

## Impact of particular indicators of urban development of cities in the Czech Republic on average road traffic intensity

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### Abstract

This paper deals with the dependency between the development of road traffic intensity and several statistic and spatial indicators, which are monitored in cities of the Czech Republic. Road traffic intensity was used as the basic phenomenon. The other city indicators are residential, productive, recreational and other areas, population and many other indicators. This analysis is a part of a large research focused on last forty years in cities of various sizes, traits, and location in the country during last forty years in ten years' time steps. Stagnating or even a decreasing number of inhabitants of cities on one side and increasing road traffic intensity is a typical characteristic in most cities. The fact concerns both cars, and lorries; motorcycle form of transport has receded for more than 80 per cent during these forty years. The paper shows that the urban development is strongly dependent on historical developments of individual cities. It means that influence of individual indicators varies in individual cities. There was an important difference between the period before and after the political change in 1989.

The aim of the paper was to analyse a long period of urban development of a high number of Czech cities and to determine if their development can be generalized for all of them or it is more individual. Future situation of cities can be more reliably derived from the historical development of individual cities than from deep statistical analyses of a higher number of cities. The result will help urban engineers for urban areas modelling.

**Keywords:** Land use, development, road traffic intensity, urban area, ArcGIS

### INTRODUCTION

Since 50-ies of the 20<sup>th</sup> century, cities of the Czech Republic have changed at a varying extent due to their technical and social development with regard to two different political and economic systems. Development and consequences of these changes have reflected a quality of our living space in our present cities. All consequences cannot be classified as positive. In order to avoid these negative consequences, analysis of the history is needed. It was the main goal of the COST Project - Modelling of urban areas to lower the negative influences of human activities.

The project dealt with a detailed evaluation of relations among urban development indicators to prepare a set of recommendations for a sustainable development of urban areas. It was processed between 2010 and 2012 at the Department of Mapping and Cartography of the Faculty of Civil Engineering at CTU in Prague. Project included analysis of the cities of the Czech Republic from the point of view of the road traffic and urban development determined by land use classes and some statistical data. Land use classes called functional classes which consist of – residential areas, production areas, recreational areas, other areas and transportation areas. The project was originally processed for fifty cities. However, all data were not available for all cities. Therefore only thirty-six cities were fully-processed.

This article is a part of a broader comparative study of the above-mentioned COST project. The main topic of this paper is to analyse various attributes which can influence road traffic. These attributes as indicators of the cities' development are described in chapter 3. The relationship was processed within fifty selected cities in the Czech Republic by a methodology which was developed by [Veprek 2009].

Road traffic is an import source of air pollution, noise, and many other problems of present life on one side and therefore it plays a substantial role in the urban area environment. On the other side, the world has

changed and relies very intensively on road traffic. Land use in urban areas has an important influence on road traffic intensity, which is one of its characteristics in these areas. Road traffic intensity – as measured in the Czech Republic – is the number of various types of vehicles passing through determined locations on selected roads in 24-hour periods. The analysis is based on seeking the dependency between road traffic intensity and particular land use and statistic indicators (Table 1). This relation is expressed by a correlation coefficient CCAI (see chapter 3).

## CURRENT STATE

Urbanisation as a phenomenon of the last fifty years is a phenomenon which occurs in most countries of the world. It is the reason why urban development is analysed by many authors in many countries. The goal of these analyses is to determine the indicators which can be managed to lower the negative impacts of urbanisation from the increasing noise and emissions of road vehicles, e.g.

Litman (2009) describes the methods for evaluating how transport planning decisions influence land use - and how land use planning decisions affect transport. He uses 12 factors as a location of development relative to the regional urban centre, which reduces vehicle mileage per capita. The higher number of people or jobs per unit areas reduces the vehicle ownership, etc. He mentions that actual impacts will vary depending on specific conditions and combinations of applied factors.

Similar argumentation about the relation between transportation and land use can be found in [Jacobson, 2013] who states that land use type distribution and transportation system are interdependent. It means that transportation elements have an influence on land structure and land use has an effect on the transportation network shape. This relation is extremely important because - from the point of view of road traffic – it can define our living space especially in cities, where the type of transportation is defined by its location, and the density of population and spatial structure of land use types in the area. For example, the street layout with the funnel type of major traffic arterials causes congestion in major streets and buildings are set far apart by vast parking areas, and wide access roads and that discourages walking among them.

