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DO BYPASS ROUTES REDUCE NOISE DISTURBANCES IN CITIES? CASE STUDY OF CHEB (Western Bohemia, CZECH REPUBLIC)

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ABSTRACT:
The increasing automobilization of society is accompanied by negative impacts on society, which also includes increased noise disturbances to which inhabitants are exposed. In an urban environment this fact is often solved by constructing bypasses and the benefit of these bypasses is disputable in many respects. The trend towards constructing bypasses has markedly applied to the Czechia, an important transit country due to its location, in the last decade. One of the traffic junctions that are used by the most in the Czech Republic is the city of Cheb, where diverting traffic from the arterial route has been solved by constructing a bypass route. In our paper we focus on the *ex ante* and *ex post* evaluations of noise loads to which inhabitants of the centre living along the former arterial route are exposed in the effort to give a true picture of changes in noise loads to which inhabitants are exposed. The evaluation itself is based on the results of the direct measurement which took place during two reference days before and after the construction of the bypass of the city of Cheb and on their statistical evaluation. There were no statistically significant changes in the noise situation before and after the construction of the bypass. The differences between individual days ($F_{3,72} = 2.039$; $p = 0.116$) and between the morning phase ($p = 0.928$) and the afternoon phase ($p = 0.200$) were not too marked. There was a marked difference in the traffic volume, especially that of trucks (-50 % in the morning phase and -26 % in the afternoon phase). The phenomenon induced demand was identified in the study area, where the traffic volume was spatially redistributed and especially the structure of vehicles running through was changed. A more marked reduction in noise loads would require other intervention in order to reduce the vehicular traffic and also monitoring the situation regularly.

***Key-words**: Bypass, Urban environment, Traffic noise, Transit, Cheb.*

1. INTRODUCTION

The political regime change in Central and Eastern Europe countries in the 1990s and the subsequent transformation period were and are currently accompanied by an increase in the road passenger and freight transport volume in the Czech Republic. Also the transit location of the country, where the largest traffic volumes are directed from NW to SE (Pucher, 1999; Pucher & Buehler, 2005; Kraft & Vančura, 2009), contributes to this fact. The increased traffic is accompanied by the worsened environment and wellbeing of inhabitants in towns and cities where transit freight and passenger traffic along an arterial road – right through the centre of the settlement in many cases – prevails. Relieving inhabitants is often solved by constructing bypasses, which should divert the main transit traffic volume from the town or city if their design and planning are of high-quality. What is described above is the most frequently declared objective of decision makers when planning the construction of a bypass (Liff et al., 1996).

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The main intention and positive effect of the construction of bypasses, i.e. a reduction in traffic loads along the original routes, are disputable. The conclusions of the *ex ante* and *ex post* evaluations of bypasses (Thompson, Miller & Roenker, 2001; Collins & Weisbrod, 2000) show that the traffic volume along the original route was not reduced. This phenomenon (induced demand) is explained by the fact that the freight traffic capacity newly made available in the centres of the towns and cities is filled by cars (Cervero, 2003). On the other hand, Liff et al. (1996) mentions a reduction of 50-70 % in traffic in the centres of settlements with up to 20,000 inhabitants. Also impacts on the local economy are evaluated differently, from neutral to positive impacts in the form of an increase in the number of jobs, retail and the price of land (Liff et al., 1996; Babcock & Davalos, 2001). The realization of bypasses and new roads in general entails also other externalities in the form of influencing (i) traffic smoothness; (ii) the number of accidents and injuries; (iii) a reduction in vibration, dust and pollutants in towns and cities; (iv) noise loads; (v) the well-being of inhabitants; and (vi) urban sprawl (Elvik et Al. 2009; Egan et al. 2003; Wafa & Shiftan, 2011; Raška et al., 2013; Balej et al. 2008, Pařil et al. 2015). Especially the development of new barriers (community severance) related to landscape fragmentation is perceived negatively (Di Giulio, Holderegger & Tobias, 2009).

