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South Moravian Mobility Study
Basic Findings and Comparison with German Data

P. Malina*, P. Kouřil, P. Šenk
Transport Research Centre, Brno, Czech Republic,
** Corresponding author: petr.malina@cdv.cz*

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ABSTRACT: Transport planning in the Czech Republic faces the problem of a lack of data on travel behaviour. The paper deals with the usability of foreign travel behaviour data for transport modelling in the Czech Republic. The authors present their findings on the example of a comparison between the results from the data analysis of a travel demand survey in the South Moravian region, which was performed in 2013 on the sample of 1000 households and a German survey Mobilität in Deutschland.

KEY WORDS: Travel behaviour, South Moravian region, transport planning.

1 THE FIRST REGIONAL MOBILITY SURVEY IN THE CZECH REPUBLIC

The point of transport planning is to secure sustainable transport development and to make transport accessible to the whole community. Data analysis of travel behaviour is a necessary prerequisite for high-quality transport planning, as well as a base for high-quality transport models. However, in the Czech Republic, the lack of coherent travel behaviour data is still apparent, with the exception of a few individual surveys, which nevertheless were carried out only on the level of municipalities (Braun Kohlová et al., 2007). The first large-scale survey performed on the regional level is the travel behaviour survey in the South Moravian Region[1]. This survey was carried out within a project involving cross-border cooperation with Austria called Transport Model AT-CZ in 2013. The data provided by this survey were used to compile and parameterize the transport model of the South Moravian Region (hereinafter SMR), but there are more possibilities for its utilization.

In the area of transport modelling alone, there is a wide scope of possible uses of travel behaviour data. With regard to the traditional four-step approach to transport modelling, a wide scope of data use is apparent when modelling travel demand. For the purposes of the Transport Model AT-CZ, three basic travel demand sub-models were created. For the trip generation model, the data were used to derive the number of trips to previously defined areas (zones), divided according to the trip purpose. The survey data were used to compile a multinomial logit model of trip distribution and travel mode choice. From all survey data, the realized trip destinations by the used means of transport were considered. The data could possibly be used for predictions related to ownership of specific means of transport, driver's

[1] Largest travel behaviour survey in the Czech Republic – Travel behaviour of residents and visitors of Prague and Prague metropolitan area – covers the area of the city of Prague and two surrounding districts.

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licenses or discount tickets for public transport (Cinzia, 2010; de Jong et al., 2004). The data also offer the possibility of validating individual submodels, provided that they were not used for compilation and parameterization of the model.

Besides transport modelling, the data can be used to study patterns of the spatio-temporal behaviour typical of a certain group of people (e. g. students, retired people) (Yu & Shaw, 2004). For example, it is possible to estimate at what time a certain group of people would travel for a specific reason. Information of this kind relates to the areas of network analyses and location tasks (Schönfelder & Axhausen, 2010), which can be utilized in social sciences, urbanism, economy or even marketing (e. g. where to place a parking lot, an ATM or advertisement, etc.).

If no data about travel behaviour are available, the companies, institutions and experts in the area of transport modelling do not have any other choice but to use data from other countries for the purposes of travel demand modelling. This approach was chosen in the case of building the Czech national model (Vachtl et al., 2012).

The problem of travel behaviour data transferability from one region to another is discussed in extensive research work. There are statistical methods to simulate new data from more extensive surveys, for example from national to regional level. Limitation is that there is a need for very detailed demographic and land-use data of a modelled area (Stopher et al., 2004). Travel behaviour data transferability from one region to another is another research topic. In that case, data have similar structure but there are certain variables for which mean and standard deviation values differ across different regions (U.S. DOT Volpe National Transportation Systems Center, 2005; Mohammadian & Zhang, 2007). Additionally, by using various statistical methods, the transferability of travel demand models itself is researched. Nevertheless, after using these statistical tests, there is no guarantee of the goodness of transferred models (Karasmaa, 2003).

The goal of this paper is to compare mean values of basic variables of travel behaviour data such as trip rates or mode shares to see how much they can differ across foreign countries. The comparison is carried out for data analysis results from the SMR and from the German survey Mobilität in Deutschland (Follmer et al., 2010).

2 PEOPLE IN THE SMR TRAVEL LESS THAN PEOPLE IN GERMANY

The travel behaviour survey in the SMR was carried out in May and June 2013. It involved 1,000 households sampled by a method of random stratified selection. To secure comparability of the data with the neighbouring cross-border areas, the KOMOD methodology was selected for the survey, since it is used for the standardization of the data not only in the original area, but also in Austria and recently in Slovakia as well. The KOMOD (Fellendorf et al., 2011) methodology unifies indicators of travel behaviour and defines the methods of selecting samples and collecting data, as well as assuring data quality. In the survey, the households were asked in person about their size, income and which means of transport they owned. Basic socio-demographic characteristics were established for each household member. The interviewed household members listed all the trips realized on a certain, previously chosen working day. Information about these trips included duration, distance travelled, used means of transport and purpose of the trip.

Below, the findings of the South-Moravian survey are compared to the result of the nationwide German travel behaviour survey Mobilität in Deutschland (MiD). This survey was carried out for the first time in 2002; however, it is a continuation of earlier mobility surveys from 1976, 1982 and 1989 (Institut für Verkehrs- und Infrastrukturforschung GmbH, 2009). The data in the comparison originate in the latest version of MiD from 2008.

The methodology used in the SMR shares a lot of features, mainly concerning the researched attributes of the households, persons, trips and means of transport. However, MiD differs in the used data collection method (phone interviews) and mainly in the duration of the survey – the data were collected over the course of a whole year, February 2008 through March 2009. To compare the results of both surveys, only the data for the given working day were used. The basic survey sample consisted of 25,000 households; a total of 50,000 households was reached by including other regional samples.

It is apparent from the survey in Germany that travel behaviour differs across individual regions – in Germany across individual states. For the purposes of comparison with the SMR, the state of Thuringia was chosen, since its basic demographic and geographical characteristics most resemble those of the SMR.

The analysis of the basic survey output revealed that a large percentage of people (18.8%) did not travel at all during the given day. In the German survey, this value is approximately 10% (it is 10.5 in Thuringia). A basic mobility attribute is the so-called “trip rate”, standing for the number of trips per person per day. In the SMR, this value is 2.2; while in German Thuringia, it is 3.3. In other surveys, for comparison, e.g. in the USA or elsewhere in Germany, this value was almost always higher than 3. This value is influenced by a high percentage of people who did not travel at all on the given day; nevertheless, similar results (between 1.7 and 2.9) like in the SMR were provided by surveys carried out in various municipalities in the Czech Republic concerning the indicator A.3 “Mobility and local transport of passengers.” (Timur, 2014). It should be noted that the methodology in these indicator A.3 Czech surveys is drastically simplified compared to the methodology used in the SMR survey.