The affects of various land use characteristics on travel activity were analysed in many other publications (e.g. Barla 2011, Ewing *et al.* 2007, Ewing and Cervero 2010, Guo and Gandavarapu 2010, Kuzmyak *et al.* 2006, Ristimäki and Kalenoja 2011).

The relation between transport and land use has an impact on business analysis, especially access management. Banister (2011) emphasizes that transportation infrastructure is one of the crucial phenomena of economic development. Transportation is a source of carbon emissions, which are assumed to have an influence on global climate change. If we want to keep the economy on its trend with the support of transportation, we have to deal with the reduction of energy and emissions in transportation, although this problem is very tough, some small successes have happened.

The trend of the growth of road traffic, which has been increasing, is unsustainable (Banister 2011). As a solution, they suggest reducing energy consumption based on a change of travel habits (shorter distances and slower speeds, with a more flexible interpretation of time constraints) with regard to the land use planning. The solution of the low carbon transport system is outlined in (Banister *et al.* 2011) so as behavioural options and possible demand reductions.

The link between land use planning and energy consumption can be presented with convincing data in scientific outputs (Bregeny in Banister 1995). However, they show how difficult is to determine the relation between land use and the consumption of energy in transportation with regard to social economic powers. Regression analysis shows that variable values of urban forms can contribute to change transportation energy consumption by 10% (Hickman-Banister 2007). Therefore the knowledge of the consequential benefits (e.g. of energy saving or quality improvement of the environment) is needed.

Some other authors focus on this topic from the point of view of commuting. Ma, Banister (2007) deal with commuting and its efficiency linked to the urban form. They take into account excess-commuting (additional journey-to-work travel represented by the difference between the actual average commute and the smallest possible average commute, given the spatial configuration of workplaces and residential sites).. Another type

of analysis is an analysis of urban expansion by the gradient analysis of multi-temporal data and influence of road traffic [Fan et al. 2009].

Smart Growth is a current analysis looking for decisions in smart planning, where the fact how land use plans will affect road traffic intensity is known. The analysis includes an integration of different land uses in closer proximity by promoting higher densities with a mixture of land uses, revitalization of cities, protection of sensitive or classic environments (e.g. farm, open space), etc. It can be shown as an example of locating houses, shops and offices in their common neighbourhood. This approach improves access for residents and employees and allows lowering of road traffic intensity. This is a typical scale of New Urbanism (Jacobson 2003).

To successfully solve this problem, cooperation between many branches must be analysed (economics, planning, technological innovations, etc.) [Banister 2011, Jacobson 2003]. Jacobson [2003] highlighted the cooperation between local and county governments.

## DATA

### Spatial data

The data which were used in the project were spatial and non-spatial. The spatial data had two different sources. One of them were the statistical data of the Czech Office of Survey, Mapping and Cadastre (COSMOC). The data are regularly (yearly) updated from land use of all parcels in the Czech Republic. The data determine forest areas, water areas, agriculture areas, built-up areas and courtyards, and other areas and barren soil in administrative city areas – indicators A, B, C, D, E, I in Table 1. Administrative city areas are entire city areas of individual cities in individual years. They were used in all cities in 1995, 2000 and 2005, in some of them also in 1970, 1980 and 1990. List of indicators used only in 2 time periods column in Table 3 shows cities with 1995 and 2000 data only.

A core city area is an administrative area of a given city at the end of 1970's. The first half of the 1980's was the first period when some villages neighbouring of cities became parts of these cities, the second half of the 1980' was the second period. Their land enlarged original administrative areas of these cities. Original city areas (before joining) were separated from these villages by agricultural or forested areas. They did not have a common historical development. It was the reason why the authors analysed the dependence of the road intensity also on land use of core areas of cities. All land use areas (residential, productive, traffic, recreational and other areas) in core city areas were processed by an image analysis and interpretation. These land use areas were derived from city plans (vector data) and aerial orthophotos and satellite images (raster data). City plans represent the actual state of land use of cities and plans for their future. However, their list of land use classes is more detailed – specifying detailed classes of all land use classes. These detailed classes were merged into the above-mentioned five land use = functional classes. The real state was verified and/or corrected using both types of remote sensing data for all cities in GIS. Orthophoto data were provided by COSMOC. Landsat data of the appropriate years were the satellite remote sensing data downloaded from <http://glovis.usgs.gov>. GIS vector data of land use/functional classes were a source of spatial data – indicators F, G, H, I, J, K in Table 1. The functional class areas can be dated by the remote sensing data measurement. Time difference between analysed years (1970, 1980, 1990, 2000, and 2005) and the remote sensing data were less than 3 years.