One of the main monitored negative externalities is the effect of noise on human health before and after the construction of new roads. Egan et al. (2003) summarizes the results of 12 studies of various localities in the centre of a settlement after the construction of a bypass, where a reduction in the noise disturbance of inhabitants was confirmed in each of them. The threshold of sound perception is individual; nevertheless, Laszlo et al. (2012) state, on the basis of research, a 4 dB (A) limit as the limit for a perceptible reduction in noise as a disturbing factor. This limit is in accordance with the conclusions of Stansfeld et al. (2009), where the noise loads were reduced by 2-4 dB L_{Aeq} after the construction of a bypass and this did not led to any changes in the psychical activity and the quality of life of inhabitants. When assessing the noise load level, the equivalent sound pressure level (L_{Aeq}) is used most frequently. This is an indicator which is used when evaluating the variable nature of noise being assessed. This is a fictive stabilized noise level which has the same effects on humans for the monitored time period as the variable noise for the same time (Alberola, Flindell & Bullmore, 2005; Nový, 1995).

Since 2002 over 150 projects concerning the construction of settlement road bypasses have been recorded in the Czech Republic (CENIA, 2016). The Environmental Impact Assessment (EIA) of road bypasses also includes the assessment of the new construction impact on noise loads to which inhabitants are exposed within Health Risk Assessment (Potužníková et al., 2012). Assessment usually takes place by predictive modelling on the basis of the future traffic volume. The noise situation on the original arterial road and its relation to the construction of the bypass was solved to a minimum extent by measuring directly *ex post* noise loads in any of the published works available. In relation to the above, we have prepared a study which is aimed at evaluating a change in noise loads by measuring directly near the heavily loaded arterial road (ŘSD ČR, 2010) in the close-to-border city of Cheb (Western Bohemia, Czech Republic), where a transit traffic bypass has been constructed.

2. STUDY AREA

The city of Cheb is situated in the west of the Czech Republic at the point where the important Frankfurt am Main – Karlovy Vary – Praha (W-E) and Nürnberg, Regensburg –

Karlovy Vary (S-N) traffic roads are connected. The district of Cheb shares approximately one half of the border length with the Germany, which proves the strong border character of the city of Cheb. With its population of 32,355 (ČSÚ, 2016), Cheb is the largest municipality of eponymous district and creates a natural centre of the region. Many services, production plants and administrative authorities are localized here. Cheb is thus the central area of the entire district. The regional importance of Cheb is also reflected in the number of persons commuting to work and to school, which was 2,108 persons in 2011 – the greatest number of those of all settlements in the district (ČSÚ, 2011).