The trip purposes analysis in the SMR revealed that the main reason people travel was for work and business trips (35% of all trips). In Thuringia, Germany, the work trips accounted for only 23% of all travel purposes and the most dominant purpose there was leisure activities (30.4%). While in the SMR, trips for education and work reasons made up almost half of all the trips (47.6%), in Thuringia, it is only 27.9%. The comparison suggests that Germans travel much more often in their free time. The results of the trip purpose analysis are summarized in Table 1.

Table 1: Comparison of trip purposes in the SMR, Thuringia and Germany.

Trip purpose	SMR	Thuringia	Germany
Work and business travel	35.0%	23.0%	20.3%
Education	12.6%	4.9%	6.2%
Shopping	17.8%	20.5%	20.5%
Leisure time activities	17.2%	30.4%	32.4%
Other (e. g. accompanying people, visiting a doctor, an office, etc.)	17.5%	21.2%	20.3%

There is also an apparent difference in the percentage of the used means of transport. While in Germany, individual car transportation is by far the most prominent transportation method (with 56%), in the SMR cars (39.1%) are rivalled by public transport (26.2%). The comparison shows that the use of non-motorised means of transport in the SMR and Germany is similar, with biking and walking combined making up 34%. All results are summarized in Table 2.

Table 2: Comparison of means of transport / travel modes in the SMR, Thuringia and Germany.

Means of transport	SMR	Thuringia	Germany
Walking	26.8%	30.0%	23.7%
Bicycle	7.2%	3.7%	10.0%
Individual car transportation	39.1%	55.9%	56.0%
Public transport	26.2%	5.9%	7.2%
Motorbike	0.4%	0.4%	0.5%
Other	0.3%	4.1%	2.5%

3 DISCUSSION AND CONCLUSION

In the Czech Republic, only a few travel behaviour surveys have been carried out, and only at the municipal level. The first regional travel behaviour survey was carried out in the SMR in 2013. The options for survey data utilization range from socio-demographic analyses to network and location tasks (analysis of the spatio-temporal behaviour patterns). Nevertheless, its main purpose lies in the field of traffic modelling.

When producing the current models, travel behaviour data are often taken from foreign countries. The difference between mean values of basic characteristics of mobility in the SMR and in Germany, or rather Thuringia, demonstrates that the use of foreign travel behaviour data for Czech conditions would be unsuitable. The survey revealed that the inhabitants in the SMR travel generally much less and, on average, take 2.2 trips a day, while the inhabitants of Germany average more than three trips a day. In addition, the comparison of the results of both surveys suggests that there are significant differences both in the purposes of these trips, and in the means of transport used.

All these conclusions support the notion that even mean values of basic travel behaviour differs between individual states and regions. Hence it is not probably appropriate to generalize the data analysis results from the SMR and apply them to other regions of the Czech Republic. A reliable data source for compiling high-quality transport models should be a survey of travel behaviour of a region in question.

If the field of transport planning in the Czech Republic is to achieve more recognition, and not only within its own borders, it is necessary to carry out travel behaviour surveys on regional as well as national levels. To support this step, new methodology for travel behaviour survey is currently being prepared in the Czech Republic. The methodology should help to create a unified national database for travel behaviour data.

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Low-Emission Zones in European Countries

M. Tögel*, L. Špička
Transport Research Centre, Brno, Czech Republic,
** Corresponding author: marek.togel@cdv.cz*

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ABSTRACT: Low-emission zones are currently one of several tools which are in use for the improvement of air quality thanks to the limited entry of vehicles to European city centres. This article describes basic characteristics and parameters of low-emission zones in comparison with other types of used restrictions and explains the evaluation system of particularly environmental benefits and impacts. These theoretic assumptions are confronted with established low-emission zones in selected European urban areas; measured benefits and impacts of individual measures are evaluated and compared.

KEY WORDS: Low emission zone, LEZ, urban access restrictions, European urban areas, environmental impact.

1 INTRODUCTION

One of the most burning issues in urban areas is currently the high air pollution level. Up to a certain extent, this situation is often aggravated by emissions of pollutants (nitrogen dioxide – NO_2, aerosols of particulate matter – PM_{10}[1], $PM_{2.5}$[2]), which are produced as a by-product of the combustion process of motor vehicle engines (NO_2, PM_{10}, $PM_{2.5}$) or as a result of the abrasion of movable vehicle parts (PM_{10}, $PM_{2.5}$). The effects of pollutants have negative effects on population health causing cardiovascular, respiratory, and malignant diseases.

An obvious solution for air pollution is to limit pollutant sources, particularly emissions from road transport. There is a wide range of tools for the reduction of emissions from road transport and their effects can be divided into global and local ones. Global tools include e.g. governmental subsidies for the purchase of electric vehicles or vehicles or buses run on compressed natural gas. In contrast, local tools can be generally called urban access restrictions (ISIS, 2010). Low emission zones are one of the types of the restrictions in use aiming to reduce the amount of emissions of nitrogen dioxide and dust aerosols.

The article is divided into four parts. The first part deals with the general idea of the concept of urban access restrictions and brings the characteristics of basic elements and parameters of one of the types of tools – low-emission zones. The next part describes the system of impacts of low emission zones with particular focus on environmental impacts. This part also contains definitions of measurable characteristics, which are necessary

[1] Dust aerosols smaller than 10 µm.
[2] Dust aerosols smaller than 2.5 µm.

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for the evaluation of effectiveness and operation of low-emission zones. Subsequently, the third part compares these theoretical approaches with the real implemented measures in several European urban areas, and points out differences in approaches to low-emission zones implementation in selected member countries of European Union. The last part of the article identifies drawbacks of low-emission zones.

2 LOW-EMISSION ZONES

The term “urban access restrictions” concerns all traffic solutions and restrictions which can be used to improve the environment in urban areas. Regarding typology, there are 2 basic types of traffic restrictions:

1) charging entry to designed zones
2) no entry to designed zones for some types of vehicles

The first approach allows to include all types of vehicles arriving to a designed zone. Regarding the effectiveness, this approach seems more complex and more flexible. The solution complexity is based on the potential effect on all vehicles arriving in a designed zone and in connection to other types of measures (e.g. public transport conception, road traffic management). The flexibility of the tools allows for easier setting of the conditions for entry (charging by vehicle types, charging by daytime, etc.), which allows for better control of the mobility of the arriving vehicles. The drawback of the approach is a demanding preparation to implement such solution, particularly to install the toll gates system and the monitoring system for the evaluation of solution effectiveness (stations for traffic emission measurement, traffic count devices, questionnaire surveys for drivers, etc.).