### Non-spatial data

Non-spatial statistical data (population data) are from the Czech Statistical Office web site ([www.czso.cz](http://www.czso.cz)). They are updated at least once per year. These are L, M, N, O, and P indicators in Table 1.

Road traffic intensity data are collected and archived since 1968 by the Road and Motorway Directorate and are from 1973, 1980, 1990, 1995, 2000, and 2005. The Directorate measures a number of passing vehicles in selected points in 24 hours. These points ((determined by their Identification numbers and geographical coordinates) are located on important roads of various classes in the entire country – both in, and out of

urban areas. We defined average road traffic intensity for the analysis. The average road traffic intensity is a sum of the measured intensities in all points of one city divided by the number of measured points. This value allowed us to compare cities with unequal number of points where road traffic intensities were measured. The number of points varied from 3 to more than 60. Indicators Q and R were provided by the Faculty of Economy.

### List of used Indicators for Correlation

18 types of indicators were used for the correlation. Table 1 shows a complete list of all indicators (in the first column) and number of cities where the indicator was used (second column). They were not complete for all analysed years in all cities. Correlation coefficients were calculated from all available values of each indicator of individual cities.

**Table 1.** List of processed indicators

Name of indicators	Number of analysed cities (at least in one time span)
A. Agricultural area in the administrative city area	36
B. Forest area in the administrative city area	36
C. The area of water bodies in the administrative city area	36
D. Built-up areas and courtyards in the administrative city area	36
E. Other areas and barren land in the administrative city area	36
F. Traffic areas in the core area	36
H. Productive area in the core city area	36
I. Residential area in the core city area	36
J. Recreational areas in the core city area	36
K. Other areas in the core city area	36
L. Population of the city	36
M. Number of inhabitants using public transport system daily	23
N. The population growth	36
O. Economically active population	36
P. Number of inhabitants commuting to work	22
Q. CO <sub>2</sub> emissions from large sources	23
R. Dust emissions from large sources	23

## METHOD

### Correlation analysis

The analysis of urban development and road traffic in many cities was performed by the statistical processing. Correlation analysis was used as a basic tool and correlation coefficients were evaluated for all cities.

The correlation analysis was evaluated for a correlation coefficient CCAI between an average road traffic intensity and particular statistic indicators. The average road traffic intensity is a sum of all measured road traffic intensities (number of vehicles passing through the location in 24 hours) in individual cities divided by number of locations where the measurement was performed

The correlation coefficient equation

$$CCAI(x, y) = \frac{\Sigma(x-x_{av})\Sigma(y-y_{av})}{\sqrt{\Sigma(x-x_{av})^2 \cdot \Sigma(y-y_{av})^2}} \quad (1)$$

was used to find dependence between indicators in Table 1 road traffic intensity as the most important source of pollution in urban areas in most cities of the Czech Republic.