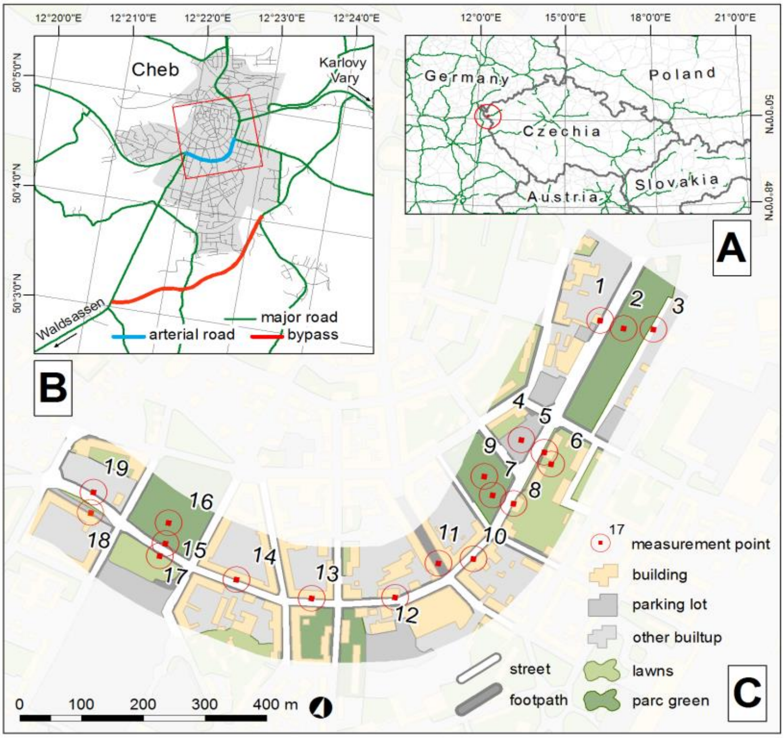

Fig. 1 Localization of the case study area and the measurement points
(data: openstretmap, ZABAGED; source: authors)

The research took place in the centre of the city of Cheb, Evropská street (**Fig. 1 B** and **C**). According to the results of the Czech Traffic Census 2010, this is the road in the town which is used the most and where the traffic volume reaches 13,299 vehicles per 24 hours (ŘSD ČR, 2010). The traffic volume in the section of Evropská street exceeds 21,000 vehicles / 24 hours (Martolos, 2007). The fact that the area of interest is of heavy traffic use is caused by the fact that national, local and transit traffic flows meet there. The section assessed is the backbone road used for moving within the city and is also used by local traffic caused by commuting. Transit traffic, which occurs in the area of interest especially due to its border location, can be described as the most problematic traffic flow. According to Jeřábek and Řehák (1999), 11 % of all cars and 14 % of trucks that cross the state border of the Czech Republic run right through the border crossings in the district of Cheb. The district of Cheb is thus the district with the most passable state borders in the Czech Republic. According to ŘSD ČR, (2010), 9.6 % of transit traffic running through the area of interest is freight traffic (which corresponds to 1,276 vehicles / 24 hours). Especially due to loads to which the area of interest is exposed due to transit traffic, the South-East Bypass was put into operation in 2015 (**Fig. 1 B**; designated II/214).

3. METHODS AND DATA

The collection of noise data was according to the applicable Czech regulations, namely ČSN ISO (1996), further implemented in the methodological instruction of the Ministry of the Environment of the Czech Republic for measuring noise loads in an outdoor environment (Ministry of Health, 2000). Measurement took place in the 1.3 km section of Evropská street (**Fig. 1 C**), which is the area of Cheb which is exposed the most to traffic loads. A total of 19 measurement points were set in this area and 15 of them were determined according to the methodology used and the other 4 points were determined in order to densify the point network. To describe the noise situation in as wide part of the daytime as possible, measurement took place both during morning hours and afternoon hours (see **Table 1** for the exact time schedule).

Table 1 - Time schedule and the conditions of the survey

	Date (Day)	Time	Height of the sound level meter (m)	Road condition	Wind speed (m/s)	Calibration max. deviation (dB)
before bypass	24. 6. 2015 (Wednesday)	14:30-17:30	1.5	dry	< 5	+ - 0.5
	25. 6. 2015 (Thursday)	8:30 -11:30	1.5	dry	< 5	+ - 0.5
after bypass	21. 10. 2015 (Wednesday)	9:00-12:00	1.5	dry	< 5	+ - 0.5
	22. 10. 2015 (Thursday)	14:00-17:00	1.5	dry	< 5	+ - 0.5

(Source: authors)

The localization and conditions of measurement corresponded to the methodology (Ministry of Health, 2000) and are given in **Fig. 1C** and **Table 1**. The duration of measurement at one station was determined to be the recommended 15 minutes (Smetana, 1998). A Voltcraft Datalogger 322 sound level meter was used for measurement and was set to measurement with A-weighting. During this noise measurement traffic was counted at individual stations, where vehicles were divided into 3 categories – cars, trucks and motorcycles (see **Table 2**).