The second type of the approach allows to limit the entry for undesirable category of vehicles, and this type can be divided into two types of zones (ISIS, 2010). In the case of so-called restriction zones, there is no entry for vehicles whose movement is undesirable for some traffic reason in a given area (traffic flow, safety, protection of transport infrastructure against damage, etc.). The most frequent example is “pushing” heavy vehicles exceeding certain weight out of the city and town centres. In the case of so-called low-emission zones, the arriving drivers are affected based on their share to the air pollution. The criterion for the entry is usually the age of vehicle or emission category. In contrast to the first approach, the second type does not necessarily require the system of toll gates to check the entry. The installation of the monitoring system is as demanding as with the first approach, while the emphasis is generally placed on the monitoring of emissions and analysis of the dynamic composition of vehicle fleet.

The main difference between both types of zones is the purpose of installation with two major goals of the measures:

- reduction of traffic congestions and improved traffic flow
- improvement of the environment through the reduction of emissions from traffic

The purpose of low-emission zones is usually to improve air quality, which is reached by the reduction of emissions from road transport. In contrast, charged entry zones, or so-called traffic restricted zones, usually aim to reduce traffic congestions and improve traffic flow. The purpose of the given types of restriction zones in selected European urban areas is shown in the following graph in Figure 1.

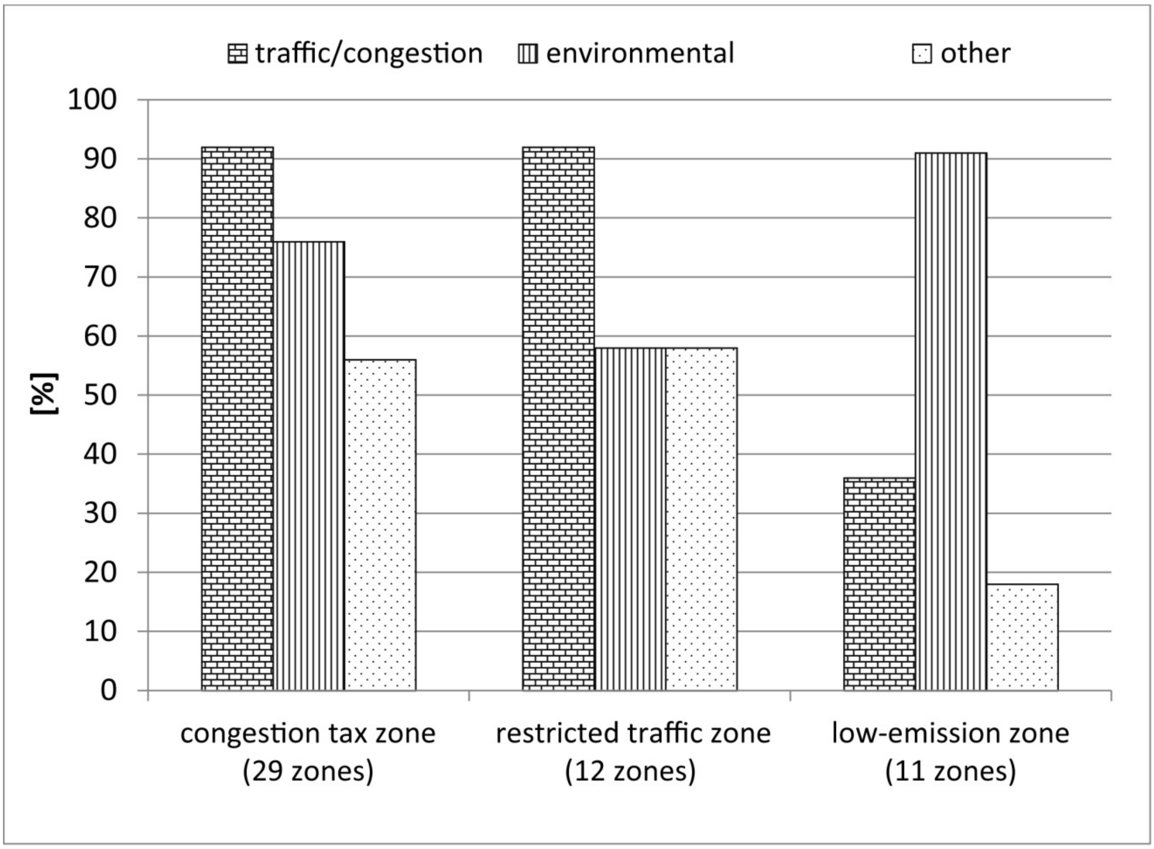

Figure 1: Purpose of introduction of basic types of restricting zones in selected European urban areas (ISIS, 2010).

The low-emission zone (LEZ) can be defined as a geographically delineated area with no entry of vehicles which fail to meet certain requirements. These requirements usually concern emission limits EURO, which are issued within EU directives by the European Parliament and the Council of the European Union. In some member countries, the conditions for entry are replaced with a different characteristic of vehicle technical conditions, e.g. vehicle age. The specific conditions allowing entry of vehicles to LEZ are specified by a country's legislation or a particular LEZ founder, usually a given responsible authority. There are three approaches to set LEZ conditions as follows:

i) conditions are specified by the legislation adopted by the government, and corresponding authorities delineate the geographical area of LEZ

ii) conditions are specified by the legislation adopted by the government, and corresponding authorities delineate the geographical area of LEZ and choose from a wider range of possible conditions specified by the legislation

iii) conditions for entry to LEZ and the geographical scope of LEZ are specified by authorities within the applicable national legislation

The above mentioned three approaches to setting conditions for vehicle entry to LEZ are consequently a cause of different economic, social, and environmental impacts. The first approach is considered the least flexible and the clearest. The second approach is an example of a combination of flexible solutions with the aim to make the given system clearer. The third approach the most considers the needs of municipalities. However, its significant drawback is the incomprehensiveness of such system in the regional and national scale.

Similarly, the responsibilities of municipalities are determined when issuing exceptions for specific vehicle categories[1]. The designed system may return to municipal authorities the right to grant exceptions, specify vehicle categories which may receive exceptions, or leave these powers fully in the responsibility of municipal authorities.

