2.41 EUR), which among the partner cities of Trolley project analyzed, is the highest.

Tables 6.5 and 6.6 show the calculation of operational unit cost for trolleybus and bus transport in Parma.

Table 6.5. Calculation of the unit cost of trolleybus transport in Parma in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	4,21	–
1.	Electricity :	PLN/VKT	–	1,629	–
1.1.	– the price of 1 kWh (net)	PLN	0,65	–	–
1.2.	– energy expenditure quota per 1 km	kWh/1 km	2,5055	–	–
1.3.	– overhead costs of oil consumption	%	0	–	–
2.	Service and repair:	PLN/VKTm	–	2,58	–
2.1.	– the cost determined by the status quo	PLN	317.646,90	–	–
II.	DIRECT COSTS VARY ACCORDING TO TIME (TIME-DEPENDENT)				87,75
3.	Amortization:	PLN/hour.	–	–	35,37
3.1.	– the price of a new vehicle	PLN	2.600.000,00	–	–
3.2.	– the amount of annual capital allowance	PLN	104.000	–	–
3.3.	– annual operating time of the vehicle	hour	2.940	–	–
4.	The remuneration of drivers and the overheads:	PLN/hour.	–	–	52,38
4.1.	– monthly salary	PLN	8.800	–	–
4.2.	– the amount of salary overheads	%	19,73	–	–

Source: Own calculations based on accounting data of provider TEP SpA.

Table 6.6. Calculation of the unit cost of bus transport in Parma in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	6,478	–
1.	Fuel and oil:	PLN/VKT	–	2,398	–
1.1.	– the price of 1 liter of fuel (net)	PLN	4,194	–	–
1.2.	– the fuel consumption per 100 km	1/100 km	41,58	–	–
2.	Service and repair:	PLN/VKT	–	4,08	–
II.	DIRECT COSTS VARY ACCORDING TO TIME(TIME-DEPENDENT)				64,85
3.	Amortization:	PLN/hour	–	–	12,47
3.1.	– the price of a new vehicle *	PLN	733.330,00	–	–
3.2.	– the amount of annual depreciation	PLN	36.666,50	–	–
3.3.	– annual working time for vehicle	hour	2.940	–	–
4.	The remuneration of the drivers and overheads:	PLN/hour	–	–	52,38
4.1.	– monthly salary **	PLN	8.800	–	–
4.2.	– the amount of salary overheads	%	19,73	–	–

Source : own study based on accounting data of provider TEP SpA

** value calculated on the basis of the average purchase price of the Solaris Urbino 12 delivered in 2012

** Based on the Italian National Institute of Statistics, www.istat.it, collection date 07.02.2013

In Parma direct costs associated with vehicle mileage are higher in the case of bus transport when compared with trolleybus transport. 1 vehicle-km of trolleybus costs 9.37PLN (2.34 EUR) and bus-10.29 PLN (2.57 EUR). These values do not reflect the cost of network maintenance, which is shown in Table 6.7. within the generic structure of the direct costs of trolleybus transport. In the structure, the share of the cost of maintaining the network is approximately 5%, other types of costs are 20–30 %.

Table 6.7. Generic structure of the direct costs of 1vehicle-km of trolleybus transport in Parma

Type of cost	Share [%]	Value [PLN]
Energy costs	15,60	1,629
Maintenance Costs	24,72	2,580
Driver's salary	29,50	3,080
Network maintenance costs	5,27	0,550
Depreciation	24,91	2,600
Total	100,0	10,439

Source: Own calculations based on accounting data of provider TEP SpA.

The calculation of the unit cost of trolleybus transport in Gdynia is shown in Table 6.8.

Table 6.8. Calculation of unit cost trolleybus transport in Gdynia in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	1,65	–
1.	Electricity:	PLN/VKT	–	0,532	–
1.1.	– The price of 1 kWh (net)	PLN	0,28	–	–
1.2.	– Standard energy consumption per 1 km	kWh/1 km	1,9	–	–
1.3.	– Overhead costs	%	–	0,268	–
2.	Service and repair:	PLN/VKT	–	0,84	–
2.1.	– the cost determined by the status quo	PLN	49.555	–	–
II.	DIRECT COSTS VARY ACCORING TO TIME				57,37
3.	Amortization:	PLN/hour.	–	–	32,05
3.1.	– the price of a new vehicle	PLN	1.590.000,00	–	–
3.2.	– the amount of annual depreciation	PLN	127.200	–	–
3.3.	– annual operating time of vehicle	hour	3.969	–	–
4.	Drivers' payment and overheads:	PLN/hour	–	–	25,32
4.1.	– monthly salaries	PLN	4.253,72	–	–
4.2.	– the amount of salary overheads	%	20,61	–	–

Source: own calculation based on accounting data of PKT Ltd. in Gdynia.

In comparing the cost of Gdynia's trolleybus company PKT sp. z o. o., the costs of one of the bus company, which is also owned by the city, can be used. The company exclusively operates diesel-powered buses, whereas the two carriers do not differ in terms of operational work.

Trolleybus operator PKT has very low traffic-dependent direct costs per unit of 1 vehicle-km, at 1.65 PLN (0.41 EUR). This is due to the fact that is owns its own comprehensive technical support, as well as the high durability of its fleet.

Direct costs related to work hours, such as depreciation, network maintenance, and drivers' salaries are already higher, despite the fact that the depreciation attributable to 1vehicle-km is the smallest among trolleybus those systems analyzed. All in all, the total direct cost of 1vehicle-km of trolleybus transport in Gdynia amounts to 6.40PLN (1.73 EUR).

The generic structure of the cost of 1 vehicle-km of trolleybus and bus transport in Gdynia is presented in Tables 6.9 and 6.10.

The direct unit cost of 1 bus vehicle-km is higher than that of a trolley by approximately 11.5%, depending on energy costs. It should be noted, however, that the bus operator payment costs provided include all employees in the company. Ensuring the comparability, bus transport would prove to be less costly than that of trolleybus transport.

Table 6.9. Generic structure of the direct costs of 1vehicle-km for trolleybus operator in Gdynia

Type of cost	Share [%]	Value [PLN]
Energy costs	12,66	0,81
Maintenance Costs	12,13	0,84
Payment	47,19	3,02
Network maintenance costs	8,44	0,54
Depreciation	18,59	1,19
Total	100,0	6,40

Source: Own calculations based on accounting data, provider PKT Gdynia Ltd.

Table 6.10. Generic structure of the direct costs of 1 vehicle-km for bus transport in Gdynia

Type of cost	Share [%]	Value [PLN]
Energy costs	30,6	2,18
Maintenance Costs	5,2	0,37
Payment	54,2	3,87
Network maintenance costs	N/A	N/A
Depreciation	10,0	0,714
Total	100,0%	7,134

Source: Own calculations based on accounting data.

Table 6.11 shows the calculation of unit costs of trolleybus transport operating in Szeged.

Table 6.11. Calculation of unit cost for trolleybus transport in Szeged in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	1,9466	–
1.	Electricity:	PLN/VKT	–	0,7146	–
1.1.	– the price of 1 kWh (net)	PLN	0,352	–	–
1.2.	– standard energy consumption per 1 km	kWh/1 km	2,03	–	–
1.3.	– overhead costs of oil consumption	%	0	–	–
2.	Service and repair:	zł/wzkm	–	1,232	–
2.1.	– the cost determined by the status quo	PLN	41.366,86	–	–
II.	DIRECT COSTS VARY ACCORDING TO TIME				
3.	Amortization:	PLN/hour	–	–	81,24
3.1.	– the price of a new vehicle	PLN	2.128.000	–	–
3.2.	– the amount of annual depreciation on	PLN	193.455	–	
3.3.	– annual operating time of the vehicle	godz.	2.381	–	–
4.	Drivers' payment and overheads:	PLN/hour	–	–	20,16
4.1.	– monthly salary	PLN	2.550[1]	–	–
4.2.	– the amount of salary overheads	%	32,8	–	–

Source: Own calculations based on accounting data provider SZKT.

The direct costs of 1 vehicle-km in trolleybus transport in Szeged amount to 1.95 PLN. This is due to the low cost of electricity coupled with low energy consumption (due to flat terrain of the city), and the low maintenance costs of vehicles.

Taking into account other direct costs (network maintenance, depreciation of vehicles and drivers' salary) cost structure is specific. More than 59 % of the cost is depreciation. This is due to the employment of the calculation method based on the depreciation of cost of a newly purchased trolleybus, for which a short, 11-year depreciation period was established. The average period of amortization in other countries fluctuates between 15 and 20 years. The second reason is the low level of usage of a trolley, which results in an annual distances serviced of about 33 000 km. The vehicles of other operators may service twice this distance (eg, Eberswalde up to 62 000 km). The result is a specifically shaped cost structure of 1 vehicle-km for trolleybus transport in Szeged, which is shown in Table 6.12.

Table 6.12. Generic structure of the direct costs of 1 vehicle-km trolleybus transport in Szeged

Type of cost share	Share [%]	Value [PLN]
Energy costs	7,40	0,715
Maintenance Costs	12,76	1,232
Driver's payment	14,82	1,430
Network maintenance costs	5,32	0,5137
Depreciation and amortization	59,70	5,762
Total	100,0	9,65

Source: Own calculations based on accounting data SZKT operator.

Tables 6.13 and 6.14 show the calculation of the operation unit cost for trolleybus and bus transport in Eberswalde.

Table 6.13. Calculation of unit cost in Eberswalde trolleybus transport in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	3,24	–
1.	Electricity:	PLN/VKT	–	1,44	–
1.1.	– the price of 1 kWh (net)	PLN	0,56	–	–
1.2.	– standard energy consumption per 1 km	kWh/1 km	2,57	–	–
1.3.	– overhead costs of oil consumption	%	0	–	–
2.	Service and repair:	PLN/VKT	–		–
2.1.	– the cost determined by the status quo	PLN	1,80		–
II.	DIRECT COSTS VARY ACCORDING TO TIME				90,36
3.	Amortization:	PLN/hour.	–	–	38,59
3.1.	– the price of a new vehicle	PLN	2.600.000	–	–
3.2.	– the amount of annual depreciation	PLN	144.444	–	–
3.3.	– annual operating time of the vehicle	hour	3.743	–	–
4.	Drivers' payment and overheads:	PLN/hour.	–	–	51,77
4.1.	– monthly payments	PLN	8.694,44	–	–
4.2.	– the amount of salary overheads	%	28,364	–	–

Source: Own calculations based on accounting data provider BBG.

Table 6.14. Calculation of the unit cost of bus transport in Eberswalde in 2011

Item	Unit cost elements	Units	Values approved	Cost of 1 VKT	Cost of 1 hour
1	2	3	4	5	6
I.	DIRECT COSTS VARY ACCORDING TO ROUTE		–	4,36	–
1.	Fuel and oil:	PLN/VKT	–	2,64	–
1.1.	– the price of 1 liter of fuel (net)	PLN	4,40	–	–
1.2.	– standard fuel per 100km	1/100 km	60,0	–	–
1.3.	– overhead costs of oil consumption	%	0	–	–
2.	Service and repair:	PLN/VKT	–		–
2.1.	– the cost determined by the status quo	PLN	1,72		–
II.	DIRECT COSTS VARY ACCORDING TO TIME				85,97
3.	Amortization:	PLN/hour.	–	–	34,20
3.1.	– the price of a new vehicle	PLN	1.280.000	–	–
3.2.	– the amount of annual depreciation	PLN	128.000	–	–
3.3.	– annual operating time of the vehicle	hour	3.743	–	–
4.	Drivers' payment and overheads:	PLN/hour	–	–	51,77

4.1.	– monthly payments	PLN	8.697,44	–	–
4.2.	– the amount of salary overheads	%	28,364	–	–

Source: Own calculations based on accounting data provider BBG.

In a comparison of the direct costs of trolleybus and bus transport in Eberswalde the trolleybus comes out on top. Taking into account the costs associated with the route (fuel /energy and vehicle maintenance) 1 vehicle-km serviced by bus costs about 34% more than by trolley. This is influenced by the relatively low energy costs associated with trolleybuses (despite the relatively high cost of electrical energy in Germany).

The total direct costs of 1 bus vehicle-km in Eberswalde amount to 9.14 PLN (2.29 EUR) and are higher than those of the trolleybus at 0.88 PLN (0.22 EUR). This indicates that, in certain circumstances – technical and organizational, economic and financial – trolleybus transport can be seen to be more effective when compared to bus.

The generic structure of the direct costs of 1 trolleybus vehicle-km in Eberswalde are shown in Table 6.15.

Table 6.15. Structure of the direct costs of one wozokm Eberswalde trolleybus transport.

Type of costs	share [%]	value [PLN]
Energy costs	17,22	1,44
Maintenance Costs	21,52	1,80
Payments	34,39	2,876
Network maintenance costs	1,24	0,104
Depreciation and amortization	25,63	2,144
Total	100,0	8,364

Source: Own calculations based on accounting data provider BBG.

The generic structure of the direct costs of 1 trolleybus vehicle-km in Eberswalde shows that the largest share is taken up by personal costs (34%). This is followed by the depreciation of vehicles and their maintenance. The lowest share of the costs is that of network maintenance, due to that fact that the network is relatively short, in very good condition and, therefore, does not require more resources. Their share of 1.2% is extremely low in the scale of all the analyzed cities.

The analysis of the direct costs of public transport operation in the cities participating in the Trolley project does not allow for easy comparison between them. In any case, it is necessary to take into account the specific conditions in individual cities influencing the level of these costs. With this in mind it is beneficial to study the data in Tables 6.16 and 6.17, which contain the amount and structure of costs of 1 trolleybus vehicle-km in all of the analyzed cities participating in the Trolley project.

Table 6.16 Direct costs of 1 vehicle-km in trolleybus transport in urban areas participating in the project Trolley [in PLN]

City	Direct costs – dependent on route		Direct costs – dependent on time of work			Total
	energy	maintenance	depreciation	network maintenance	payment	
Salzburg	0,714	1,800	2,312	1,629	3,170	9,63
Parma	1,629	2,580	2,600	0,550	3,080	10,44
Gdynia	0,810	0,840	1,190	0,540	3,020	6,40
Szeged	0,715	1,232	5,762	0,514	1,430	9,65
Eberswalde	1,440	1,800	2,144	0,104	2,876	8,36

Source: Own calculations based on previously presented data.

Table 6.17 Structure of the direct costs of 1 trolleybus vehicle-km in urban areas participating in the Trolley project [%]

City	Direct costs dependent on the route		Direct costs – dependent on the time of work			Total
	energy	maintenance	depreciation	network mainte-nance	payment	
Salzburg	7,42	18,70	24,02	16,92	32,94	100,00
Parma	15,60	24,72	24,91	5,27	29,50	100,00
Gdynia	12,66	13,13	18,59	8,44	47,19	100,00
Szeged	7,40	12,76	59,70	5,32	14,82	100,00
Eberswalde	17,22	21,52	25,63	1,24	34,39	100,00

Source: Own calculations based on previously presented data.

Large differences in the overall activity of trolleybus operators in the cities participating in the Trolley project, which determine the cost of one trolleybus vehicle kilometer, prevent the drawing of firm conclusions concerning the relative level and generic structure due to the influence of various conditions, which are largely described in this, and earlier sections of this paper.

Chapter 7. Economic Efficiency of Trolleybus Transport

7.1. The Assessment Method of the Economic Efficiency of Trolleybus Transport

Every major investment decision needs sound analysis of its potential economic outcomes. Undoubtedly, building a new trolleybus network and the development of new lines within an existing one is an example of such a venture. Long-term financial outcomes also lead to decisions concerning the current modernization of the infrastructure and the trolleybus fleet, or generally about maintaining the trolleybus traffic on a given line or network. In all these cases, the analysis of economic efficiency is a helpful tool, which enables conscious and informed decisions to be made.