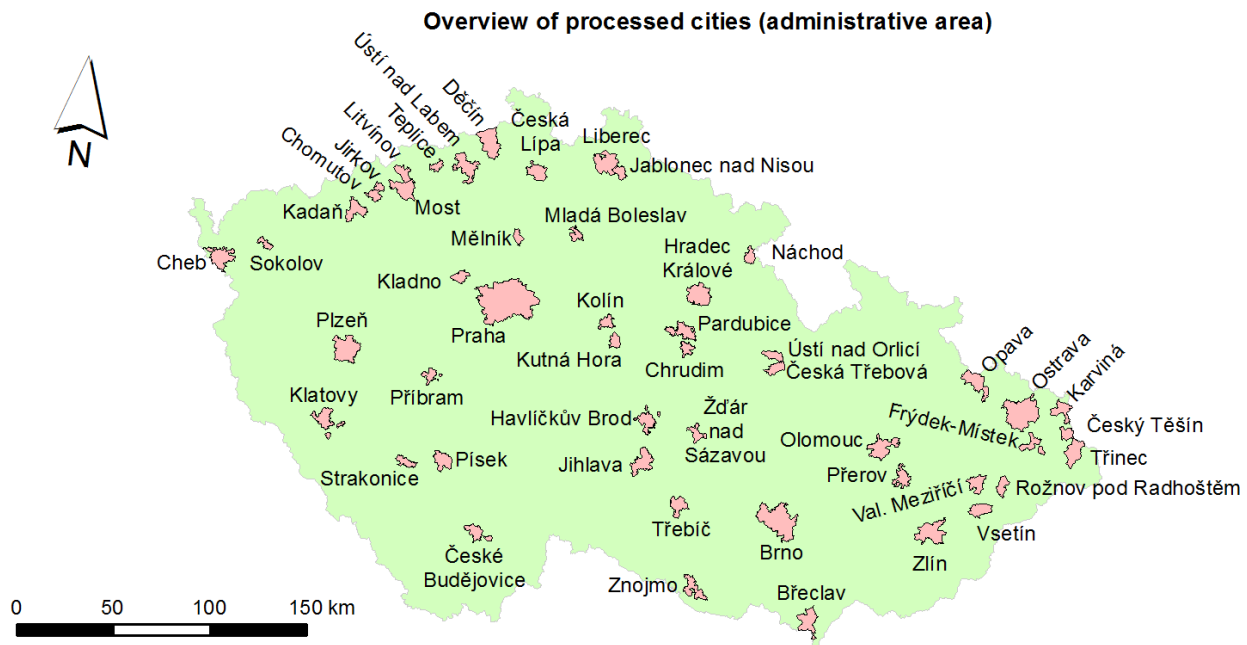
The correlation coefficient CCAI as a single value for each city shows how strong the linear dependency between traffic intensity and the particular indicator is. This correlation coefficient was determined for three periods: 1970 – 2005, 1970 – 1990, and 1995 - 2005 in Microsoft Excel (“corel” function). Values of the correlation coefficient were divided into five classes:

**Table 2.** Dependency type distribution

Dependency	Absolute value of correlation coefficient
very strong	0,800 – 1,000
strong	0,600 – 0,799
inconclusive	0,400 – 0,599
weak	0,200 – 0,399
very weak	0.000 – 0.199

For a better assessment of each type of a motor vehicles, the “unit vehicle” (UV) variable was developed. This variable is defined by:  $UV = 2 * T + O + 0.5 * M$ , where T is the number of trucks, O is the number of cars and M is the number of motorcycles [Stolbenkova 2012].

All correlation coefficients cannot be determined for each city since the data were insufficient for some cities [Hornik 2013]. For correlation analysis, it is case the result of the correlation coefficient has two values only: -1 or +1 [Hornik 2013], but this cannot reflect the true intensity of dependency, but only its orientation (direct / indirect correlation). In Table 4, there is a list of cities where the CCAI was not computed from all indicators. The correlation coefficient was computed from all indicators for Olomouc, Liberec, Hradec Králové, Ústí nad Labem, Pardubice, Zlín, Kladno, and Chomutov. The correlation coefficients were not computed for Prague.

**Fig. 1.** Administrative areas of processed cities in the Czech Republic**Table 3.** List of used indicators for each city

City	List of indicators which were used	List of indicators used only in 2 periods	List of indicators which cannot be used
Brno	A,B,C,D,E,G,L,M,N,O,P,Q,R		F,H,I,J,K
Ostrava	F,H,I,J,K,L,M,N,O,P,Q,R	A,B,C,D,E,G	
Plzeň	A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,Q,R	P	
Most	A,B,C,D,E,F,G,H,I,J,K,L,N	M	O,P,Q,R
Karviná	A,B,C,D,E,F,G,H,I,K,L,N		J,M,O,P,Q,R
Frýdek-Místek	A,B,C,D,E,F,G,H,I,K,L,N,O		J,M,P,Q,R