The Czech legislation gives municipalities the right to introduce a low-emission zone within their jurisdiction in compliance with Act No. 201/2012 Coll., on Air Protection. Municipalities are allowed to introduce a LEZ in case it is located within a special protected area, in a spa town, or in case the corresponding air quality limit values are exceeded within such municipality. Municipal authorities are allowed to grant and exception to all permanent residents within the low-emission zone. Similarly, in cases specified by the legislation, a temporary or permanent individual exception may be granted to specific vehicles[2] or specific people[3]. Municipal authorities are allowed to specify emission vehicle categories which are allowed to enter LEZs. In addition, municipalities are responsible for the delineation of LEZ area, in order to ensure a detour for transit traffic (Act No. 201/2012 Coll.). The above mentioned situation in the Czech Republic can be classified as the second approach for specifying conditions for LEZs. Based on the research of the situation in selected European countries which introduced LEZs, general basic parameters which need to be specified before the introduction of LEZ are summarized below:

- delineation of LEZ
- types of vehicles for which no entry to LEZ applies
- emission category of vehicles with allowed entry to LEZ
- time applicability of conditions for allowed entry to LEZ
- system of specifying emission categories to specific vehicles
- system of granting exceptions to groups of vehicles or specific vehicle owners
- determination of the validity of conditions to entry to LEZ for vehicle from foreign countries
- determination of sanctions for violating conditions for entry to LEZ

A LEZ founder needs to specify all these parameters either directly on the basis of their responsibilities, or the specification of parameters is given by the legislation. The mentioned parameters allow to create typologically different LEZs which may vary significantly in their efficiency and effectiveness.

3 SYSTEM OF EVALUATING EFFECTIVENESS OF LOW-EMISSION ZONES

The monitoring of impacts in relation to the implementation of low-emission zones allows their founder to justify and defend the use of the given tool. The system of effectiveness evaluation of LEZ should reflect the aims and expectations for which a LEZ is introduced. The purpose of LEZs is to improve air quality and consequently to improve the health of population exposed to pollutants. This causal relation (emission reduction → air quality improvement → population health improvement) needs to be perceived with some

[1] e.g. vehicles of integrated rescue system, vehicles transporting impaired people, vehicles of residents inside LEZs, etc.
[2] Vehicles with special equipment, vehicles designed for transport of goods to cultural and special events, and vehicles transporting fuels for hospitals, social institutes, and education facilities.
[3] Ill or impaired people, people whose working hours prevent them from travelling by public transport, and people who would be unable to run their business.

uncertainty. The final goal of the whole measure may by affected by many other external factors, which have effects independently of the implemented measure. The effects of these factors may significantly change the evaluation monitoring measurements, therefore, it is necessary to distinguish the effects by the degree of direct or indirect relations and determine for which effects the effects of external factors need to be taken into account. A study evaluating the benefits and impacts of a LEZ in London (TfL, 2008) also produced a hierarchy of impacts which can be observed as a consequence of a LEZ introduction. The system of LEZ impacts is shown in Figure 2.

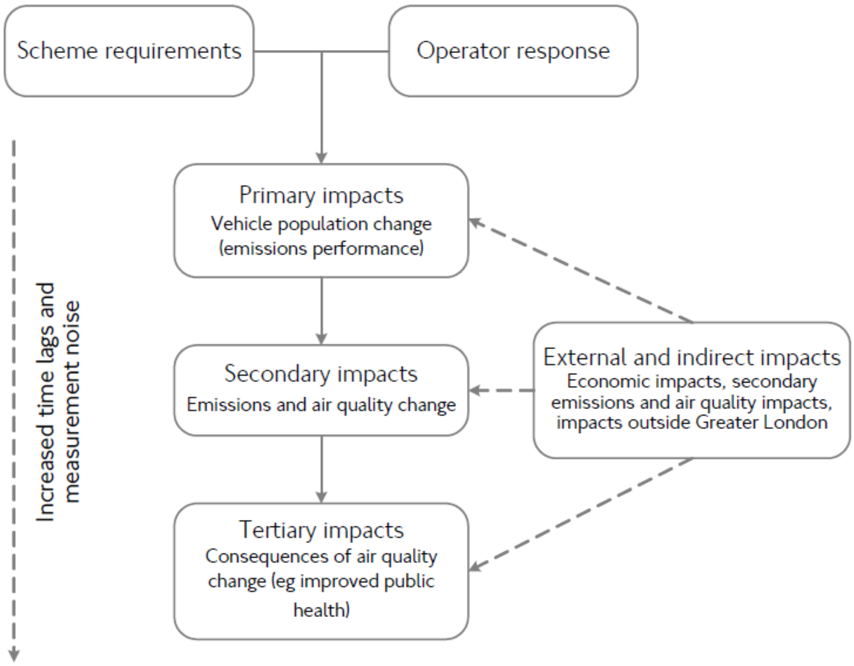

Figure 2: Scheme of impacts as a consequence of LEZ introduction (TfL, 2008).

Impacts can be divided into primary, secondary and tertiary (direct) ones. With the increasing degree of impacts grows the effect of external factors (indirect) and the delayed time in which the given impacts manifest. Since the purpose of LEZ introduction, i.e. air quality improvement and population health improvement, is only reached by secondary and tertiary impacts, it is necessary to set the evaluation system in order to identify the impacts independently and precisely. In general, two basic approaches for identification of impacts are distinguished: modelling and empirical measurement.

The primary impact of LEZ introduction is the change in the dynamic composition of vehicle fleet. The vehicles which are affected by LEZ restrictions will be measured for the share of emission categories within the vehicle fleet. This investigation can be performed through direct empirical measurements with the use of available technologies. Studies from London and Berlin show that these measurements are performed by vehicle count on certain representative transit profiles. The aim of the measurements is to determine the composition of vehicle fleet by emission categories within a given area under conditions without an introduced LEZ and with an introduced LEZ. The difference of these two situations identifies the primary impact of LEZ. The external factor affecting the dynamic composition of the vehicle fleet is the so-called natural renewal of vehicle fleet. This is based on economic conditions in a given municipality, general technological possibilities, and the legislation of a given country. The significance of different external factors may vary. The predictions of external factors are usually based on previous measurements of the dynamic composition. Therefore, to evaluate primary impacts correctly, it is necessary to begin the monitoring of the dynamic composition of vehicle fleet several years prior the LEZ introduction. The experience from London and Berlin clearly show that drivers' feedback on LEZ conditions comes before the implementation of LEZ (Tfl, 2008; Lutz & Rauterberg-Wulff, 2009).

In order to identify secondary impacts, it is necessary to use the results of the primary impacts and take into account the effect of external factors, particularly weather conditions in a given area and emissions from a different source of pollution. The secondary impact is the change in emissions from road transport and change in air quality. The emissions from road transport can only be identified through the emission modelling within a given area with the use of the so-called emission factors[1] and traffic performance (TfL, 2008). In order to determine traffic performance, it is necessary to measure the dynamic composition of vehicle fleet and traffic volume within a given area. The conversion of the modelled emissions to imissions is performed with the use of the so-called dispersion studies. These studies model the dispersion of emissions of selected pollutants, while the local weather conditions and contributed emissions from other sources of pollution are simulated. This procedure helps to estimate the real impact of the LEZ introduction. The real imissions of NOx and PM10 can be also measured directly through the network of monitoring stations, however, it is impossible to determine precisely the contributed imissions from other sources than road transport and therefore also to determine the impact of the LEZ introduction. Despite this, these measurements are performed in German and British urban areas (Tfl, 2008; Lutz & Rauterberg-Wulff, 2009).