For many years, economic analysis for investments in the public sector in Poland was seldom carried out. The decisions taken were usually of a political nature, and not in the best interests of the issue at large. However, in the case of trolleybus networks there are traces of analysis and discussion in literature. Nowadays, most infrastructure investments, including new trolleybus lines and their modernization, are financed by EU funds, in which case the analysis of efficiency is required. However, some authors of feasibility studies try to avoid the direct comparison of two action scenarios, which differ only in their choice of traction, i.e. identical "bus" and "trolleybus" variants.[1,2]

The TROLLEY project, aimed at openly drawing a comparison between the efficiency of buses and trolleybuses. This chapter will present a general analysis of the efficiency of trolleybus transport as an alternative to classic buses, together with indications of conditions in which trolleybuses are a more advantageous solution.

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[1] See eg.: J. Kaczmarczyk, 50 lat trolejbusów w Gdyni, „Transport Miejski" 3/1994, pp. 10–11, K. Szałucki, O. Wyszomirski, Postanie Przedsiębiorstwa Komunikacji Trolejbusowej jako kolejny etap restrukturyzacji gdyńskiej komunikacji miejskiej, „Transport Miejski", 3/1998, pp. 22–24. The matter of trolleybus communication efficiency can be found also in number 4/1989 of „Transport Miejski", with two notes on the subject, in the context of the possible construction of trolleybuses in Krakow, as well as in number 10/1989, where the main subject are trolleybuses in Słupsk and Dębica (both networks do not exist anymore).

[2] The current guidelines concerning economic and financial analyses for EU projects can be found in: Niebieska księga, Sektor transportu publicznego, Jaspers, Warszawa 2008 (http://www.pois.gov.pl/WstepDoFunduszyEuropejskich/Documents/BlueBookPublicTransport_21_09_forPDF.pdf, January 2, 2013).

The elaboration of the model and the discussion of conclusions will take place in three stages. The current part contains general assumptions of the model, whereas the following part discusses data units concerning internal and external costs of trolleybus transport, as well as the results of modeling the efficiency of trolleybus transport for different sets of assumptions. Then cross-sectional study of the results will be presented, the aim of which is to define the factors determining the economic efficiency of trolleybus transport.

The analysis of economic efficiency can be carried out using two basic methods:[3]

- Taking into account only the cash flow statements – such an analysis is called a financial analysis.
- Taking in to account the cash flow statements, as well as the external costs, i.e. those costs which are not directly covered by the party who generates them (eg. pollution costs); such an analysis is called an economic analysis, as well as a social-economic analysis, due to the fact that external costs are also described as social costs.[4]

The following study will take into consideration both of the above-mentioned concepts.

The financial analysis will take into account:

- the cost of the trolleybus infrastructure – its construction and maintenance;
- the cost of the trolleybus fleet and, correspondingly, the bus fleet – its purchase and maintenance;
- the cost of energy – electricity (trolleybuses) or diesel fuel (buses).

The economic analysis additionally will take into account (for buses, as well as trolleybuses):

- the cost of pollution emission;
- the external cost of noise pollution.

What should be emphasized is the fact that non-discriminatory costs were omitted, such as the remuneration of the drivers of the vehicles.

In both cases, the sum of costs will be calculated for a period of 30 years, after which the residual value of the infrastructure is assumed to be 35%. During this time period, the trolleybus fleet will be changed several times, where the operation periods of the vehicles are not divisors of 30, which is why the costs of trolleybus fleet are counted not as a single financial cost, but as a long-term straight-line depreciation throughout the whole operation period. It is quite an inconsequence, as the financial analysis is generally carried out on the basis of cash flow statements. This exception is, however, the simplest solution to the problem connected with the fraction amount of vehicle life cycles during the period of analysis.

The costs for the operation period (the life cycle costs) are calculated by adding up and then discounting, thus calculating the present value of the costs which will be carried in the future, as presented in the formula:[5]

[3] Ibid.

[4] See eg.: H. R. Varian, Mikroekonomia, Kurs średni – ujęcie nowoczesne, Wydawnictwo Naukowe PWN, Warsaw 2005, pp. 597–602.

[5] See eg.: M. Podgórska, J. Klimkowska, Matematyka finansowa, Wydawnictwo Naukowe PWN, Warsaw 2005, pp. 36–66.

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

where:

LCC – Life-Cycle-Cost;

t is the number of the specified period (the successive year of analysis);

Ct are the costs carried in the specified period (expressed in current prices);

r is the discount rate, amounting to 5% in the financial analysis and 8% in the economic analysis.

To differentiate between the financial and economic analysis, LCCF and LCCE will be distinguished; i.e. the financial and economic life cycle costs accordingly.

All of the models use the concept of the so-called break-even point, which is expressed as the critical traffic intensity. The break-even point shows an average amount of departures for which the life cycle costs (both economic and financial) are equal for bus and trolleybus transport. If the level of traffic exceeds this point, the electrical traction is more cost-effective than a regular bus. This stems from the intuitive (at the stage of designing the model) assumption that with heavy traffic, trolleybuses are more cost-effective. This assumption shall be verified in the course of further analysis.[6]

Thus, LCC shall be calculated as a traffic intensity function. Traffic intensity is expressed by the amount of departures in one direction during one weekday, where it has been assumed that the year consists of 295 equivalents of weekdays, e.g. during the year there are 225 weekdays and 140 Saturdays, Sundays, holidays and days included in long weekends, with an average level of traffic at 50% of a normal weekday.

7.2. Primary and External Costs of Trolleybus Transport

As mentioned before, the internal costs of trolleybus transport have been divided in to three basic groups: infrastructure, vehicles and energy.

Infrastructure costs and vehicle purchase have been determined on the basis of individual analyses concerning experiences in Gdynia and Lublin, two Polish cities in which trolleybuses, are in service and which have modernized and developed their networks in recent years.

Assumptions concerning infrastructure costs are presented in Table 7.1. It is assumed that one linear kilometer of traction network costs 1.5 million PLN, whereas a traction substation – 1.3 million PLN. For every 10km of network approximately 3 substations are required.[7]

The yearly maintenance cost of one linear kilometer of traction network is 100,000 PLN per year.

[6] It is also called the critical point or the point of balance. Rachunkowość zarządcza i rachunek kosztów. Praca zbiorowa pod red. G. K. Świderskiej, Difin, Warsaw 2002.

[7] If not stated differently – one linear kilometre of network is one kilometre of a two-way network. The analysis is conducted in netto prices (VAT not included).

Table 7.1. Basic Parameters Concerning Investment and Operational Costs of Trolleybus Infrastructure

Traction network [PLN/km]	1 500 000
Traction substations [PLN]	1 300 000
Number of substations per km of network	0.29
Yearly maintenance costs [PLN/km]	100 000
Residual value of infrastructure (after 30 years)	35%

Assumptions concerning purchase and maintenance costs of vehicles are presented in Table 7.2.

It is assumed that a trolleybus is 27% more expensive than a bus, however, its life cycle is considerably longer, reaching 20 years, whereas that of a bus is 12 years. Due to this fact, however, the maintenance costs of a trolleybus are over 25% higher than those of a bus.

The assumed purchase costs of a trolleybus and a bus (980,000 PLN and 770,000 PLN accordingly) are a result of the analyses of tender procedures. In both cases it concerns a standard (12-meter) low-floor, well-equipped passenger vehicle, yet without additional technical equipment, such as batteries or supercapacitors.

Table 7.2. Basic Parameters Concerning Investment and Operational Costs of a Trolleybus

Cost of bus [PLN]	770 000
Cost of trolleybus [PLN]	980 000
Bus operation period [years]	12
Trolleybus operation period [years]	20
Bus operation costs [PLN/km]	1.05
Trolleybus operation costs [PLN/km]	1.3

Assumptions concerning energy costs are in Table 7.3. Analysis has shown that in city traffic a bus uses about 40 l/100 km, whereas one liter of diesel oil costs about 4 PLN net. Diesel oil prices show movements of about 4% per year (real growth), which was assumed for the whole analysis period.

A trolleybus uses 190 kWh of energy / 100 km, and 1 kWh costs 0,30 PLN. Electric energy costs are characterized by a lower price movement – initially it has been assumed at 2% per year in real growth.

Table 7.3. Basic Parameters Concerning Energy Costs

Bus – petrol consumption [l/100km]	40
Bus – cost of petrol [PLN/l]	4.00
Bus – real yearly growth rate of petrol prices [% per year]	4%
Trolleybus – electric energy consumption [kWh/100 km]	190.00
Trolleybus – cost of electric energy [PLN/kWh]	0.30
Trolleybus – real yearly growth rate of electric energy prices [% per year]	2%

Assumptions concerning the individual value of emission and external costs, which are included in Tables 7.4 and 7.5, are as follows:

The EURO 5 norm – for the absolute magnitude of the pollution emission in the case of buses.

The average value of emissions from the Kozienice power station for the absolute magnitude of pollution emission in the case of trolleybuses.

European Union Guideline no 2009/33 for individual costs of CO2, NMHC and NOx emission.[8]

The analyses of the group: Mayeres, Ochelen i Proost – for the remaining contaminations not included in the above-mentioned guideline (CO, PM10), as well as for noise.[9]

External costs of noise have been assumed for trolleybuses at the level of 1/6 of the cost of bus noise.

The calculation has been created for the rate 4 PLN = 1 EUR.

Table 7.4. External Costs of Pollution Emission

Pollution	CO	NMHC	NOx	PM10	CO2
Bus Euro 5 [g/vehkm]	0.040	0.110	2.830	0.030	1400.000
Trolleybus [g/kWh]	0.086	0.000	1.822	0.220	811.300
Individual external cost of emissions [EUR/g]	0.00001	0.00100	0.00440	0.08931	0.00009

Table 7.5. External Costs of Noise Pollution

Bus – costs of noise [EUR/vehkm]	0.06
Trolleybus – costs of noise [EUR/vehkm]	0.012

The basic results of modeling for the aforementioned assumptions are presented in Fig. 7.1 and 7.2. The financial break-even point, calculated in Fig. 7.1 is about 190 departures per working day, which corresponds to a frequency of ca. 5 minutes. This means that in Polish conditions, with the earlier described assumptions, trolleybus transport is essentially more efficient than buses, if the amount of departures in a weekday is over 190 on a given section. Of course, if the whole network is taken into consideration, consisting as it is of unevenly loaded sections, then the value of the break-even point refers to the average traffic density as measured along the length of the network.[10]

8 Directive 2009/33/Ec Of The European Parliament And Of The Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles, Official Journal of the European Union L 120/5, 15.5.2009

9 I. Mayeres, S. Ochelen and S. Proost: The marginal external costs of urban transport, "Transportation Research", Part D: Transport and Environment, 1996, nr 1, pp. 111–130.

10 The figures of frequency are exemplary and have been calculated with the assumption that trolleybuses or buses ride from 6 a.m. to 10 p.m. in even intervals.

It should be emphasized that the inclination of the curve depicting the overall cost of trolleybus transportation (red curve) is smaller than that of the blue curve. This means that the floating charges of trolleybus transport are lower than in the case of bus transport.

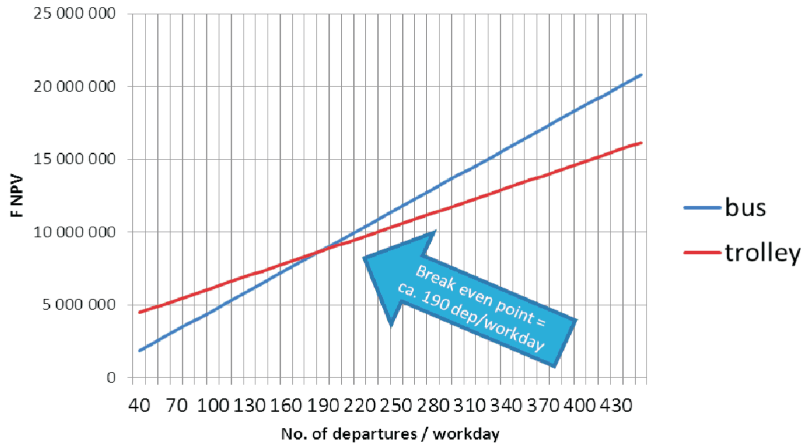


Fig. 7.1. Results of the Financial Analysis in the Initial Scenario

The results of the economic analysis in the first scenario might be considered quite surprising (see Fig. 7.2), as the break-even point is moving up in this case and is about 250 during a workday, which corresponds to a frequency of ca. 4 minutes. This means that the inclusion of external costs is "non cost-effective" for trolleybus transport.

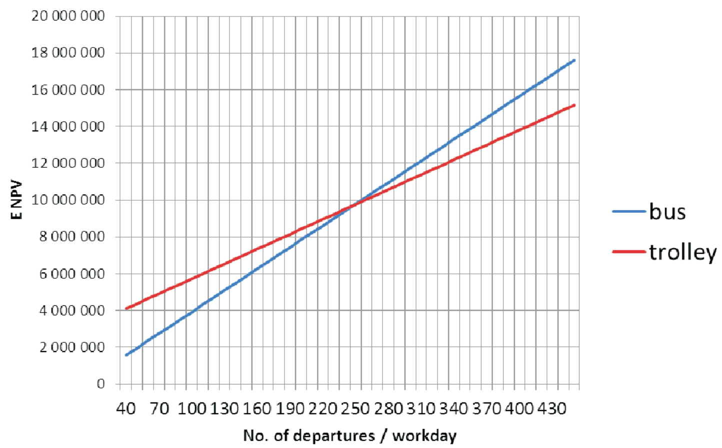


Fig. 7.2. Results of the Economic Analysis in the Initial Scenario

These unfavorable results are caused by the fact that modern diesel engines emit a relatively small amount of pollution, whereas in the model it was assumed that the overall electric energy, with which trolleybuses are powered, comes from coal power plants, with the assumption of the real emission level for Poland. This can be clearly seen on Fig. 7.3 (purple section). It should be emphasized that the model does not differentiate, within the majority of available studies, between the financial values of particular emissions in different locations.

In addition, Fig. 7.3 indicates that the greatest advantage of trolleybuses is the low cost of energy, which in electric tractions are about 4 times lower than in the case of buses. Assuming that in the full cost model the energy is ca. 25%, then the reduction of energy costs is ca. 18% of the overall cost.

Yet infrastructure is a serious cost-driving factor in the case of trolleybus transport, which may constitute half of the costs, given low traffic. This proves the initial assumption that trolleybus technology is justifiable in the case of heavy traffic where the costs of infrastructure are divided by the large volume of passengers and passenger-kilometers.

Moreover, what is worth noticing is the fact that the vehicle costs of the two compared tractions barely differ, as the longer operation time of the trolleybus compensates its higher purchase and maintenance costs..

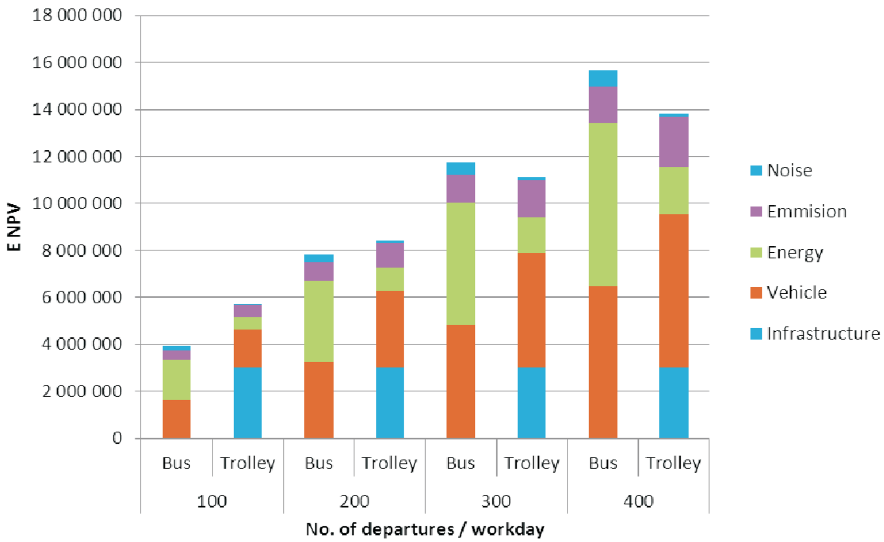


Fig. 7.3. The Detailed Structure of Financial and Social Costs in the initial Scenario

In the next parts of the current analysis, the assumptions of the model will be changed and an interpretation of the results stemming from the new assumptions will be carried out.