Opava	A,B,C,D,E,G,I,L,N	M	F,H,J,K,O,P,Q,R
Děčín	F,H,I,J,K,L,N	A,B,C,D,E,G,M	O,P,Q,R
Teplice	A,B,C,D,E,F,G,H,I,J,K,L, N	M	O,P,Q,R
Jihlava	A,B,C,D,E,F,G,H,I,J,K,L, N	M	O,P,Q,R
Přerov	F,H,I,J,K,L,N	A,C,D,E,G	B,M,O,P,Q,R
Jablonec nad Nisou	F,H,I,J,K,L,N,O,Q,R	A,B,D,E,G	C,M,P
Mladá Boleslav	A,B,C,D,E,F,G,H,I,J,K,L, N		M,O,P,Q,R
Třebíč	A,B,C,D,E,F,G,I,J,K,L,N	H	M,O,P,Q,R
Česká Lípa		A,B,C,D,E,G,L,N	F,H,I,J,K,M,O,P,Q,R
Znojmo	A,B,C,D,E,F,G,H,I,J,K,L, N,O,P,R	Q	M
Příbram	F,H,I,J,K,L,N,O,P,Q,R	A,B,D,E,G	C,M
Cheb	F,H,I,J,K,L,M,N,O,Q,R	A,C,D,E,G,P	B
Kolín	A,B,C,D,E,F,G,H,I,J,K,L, N,O,P,Q,R		M
Písek	F,H,I,J,K,L,N	A,B,C,D,E,G	M,O,P,Q,R
Vsetín	F,H,I,J,L,N	A,B,C,D,E,G	K,M,O,P,Q,R
Valašské Meziříčí	A,B,E,F,G,H,I,J,K,L,N		C,D,M,O,P,Q,R
Litvínov	A,B,C,D,E,F,G,H,I,J,L,N	M	K,O,P,Q,R
Český Těšín	F,H,I,J,K,L,N	A,B,C,D,E,G	M,O,P,Q,R
Břeclav		A,B,C,E,L,N	D,F,G,H,I,J,K,M,O,P,Q,R
Sokolov	A,B,C,D,E,F,G,H,I,J,K,L, N		M,O,P,Q,R
Havlíčkův Brod	A,B,C,D,E,F,G,H,I,J,K,L, N		M,O,P,Q,R
Žďár nad Sázavou	A,B,C,D,E,F,G,H,I,J,K,L, N,O,P,Q,R		M
Chrudim	A,D,E,F,G,H,I,J,K,L,N,O, P,Q,R		B,C,M
Strakonice	A,B,D,E,F,G,H,I,J,K,L,N		C,M,O,P,Q,R
Klatovy	A,B,C,D,E,F,G,H,I,J,K,L, M,N,O,Q,R	P	
Kutná Hora	A,B,C,D,E,G,H,I,J,L,N,O, P,Q,R		F,K,M
Jirkov	L,N		A,B,C,D,E,F,G,H,I,J,K,M,O, P,Q,R
Náchod	A,B,C,D,E,F,G,H,I,J,K,L, N,O,P,R		Q,M
Mělník	A,B,C,D,E,F,G,H,I,J,K,L, N,O,P,Q,R		M
Kadaň	F,H,I,J,K,L,N		A,B,C,D,E,G,M,O,P,Q,R
Rožnov pod Radhoštěm	A,D,E,F,G,H,I,J,L,N		B,C,K,M,O,P,Q,R
Česká Třebová	F,H,I,J,K,L,N	A,B,D,E,G	C,M,O,P,Q,R
Ústí nad Orlicí	F,H,I,J,K,L,N	A,B,C,E,G	D,M,O,P,Q,R

The correlation coefficient shows if the development of one variable depends strongly (high correlation) on the development of the other. We have received values for 17 indicators in 36 cities in 3 time spans with the above-mentioned missing values of indicators (Table 3). To make an overall evaluation for all cities, we decided to compare individual time spans individually for all indicators and individual indicators among themselves in these individual periods.

Due to the lack of certain data in several periods and cities, two approaches to evaluate correlations of all cities were used.

The first approach uses a procedure of weighted sum. Six extreme values of correlation (3 positive and 3 negative) are chosen for each city. Each of the three values of each indicator is weighted by values 1 to 3 (min. to max. – positive and negative). The most important indicators are selected by the sum of these values.