$$L_{Aeq} = 10\log \sum_{i=1}^{n} 10^{0,1 L_{pAi}} \qquad (1)$$

The data obtained were used to calculate the equivalent sound pressure level L_{Aeq} according to (**1**), where L_{pAi} is the sound pressure level A in the i-th interval. To determine the similarity of the values measured on individual days, statistical surveys using a single-way ANOVA test with post-hoc comparison according to the Tukey-HSD method were used. The homogeneity of variances was tested using Bartlett's test. The above testing took place in an R package environment (R Development Core Team, 2016). All cartographic outputs were created in an ArcGIS 10.3 environment with data materials corresponding to a scale of 1:10 000.

4. RESULTS

Table 2 shows that there was a decrease in the number of trucks (TR) after the construction of the bypass in all cases. There was a decrease of more than 50 % in the number of trucks for the morning counting of vehicles and a decrease in the number of TRs was more than 26 % for the afternoon counting. For cars (CA), there was a decrease of just under 15 % in the morning hours and an increase of 3 % in the afternoon hours. For traffic as a whole (without motorcycles, which are a rather seasonal thing), there was a total reduction of 7.9 % in traffic after the construction of the bypass.

Table 2 – Structure and numbers of vehicles during the period of survey

25. 6. 2015 morning (before bypass)			21. 10. 2015 morning (after bypass)			24. 6. 2015 afternoon (before bypass)			22. 10. 2015 afternoon (after bypass)		
CA	TR	MT	CA	TR	MT	CA	TR	MT	CA	TR	MT
1,833	190	20	1,561	94	1	2,138	143	11	2,204	105	3

(CA – cars, TR – trucks, MT – motorcycles; source: authors)

From the viewpoint of the total noise load (L_{Aeq}) on all four measurement days, individual stations (**Table 4** Supplement) show strong spatial heterogeneity and can be divided (according to the quartile of the mean for all four measurement days) into four characteristic groups. The stations (**Fig. 1**, points – 3, 6 and 9) with the lowest measured noise loads (57-61 L_{Aeq}) were situated in the areas covered with park green. The second group of measurement points (points – 2, 5, 7 and 15-19) with higher noise loads (63-67 L_{Aeq}) was localized in unclosed built-up areas and areas where green vegetation was present. The measurement points (points – 1, 4, 8 and 10-14) in the last two groups were situated in closed built-up areas or in space closed on one side and showed the highest values of L_{Aeq} (68-76).

Table 3 – Differences between points (sound pressure level L_{Aeq} – dB) (M – morning, A – afternoon)

Point no.	L_{Aeq} (M)	L_{Aeq} (A)	Point no.	L_{Aeq} (M)	L_{Aeq} (A)	Point no.	L_{Aeq} (M)	L_{Aeq} (A)
1	-0.46	0.42	7	7.73	-6.57	13	-1.47	11.05
2	-2.32	-3.12	8	-1.23	8.96	14	8.9	9.48
3	-1.37	0.65	9	-6.47	12.79	15	3.38	-5.3
4	-0.08	17.28	10	-0.63	-0.29	16	3.99	8.97
5	-0.63	0.22	11	0.1	8.78	17	16.74	-3.52
6	0.48	6.05	12	1.29	0.7	18	-1.22	-0.93
						19	-2.86	12.4

(Source: authors)

There was a decrease of over 4 dB L_{Aeq} (detailed in the introduction) in the noise loads between individual measurement points (**Table 3**) in the case of the morning measurement before and after the construction of the bypass in the case of point 9 only. There was an increase of the same limit value in the case of points 7, 14 and 17. In the case of the morning measurements, points 7 and 15 exceeded a difference of 4 dB L_{Aeq} in the negative direction. An increase of the same limit value was showed by points 4, 6, 9, 11, 13, 14, 16 and 19 – put in all the four groups by noise load volume above.