The identification of tertiary impacts, which includes population health improvement, is the most demanding of all the mentioned ones. The reason is the long delay when the LEZ impacts become obvious on the population health condition and also due to the large amount of external factors which affect the population health condition. There are 3 basic aspects of problematic measurements of tertiary impacts: Firstly, although the clear relation between the harmful effects of pollutants and increasing mortality rate of population is known, the given impacts are very slight in the total mortality rate context. Secondly, there are many parallel processes which influence population health[2]. Thirdly, population health is influenced by lifestyle and the work environment (TfL, 2008).

4 INTRODUCTION OF LOW-EMISSION ZONES IN WESTERN EUROPEAN COUNTRIES

Based on the available monitoring reports and evaluation studies, it was possible to evaluate and compare experience with the introduction of LEZs in London, German urban areas, and Swedish urban areas. The procedures for the introduction, parameters and evaluation indicators of LEZs vary for different countries. In general, two basic types of the introduced LEZ systems are distinguished.

[1] Emission factors specify the average extent of emissions of a given source for a given substance for a specific type of activity. Emission factors for road transport are usually specified in grams of emissions per a driven kilometre, in grams of emissions per a gram of burnt fuel, or in grams of emissions per a vehicle engine start-up (Hausberger et al., 2009).

[2] Health programmes, anti-smoking policy, etc.

4.1 Northern system

In Swedish, Danish, and British urban areas, the LEZs which restrict entry just for heavy vehicles[1] are introduced. Personal vehicles are not included since their lower contribution to PM10 emissions is assumed in comparison with heavy vehicles. In addition, there is an assumption of faster natural renewal of personal vehicles and therefore higher proportion of emission categories meeting stricter limits. The given system is based on the EURO emission limit classification. The given system uses the information on vehicle emission categories from the national vehicle database. Vehicle emission categories are checked by either a camera system at the entry to the zone, or by random inspection within the LEZ. The restrictions of LEZs are also applicable for foreign vehicles and the restrictions are applicable 24 hours 7 days a week. Since the methodology of monitoring of LEZ impacts varies in different countries, even in time conditions, the effectiveness of the measure cannot be compared between the studied urban areas.

In the Swedish city of Gothenburg, the effectiveness of LEZ introduction between 1996 and 2006 was analysed. Based on the results of the study, it is estimated that the emissions of NOx were reduced by 7.8% and emissions of PM10 by 33.2% thanks to the introduction of the LEZ. The highest reduction was reached in the category of vehicles over 16 tonnes. In the case of the city of Gothenburg, the entry to LEZ was allowed to vehicles which had been in the register of vehicles for less than 8 years (Trafikkontoret, 2006).

In February 2008 in London, a LEZ was introduced which restricted entry for vehicles over 12 tonnes, unless they met the EURO 3 emission standard. This was the first stage of the whole project. In July 2008, the second stage was implemented restricting the entry for vehicles from 3.5 to 12 tonnes which failed to meet the EURO 3 emission standard. In October 2010, the third stage was launched. This stage restricts the entry for light commercial vehicles up to 3.5 tonnes and microbuses. The requirements for the emission standard stayed unchanged in this stage. In the final stage 4 (January 2012), the conditions for entry to the LEZ for all so far included vehicles were tightened – all vehicles to enter need to meet the EURO 4 emission standard. A monitoring study published in 2008 evaluated the impacts of the introduction of the LEZ. The dynamic composition of vehicle fleet, which was particularly focused, was identified with the use of a camera system (ANPR[2]). The results clearly reflect the response of drivers who were included in the first stage. In March 2007, 58% vehicles complied with the future conditions, while in December 2007 the proportion of vehicle meeting the conditions of stage 1 reached 70%. The compliance with the conditions for other vehicle categories included in stage 2 stayed virtually unchanged. It is to say that the operators get prepared for the conditions of LEZ only in the last months before the LEZ introduction (TfL, 2008).

The system of effectiveness evaluation of the LEZ in London concerning the reduction of emissions NOx a PM10, is based on three types of components which were monitored in three stages. The first monitoring stage processes information on the so-called natural change in emissions from road transport. The data are obtained from database LAEI[3] from 2004 – 2006. The second stage of monitoring is focused on the natural change in emissions from road transport without the effects of LEZ from 2006 – 2007. In order to determine this change, the data from LAEI and data from the national database of vehicle register are compared. The third stage of monitoring estimates the value of the third component, so-called

[1] Buses, microbuses, light commercial vehicles, and heavy vehicles.

[2] Automatic Number Plate Recognition.

[3] London Atmospheric Emissions Inventory. A database monitoring emissions from point (e.g. factories), line (e.g. roads), area (e.g. quarries, industrial area), and volume (e.g. air transport) sources since the 1920s (TfL, 2008).

the change in emissions from road transport as a consequence LEZ introduction. The data are obtained from the system ANPR during 2007. The benefits of the LEZ introduction can be estimated through the comparison of all components. The change in emissions as a consequence of the natural renewal of vehicle fleet, which is given by the external factors (economic, technological, etc.) was, on the basis of the first ad second monitoring stages, determined to the value of -6.9% for NOx emissions and -4.8% for PM10 emissions. The change in emissions as a consequence of LEZ introduction was -3.2% for NOx emissions and -1.8% for PM10 emissions. Prospectively, the whole change in emissions from road transport in London for 2015 is predicted to reach the values of -37.6% for NOx emissions and -16.8% for PM10 emissions. The predicted change is not entirely the effect of LEZ introduction, but includes the change in emissions as a consequence of the natural renewal of vehicle fleet (TfL, 2008).

4.2 German system

German urban areas have been allowed to introduce LEZs since March 2007. The first LEZs were introduced in 2008, namely in Berlin, Cologne and Hannover. The system of German LEZs differs from the British and Scandinavian ones in stricter conditions, since it restricts entry for all types of double-track vehicles which fail to meet the emission standards. The admissible emission vehicle categories are specified by responsible administrators for each of the LEZs. The system does not check emission vehicle categories through the national vehicle register, but introduces the system of stickers. Every vehicle entering a LEZ is obliged to have a sticker with the applicable emission category on a visible place (Lutz & Rauterberg-Wulff, 2009).