Firstly, it is crucial to take into consideration a situation in which electric energy comes from sources which do not cause the emission of carbon dioxide; that is, from the so called zero-emission sources of electric energy (eg. hydro-electric, wind turbine or atomic power stations). In the discussed model, other assumptions remain the same.

In this case, the results of the financial analysis, presented on Fig. 7.1, do not change. However, the results of the economic analysis (see Fig. 7.4) indicate that with the usage of zero-emissions, the break-even point of the trolleybus transport – taking into consideration external costs – declines to ca. 170 departures per day, which corresponds to the frequency of ca. 5.5 minutes in workdays.

In the "zero-emission" scenario the trolleybuses are characterized by external costs which are 20-times lower than in the case of buses (see Fig. 7.5).

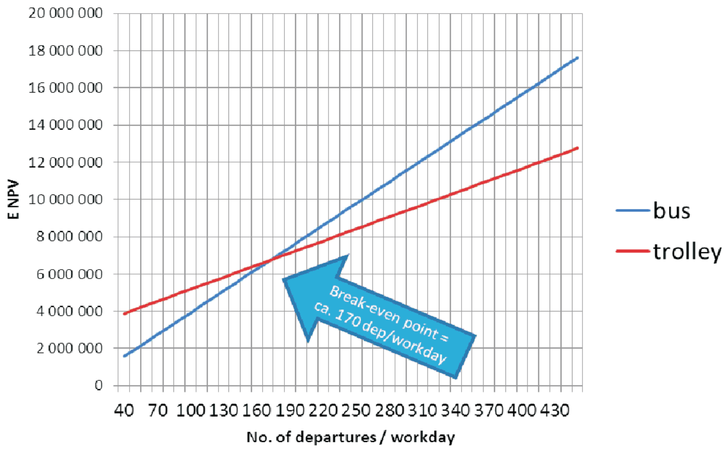


Fig. 7.4. Results of the Economic Analysis in the "Zero-Emission" Scenario

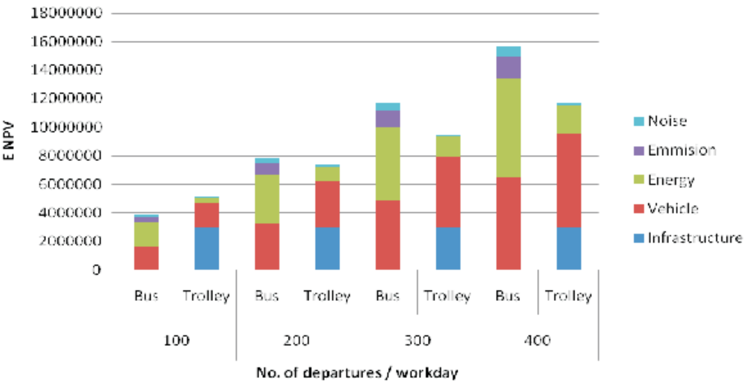


Fig. 7.5. The Detailed Structure of Financial and Social Costs in the "Zero-Emission" Scenario

In the last analysis the price of diesel oil was assumed at 4 PLN/l (net) and its dynamism at 4% per year. The substantial contribution of energy costs to the general cost structure and the inconstancy and differentiation of diesel oil prices in various countries requires that a modeling with different assumptions also be carried out.

Thus, in the following part diesel oil prices will be assumed at a higher rate of 5 PLN/l and a slightly higher dynamism of its real growth (5% per year instead of 4% per year). Combined with zero-emission energy sources, this creates a set of assumptions, which more closely resembles the conditions in Western Europe. However, due to the convergence process, it should be expected that in the long run the presented assumptions would have more in common with the conditions in Poland

In this case the results of the financial analysis considerably change in favor of trolleybus transport (see fig. 7.6). The break-even point is only 120 departures per weekday, which corresponds to a frequency of 8 minutes. This considerable shift of the break-even point shows that the assumptions of the model are very flexible when prices of diesel oil are concerned, as well as demonstrating the vast influence these prices have on the efficiency of electric traction as a means of public transportation.

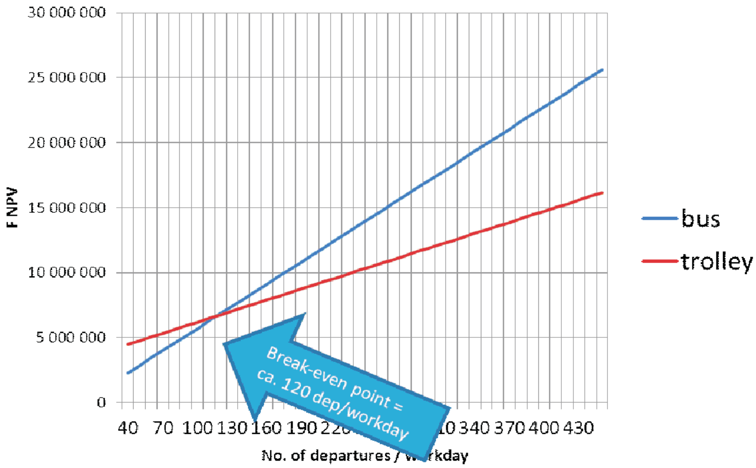


Fig. 7.6. The results of Financial Analysis in the High diesel Oil Prices Scenario.

This also obviously changes the results of the economic analysis (see fig. 7.7), where the break-even point is ca. 110 departures per weekday, which still corresponds to an average frequency of ca. 8 minutes.

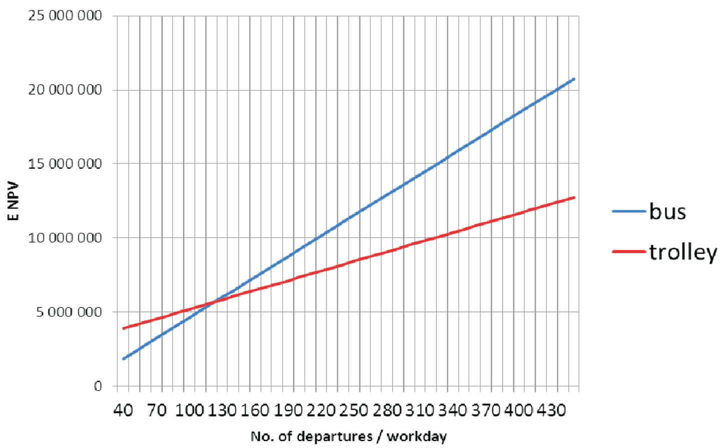
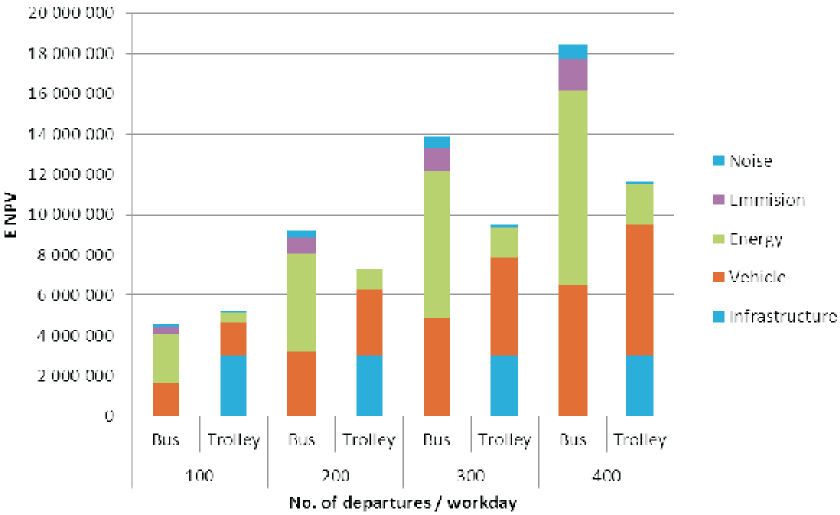


Fig. 7.7. The Results of Economic Analysis in the High diesel Oil Prices Scenario.

The cost structure analysis (see Fig. 7.8) indicates that in the high diesel oil price scenario the overall energy cost in the case of trolleybus transport is ca. 1/5 that of bus transport.

It should also be emphasized that despite the fluctuation of the diesel oil prices, the model constructed is considerably less flexible in terms of electric energy prices, as these have a smaller contribution to the life cycle costs of trolleybus transport. Moreover, electric energy prices are also considerably more stable.



Fig,. 7.8. A detailed Financial and Social Cost Structure in the High diesel Oil Prices Scenario

In the final scenario the prior existence of trolleybus infrastructure already exists, i.e. Only maintenance costs, not construction costs are included. The assumption concerning low diesel oil prices is once again taken into account, this time in conjunction with zero-emission energy sources. Naturally, infrastructure maintenance costs at an unchanged level, are still included.

It should be emphasized that this scenario concerns not only cities, which have a trolleybus network, but also those cities in which its construction is financed through external sources, such as EU, governmental or federal grants.

The results of the modeling indicate that, with such changed assumptions, the break-even point achieved is considerably lower than in the earlier scenarios. In the case of the financial analysis it is ca. 95 departures per weekday, which corresponds to an average frequency of 10 minutes (see Fig. 7.9), whereas in the case of the economic analysis – ca. 80 departures, thus the critical frequency is ca. 12 minute (see Fig. 7.10).

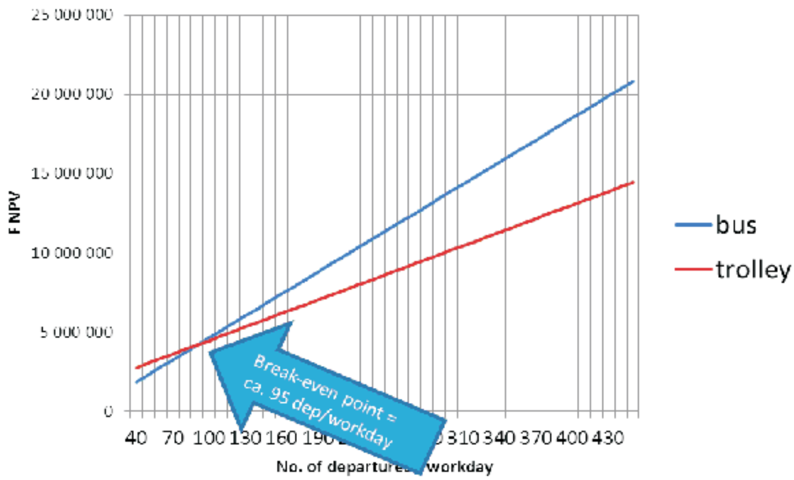


Fig. 7.9. The results of the Financial Analysis in the no Investment Costs for Infrastructure Scenario

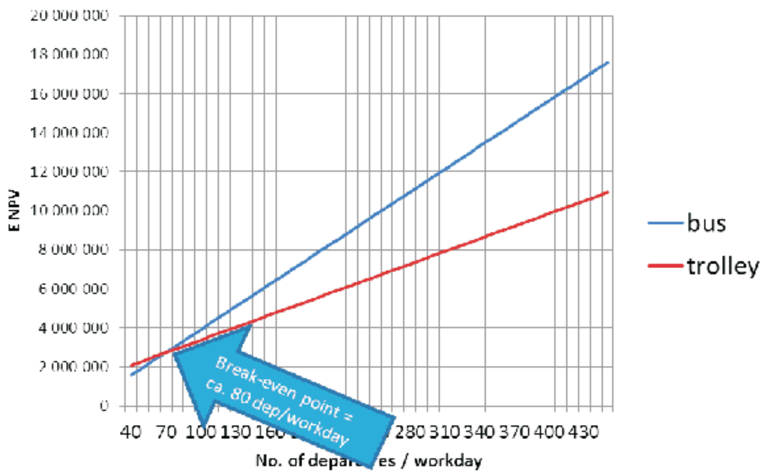


Fig. 7.10. The Results of the Economic Analysis in the No Investment Costs for Infrastructure Scenario

In the analyzed scenario, the infrastructure costs – limited to the maintenance costs – still remain a considerable component of the life cycle cost in trolleybus transport (see Fig. 7.11), yet their contribution is lower than in other cases. Above the break-even point, the most important component of the life cycle costs in the case of trolleybus transport is the cost of the trolleybus fleet.

It should be emphasized that in the case of heavy traffic (300 departures per weekday), trolleybuses can ensure savings of 20% financially and 25% when external costs are concerned.

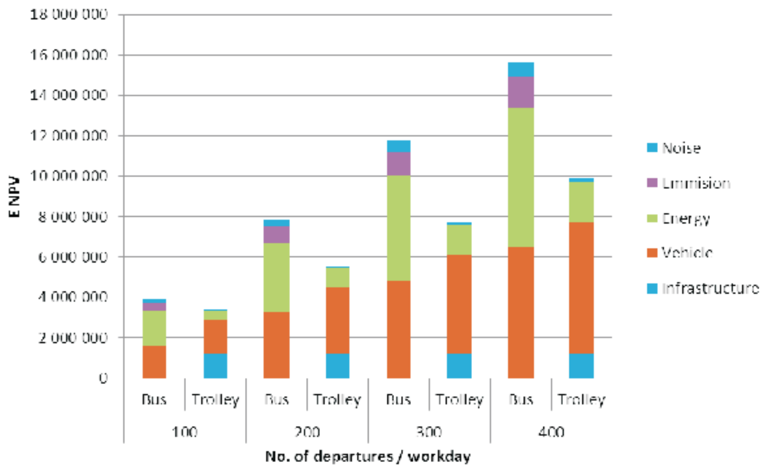


Fig. 7.11. A detailed Financial and Social Cost Structure in the No Investment Costs for Infrastructure Scenario

To conclude the above-mentioned points, it should be stated that for newly constructed networks, the break-even point for trolleybus transport is ca. 110–250 departures per weekday, depending on local conditions, which corresponds to an average frequency of 4–8 minutes. These figures concern a situation in which the construction of the infrastructure is fully financed by the self-government and takes into consideration the external benefits.

When account investment costs for infrastructure, which are applicable in the case of existing networks or those financed through external sources, are not taken into account, the break-even point decreases to 80–95 departures per day, thus to the frequency of ca. 10–12 minutes.

The full configuration of break-even points is in Table 7.6.

Table 7.6. The Configuration of Break Even Points of Trolleybus Transport

	Initial scenario	"Zero-emission" scenario	High prices of diesel oil scenario	No investment costs for infrastructure scenario
Break-even point in the financial analysis [departures in a weekday] (average frequency)	190 (5 mins)	190 (5 mins)	120s (8 mins)	95 (ca. 10 mins)
Break-even point in the economic analysis [departures in a weekday] (average frequency)	250 (4 mins)	170 (5.5 mins)	110 (8 mins)	80 (ca. 12 mins)

It should be noted that the following are favorable to the economic efficiency of trolleybus transport:

- Heavy traffic on a given network – this, above all, should stem from sound decisions concerning area planning and the choice of routes for trolleybus communication.

The intensity of traffic can also be stimulated by the transport authority, especially in a situation in which there are twice as many bus lanes as those of trolleybuses.

The model presented shows that in such a situation, the marginal cost in trolleybus transport is lower than that of bus transport, and if possible, the former should be used. (The curve presenting the overall cost of trolleybus communication is less inclined than the analogical curve of the bus communication).