Individual measurement days (n = 4) showed a relatively low intra-group variability (5-7 L_{Aeq}). When the differences between individual localities in the morning measurement hours are summarized, there was an increase of 1.24 L_{Aeq} after the construction of the bypass. During the days when measurement took place in the afternoon hours there was also an increase, which was 4.1 L_{Aeq}, after the construction of the bypass.

All measured values of the equivalent sound pressure level at all stations (n = 19) for individual four days of noise load measurement was statistically tested. Any statistically significant difference between individual groups (days) of measurement ($F_{3,72} = 2.039$; $p = 0.116$) has not been found out from the conclusions of the one-way ANOVA (**Fig. 2 A**) comparison. The results of the multiple comparison of average values using the Tukey's HSD did not show any significant differences between the values measured (**Fig. 2 B**) in the morning (A_A-A_B; $p = 0.928$) and in the afternoon (M_A-M_B; $p = 0.200$). A similar conclusion also applies to the other differences observed between the groups (**Fig. 2 B**).

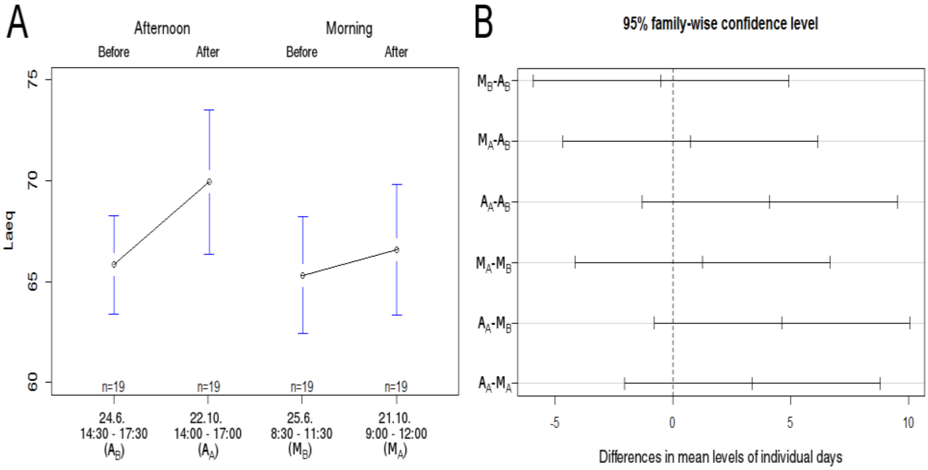

Fig. 2 – A – Noise level (L_{Aeq}) mean plot with 95% confidence intervals; **B** – differences in mean levels between individual days. *(Source: authors)*

Although the above results of this research show that there was a reduction in the number of vehicles running along the arterial road leading through the centre of the city of Cheb, there was not any statistically significant change in the noise load level. The change in the equivalent sound pressure level after the construction of the bypass was +2.7 dB (A) on average.

5. DISCUSSION AND CONCLUSION

In this research we focused on a change in traffic noise loads in the centre of a city before and after the construction of a bypass. Cheb (W Czechia), a border settlement exposed to transit traffic loads, was used as an example. By comparing *ex ante* and *ex post* a reduction and a change in the vehicle structure after putting the bypass of the route studied into operation was found out. The improvement of the noise situation was found out not to be statistically significant.

The above results show a change in the structure of vehicles along the studied route. The number of trucks decreased largely, which was certainly one of the main objectives and intentions not only of this construction (Martolos, 2007), but generally of most of similar projects (Liff et al., 1996). On the other hand, only a slight decrease or rather stagnation in the number of cars running through was found out. The situation which has occurred corresponds with the conclusions of other studies (Thompson, Miller & Roenker, 2001; Collins & Weisbrod, 2000; Handy at. al. 2000) and the phenomenon given can be explained by subsequent induced demand.