In Berlin in January 2008, a LEZ was introduced allowing entry of vehicles of emission category 2 and higher[1]. After introducing the LEZ, a change in the dynamic composition of vehicles in comparison to 2007 occurred, particularly in categories of utility and heavy vehicles. The proportion of vehicles of category 1[2] decreased by 29% for utility vehicles and by 10% for heavy vehicles. The proportion of vehicles in the highest monitored category (Euro 4 and Euro 5) decreased by 34% for utility vehicles and by 22% for heavy vehicles. Regarding personal vehicles, the proportion of the worst emission category 1 decreased by 1.4% and the proportion of vehicles in the highest emission category (Euro 4 a Euro 5) increased by 6%. The dynamic vehicle composition according to emission standards is usually measured by traffic count on a representative road segment. The modelled impact of LEZ introduction on PM10 a NOx emissions is always related to the modelled situation without LEZ introduction. The benefits of LEZ introduction are not based on vehicle categories, but are related to the whole vehicle fleet. In contrast to 2007, PM10 emissions were reduced by 25% and NOx emissions were reduced by 15%. For the modelling of emissions from vehicles the emission factors defined in HBEFA methodology, which was produced by Graz University of Technology, Austria, (Lutz & Rauterberg-Wulff, 2009) are used.

In July 2008 in Munich, a low emission zone was introduced restricting entry for vehicles of category 1. The Munich study does not analyse the changes in the dynamic composition of vehicles by emission standards, but identifies the proportion of vehicles which fail to meet the determined conditions for entry and which are to be restricted for entry to LEZ. The mentioned information comes from the statistics obtained from the data of the local

[1] Vehicle with diesel engines meeting minimum emission limits Euro 2 or Euro 1, if equipped with diesel particulate filter, or vehicles with petrol engines meeting minimum limits Euro 1, equipped with a catalytic converter (Lutz & Rauterberg-Wulff, 2009).

[2] Vehicles failing to meet emission limits Euro or meeting Euro 1 which are not equipped with a catalytic converter for petrol engines or with diesel particulate filter for diesel engines (Lutz & Rauterberg-Wulff, 2009).

vehicle register institute. The analysis was performed for the vehicle registered in LEZ, out of LEZ, and for vehicles registered in the whole city of Munich. The percentage of vehicles which fail to meet the conditions for entry to the LEZ does not vary much for all monitored areas. The proportion of personal vehicles which fail to meet the corresponding conditions ranges between 2.8 and 3.6%. The proportion of heavy vehicles which fail to meet the given conditions ranges between 30.5 and 31%. The expected reduction of PM10 emissions thanks to the LEZ introduction is estimated to approx 17%. The expected reduction of NOx emissions was not analysed in detail in the study (BSUGV, 2008).

In Cologne in January 2008, a LEZ was introduced which allowed entry just for vehicles of category 2 and higher. The reduction of emissions from transport in the introduced low-emission zone was predicted on the basis of the measurement of a representative road segment in the city. After the LEZ introduction, the expected reduction of PM10 emissions reached 18% in the minimum version and 27% in the maximum version. The reduction of NOx emissions reached 16% in the minimum version and 27% in the maximum version. Information on the static or dynamic composition of vehicle fleet was not found (Arentz, 2008).

5 DRAWBACKS OF THE USE AND EVALUATION OF LOW-EMISSION ZONES

The first drawback of LEZs as tools for the emission reduction is in their non-complexity. Since the goal of the LEZ introduction is to speed up the process of the natural renewal of vehicle fleet, the given solution system makes pressure on vehicle users just to acquire more environmentally friendly vehicles. The effectiveness of such solution may be relatively beneficial, but otherwise fails to give advantage to vehicle drivers to use any alternative transport modes. While the so-called charged entry zones can be used for transport as well as the environmental goals, the low-emission zones and the traffic restriction zones reach these goals separately. A possible solution is also to use a combination of both types of restrictions like in London or Stockholm, where both types co-exist (TfL, 2008; Hugosson et al., 2006).

The other drawback of low-emission zones is their non-homogeneous methodology of evaluating effectiveness and impacts. This difference is particularly caused by different variations and types which exist in European urban areas. This fact makes the analysis of comparisons of more types of low-emission zones more difficult. The difference between conditions for entry to LEZs in some countries is also rather problematic. For example, since the beginning of LEZ concept introduction German long distance bus operators have criticized the arbitrary specification of the allowed emission categories by the founders of LEZs in German urban areas. The reason that in national scale this competence creates a chaotic map of restrictions and limitations to which the operators find too difficult to adapt (Leonard, 2011).

The most frequent recommendations of experts concerning the given issue are particularly related to long-term planning and awareness, harmonization of basic parameters of LEZ in European countries (particularly a unified vehicle registration by emission categories), and to the unification and determination of evaluating indicator definitions for subsequent comparative studies (Ricci, 2011; ISIS, 2010).

6 CONCLUSION

Low-emission zones have recently become one of the most frequently used tools for dealing with the issue of air pollution in the centres of European urban areas. Typologically, LEZs are tools included in a wider set of restrictions and limitations called urban access restrictions. Designing LEZs requires to determine 8 basic parameters which may create different types of zones and reflect a purpose or policy of a given city or country. The evaluation of effects and benefits of LEZ is based on the monitoring of primary, secondary and tertiary impacts of LEZ, which are often influenced by external factors. The studies from selected European urban areas which describe LEZ introduction and evaluation of their effectiveness distinguish two types of the used systems so far. The Northern system restricts entry for just heavy vehicles by specific emission categories, while in some countries the system is based on unified conditions for all urban areas and uses the national vehicle database. In contrast, the German system restricts entry for all types of double-track vehicles by certain emission category, provides LEZ founders with competence to determine the admissible emission categories, and uses the system of emission stickers. The general criticism stresses the idea and purpose of LEZ as such, harmonization of approaches when evaluating LEZ effectiveness, and unification of rules and conditions restricting entry to LEZ. The LEZ introduction has experienced a rapid growth after 2000 (ISIS, 2010), however, the methodology for the evaluation of effectiveness and benefits of this tool is only beginning to rise. Deeper preparation of methodology for evaluating particularly the tertiary impacts, which manifest in the long-term run, is expected in the following years. This article deals with the methodology of evaluating particularly primary impact of LEZs, which are used for the initial evaluation of effectiveness of this tool.