However, the decision can be obscured by the average cost calculation, which may be higher for the trolleybus traction; yet, one should be aware that the average cost in trolleybus communication takes into consideration infrastructure costs, which are of fixed character. A solution that broadens the knowledge of the decision makers, concerning the real shape of the overall cost curve, may be dividing the rate paid to the public transport operator into two parts – a fixed part for the maintenance of infrastructure and a variable part, dependent on operation works.

- Fluctuating fuel prices – investing in trolleybus communication can be treated as a safeguard against fluctuating fuel prices, even in situations where trolleybuses show a slightly lower efficiency; this inefficiency becomes the equivalent of the cost of a hedge contract.
- Low emission and zero-emission energy – due to its reliance on coal energy, trolleybus communication can be characterized by a higher level of external costs than bus communication.
- External financing – at a time where there is the possibility of EU funding, investing in trolleybus communication is a good idea for ensuring a continual decline of operation costs, which in the current economic climate, are quite difficult to achieve while realizing other projects (e.g. the expense associated with the maintenance of trolleybus networks; modern buses which use a considerable amount of petrol; doubts arising in regards to the effectiveness of intelligent transport systems).

Finally, it should be noted that the model presented above could, in terms of the economic analysis, overestimate the break-even point of trolleybus communication, as with the available resources it produces an equal amount of pollution emissions in city and rural areas. This overestimation concerns only the emission scenario, thus the size of the deformation is not considerable. However, taking into consideration the differentiation of the harmfulness of pollution emitted in city and rural areas creates a desired direction for completing the model.

The input data of the model is approximated and in the case of a concrete investment they may be shaped differently than in the example presented. Thus every investment decision should be made on the basis of a separately parameterized efficiency model, and the figures presented treated only as auxiliary.

Chapter 8. Marketing in Developing the Image of Trolleybus Transport

8.1. Conditions Shaping the Image of Trolleybus Transport

In this section characteristics of the city will be presented in relation to marketing philosophy. Subsequently, the focus will be shifted to the role of public transport in developing a city's competitive marketing advantage. After the above has been considered,, issues involving the development of the image of trolleybus transport's will be presented.

Image is an element of a brand (including the brand of a city). It has an influence on its perceived value. It is also a central factor in the positioning of a product within various markets[1]. The development of the image of a city constitutes a constant process of management of a given location, the division of the residents according to target groups, as well as the selection of suitable attractions. These actions form the basis of a wide range of marketing activities aimed at both internal and external users of a city.

In terms of the degree of aggregation, a product in the marketing of a city may be considered:

- a "city mega-product";
- a partial product, forming part of the "city mega-product", which can be considered a separate product in the exchange process.

The concept of a "city mega-product" encompasses both material ingredients, such as technical and social infrastructure, residential, commercial and industrial buildings, and non material ingredients, such as a specific "social atmosphere" (determined by its inhabitants attitudes towards problems and the future), the openness of the city, its image among visitors and locals (related to the level of social optimism and a sense of identification with the place of residence), history and tradition, and natural conditions. The composition of these factors forms the general "image" of the city mega-product, which is a subjective category and varies depending on the type of customer, his preferences, the degree of recognition of his needs, and his purchasing power[2]. Individual components of the product have a relatively

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[1] Doole I., Lowe R.: International Marketing Strategy. Analysis, development and implementation. Published by South-Western Cengage Learnings 2008, 5th edition, p. 283.

[2] M. Wołek: Transport publiczny w kształtowaniu wizerunku miasta. [In:] XI Symposium of the Faculty of Management and Computer Modelling. Published by Kielce University of Technology, Kielce 2013 [in print].

varied meaning for specific groups of buyers. An extreme case is that of "niche" cities offering specialized products that are difficult to create and to imitate, which is a significant entry barrier for potential competitors. Such products are aimed at relatively narrow target groups and concern needs of higher priority and changes in the way in which free time is spent in rich post-industrial societies.[3].

However, for its users, the city mega-product is seen through the lens of partial products, which to them have the greatest importance. The dysfunction of one of them, with others remaining at a relatively high level can play a part in reducing the extent to which the consumer the customer is satisfied. An example of this process can be found in an inefficient transport system, which makes it difficult to access various sub-products located within a city, thus increasing the cost of their acquisition by adding the external costs of transport congestion. This may lead to substantial disparities in the development and perception of the city, expressed by disproportionate urbanization[4]. In addition, the same partial product can be perceived and evaluated differently depending on who the "users of the city" are. Their large variation makes the development of the image of a city a complex, long-term project.

One of the key partial products of the city is public transport, which determines the spatial and temporal availability of the city. The public transport system in a city can be analyzed as:

- an element of the city's transport system (public and private transport);
- a significant beneficiary of budget expenditure;
- an instrument of social politics (influencing the availability of urban goods with the help of a tariff-ticketing system);
- an element of municipal services and labor markets;
- a factor effecting the competitiveness of a city;
- a partial product of the city's marketing concept.

Reasons for considering public transport a partial product which has an impact on developing the image of the city include:

- its impact on the city's development;
- the fact it determines the availability of other partial products;
- its impact on the perception of the city, both by residents and visitors;
- the fact it uses innovative technological and organizational solutions;
- the growth in importance of environmental issues and the related quality of life in the city.

Basic reasons for developing the image of public transport in European cities include:

- the problem of private automotive transport and the varied speed of its development;
- the uncontrolled suburbanization processes („urban sprawl");
- rising passenger expectations for quality of services (a car being a strong alternative),
- public transport development projects, which by themselves may be considered proof of attractiveness within the market;
- financial constraints associated with high public debt;
- a change in passenger structure requiring new forms of marketing communication to be sought.

[3] Wołek M.: Marketingowe kształtowanie przewagi konkurencyjnej miasta. Studium na przykładzie Gdyni. Faculty of Economics of the University of Gdańsk, Sopot 2005. Typescript, p. 167.

[4] Ibidem, p. 168.

Trolleybus transport is currently not considered a modern and efficient means of urban transport. This is particularly evident among those decision-makers, who in shaping the development of urban transport policy, do not take trolleybus transport in account. This is due to a great number of reasons, which can be categorized as follows:

- economic issues (additional costs required for the construction of the overhead wire infrastructure and a higher unit cost compared to a standard bus);
- operational issues (additional costs associated with maintaining the overhead wire infrastructure, the existence of other means of urban transport with electric traction);
- architectural issues (the presence of overhead wires lowers the value of urban space, especially in the city center);
- political issues (previous decisions on developing other means of transport, such as gas or hybrid buses);
- image issues (reluctant support for trolleybus transport – a somewhat antiquated "old-fashioned" means of urban transport).

The biggest barrier affecting the positive exchange of experience and the promotion of the development of trolleybus transport, is the relatively small number of cities in which this form of transport is currently used in comparison to its heyday. A large number of such are outside the European Union, which is an additional difficulty affecting in establishment of cooperation and the the search for sources of funding. Due to a lack of demand for trolleybuses in the European Union, they are produced in small batches, which is reflected by a higher unit price. In addition, trolleybus transport is usually the first to receive cutbacks in a situation where there are limited resources available for appropriate maintenance of public transport, leading to a gradual deterioration of the quality of services. This is particularly noticeable in relation to bus transport. As a result, after a period of gradual reduction in the range of trolleybus transport services, a decision is often made to close them down althogether. This tends to be justified by rising fixed costs associated with the need to maintain the additional power supply infrastructure and an outdated fleet. By analogy to the negative phenomena in the urban transport market one can speak of a "spiral decline in trolleybus transport", the essence of which is the reduction of the supply, which leads to the reduction of the attractiveness trolleybus transport and an increase in fixed costs. This in turn is a prerequisite for further activities limiting the scope of operation of trolleybus transport and the deterioration of its market position especially in favor of the more flexible (independent of the necessary power supply infrastructure) bus transport.

An image is shaped by traits ("attributes"), whose importance is a matter of a passenger's subjective evaluation. „How a passenger perceives the reality of the situation depends not only on his personal experience of the service but also on associated services, on the information he receives about the service (not only that provided by the company, but also information coming from other sources), on his personal environment, etc.[5]"

Offering integrated services under a single brand associated with modernity fosters a positive image of public transport. Cain et al. (2009) found that "full bus rapid transit (BRT)

[5] WG 3 "Market Organisation – Contracts, incentives and monitoring". Background Paper for the fourth WG Meeting in Prague, 9th and 10th October 2008 SPUTNIC – Strategies for Public Transport in Cities, p. 13, http://www.sputnicproject.eu

is perceived by everyone as superior to regular bus services in the Los Angeles region. In contrast, although other high-quality bus services (non-BRT) also were highly regarded by their users, the general public's view was influenced by the same negative perceptions as regular buses. Hence, modal familiarity led to a higher acceptance of the respective transport mode[6]".

In identifying barriers to the development of trolleybus transport two main target groups should be taken into account: decision-makers responsible for the development of transport policy (politicians, administration, public transport authorities and transport unions, the management of transport operators) and residents, who are also a diverse group. Fig. 8.1. illustrates both this and the main differences between the two groups.

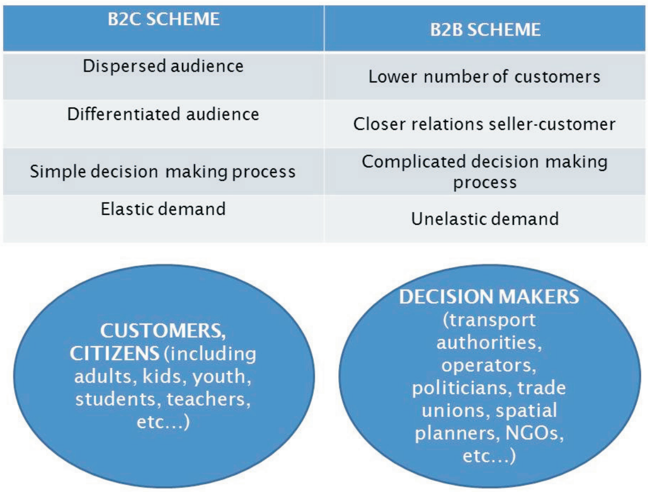

Fig. 8.1. Different groups selected for marketing communication
Source: self-study based on Ph. Kotler, K.L. Keller: Marketing. REBIS Poznań 2012, p. 202–203.

There are significant differences in the transport behavior of the residents and their evaluation of individual means of urban transport. For example, there are differences in the evaluation of quality parameters of bus and trolleybus services in Gdynia (Poland) which are described in chapter 3.2 and 3.4.

"It is important to understand the needs and desires of people who have different motivations affected by different factors". E. Venezia states that "there is a general idea among non-users that public services are badly organized and not adequate to their needs. In fact, it may be that public transport is better than what they think, but they simply don't know anything about it or they have a distorted idea of it[7]". Based on data gathered in marketing research conducted by Public Transport Authority in Gdynia and then processed in the framework of TROLLEY project, it can be said that the frequency with which people travel

6 M. Scherer, K. Dziekan: Bus or Rail: An Approach to Explain the Psychological Rail Factor. "Journal of Public Transportation" 2012 Vol. 15 Nr 1, p. 77.

7 E. Venezia: Sustainability in Cities: Greater Responsibility and Efficiency. [In:] Urban Sustainable Mobility. Ed. By E. Venezia. FrancoAngeli, Milano 2011, p. 101.

by public transport affects the semantic differential of transportation less than the frequency of traveling by car. Differentials created by travelling always by public transport or travelling mostly by public transport are equally by car and public transport are convergent while those created by inhabitants travelling mostly by car and always by car are significantly different[8]. This means that regular users of trolleybus transport determine its image on the basis of their own experiences, while sporadic users – on the basis of ideas and fragmentary opinions he had heard from other people. This is an indirect confirmation of the previously cited Author's thesis and points to the need for various promotional activities depending on a number of factors that determine the communication behavior of residents.

Trolleybuses are a mature means of public transport. The improvement of its efficiency using modern technology, the growing independence from the network, as well as ecological advantages are obvious among decision-makers and the majority of passengers in cities operating this mode of public transport.

Tab. 8.1. SWOT analysis of trolleybus transport: a promotional perspective

Strengths	Weaknesses
Mature and tested technology. Reliability. Well known service costs (also in longer period). Stable energy prices. Lack of local emissions. Partial independence of the network. Long life-cycle. Better performance in hilly terrain. Energetic efficiency. Strong market position in a few European countries.	Dependence on the network infrastructure, which is regarded as factor which decreasing the quality of urban space. Higher costs of acquisition of rolling stock. A rather weak image. Seen as an "out-of-date" mode of transport. High costs of introduction due to the need for infrastructure investment.
Opportunities	Threats
High capacity for implementation of innovative solutions (supercaps, batteries, etc…). Growing importance of ecological issues. Unstable oil market. Development of batteries and other electric energy storage technologies. Appropriate to the smart city concept (integrating transport, energy and ICT issues). Development of electric vehicles resulting in lower prices of components and spare parts.	Stigma of "market niche". Rise in electricity prices. Further development of the hybrid bus treated as a substitute for the trolleybus. Inappropriate comparison to the tram system.

Source: M. Wołek: S.I.I. Report of Existing Promotion Activities. Report prepared within TROLLEY project. Final Report. TROLLEY Project, Central Eastern Europe Programme, May 2013, p. 11.

However, in some cases the advantages of trolleybus transport can be viewed negatively, i.e. long life-cycle of electric vehicles might be regarded as an disadvantage in comparison

[8] K. Hebel, M. Wołek, O. Wyszomirski: WP5: Improved Image and Patronage. Output 5.1.4 – Survey on Perception of Trolleybuses. Final Report ver. 3.0. TROLLEY Project, Central Eastern Europe Programme, December 2012, p. 53–54.

to a standard diesel bus. Longer service, for example, means that trolleybus vehicles are less likely to be seen as modern when compared to bus fleets which are renewed more frequently.

Some weaknesses and threats presented in Tab. 8.1 are strictly a matter of image and are based on well-established stereotypes, especially in cities that do not have trolleybus transportation. This is why the framework of TROLLEY project includes activities aimed at identifying interesting measures for the of promotion of trolleybus transport, taking into account local conditions and low financing costs needed for the implementation of said measures.

Developing the image of a city is a long-term process, which is also difficult to measure. It has a significant impact on the ability of the city to compete. Public transport is one of the key components of a city mega-product and can significantly determine its image, especially among its residents, due to the fact that it facilitates access to other partial products.

In conclusion, the development of the image of trolleybus transport is essential because of:

- the varied meaning of the image of trolleybus transport for a comprehensive (holistic) image of public transport;
- the fact that in some cases trolleybus transport acts as a leading factor in determining the image of a given city's transport system;
- ecological values of trolleybus transport;
- the negative stereotype of trolleybus transport among decision makers and residents of cities which do not operate trolleybuses.

8.2. The Desired Scope of Marketing Research in Trolleybus Transport

The specificity of public transport determines the extent of market research carried out in relation to the trolleybus transport subsystem.

In broad terms, marketing research in urban transport includes:

- the behavior and transport preferences of residents, their evolution and trends;
- the degree to which the service properties (parameters) meet the residents' transport preferences;
- the residents' attitude towards the service properties (parameters); towards the suitability of the service;
- the degree to which needs and demand are satisfied;
- decisions made by the residents in relation to transport services;
- factors determining the choice of transport services.

The focus of research concerning the needs and demands of transport is their size in relation to spatial relationships, goals and time periods (day of the week and time) for which they are reported. The subject matter are residents and passengers of public transport, while the spatial scope of research often involves:

- stops and vehicles;
- households;

- workplaces;
- ticket offices.

In terms of research concerning demand, one can specify not only the number of passengers using public trolleybus, but also their structure on the basis of the ticket they use and their authorization for a discounted or free ride. This not only allows for the study of the economic and financial performance of individual trolleybus lines, or even courses, but also allows passenger segments to be indentified and distinguished on the basis of an adopted criterion.