The second approach uses a sum of all correlation coefficient values in cities where all indicators were known. This was done by 3 ways:

- sum of absolute values of the correlation coefficient
- sum of positive values of the correlation coefficient
- sum of negative values of the correlation coefficient

Sum of absolute values shows which indicators have the highest influence on the road traffic intensity regardless their sign. Low values prove a low correlation both positive, and negative. Sums of positive/negative correlation coefficients of all cities of individual indicators in one time span present which indicator has the highest positive/negative influence to the road traffic intensity in that span. The final calculation of the average values of correlation coefficients (one value for one indicator of all cities unlike the sums mentioned above) was used to show what the dependence of road traffic intensity in all cities to indicators as one value for each indicator. This value does not show variability of individual cities as it smoothens them out by averaging.

### Multiple linear regression

Multiple linear regression (MLR) is a multivariate statistical technique. It was performed on software called SPSS (Statistical Package for the Social Sciences). SPSS is a computer program used for statistical analysis and further for survey authoring and deployment, data mining, text analytics, and collaboration and deployment. MLR can model the linear relationship between a dependent variable and more than one explanatory (independent) variable. The mathematical formula applied to the explanatory variables to best explain or predict the dependent variable is the following:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon$$

A dependent variable (ARTI) is the variable representing the process which should be predicted or understood. Explanatory variables (attributes of population, land use, etc.) are the variables used to model or to predict the dependent variable values. The dependent variable is a function of the explanatory variables. Regression coefficients are values, one for each explanatory variable, that represent the strength and the type of the relationship the explanatory variable has to the dependent variable (ESRI 2011) There are a few main assumptions of a regression analysis.

1. Independent variables should not be highly intercorrelated (the assumption of the absence of multicollinearity). Multicollinearity leads to an unstable correlation matrix and can produce unreliable regression estimates, significance levels and confidence intervals.
2. There will not be outliers that could distort results.
3. The variables are related in a linear fashion. Since multiple regression is based on Pearson's correlation coefficient, which is only sensitive to linear relationships, gross departures from linearity will mean that important relationships will remain undetected.
4. The variables are normally distributed (de Vaus 2002).

In order to prevent the multicollinearity, values of explanatory variables were modified by creating an interaction variable (e.g. Population density).

This method was used to analyse not only the data by a different tool, but to also analyse different development due to the political and therefore economical regime. The political change was in 1989. The analyses were done separately for the 1970 – 1990, 1995 – 2005, and 2000 – 2005. Comparison of individual time spans shows if the political change in 1989 has had an influence on the dependence between road traffic and all indicators. The new political regime changed ownership from the state one to a private one of many industrial non-industrial objects, changed a system of planning, etc.

## RESULTS

### Correlation analysis

The data with the strongest influence to the road traffic development in the cities were determined from CCAI. From the point of view of frequency of extreme values (positive and negative) of indicators, indicator N (Population growth) was a parameter with the highest negative correlation for 50% of the analysed cities. Indicator K (Other areas of land use in the core area) was a parameter with the highest positive correlation in 16% of the analysed cities.

The first approach of the analysis uses a procedure of weighted sum. Six extreme values of correlation (3 positive and 3 negative) are chosen for each city where each of the three values of each indicator is weighted by values 1 to 3. The most important indicators are selected by the sum of these values. By this approach, the highest sum of the weighs has N indicator (population growth), which is followed by I indicator (Residential area in the core area) and R indicator (Dust emissions from large sources). The highest sum of the positive weigh has I indicator (Residential area in the core area). The highest sum of the negative weighs has N indicator (Population growth).

The second approach uses a sum of correlation coefficient, and sum of negative values of the correlation coefficient.

This approach takes into account all values, so the indicators with lower contributions to the final value are also included. This approach is figured in the charts below.