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Comparison of Noise Level Measurement of Road Surfaces in the Czech Republic Using the Close Proximity Method

V. Křivánek*, K. Effenberger
Transport Research Centre, Brno, Czech Republic,
** Corresponding author: vitezslav.krivanek@cdv.cz*

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ABSTRACT: Transport Research Centre (CDV) owns a uniquely-constructed trailer in the Czech Republic which serves for road surface noise level measurement using the CPX dynamic method. It is specialised equipment which is in accordance with the ISO 11819-2 standard design used in the Czech Republic. Within the EU, the measurements using the CPX method are conducted by several, primarily research-focused, institutions. In order to determine whether CDV results are eligible for international comparisons, comparison noise level measurement using the CPX method was conducted in the Czech Republic during joint work on the CESTI project (TE01020168 - Centre for Effective and Sustainable Transport Infrastructure) between CDV and Eurovia Services s.r.o. The measurement was conducted by CDV using a specially-constructed trailer. Eurovia used a specially-modified regular road vehicle manufactured in France. Results of comparison measurements at 50 km/h show that the noise level was systematically higher on most surfaces analysed by the Eurovia company. The average difference in 14 measurements was 0.6 dB(A): as far as the measurement uncertainty is concerned, the acquired results are compatible.

KEY WORDS: CPX method, road-noise measurement, comparison measurement, noise tyre/pavement.

1 INTRODUCTION

Transport has become an important factor influencing our lives, both in positive and negative ways (Potužníková et al., 2012). These days, noise represents one of the most frequent environmental pollution sources. In Europe, noise is becoming one of the most frequently discussed topics: it is one of the five key European road infrastructure issues related to long-term road transport (2002/49/EC, 2002) as regards its negative influence on the environment and human health.

Sources of car noise mainly include the following (Sandberg & Ejsmont, 2002): vehicle power units (motor, radiator, transmission system, exhaust pipe), vehicle tyres (tyre rolling on road surface), vehicle aerodynamics (air flow around the vehicle), vehicle brakes, vehicle bodywork (and its “rattling”), vehicle load. At low speeds (approx. 40 km/h for passenger vehicles and approx. 60 km/h for freight vehicles), in vehicles equipped with combustion engines, the main source of noise is the power unit. At higher speeds, tyre noise, caused by their rolling, becomes more dominant: this concerns the speeds of up to around 200 km/h.

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At higher speeds, aerodynamic noise, caused by air flow around the vehicle, becomes dominant. Regarding the majority of main roads and speed limits, the dominant source of noise comes from the contact of tyres with road surface, which is caused by a combination of physical processes (Bernhard & Waysona, 2005). The reduction of noise originating from the contact of tyres with the road surface is a significant measure on the part of the source (Raitanen, 2005; Ahammed & Tihge, 2008). The monitoring and timely exchange of the wearing course of road surface can significantly contribute to long-term sustainability of transport and decrease negative impacts on the environment and health, owing to effective restrictions of excessive noise load from road transport (Morgan, 2006; Máca et al., 2012).

Practical monitoring (Paje et al., 2010; Wong et al., 2009) is frequently performed using the dynamic CPX method. The measurement using the CPX method is conducted in accordance with ISO 11819-2 (ISO/DIS 11819-2, 2012) and 11819-3 (ISO/TS 11819-3, 2012) standards at speeds from 40 km/h (Mak et al., 2011). This method neither depends on traffic flow nor on travel on road: it can be applied anytime, provided the required meteorological conditions have been met (Ejsmont & Mioduszewski, 2009); it also enables assessment of both short and long road segments and following segments. The basic description of the measuring process using the CPX method was given in the previous issue of ToTS (Křivánek, 2013). The CPX method is used for (Mak et al., 2012): monitoring of acoustic behaviour of road surface over several years of its usage, comparison of noise levels on individual road surface types, verification of the efficiency of low-noise road surfaces, etc. In comparison with other measurements, the CPX method is more practical, less demanding on measuring conditions, and also faster, more economical and capable of excluding partial disturbing components. The disadvantages of the CPX method are that it only records the tyre/surface noise, i.e. it does not account for effects of the surroundings on noise reduction, and the fact that it requires a minimum length of a measured road segment (starting and braking distance).

Since 2011 CDV has conducted noise level monitoring of individual surface types using the CPX method (Křivánek et al., 2012) on selected road segments in the Czech Republic, with strict observation of newly designed standards ISO 11819-2 and 11819-3, in order to secure long-term repeatability and comparability of results with foreign data in a long-term time horizon, so that the results can be objectively compared (Křivánek et al., 2013). There was an opportunity for basic evaluation of results within the CESTI research project: it was possible to implement simultaneous independent measuring using another device than the specialised CDV trailer.

2 CPX MEASURING DEVICE PARAMETRES

CDV conducted measurement of noise levels from tyre/road surface contact using the CPX method in accordance with the ISO standard (ISO/DIS, 2012), with a specialized trailer towed by a specialized passenger car, as shown in Figure 1. The tyre used was Uniroyal Tigerpaw 225/60-R16 from the USA, designated as SRTT (Standard Reference Test Tyre). It is one of two tyres recommended in the proposed ISO 11819-3 standard (ISO/TS 11819-3, 2012).

Eurovia conducted noise measurement using the CPX method in accordance with the French national standard (LCP No. 63, 2008) with a standard passenger car, which was customised in order to meet the measurement requirements, as shown in Figure 2. This is similar to the proposed ISO 11819-2 standard (ISO/DIS 11819-2, 2012): however, the national standard (LCP No. 63, 2008) does not indicate a tyre type to be used, it only lists specific requirements on them (such as the depth of tyre tread, which must be higher than 2/3 of the original value). During their measurement, Eurovia used the Michelin 195/60/R15 tyre.