The scope of transport behavior research usually concerns:

- the implementation of urban travel;
- the modal split;
- commuting to work and education;
- the structure of transport on an average day;
- the hierarchy of importance of transport demands;
- assessment of public transport, particularly from the perspective of meeting transport demands;
- factors determining how urban transport is implemented.

The primary purpose of researching the residents' transport behavior is to develop a strategy of shaping the market in order to maintain the loyalty of existing passengers and attract new ones. To develop such a strategy it is necessary to identify the modal split between public and individual transport and the factors determining it. Complementary research is recommended to ascertain the potential reaction of residents to changes in the transport offer mirroring their preferences.

Researching transport behavior enables the modal split between different types of transport to be determined. It allows trolleybus transport's share of the market to be indentified, measured by the number of trips made by residents within a certain period of time (usually a single day). For example, the results of research performed in Gdynia in the year 2010 r. led to the conclusion that with 30% share in transport measured by the number of vehicle-kilometers trolleybuses carry over 32% of public transport passengers organized by ZKM Gdynia.

The share of trolleybus transport may also be determined in relation to the most important destinations, such as commuting to work and education. This allows appropriate adjustment of the transport offer in order to meet basic transportation needs. It is recommended that the participation of trolleybus transport at particular times of the day (hours) is studied in order to identify the share of this means of transport in the implementation of urban travel for those periods of time. This, in turn, triggers justified changes to the schedule, adjusting the supply to the demand and to the adopted rules for determining the modal split between different types of transport.

While researching transport behavior one can also explore specific reasons (other than those arising from trolleybus routes and hours of operation) for choosing trolleybuses or sacrificing trolleybus travel in favor of other types of transport.

It is recommended that the order of importance of transport demands for trolleybus transport is determined. As part of comprehensive marketing research, the order of importance of transport demands is most commonly aimed at public transport as an integrated form of services, but in appropriate cases, trolleybus transport can be treated as a separate segment of supply. Complementary to the research on transport demands, research should be conducted with the aim of examining the degree to which trolleybus transport meets demand. The results achieved for the cross-section of the various segments of the supply (separately for tram, bus, trolleybus and other transport) allow for the comparison and highlighting of significant differences in the perception of different subsystems' transport offer, as well as the perceived degree of integration of public transport.

In the course of research on transport preferences it is advisable that the required level of travel comfort is determined. The target level can be determined by the desired access to a seat and vehicle equipment (air conditioning, voice announcements of stops, electronic information about the vehicle's route, etc.). Equipment which raises the level of passenger comfort is important only to a certain degree: it raises the costs of purchase and operation of vehicles, and it is not always required by the passenger and does not have to influence the choice of public transport in the implementation of urban travel. Market research results in various cities in Poland indicate, that the most important demands recognized by passengers are punctuality, frequency, immediacy of connections and availability. Vehicle equipment was lower in the ranking, among less essential demands. On the other hand, urban transport is increasingly being forced to compete with private cars especially at the level of the, so called, "enhanced product", or services that meet not only the basic needs, but also include additional equipment, ensuring a high level of comfort.

In addition to research related to the offer of trolleybus transport service, its degree of adaptation to the needs of residents, the order of importance of transport demands, their degree of compliance and the image of trolleybus, research can be carried out to assess the functionality and ergonomics of solutions adopted in the design of trolleybuses by manufacturers. Research can be carried out in relation to vehicles provided by manufacturers for tests in typical urban operating conditions. From a passenger's point of view research may concern:

- the seating arrangement;
- the ease of entry and exit;
- interior aesthetics;
- the comfort of travel;
- efficiency of ventilation, heating and air conditioning;
- noise, vibration and shock levels.
- The research in the group of drivers may concern:
- driving ergonomics;
- ventilation, heating and air conditioning efficiency;
- controls distribution functionality.

Although this research is conducted by vehicle manufacturers, and the solutions are the result of many years of experience, certain solutions may be modified based on the results of market research (e.g. the seating arrangement), and the required changes can be included in the terms of the tender specifications.

8.3. Means of Developing the Image of Trolleybus Transport

Case study analysis was used in order to identify and select promotional activities for trolleybus transport. The literature defines Case Study as „[…] a one which investigates the problem to answer specific research questions and which seeks a range of different kinds of evidence[9]". Another description of case study analysis states that it is „an inquiry that focuses on describing, understanding, predicting and/or controlling the individual (i.e. process, person, household, organization, group, industry…)[10]" or an „empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident[11]".

Case study research is a kind of intensive research. Opposite to survey, which is an extensive research made between units of observation, case study is a research made "within the unit of observation[12]". Despite this recognition, collection of selected case studies made it possible (to some degree) to compare them and to draw conclusions on the basis of „cross-case analysis" which is about the „guts" of the case, seen in its wholeness. There is a platform, though, on which sets of wholeness are compared[13]". In the case of this study, promotional activities related to trolleybus transport were the "platform" for comparative analysis.

The advantage of case studies in the context of research in the framework of the TROLLEY project was the fact that they are:

- far from theory;
- a living example – possible to visit, present and follow;
- very attractive when communicating with decision-makers, politicians, media and general audiences;
- possible to describe complexly when using real data.

The analysis concerned nine European cities from seven countries. The largest of the presented trolleybus transport systems is Vilnius (Lithuania), while Landskrona (Sweden) is the smallest, both in terms of the number of trolleybuses in operation and the number of vehicle-kilometers. One of the cities, Lviv (Ukraine), also uses tram transport, while two cities, Salzburg (Austria) and Gdynia (Poland), also make use of the railway.

The scope and structure of promotional activities undertaken in the analyzed cases were dependent on:

- isolating a specific target group for a wider operator/transport organizer marketing strategy or for an urban development strategy;

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9 P. Gillham: Case Study Research Methods. Published by Continuum, London 2000, p. 1.

10 A.G. Woodside: Case Study Research: Theory, Methods, Practice. Emerald, Bingley 2010, p. 1.

11 R.K. Yin: Applications of Case Study Research. SAGE, Los Angeles-London 2012, p. 4.

12 P. Swanborn: Case Study Research. What, why and how? SAGE Publ., London & Thousand Oaks 2010, p. 5.

13 G. Thomas: How to do Your Case Study: A Guide for Students & Researchers. SAGE, Los Angeles – London – New Delhi – Singapore – Washington DC 2011, p. 141.

- the stage of development of trolleybus transport (e.g. celebrating round anniversaries in Salzburg, the need to emphasize various advantages of trolleybuses in order to inform the general community of Landskrona during the first period of its operation);
- implementation of specific projects of modernization and development of trolleybus transport (e.g. the introduction of new vehicles in Gdynia and Parma, plans associated with the introduction of trolleybus transport in Leeds, fleet refurbishment as an opportunity to organize an "open farewell" to old vehicles in Eberswalde);
- other celebrations and events (e.g. European Week of Sustainable Mobility, European Trolleybus Day, conferences etc.);
- educational activities usually aimed at strictly isolated target groups (like Gdynia).

Table 8.2 shows the promotional messages used in developing the image of trolleybus transport in selected European cities.

One of the most important promotional messages related to trolleybus transport concerned its ecological values (among others: Eberswalde, Landskrona, Vilnius, Solingen). In some cases, the fact that the trolleybus operator was supplied by electricity from renewable sources, was in itself an attractive promotional message, which could be easily integrated into the overall ecological campaign. (Landskrona, Eberswalde, Solingen). Moreover, in some of the cities trolleybus transport uses associations with reliability and high service frequency, resulting from the spatial technology of trolleybus lines (like Landskrona).

Table 8.2. Key Messages in Developing the Image of Trolleybus Transport in Selected European Cities

City	General Promotional Message	Tools and themes
Eberswalde	eco-friendliness	100% non-emission energy
Gdynia	innovative system open for further development	Education of citizens
Landskrona	eco-friendliness	"humanization" of each vehicle by giving it a female name starting with "El" (like "electric")
Lviv	eco-friendliness	Education of employees and passengers
Parma	modernity	Integrated promotional toolbox to rebrand trolleybuses
Salzburg	most comfortable	
Solingen	eco-friendliness	100% non-emission energy
Vilnius	eco-friendliness	

Source: self-study.

Table 8.3 presents in a synthetic form the scope and object of actions aimed at developing the image of trolleybus transport in selected European cities. The means most widely used in the development of the image of trolleybus transport was the organization of events and campaigns, often accompanied by outdoor advertising on trolleybuses.

Fig. 8.2. The formal introduction of new trolleybuses into operation in Parma became a great opportunity to showcase the environmental and operational advantages of trolleybus transport. Above: two generations of trolleybuses: Van Hool and Breda Menarini, in the city centre.
Photo: M. Wołek, May 2012.

Historic vehicles are used equally as often, mostly during special events (e.g. anniversary celebrations of trolleybus transport operations, the European Week of Sustainable Mobility, the introduction of new a fleet). The slogan and the logo belong to a means less commonly used in developing the positive image of trolleybus transport. Such means also includes the "humanizing" of trolleybuses in Landskrona by giving them female names starting with "El", which evokes associations with electric transport.

Table 8.3. Scope and object of promotional activities for trolleybus transport in selected European cities.

	Eberswalde	Gdynia	Landskrona	Lviv	Parma	Salzburg	Solingen	Vilnius
Logo	v		v			v	?	
Slogan	v					v	?	
Folders	v	v			v	v	?	v
Journal	v	v					?	
Postcards		v				v	?	
Outdoor	v			v	v		v?	
Outdoor on vehicles		v		v			v?	v
Regular events	v	v			v	v	v?	
Occasional events	v	v	v		v	v	v	v
Old-timers	v	v	v			v	v	
Games		v						
Toys	v							
Dedicated campaigns			v	v		v	v?	

Source: self-study.

As an example of an integrated, yet diversified set of means aimed at developing a positive image of trolleybus transport one should mention BBG (Barnimer Bus Gesselschaft), which also provides services in the regional bus transport market and other in cities in the county (Bernau and Bad Freienwalde). Trolleybus transport passengers account for about 44% of all BBG passengers.

The main groups targeted by BBG in the urban market of Eberswalde are senior citizens, children and adolescents. These groups differ significantly and hence, in terms of promotional activities, different means are required.

The operator widely uses social media to provide information for residents and passengers. Its Facebook page complements the operator's extensive website containing, among others, photos, promotional material, a film promoting trolleybus transport, current information and trivia).

The most traditional form of communication used is the magazine "Unterwegs", available in electronic format, in which trolleybus transport issues are from time to time discussed.

BBG's universal message addressed to the general community concerns the benefits of green trolleybus transport and is spread by the company's website, Facebook page, electronic and printed brochures, as well as exhibitions and conferences.

Fig. 8.3. Poster Advertising the Benefits of Green Trolleybus Transport in Eberswalde
Source: official Facebook profile of BBG, 18.01.2013.

Fig. 8.3. shows a poster advertising the fact that since early 2013 trolleybus transport is supplied with electricity from fully carbon-free sources.

The companies status as one of the leading trolleybus operators in the field of innovative technological solutions (such as supercapacitors installed in trolleybuses) and their use of modern vehicles is reflected in a modern logo design (designed only for trolleybus transport) and a slogan. In 2010, the logo was used as a model to create a plush mascot "Strippi" whose picture was on every new Solaris Trollino trolleybus introduced into service (Fig. 8.4).

The mascot also served to create a local postage stamp available in the Barnim district. In addition, the website offers downloadable wallpapers containing the image of the mascot and commemorating 70 years of trolleybus transport in Eberswalde.

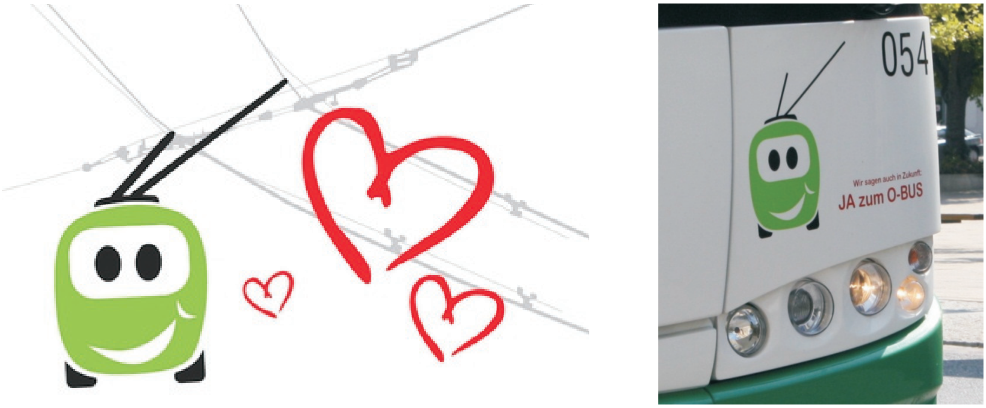

Fig. 8.4. The Strippi mascot and its exposure on trolleybuses in Eberswalde
Source: http://www.bbg-eberswalde.de/maskottchen.php, downloaded: 18.01.2013 and M. Wołek, April 2011.

The introduction of new vehicles to the fleet made it possible to organize a series of events promoting trolleybus transport, including a ceremonial "goodbye" to old trolleybuses, one of which was covered with goodbye messages from residents during an "open day" (Fig. 8.5). The vehicle was still operated for some time in Eberswalde before it was transferred to Budapest.

The celebration of the 70th anniversary of trolleybus transport in the city was also an opportunity to step up promotional activities, highlighting the green advantages of trolleybuses and the fact that only three cities in Germany have this kind of urban transport in operation.

The fact that the tradition of trolleybus transport in Eberswalde is more than 70-year old is also reflected in the slogan on the operator's website ("Barnimer Busgesellschaft Deutschlands ältester O-busbetrieb" – "BBG is the oldest trolleybus company in Germany").

Apart from the plush mascot mentioned before, BBG undertakes a number of other activities aimed at children and young people. One of them consisted in installing seats behind the front passenger door of new trolleybuses so it would allow children to pretend to drive and observe the driver's work (Fig. 8.6).

Fig. 8.5. Trolleybus No 811 on line 861 covered with "personal" goodbye messages from residents of Eberswalde.
Photo: M. Wołek, April 2011.

Research conducted in the framework of TROLLEY project in 2010 has shown that trolleybuses in Eberswalde are viewed as a modern mode of transport. More than a half of respondents claimed that trolleybuses are modern (ranks „good" and „very good"), and only less then fifth stated opposite opinion. (bad and very bad)[14]. It should be noted that only 2% of respondents had no opinion on the matter. The study was conducted at a time when modern vehicles were being put into service, so it can be assumed that it did not have a decisive impact on the assessment of the modernity degree of Eberswalde trolleybus transport.

Fig. 8.6. Special seat for children in a Solaris Trollino in Eberswalde.
Photo: M. Wołek, April 2011.

[14] M. Wołek, K. Migdał-Najman, K. Najman: Local Trolley Guides. Final Report. TROLLEY Project, April 2011.

Another example of effective measures aimed at developing a positive image of trolleybus transport is Salzburg (Austria). Trolleybus transport, just like in Eberswalde, has been operating in the city since 1940 and is a key element of its urban transport system.

It is distinguished by a distinct logo ("Stadt-Bus") and slogan referring to the ecological values of the trolleybus "Sauber. Leise. Obus" – "Clean. Quiet. Trolleybus". In addition, there are other slogans used to emphasize the city – creating role of trolleybus transport, including "Where we operate, the city lives!", "Trolleybus – The highest stage of evolution" (Fig. 8.7).

Fig. 8.7. Using "catchy" slogans in promoting trolleybus transport in Salzburg
Photo: Salzburg AG.

One of the most important target groups for marketing in Salzburg are senior citizens. With them in view, Salzburg AG take integrated action covering, among others:

Training for older passengers to safely use trolleybus transport, so they can travel alone. Training includes issues related to the physical access to the vehicle, voyage planning, searching for information on available alternatives, finding their way on individual stops, learning the tariff-ticketing system and passenger safety. This results in not only an increase in the number of passengers and revenue from sales of services for the operator, but it also socially activates the ever growing population between age 70 and 85 years old.