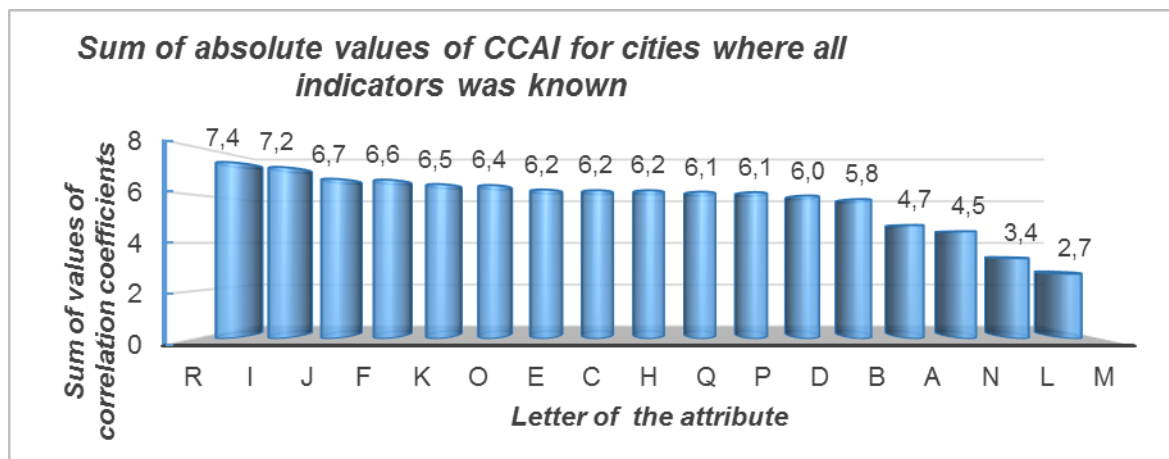


Fig. 2. Chart of sum of absolute values of CCAI

It is shown (Fig. 2) that R indicator (Dust emissions from large sources) has the highest absolute value of the CCAI correlation coefficient from all processed cities for which all indicators was known in more than two time spans. These values show that Dust emissions (R indicator) and Residential area in the core city area (I indicator) have the highest influence on road traffic intensity, however, their influence can be both negative and positive (see Fig. 3 and Fig. 4).



Fig. 3 presents the Residential area in the core area (indicator I) to have the highest direct influence to the average road traffic intensity. The positive influence does not occur in all cities.