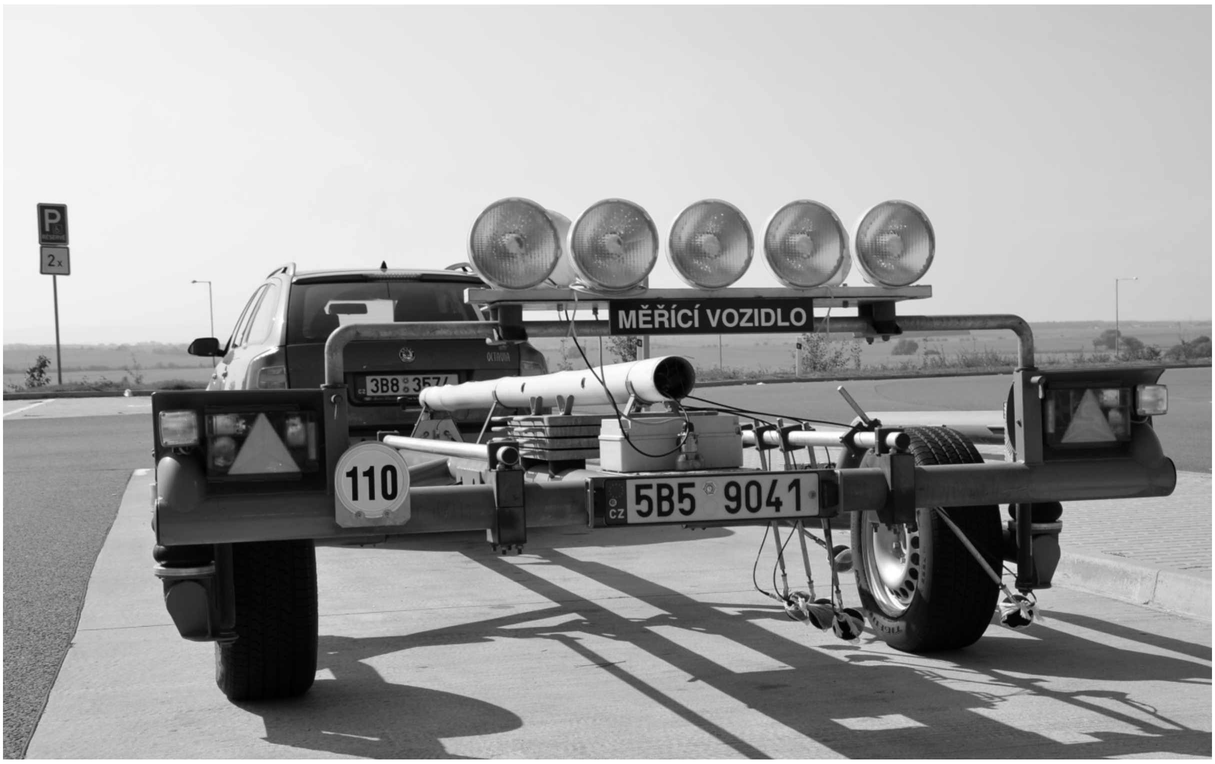

Figure 1: CDV measurement vehicle, CPX method.

Figure 2: Eurovia measurement vehicle, CPX method.

Detailed view of tyre tread on the tyres used is shown in Figure 3. The influence of the chosen measurement tyre represents the biggest uncertainty of noise levels from tyre/road surface contact (Morgan et al., 2009) - each device was equipped with a different measurement tyre, it can therefore be expected that differences between the measured values were caused by this fact.

Figure 3: Michelin Energy 195/65-R15   Uniroyal Tigerpaw 225/60-R16.

Comparison of individual partial parameters of the respective complex setups for CPX measurement is given in Table 1.

Table 1: Parameters of CPX measurement devices.

Parameter	CDV	Eurovia
Standard	ISO/CD 11819-2 Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 2. (ICS 17.140.30 from 20 December 2012)	"Mesure en continu du bruit de contact pneumatique/chaussée, Méthode d'essai n°63 LCP" from 2008
Measurement	On a measurement trailer, towed by Škoda Octavia, engine 2.0	Directly on the car – Renault Scénic, engine 1.9 TDi
Tyre	Uniroyal Tigerpaw 225/60-R16	Michelin Energy E3A195/60/R15
Tyre pressure	200 kPa	220 kPa
Tyre mileage	12 000 km	125 000 km
Number of microphones	5	3
Microphone type	Brüel & Kjær, type 4189	Brüel & Kjær, type 4189
Speed measurement	GPS	Independent wheel tachometer
Temperature measurement	Infrared sensor	Infrared sensor
Measurement uncertainty	+/- 1,0 dB(A)	+/- 1,4 dB(A)

3 MEASURED SURFACE NOISE LEVEL VALUES USING THE cpx METHOD

The compared result of measurement is represented by the equivalent level of acoustic pressure A of the tyre/road surface contact. The acquired data underwent post-processing, which eliminated possible disturbing influences. Furthermore, necessary corrections were performed using the acquired actual speed values, air temperatures and road surface temperatures. Table 2 shows corrected equivalent acoustic pressure A levels at reference speed 50 km/h and reference temperature 20°C.

Table 2: Selected measurement results, CPX method.

Measured segment	Surface type	Tyre Uniroyal Tigerpaw 225/60-R16, corrected L_{Aeq} to ref. values [dB(A)]	Tyre Michelin Energy 195/60/R15, corrected L_{Aeq} to ref. values [dB(A)]
Experimental measurement segment 1	Viaphone	**89,2± 1,0**	**91,0± 1,4**
Experimental measurement segment 2	Viaphone	**89,2± 1,0**	**89,9± 1,4**
Experimental measurement segment 3	Viaphone	**89,3± 1,0**	**90,5± 1,4**
Experimental measurement segment 4	SMA8 LA	**90,0± 1,0**	**90,5± 1,4**
Experimental measurement segment 5	SMA 8	**92,5± 1,0**	**93,2± 1,4**
Experimental measurement segment 6	SMA 8	**92,5± 1,0**	**93,2± 1,4**
Experimental measurement segment 7	SMA 11S	**93,7± 1,0**	**94,7± 1,4**
Experimental measurement segment 8	SMA 11S	**93,8± 1,0**	**94,9± 1,4**
Experimental measurement segment 9	mixture PA 8	**88,4± 1,0**	**88,3± 1,4**
Experimental measurement segment 10	mixture PA 8	**90,7± 1,0**	**90,4± 1,4**

4 CONCLUSION

In order to verify possibilities of using the results acquired from the CPX method measurement in the Czech Republic, as well as for purposes of international comparisons, using a specially-constructed CDV trailer, comparison measurements with the equipment of the Eurovia company during work on the CESTI project were conducted on selected sites in the Czech Republic. Although both measurement systems show minor differences, as demonstrated in Table 1, with the highest uncertainty originating from the use of different measurement tyres, the results are, as far as measurement uncertainties of the respective methods are concerned, comparable (see Table 2). Comparison measurement results at 50 km/h showed that noise on a majority of surfaces is systematically higher on the Eurovia device. This systematic deviation differs according to the actual surface type, which presumably owes to varying tyre treads. In 12 out of 14 measurements, noise levels measured by Eurovia were higher. The average difference in noise levels in all measurements was 0.6 dB(A).

The acquired results correspond with the data from foreign academic texts (Schwanen et al., 2007), which also analyse results of comparison CPX measurements: 13 segments showed higher noise levels for a similar tyre – Michelin Energy 205/65-R15, 5 segments showed the same noise levels and 4 segments showed higher noise levels for a tyre Uniroyal Tigerpaw 225/60-R16.

It can be said that the device used by CDV for monitoring noise levels of individual surface types using the CPX method, provided this monitoring is conducted in accordance with up-to-date designs of the ISO 11819-2 and 11819-3 standards, enables long-term repeatability and comparability of results with foreign data in a long-term horizon.

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