Appropriate equipment of stops and trolleybus interior, including the right choice of colors and visible information visibility, providing adequate space for wheelchairs and luggage, and the distribution of at least some stop buttons so that passengers can press them without having to get up.

Promotional message addressed directly to senior passengers (Fig. 8.8).

Proper dress and behavior of staff, ranging from trolleybus drivers and ending with personnel involved in customer relations.

Publishing printed materials designed for senior passengers, showing the possibilities of spending free time in the city based on traveling using selected trolleybus lines (Fig. 8.9).

Such folders were issued for each of the trolleybus lines operating in the city and contain the necessary information for senior citizens.

Highlighting those characteristics of trolleybus technology which are considered to be important from the perspective of senior passengers, especially in comparison with the bus, such as a smoother ride, its impact on improving safety and low noise.

Fig. 8.8. Promotional materials targeting senior residents of Salzburg offered by SAG
Source: Salzburg AG.

Fig. 8.9. Publishing materials dedicated to senior citizens on trolleybus line No. 4 in Salzburg
Photo: Salzburg AG.

To enhance the image of trolleybus transport as a modern and ecological mode of transport, the operator advertises the fact that trolleybuses' energy supply comes 100% from renewable energy sources, thus reducing CO2 emissions by 51,000 tons a year. In addition, a modern fleet serves to reinforce the development of a positive image, including the newly purchased Solaris Trollino Metrostyle (Fig. 8.10) with a modern design and rich interior. Introducing new vehicles and new lines (like line 12 at the end of 2012) is accompanied by promotional events of various types.

Fig. 8.10. Solaris Trollino Metrostyle in Salzburg
Photo: Salzburg A.G.

In Salzburg the trolleybus network is being used for promotional activities and thus demonstrates an example of how this disadvantage of trolleybus transport can be repositioned as an advantage. Network is the confirmation of stability and certainty of reliable service, especially for older people. Such action, however, can only take place if other elements of the trolleybus transport create a high-quality service and clearly defined benefits for passengers.

An activity which was introduced thanks to the TROLLEY project is the European Trolleybus Day. The core idea behind it was to establish a day, during which all European cities celebrate trolleybus transport exclusively. It was celebrated for the first time on September 18, 2010. From that day on, the event is celebrated each year in September by a steadily growing number of cities, including those that don not have trolleybus transport yet (like Leipzig). In addition, cities that do have trolleybus transport, but are not partners of the TROLLEY project, also join the celebration (in 2012 – Lublin and Tychy in Poland).

Typical activities of the European Trolleybus Day are open days (in Szeged and Brno), accompanying events with competitions and activities for children and young people (in Salzburg, Parma, Gdynia), exploring technical facilities for children and young people and exhibitions of trolleybus photos (Gdynia). The celebration of the 3rd European Trolleybus Day in Gdynia were accompanied by a photo contest "My trolleybuses, my city".

European Trolleybus Day is also becoming an increasingly important part of the European Week of Sustainable Mobility, during which special lines with historical vehicles are organized, an activity that has become somewhat a tradition in Salzburg and Gdynia (Fig. 8.11).

Fig. 8.11. A historic Saurer trolleybus during the celebration of the Second European Trolleybus Day in Gdynia in 2011 on a special trolleybus line 68 (line number represents the number of years of trolleybus transport in the city)
Photo: M. Wołek.

Organizing the European Trolleybus Day allows the advantages of trolleybus transport to be presented to people who do not normally use public transport.. It provides an opportunity for the exchange of experiences in promoting trolleybus transport and for cooperation amongst the cities in which it maintains a strong market position.

The European Trolleybus Day constitutes an integration platform for various promotional activities and gives them an international character (through cooperation and the exchange of experience). It also helps specific promotional activities aimed at a specific target group (such as passenger car drivers, children and students of a specific age) to be addressed. The activities are predominately low-cost, therefore, the European Trolleybus Day can be included without difficutly in the calendar of promotional activities of each city, which uses this mode of transport.

8.4. Previous Experience in the Development of the Image of Trolleybus Transport within the Framework of the TROLLEY Project

The image of trolleybus transport was examined using a semantic differential, which shows the individual preferences of respondents in relation to particular properties. The study of semantic differentials of trolleybus transport was carried out in six TROLLEY project partner cities in October of 2010. The research methodology is presented in Chapter 3.3.

In total, the study included 1,070 respondents. The largest share of respondents were citizens of Szeged and Gdynia. Among all respondents 48% were male and 52% female. The study included people over 16 years of age. The oldest age group were people over 71 years of age. The participation of different age groups varied in cities, which had an impact on the comparability of the research results in individual cities. In Szeged and Eberswalde the largest group consisted of young people, between 16–30 years old – 52.6% and 49.7% respectively. The most adequate distribution of age groups was observed in Gdynia and Parma. Employed people constituted 44.7% of the respondents, students 25%, and pensioners 21.5%. The respondents group also included people of different socio-professional status, such as the unemployed and those not seeking work (8%).

The most people traveling via trolleybus transport on a daily basis live in Szeged (56.5%), Eberswalde (48.9%) and Gdynia (44%). In addition, a large group of people were traveling several times a week – 26.2%.

Respondents used trolleybuses for travel to work (20%), schools and universities (14.3%), shopping (16.8%), personal matters (23.4%), for social purposes(16.8%) and other matters (8.3%). One third of the respondents did not have a car.

The study analyzed the following image shaping features of trolleybus transport:

- speed;
- comfort;
- environmental friendliness (eco-friendliness);
- modernity;
- safety.

The semantic differential shows the preferences of the respondents due to many features. These preferences are assessed for the intensity of their validity. In the present study a scale of 1–5 was used where grade 3 means neutral/ indifferent view. Values higher than 3 indicate a positive evaluation, lower values – a negative evaluation of a certain feature. For example, a grade higher than 3 awarded for the speed of the trolley communication in the evaluation means that the respondent considers the journey to be quick. Ratings below 3 mean that the

Fig. 8.12. Aggregate semantic differential for cities surveyed in 2010

Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 30.

respondent considers the journey as slow. The other levels (4–5 and 2–1) indicate the intensity of the respondent's feelings[15].

The aggregate semantic differential for trolleybus transport for all analyzed cities was presented in Fig. 8.12. Semantic differentials for trolleybus transport defined for all analyzed cities are shown in Fig. 2-7.

In Brno, the best scoring trolleybus transport feature was its environmental friendliness (Fig. 8.13). The respondents were neutral towards safety, comfort and the modernity of trolleybuses.

Fig. 8.13. Semantic differential of trolleybus transport in Brno in 2010

Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 26.

Residents of Eberswalde recognize trolleybuses as an ecological and safe means of transport (2/3 of the respondents rated this trait the highest). Its speed and modernity was less valued (although almost half of the respondents gave that trait "4" and "5" points), as shown in Fig. 8.14. It should be noted, however, that the trolleybus fleet renewal process in the city was started in the same year in which the study was conducted. Articulated trolleybuses built in the early '90s were replaced by twelve Trollino Solaris 18 vehicles, which operate on two lines perfectly matched to the spatial structure of 40,000 city.[16].

Residents of Gdynia evaluated trolleybus transport as friendly to the environment and modern – about 2/3 of Gdynia transport passengers indicated the trolleybus as a modern

[15] K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 23.

[16] K. Hebel, M. Wołek: Development the Image of Trolleybus Transportation. [In:] Contemporary Transportation Systems. Selected Theoretical and Practical Problems. The Transportation as the Factor of the Socio-Economic Development of the Regions. Ed. by R. Janecki, S. Krawiec, G. Sierpiński. Publishers of the Silesian University of Technology, Gliwice 2012, p. 199–208.

means of transportation (total of “4” and “5” scores), as shown in Fig. 8.15. The speed, comfort and safety have also received high scores. This is due to the consistent support of public authorities for this means of urban transport. Modern vehicles, some equipped with a traction battery, certainly have an impact on the passenger evaluation of public transport in Gdynia. Some of them were introduced into operation before the start of market research.

Fig. 8.14. Semantic differential of trolleybus transport in Eberswalde in 2010
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 “Local Trolley Guides”. Final Report. TROLLEY Project, April 2011, p. 24.

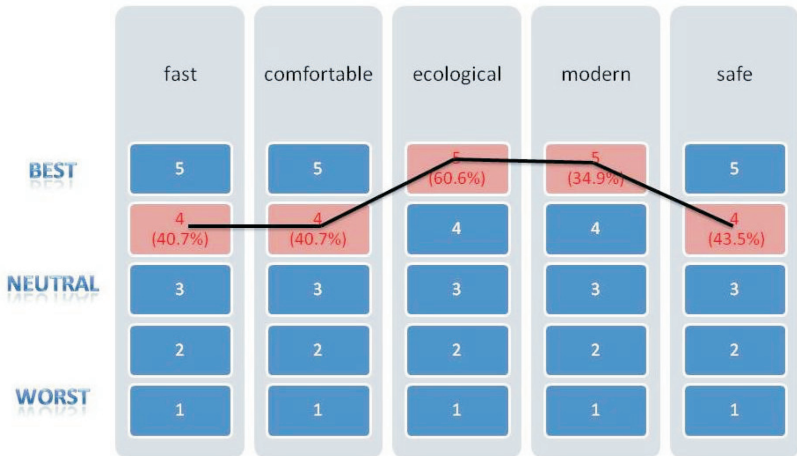

Fig. 8.15. Semantic differential of trolleybus transport in Gdynia in 2010
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 “Local Trolley Guides”. Final Report. TROLLEY Project, April 2011, p. 24.

In Parma, trolleybuses are evaluated as an ecologically friendly means of transport. Their safety was less valued, which is represented by Fig. 8.16. The residents of Parma were neutral towards the speed, comfort and modernity of trolleybuses. The research in Parma was carried out before the purchase of new vehicles for trolleybus transport, hence the lower rating of comfort and modernity.

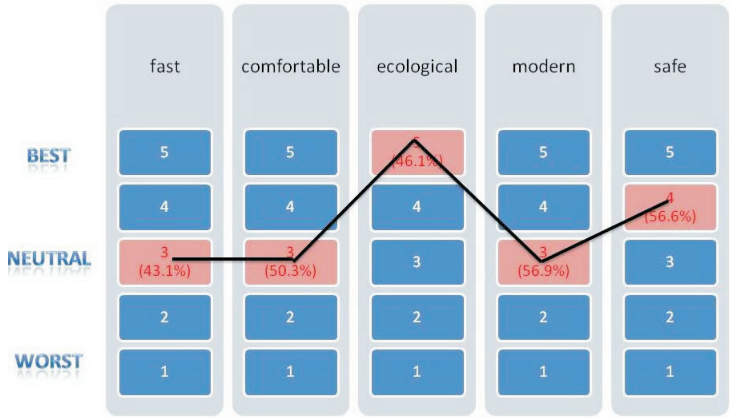

Fig. 8.16. Semantic differential of trolleybus transport in Parma in 2010
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 25.

Residents of Salzburg (Fig. 8.17) evaluated the most traits at the highest level, namely, comfort, environmental friendliness, modernity and safety. Only speed was rated neutral, due to the low operating speed of trolleybuses in the city center, despite the existence of bus lanes on some streets. Nearly four fifths of respondents in this city consider trolleybuses a modern means of public transport (sum of the respondents who gave this trait a 4 or 5).

In Szeged (Hungary), residents considered trolleybus transport environmentally friendly (almost half of the respondents gave this trait the highest score – 5). They also appreciated the speed and comfort, but had a neutral attitude towards modernity and safety of travel, as shown in Fig. 8.18.

The positive image of trolleybus transport is deeply rooted in the matters of ecology. The next best evaluated traits are safety, comfort and speed.

The declarations of all surveyed respondents in regards to the five attributes were summed up in order to assess the diversity of the researched cities. Figure 8 represents a map of the perception of the cities. Axes in the chart are an abstract evaluation of their similarity. The closer the cities are to each other, the more similar they are. Each part of the graph shows the importance of the five surveyed actors.

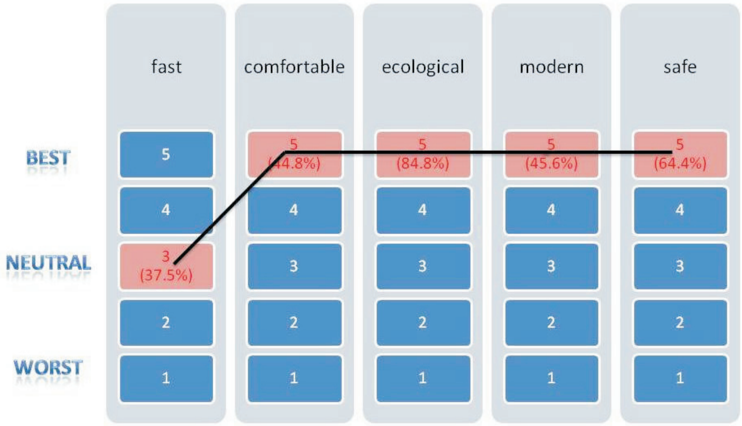

Fig. 8.17. Semantic differential of trolleybus transport in Salzburg in 2010
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 25.

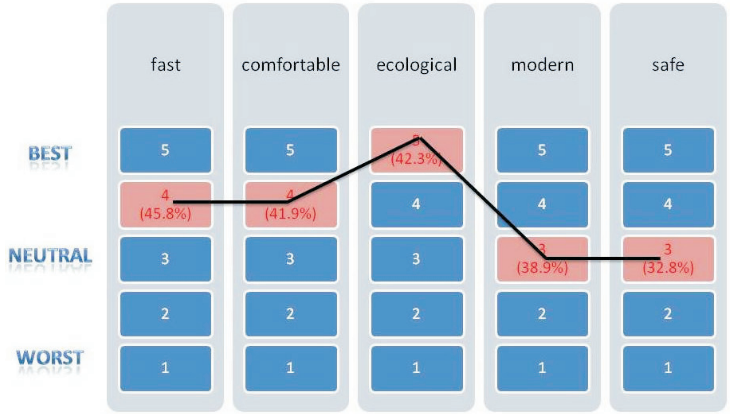

Fig. 8.18. Semantic differential of trolleybus transport in Szeged in 2010.
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 26.

In regards to Fig. 8.19 it might be stated that eco-friendliness was preferred in Szeged. Also the importance of comfort and speed was pointed out. Safety and fashion received neutral ratings. In Gdynia the respondents considered the aspects of eco-friendliness and modernity, as very important. Comfort and speed were important. In Eberswalde the respondents preferred safety and eco-friendliness as very important. Speed and modernity were also important. Comfort received neutral rating. Modernity, comfort, safety and eco-friendliness, were graded highly, while the speed of travel remained neutral in Salzburg.

Parma and Brno have very similar characteristics with respondents indicatinh eco-friendliness as very important and safety as an important factor. The other features were graded as neutral.

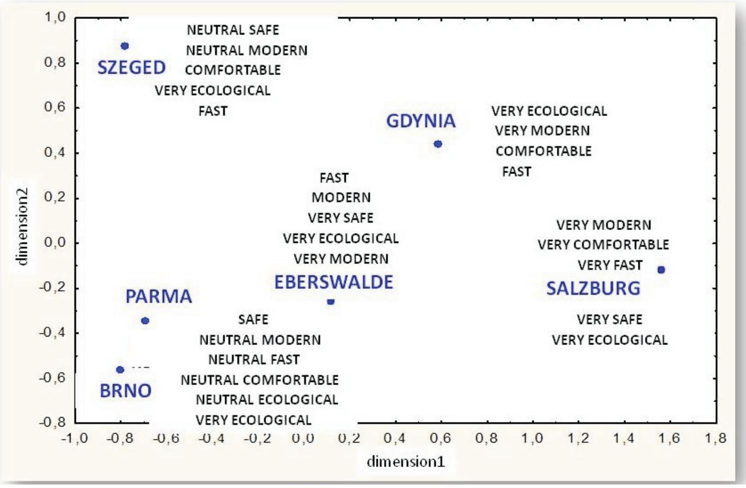

Fig. 8.19. Map showing the perception of the cities in regards to the surveyed travel features.
Source: K. Migdał-Najman, K. Najman, M. Wołek: Improved image and patronage. Output 5.2.4 "Local Trolley Guides". Final Report. TROLLEY Project, April 2011, p. 33.