Cervero (2003), elaborating the induced demand term, divides impacts of changes in the traffic network into short-term impacts and long-term impacts. The first type can be termed changes in the behaviour of drivers. An increase in traffic along the Cheb arterial road can be induced by releasing the route by trucks and it is subsequently used more by car drivers, who would solve their way by bypassing the arterial road or select a different form of transport before the construction of the bypass. The second impact type – long-term is characterized especially by a change in land use and thus by the residential development and especially services in the surroundings of the road (this construction and services generate further traffic). This process will most probably also apply to the surroundings of the SE bypass of Cheb, due to its edge location, accessibility of land and the precondition in the form of the possibility of building in the area in the local zoning plan.

Another reason due to which we consider that the increase in the number of cars on the arterial route after the construction of the bypass is not accidental is the centrality of the settlement. Cheb is a natural commuting centre (school, work and office). Other reasons due to which there was not a reduction in traffic as described by Liff et al. (1996), i.e. a traffic reduction of 50-70 %, can be found in the orientation of the traffic routes. In the case of Cheb, traffic crosses in the directions from NW to SE and from SE to W in the centre or in its surroundings (**Fig. 1 C**). Therefore, this is not a simple diversion in one direction (the bypass solves only a part of transit traffic).

Last but not least, also the fact that the bypass was not recorded in navigation systems at the time when the research was carried out is taken into consideration and thus it is possible to assume that the bypass will be prospectively used to a greater extent, at the expense of the arterial road leading trough the centre of the city, after updating the navigation map materials and also after taking account of the general trend towards increased automobilization.

The reduction in the freight traffic volume on the solved arterial route (Evropská street, **Fig. 1 C**) was not reflected in an adequate reduction in noise loads. According to the conclusions of the study by Öhrström (2004) where the noise load was provably reduced (-14 dB A) and the well-being of inhabitants (in the meaning of psychical comfort and time spent in outside areas) living in the surroundings of the studied road was improved and at the same time there was a radical decrease in the number of vehicles running through (a decrease from 25,000 to 1500). The radical improvement of the situation, if we disregard the specifics of the local conditions, would therefore have to be connected with a radical decrease in the traffic volume – e.g. by excluding fully freight traffic and reducing car traffic. When divided into morning measurement and afternoon measurement, there was an increase of 1.26 dB (A) in the noise load in the first case and an increase of 4.11 dB (A) in the latter (afternoon comparison) in the case of our case study. Considering that the changes described above are insignificant for human perception (Stansfeld et al., 2009; Laszslo et al., 2012), we cannot talk about a marked decrease in the disturbance to the population due to noise in the studied case.

In addition to impacts on inhabitants along the arterial road, impacts on population living outside the centres of settlements – near the bypass – must be solved. Egan et al.

(2003) points to complaints made by inhabitants living in the surroundings of the bypass concerning the noise caused by increased, newly redistributed traffic. A similar situation was also noted in the case solved by us, where a complaint made by inhabitants of the municipal part of Háje (south part of the settlement, **Fig. 1 B**) with the local authority of the municipality was solved one week after putting the bypass into operation (Zeman, 2016).

If we should answer the question whether the construction of bypasses in general and universally contributes to a reduction in noise loads to which inhabitants are exposed in the centres of the settlements, the answer would be ambiguous. In addition to provable improvement in the perception of noise disturbance (Egan et al., 2003), there are cases, such as our study area, where the values of physical loads remained constant. In addition to the induction of demand discussed above, an important part is indisputably played by the geography of the settlement and the future traffic arrangement, which should be taken into account in the preparatory part of the project.

Despite the unproved decrease in noise loads in the surroundings of the route being solved, we cannot unambiguously talk about a negative influence of the bypass. To gain a deeper insight into the problems of impacts of new construction, it would be appropriate to elaborate the work more to include a qualitative survey (structured interviews) among inhabitants and decision makers concerning the original route and the bypass and also to use the existing methodology for re-evaluating after a longer time.

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