The differences in the image of trolleybus transport in individual cities stem on one hand from the experience of trolleybus travel, and on the other hand, from the specificity of the community sample.

Trolleybuses are a key characteristic of transport systems of the cities in which they operate. In all cities researched they received the highest ratings because of their eco-friendliness. Regardless of the city being researched, ecological friendliness was evaluated very high among passengers of trolleybus transport. It proves the high level of environmental awareness in relation to trolleybus transport among the researched cities. 54% of respondents find trolleybus transport as "very ecological". There are significant differences in the assessment of parameters such as speed, comfort and safety. Trolleybus transport may, therefore, become an important element in developing a positive image of public transport, in some cases, becoming its "flagship", as it is already in Salzburg (Austria)[17].

In order to improve the image of trolleybus transport in the framework of the TROLLEY project, a wide promotional campaign named "EBUS – the smart way" was launched. The aim of this campaign was to show the trolleybus as a modern means of transport, a flexible platform for a number of innovations that are currently in an experimental phase, which promise to make trolleybuses a very attractive and effective means of transportation.

[17] K. Hebel, M. Wołek: Development the Image of Trolleybus Transportation. [In:] Contemporary Transportation Systems. Selected Theoretical and Practical Problems. The Transportation as the Factor of the Socio-Economic Development of the Regions. Ed. by R. Janecki, S. Krawiec, G. Sierpiński. Publishers of the Silesian University of Technology, Gliwice 2012, p. 199–208.

Chapter 9. Directions and Determinants of Trolleybus Transport Development

9.1. The Potential of Trolleybus Transport in an Era of E-Mobility

The increasing awareness of 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 ground-breaking solution, provided that the energy supply chain does not emit excessive amounts of CO_2.

Electricity as an energy vector for vehicle propulsion offers the possibility to substitute oil with a wide variety of primary energy sources. This could ensure the security of the energy supply and the widespread use of renewable and carbon-free energy sources in the transport sector, which could contribute towards achieving the European Union target of reduced CO_2 emissions.

The 'tank-to-wheels' efficiency of electric vehicles is a factor approximately 3 higher than internal combustion engine vehicles. Electric vehicles emit neither CO_2, nor other pollutants such as NOx, NMHC and PM when in use. Electric vehicles operate quietly and smoothly, thus creating 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.

The 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 will also be an essential part of the of the European Innovation Partnership (EIP) "Smart Cities & Communities"[1]

The EC Vice-President Siim Kallas, responsible for transport, said at the occasion of the announcement of the cross-European electromobility initiative "Green eMotion"[2]: "*Transport is current 96% dependent on oil for its energy needs. This is totally unsustainable. The Transport*

1 http://ec.europa.eu/eip/smartcities/index_en.htm)

2 http://ec.europa.eu/commission_2010-2014/kallas/headlines/news/2011/04/2011_04_01_electromobility_en.htm

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 renewable sources like wind, hydroelectric or solar power would release no greenhouse gases whilst in motion. Even in regions and countries where much 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 due to the fact that power plants use energy more efficiently than ICE[3]s (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 of trolleybus cities this "new" development is more a "back to the future!", as the trolleybus has already presented itself as a fully developed, technically secure and economical electromobility system over the past decades. However, electromobility with trolleybuses incorporates a number of elements (in addition to 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 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 first and final mile of a door-to-door trip.

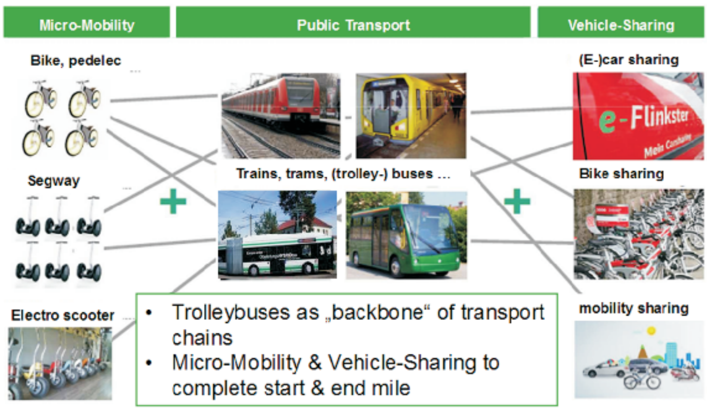

Fig. 9.1. Electric intermodal passenger transport chains with trolleybuses
Source: Spath, IAO, 2011 (modified).

[3] ICE – Internal Combustion Engine

The focus of the European Commission and other EU institutions on electric mobility, as is mentioned above, is mainly concerned with electric cars and has only recently began to shift towards the electrification of bus systems in Europe. However, trolleybus transportation is hardly mentioned in any official document with research topics primarily targeting the 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 the trolleybus over such technologies is its reliability, already proven by more than one hundred years of practical experience. Meanwhile the Commission has recognised that trolleybuses are still playing a crucial role in urban mobility and that trolleybus systems can be an important "bridging technology" for the smart electromobility of the future based on research topics like smart infrastructure concepts that exploit synergies between the electrical infrastructure of trolleybuses/trams, smart grids and the wider urban electromobility infrastructure, or the testing of 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 the backbone of urban transport due to the many benefits they undoubtedly offer to citizens, could play an important role in the furture development of electric transaction based urban mobility/electric mobility

Nevertheless, as a mode of transportation the trolleybus needs to develop in order to be competitive with other forms of transportation, as well as to be attractive to its users in the future.

The disadvantage of trolley bus systems, in as far as the need to be permanently connected to overhead wires, has already been solved by means of hybrid or dual mode power (the second power source can be not only an internal combustion engine, but battery or supercapacitors have also been implemented by various operators). For example trolleybus operator (TEP) of Parma, Italy purchased nine Van Hool ExquiCity 18 vehicles equipped with "supercaps" (Maxwell Double Layer HTM Power) to test a Kinetic Energy Recovery System (KERS). A further example is 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 in 2013 demonstrated that a distance of 4 kilometres can be driven in battery mode (without catenary-connection) and is ideal for ensuring the optimised life cycle of the lithium-ion battery on a line of 18 kilometres in length. With a trolleybus connected to the overhead wire by way of a catenary connection, the battery can be recharged via the electric motor during breaking. As a result of these technological innovations, trolleybuses can operate without wires for several kilometres more efficiently than when run on diesel. However, in order to guarantee 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 allowing for automatic wiring and dewiring (while driving) still is needed. This would reduce the infrastructure costs of expensive, visually intrusive crossings and would provide more flexible possibilities for the extension of routes within existing trolleybus networks.

Fig. 9.2. A TROLLEY pilot investment: Europe's first Trolley-Battery-Hybrid-Bus in Eberswalde
Source: Barnim Bus Company.

The up-to-date overhead components allow the road traffic flow speed at junctions to be maintained, which prevents the problem of speed restrictions. Furthermore, modern collectors made of composite glass or carbon reinforced polyester with retraction systems give trolleybuses better manoeuvring capabilities when connected to the overhead axis, thus enabling them to perform better in road traffic. Thanks to these and other new on-board technologies, trolleybuses and their passengers are now better protected against electric shock even during severe weather conditions.

It can be expected that future technological progress and development will concentrate on further improving efficiency and competitiveness with bus transportation, e.g. vehicle weight reduction and in particular the reduction of investment costs which is considered as the main obstacle and disadvantage.

As mentioned above trolleybuses are an important "bridging technology" towards electromobility solutions and trolleybus networks could become a backbone for 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 vehicles – it is relatively easy in the 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 a catenary network at selected trolleybus or tram stops (Vienna, AT).

The same scheme could be applied to private electric cars; ideally during parking at P+R facilities where cars may remain for several hours. Public transport operators could become providers of universal mobility, which could be beneficial not only for car users, that is private customers, but also for PT operators themselves. Their electricity consumption depends on traffic volumes which are significantly higher during peak hours, whereas the sale of electricity to private vehicles during off-peak periods 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 prevents them being used by other customers. This restriction, which applies in certain countries, shows the need for the harmonisation of standards within the EU and is already the case of other modes where PT operators can sell fuel (diesel or CNG) to external users.

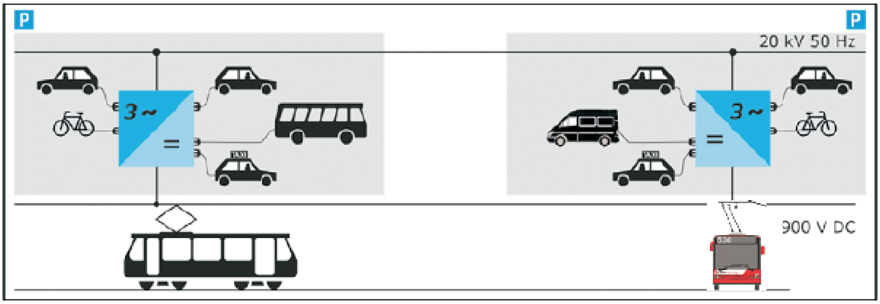

Fig. 9.3. The dual use of the power supply infrastructure of existing tram and trolleybus systems as loading stations for other e-vehicles (e-cars, e-bikes etc.)
Source: Müller-Hellmann, VDV-Förderkreis (modified)

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 are also able to support the integration of zero-emission freight transporters into urban mobility systems. Although they are generally seen as a mode of passenger transport, there are several examples of trolleybus lorries. Besides the current Siemens R&D project (Germany) for long distance freight distribution, electric trucks powered from overhead network are used in places requiring an ignition-free environment (ie. mines). Urban delivery services perhaps constitute both the most attractive and appropriate potential utilization of the trolleybus network. Lorries can be supplied with electricity from an overhead network where available and powered by batteries in streets where such equipment is lacking. The above has been applied in the former U.S.S.R. since the 1960s, though the "independent power" is supplied from an auxiliary diesel or petrol engine while current electromobility technology enables the use of battery power, the battery recharging as the trolleybus is in motion. The wider application of such technology could constitute the contribution of the trolleybus to urban logistics, which is another important EU transport policy topic.

9.2. The Future Role of Trolleybus Transport Systems with Particular Emphasis on the Cities Participating in the Trolley project

Innovations in the development of urban transport foster measures aimed at the modernization of the existing sub-systems of urban transport and thus provide trolleybuses with future prospects of functioning in urban transport services.

The development policy of trolleybus transport should be directed towards coordinating and continuing the process of improvement of the subsystem, including increasing cost savings, functionality and environmental acceptance.[4]

The recognition of the trolleybus as a mode of transport for the future is motivated primarily by the fact that it is able to contribute to sustainable development and to improve the quality of life in urban areas. It is also determined by the following features:[5]

- it is friendly and acceptable from the point of view of the environment (it does not emit exhaust fumes and has a lower noise level in relation to other modes of transport)
- it is economically efficient thanks to renewable energy sources,
- it does not require large, long-term investments as both the fleet and infrastructure benefit from very good technical solutions,
- the prices and costs of the fleet will decrease and its quality will increase with the rapid development of trolleybus subsystems,
- it has a longer longevity and it is more comfortable for passengers than regular buses due to the spacious interior and the fact that its energy is produced outside the vehicle,
- it has excellent traction, while staying dynamic and safe regardless of the topography and the number of passengers,
- it is flexible and performs well an all routes thanks to an auxiliary drive,
- it can recuperate and store energy,
- it is highly efficiency, capacious and enables operation on dedicated routes which allow for a high operating speed,
- it is appropriate from the point of view of the requirements of the local community, providing a balance between the transport potential and the impact on the environment.

Modern, low-floor trolleybuses may be threatened by the technical development of buses, which is heading towards their electrification. The development is forced by the introduction of an environmental tax on diesel vehicle operation, as well as by the increase in diesel prices. Time will tell whether the conventional trolleybus with an auxiliary battery drive, or the electric bus, which combines the benefits of the conventional bus and the trolleybus, will be used to a greater extent in the future.[6]

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[4] S. Tica, S. Filipovič, P. Zivanovič, O. Bajcetič, Development of trolleybus passenger transport subsystems in terms of sustainable development and quality of life in cities, "*International Journal for Traffic and Transport Engineering*", 2011, 1 (4), p. 202.

[5] Ibidem, pp. 203–204.

[6] U. Langer, *Vergleichende Untersuchung der Energie Kosten und Emissionsbilans im Öffentlichen Nahverkehr bei Einszatz von Oberleitungsbussen und Dieselbussen der Stadtwerke* Solingen, www.obus-ew.de, 14.02.13.

Electric and hybrid buses equipped with batteries are used in a number of cities in different countries. Among cities operating vehicles with sodium-nickel-chlorine batteries the best known are: Bologna and Rome in Italy, Lyon in France, and Adelaide in Australia. The vehicles operating in these cities were produced by companies such as IVECO, Tecnobus, BredaMenariniBus and DesignLine, and are operated by local transport companies. The typical operating range of these vehicles is the service of lines connecting car parks with urban centers and lines running through the areas excluded from general traffic, such as historical sites.[7]

Sodium-nickel-chlorine batteries have proved to be reliable and suitable for vehicles used in the carbon-free or low-emission local public transport. The best operating range, amounting to 16 hours and 180–220 km, is offered by BredaMenariniBus 240 EI HEV. DesignLine TINDO EV electric buses provide approximately the same range.[8]

Taking into consideration the technological progress in the construction of electric buses it is not easy to identify a clear global trend in the development of trolleybus transport. Cities operating trolleybuses do not generally doubt the reasons for maintaining trolleybuses, greatly appreciating their role in public transport networks. This means there is no visible trend against trolleybuses. These cities plan either to maintain the current state of affairs, assuming the strategy of survival, or to strengthen and expand trolleybus transport, assuming the strategy of development. Even if, from a purely economic point of view, the trolleybus is a more expensive option than a bus run on diesel or natural gas, this disadvantage is offset by its environmental benefits. Moreover, it is difficult to find arguments for the abolition of trolleybus transport when at the same time there is significant development in the tram systems that also use overhead networks. Furthermore, in practice, there are examples of the beneficial coexistence of the two sub-systems of public transport.[9]

The future of trolleybuses is associated largely with technical progress. The use of semiconductor and microprocessor technology allows for the efficient use of energy. In turn, the auxiliary drive enables the flexibility of movement. In some cities trolleybuses are equipped with an auxiliary combustion engine and in others an auxiliary battery drive. A combustion engine emits harmful substances into the atmosphere at the location where the vehicle operates, so it can be used only as a fallback or a temporary solution in the event of the closure of streets, and therefore, it is difficult to consider it a solution with prospects for the future. A battery powered drive, being as it is clean, may have a broader application beyond that of emergencies and temporary use. It is possible to use it as a second drive allowing for the fully-fledged operation of trolleybuses on routes not covered by the trolleybus network, extending the route network. Currently operated battery equipped trolleybuses treat the battery drive as secondary due to its small range, which does not exceed a few kilometers. Technological progress in terms of battery design has given rise to the possibility of equipping trolleybuses

[7] G. Lodi, R. Manzani, G. Crugnola, *Batteries for full electric and hybrid buses: fleet operation results and relevant battery improvements*, The 25th World Battery Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition, Shenzen, China, Nov 5–9, 2010, p. 1.

[8] Ibidem, pp. 5–6.

[9] A. Kuehn and Norconsult AS, *Trolleybus and Gasbus Technology. Trends, Developments and Comparisons*, Karlsruhe (Germany), Bergen (Norway) 2010, www.hordaland.no, 14.02.2013.

with lightweight batteries no bigger than the ones currently used, allowing them to operate over longer distances. It is already possible to equip trolleybuses with energy efficient lithium-ion or sodium-nickel-chlorine batteries.

Sodium-nickel-chlorine batteries are about 70 percent lighter and 30 percent smaller than conventional ones and capable of functioning over at least several kilometers.[10]

The advantage of the trolleybus is the possibility to charge the battery on route using the overhead wire. There is no need for charging stations to be built or special booms in the pavement.

The technical development of the battery can help in predicting the development of the trolleybus in the cities in which they operate using both conventional and battery drives. It is more difficult to predict the strategy of cities where, as of yet, trolleybuses are not in service, where both electric buses and modern trolleybuses using two drives are possible solutions.

Six cities participating in the Trolley project, which operate trolleybuses are likely to adopt a strategy in which trolleybuses are developed as vehicles with two drives. None of these cities intends to dispose of trolleybus transport, on the contrary, they have clear plans to invest in the fleet and infrastructure.

Salzburg launched two new trolleybus lines in 2012, increasing their number to twelve. Launching the second one entailed the extension of the trolleybus network by 600 meters. Future plans involve extending the network to neighboring areas, including the German city of Freilassing. The year 2012 saw the beginning of the introduction of the new Metrostyle fleet to Salzburg. Over the next five years (2013-2017) 26 new articulated trolleybuses will be put into service and the contract may be expanded by 14 additional vehicles, including 9 bi-articulated trolleybuses with a proportionally higher capacity. The introduction of new trolleybuses will mean that Obus SLB's last high floor vehicles will be removed from service by 2017.

The city of Eberswalde exchanged its entire trolleybus fleet between 2010 and 2012. The fleet now consists of articulated, low-floor vehicles with an auxiliary combustion engine and supercapacitors for storing recuperated electricity. Taking into consideration the life of trolleybuses currently owned by Barnim Bus GmbH, the vehicles can be operated for more than 20 years.

The new batch of Solaris trolleybuses in Eberswalde included the first vehicle in Europe equipped with a lithium-ion battery, which has replaced the diesel engine, used as an auxiliary drive in the previously delivered units. In addition to the overhead network drive and the lithium-ion battery, this vehicle can also use a third electric drive in the form of supercapacitors, which store electrical energy. In order to fully recharge the battery, the vehicle needs to remain connected to the overhead wire for 20 minutes. Introducing the innovation to this trolleybus took place within the framework of the Trolley project.[11]

In the years 2012 and 2013 the city of Gdynia introduced ten trolleybuses, five brand new purpose built vehicles and five obtained through conversion, all of them non articulated low floor vehicles with an auxiliary battery drive. Moreover, plans were made to purchase more new vehicles and to convert more used buses to trolleybuses with an auxiliary battery.

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[10] Sodium Nickel Chloride Technology, FIAMM S.p.A. Industrial Batteries, www.fiamm.com,14.02.2013.

[11] Europe's first Trolley-Battery-Hybrid-Bus operating in Eberswalde, www.trolley- project.eu, 14.02.2013.

In 2013 the city of Gdynia joined another urban transport development project co-financed by the European Union under the name of „Civitas Dynamo". In the framework of this project, two trolleybuses will be equipped with new batteries which will ensure higher energy efficiency, and thus further range than the ones used currently. The initial assumption is that they will be lithium-ion batteries, however, another type may be used if it is found to be more efficient. Trolleybuses equipped with the new batteries are to be operated on the line with a route partially deprived of the overhead wire. In this section of the route trolleybuses will use the battery drive.

The plans also include providing a newly built residential district on a hill with trolleybus service without investing in new overhead wire infrastructure. Trolleybuses equipped with energy efficient batteries will move through the district using the battery drive. Only the loop, which will be built in the district, will be equipped with overhead wires enabling the batteries to be recharged when the vehicles are stationary. In one variation of the project, the overhead network will be built on the access road to the district from the main road equipped with a trolleybus network. The second variation assumes that the trolleybuses will use the drive battery immediately after leaving the main road. These trolleybus line will be operated by newly purchased trolleybuses with an auxiliary battery drive with appropriate energy efficiency.

In addition, in Gdynia the decision was taken to continue the conversion process of used buses into trolleybuses equipping them with the most efficient batteries available, so as to form a second drive, in addition to the auxiliary drive.

In Parma since 2012, as well as in Salzburg, new low-floor articulated Van Hool ExquiCity trolleybuses are being introduced. They have a modern design body shaped like a tram Metrostyle. In total, nine of them were purchased. This investment marks the beginning of the revitalization of trolleybus transport in the city.

A new fleet is also being acquired in Szeged. In 2012, the fleet was enhanced by 6 used Skoda 15 Tr and one used Skoda 21 Tr. A new solution in Szeged is the introduction of the first trolleybus with an auxiliary battery drive.,There are plans to purchase 13 new trolleybuses by the end of 2014

9.3. The Psychological Conditions of Choosing Trolleybus Transport for Daily Urban Travel

Over the past years, the daily need for individual movement in urban areas has resulted in the unbalanced development of individual transport and has began to cause significant environmental problems. The increase in urbanization and in the share of private cars in everyday urban journeys contributes significantly to the pollution of air and water, the devastation of the landscape, as well as to buildup of noise. All these factors have a negative impact on the quality of life in urban areas and stand in the way of the implementation of sustainable development.

Psychology is the field of science which is widely used in urban planning and predicting the behavior of city inhabitants, through the knowledge gained from research on social behavior, human needs, attitudes and their impact on human activities. The conclusions of the research conducted in the field of environmental and social psychology may be considered of particular importance. Environmental psychology is used for sound management of the environment in urban areas and to ensure their citizens a better quality of life as well as physical and psychological well-being. This area combines knowledge of psychology with knowledge of other disciplines such as geography, sociology, ecology, and urban planning. Among other things, it is focused on the development of effective ways to protect the environment, appropriate urban planning, as well as the promotion and expansion of environmental awareness among citizens [12]. Social psychology focuses on the broadly understood social impact, or the way in which behavior, feelings and way of thinking of some people influence the behavior, thoughts and feelings of others [13]. Theories derived from this field of psychology allow the specific factors affecting the transport behavior of individuals to be defined by reference to human cognition, attitudes, habits, and emotional processes. Numerous theories in social psychology state, in contrast to the assumptions of microeconomic models, that human behavior is not always rational, and decisions made by individuals take into account other factors aside from minimizing costs and maximizing benefits [14]. From this point of view, it is necessary to take into account the role of private and public means of transport in modern society, with particular emphasis on their values beyond those associated with movement.

The travel behavior of individuals is a result of a number of general and individual circumstances. Among the most important factors that influence them are:

- situational factors,
- economic conditions,
- social norms,
- demographic factors,
- an individuals' mobility during their lifetime,
- attitudes,
- habits.[15]

Detailed knowledge of these conditions in respect of urban residents is vital in the promotion of sustainable forms of public transport. Over the years, much attention has been paid to the role played by peoples' attitudes in the decision-making processes and human behavior. Recent studies, however, show a clear psychological shift from the long-continued tendency to consider human attitudes as having a vital influence on their decisions to taking into account the significance of human habits [16]. It was not only the results of numerous studies,

[12] A. Baum, P. Bell, T. Greene, *Psychologia środowiskowa*, GWP, Gdańsk 2004, p. 10–17.

[13] B. Wojciszke, *Człowiek wśród ludzi: zarys psychologii społecznej*, Wydawnictwo Naukowe Scholar, Warszawa, 2009, p. 17.

[14] V. Van Acker, B. Van Wee, F. Witlox, *When Transport Geography Meets Social Psychology: Toward a Conceptual Model of Travel Behaviour*, "Transport Reviews", 2010, Nr 30 (2), s. 219–240.

[15] O. Siegmar, *The psychology of transport choice*, "Corpus", The SPC Knowledge Hub, March 2010, pp. 1–4.

[16] S. Kenyon, G. Lyons, *The value of integrated multimodal traveler information and its potential contri-*

but also the unsuccessful campaigns promoting public transport that show that the environmental attitudes of individuals do not have a significant effect on their daily travel behavior, which is routine and highly recurrent. Human attitudes cannot, therefore, in this case used exclusively when predicting the choices made in daily urban travel. Therefore, deeply rooted habits, which facilitate everyday existence, should also be considered in predicting transport behavior. Campaigns promoting ecological solutions and sustainable development must deal with the common irrationality and complexity of human behavior. One cannot, therefore, seek universal solutions that will be suitable for every city or public transportation. Each case should be approached individually and the solutions should be "tailor made", matched to the characteristics of particular socio-economic conditions. For each type of transport policy, it is possible to use two types of measures leading to the sustainable travel behavior of inhabitants - "hard" and "soft". The former include, for example, fiscal policy, parking fees, or marked areas where traffic is prohibited for private cars. They are designed to increase the competitiveness of public transport over private cars. The "soft" means are information campaigns and social marketing promoting sustainable development and environmental conservation. Especially from the point of view of their creators it is important to know about the determinants of the daily travel behavior of individuals, as the campaign creators' success largely depends on the degree of adaptation to a specific group of people and the particular mode of transport, for example the trolleybus. Moreover, "hard" and "soft" means should not be used separately, as studies show that they are more effective when used simultaneously[17].

Habitual car users often have negative ideas about public transport, which are contrary to reality. The purpose of public transport management units is therefore to take the initiative and enable such persons to verify their views and to change them. A sudden, strong situational change, such as the need to abandon the car, may invalidate existing habits, provided that the experience it brings is positive, for example if the lines and journey time are actually better than the person had expected [18]. While estimating the level of their satisfaction with public transport services habitual car users do not take into account how quickly one gets used and adjusted emotionally to changes in his environment. Research shows that people travelling only by private modes of transport, after the initial estimate of their anticipated level of satisfaction with the use of public transport and then the actual use of the services, assess their level of satisfaction significantly higher, which indicates that they adapt to new conditions [19]. Knowledge of how people predict their level of satisfaction, how distorted and

bution to modal change."Transportation Research Part F: Traffic Psychology and Behaviour", 2003, No 6(1), pp. 1–21.

17 O. Siegmar, op. cit.

18 S. Fujii, T. Gärling, R. Kitamura, *Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural change on cooperation in a real-life social dilemma.* "Environment and Behavior", 2001, No *33*(6), pp. 796–808.

19 S. Fujii, T. Gärling, R. Kitamura, *Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural change on cooperation in a real-life social dilemma.* "Environment and Behavior", 2001, No *33*(6), pp. 796–808.

how significantly different from the actual level it can be, should prove to be useful for public transport management[20].

Recent studies show that the way in which people evaluate the effectiveness and attractiveness of public transport depends largely on whether they drive their own car and how pleasant they find driving it. As it turns out, people who not only like driving a car but also perceive private transport as giving them a sense of independence and social status are less concerned about the negative impact that excessive production of gas and oil derivatives has on the environment. According to the conclusions drawn from the studies it is impossible to expect the people who highly appreciate driving cars to completely abandon this mode of transport in favor of public transport. One should instead look for ways to stimulate the interest of such individuals in particular forms of public transport, such as trolleybuses, which, as with a car, not only offer a way in which to travel from one place to another. As a mode of transport powered by electricity the trolleybus fits the concept of a healthy lifestyle, which is nowadays increasingly fashionable. Public transport in this sense should not be considered as an alternative to all daily urban travel, but at least a part of it. At the same time the policies of major cities should be aimed at reducing the importance of positive psychological, functional and cultural values attributed to private transport.[21]

In accordance with the Change Model during the decision-making process people pass through four successive stages (Fig. 1). Initially there is the precontemplation stage, during which the real desire for change has not yet appeared in their minds. Next comes the contemplation stage, in which the desire to change becomes conscious and subsequently finds itself at the level of introducing the new attitude in life. Finally comes the maintenance stage, during which the new behavior is instilled as part of their daily conduct.

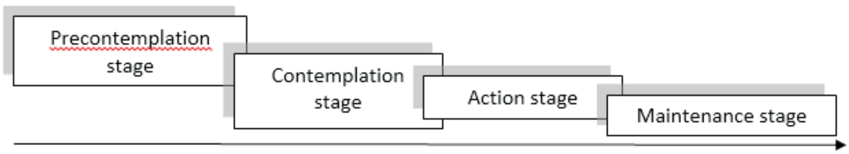

Fig. 9.4. Stages of the decision making process for changing behavior
Source: own work based on: J.O. Prochaska, C.C. DiClemente, The transtheoretical approach: Crossing traditional boundaries of change. Homewood IL: Dow, 1984, w: B. Gatersleben, The psychology of sustainable transport, "Psychologist" 2002, Nr 25 (9), p. 676–679.

Thus, in order to significantly alter human behavior, one should consider the specificity of the current stage of making a decision, as well as interact with him via three different channels of persuasion – affective, rational, and by direct effect. For example, making people aware of the costs to be borne by the environment in connection with the abuse of daily car trips in

[20] S. Fujii, T. Gärling, R. Kitamura, *Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural change on cooperation in a real-life social dilemma.* "Environment and Behavior", 2001, No *33*(6), pp. 796–808.

[21] L. Steg., *Can public transport compete with the private car?* "IATSS Research" 2003, No 27 (2), pp. 27–35.

urban areas by presenting them with rational facts [22]. Also trying to influence their emotions, can make individuals go from the precontemplative to contemplative stage, in which the desire for change will appear. It is also important to give people adequate access to information about public transport services, so that it is easily accessible not only to its regular users, but also to those traveling by private transport. Individuals often refrain from using public transport on account of erroneous knowledge concerning the services offered and the absence of appropriate advertising and promotion of new routes or a newly introduced fleet. A different approach is required in the case of people who are already at the stage of action, that is, for example, who try out a given mode of public transport, such as the trolleybus. At thos juncture it is appropriate to support their motivation to continue the action taken by providing them with positive experiences associated with it, for example by ensuring comfortable travel.

Symbolic and affective aspects often constitute a major obstacle to reducing reliance on cars as a mode of daily transport in favor of public transport. People who are emotionally attached to their cars drive them more often and express more negative views towards public transport than those less tied to their cars[23]. Using the basic mechanisms of social influence, which include the social proof of fairness, people can be persuaded to reflect the behavior of others in their daily activities. For example, if someone who is well-liked or considered an authority acts in a certain way, then very often people will follow suit. In regards to social campaigns promoting the use of trolleybuses, known and respected individuals could emphasize their environmental activities and the important role they fulfill in their lives. This would lead to the average person associating them with something trendy and popular, hence building up a positive image. The giving up of excessive use of the car in favor of public transport, especially its most environmentally friendly modes, such as trolleybuses, fits perfectly into the dos of pro-environmental behavior.

In summary, various psychological factors, the study of which is performed by social and environmental psychology, explain to a significant extent the daily travel behavior of individuals. Psychological knowledge concerning human attitudes, habits, self-satisfaction and affective reactions can be used by public transport organizers as a reference point for understanding the travel behavior of urban residents. At the same time it can affect the development of information campaigns that promote the use of environmentally friendly modes of public transport like trolleybuses, contributing to an increase in the number of people limiting their daily use of cars.

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[22] Prochaska, J.O., DiClemente, C.C., op. cit.

[23] B. Gatersleben, *The psychology of sustainable transport*, “Psychologist” 2002, No 25 (9), pp. 676–679.

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"(...) A significant part in the creation of urban transportation systems is now played by those means of transportation which run on electric power. In this respect, the monograph entitled *The Trolleybus as an Urban Means of Transportation in the Light od the Trolley Project* is a particularly valuable publication. It contains deliberations on import_ant and current scholarly issues. It is also indispensable in the light of business practice".

From the review written by Dr. hab. Tadeusz Dyr, Associate Professor, Faculty of Economics, Kazimierz Pulaski University of Technology and Humanities in Radom