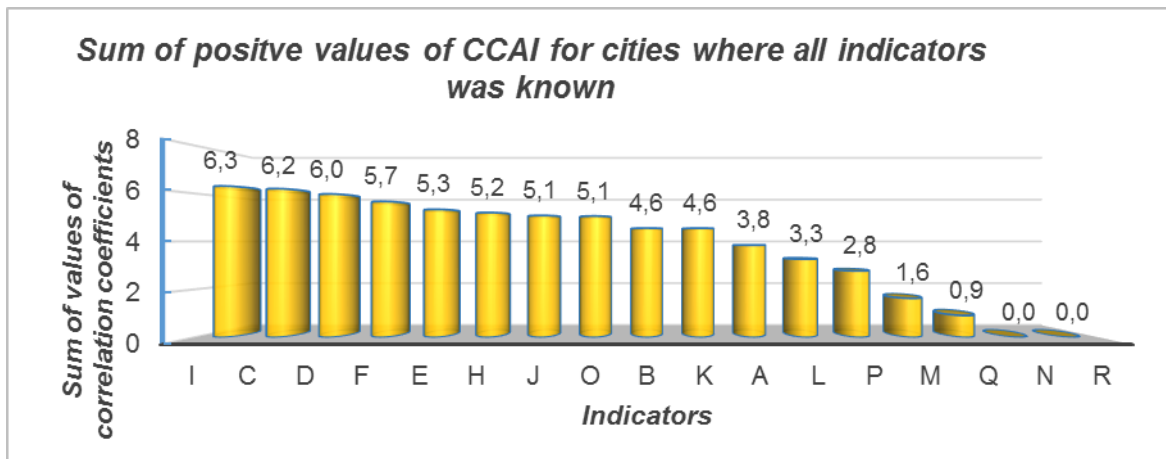


Fig. 3. Chart of sum of positive values of CCAI

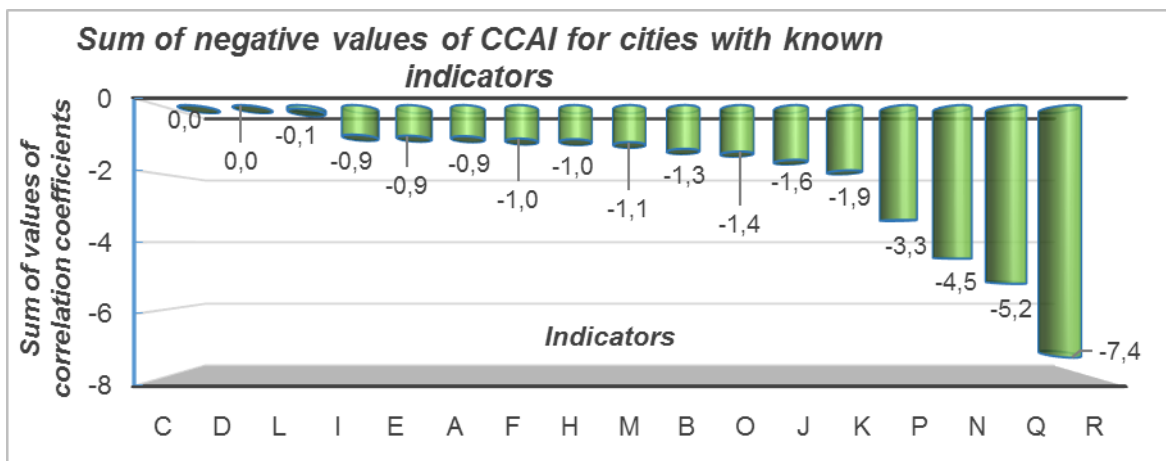


Fig. 4. Chart of sum of negative values of CCAI

The indicator R (Dust emissions from large sources) has the highest negative sum (Fig. 4) and the lowest positive sum (Fig. 3) since this indicator has negative correlation coefficient for each city in this analysis. Therefore this indicator can be proclaimed as an indirect correlation indicator. What is interesting, is that indicator L (Population of the city) with one of the lowest negative sum is only in the middle of positive sum has also a low positive sum.

Average values of the absolute correlation coefficient values were also processed but unlike the above charts from all processed cities. It ensues from Fig. 4 that the highest average CCAI has F indicator (Traffic areas in the core area). This result was expected since it is obvious that traffic areas have a strong impact on traffic development.

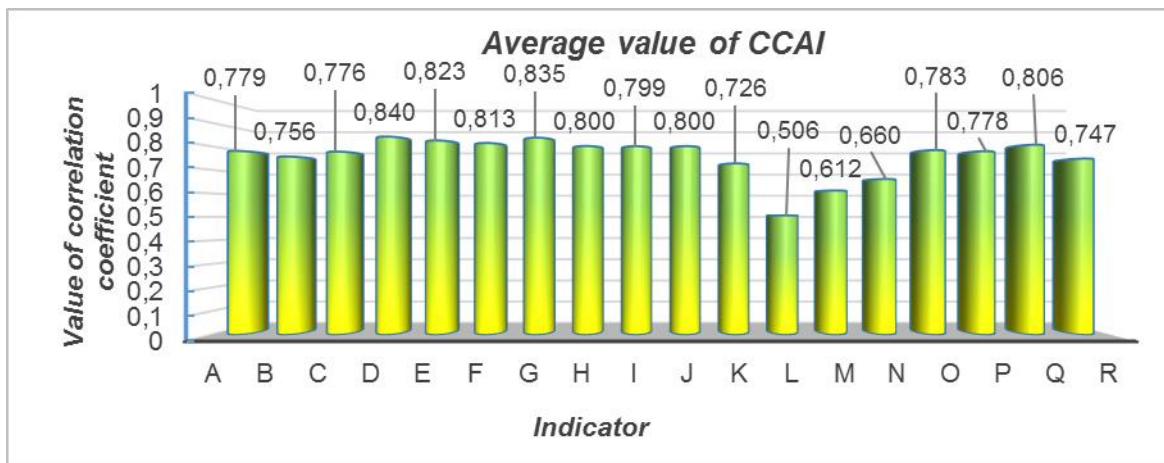


Fig. 5. Chart of average values of CCAI (from absolute value of CCAI)

**Multiple linear regression analysis**

Results of the multiple linear regression are in Table 4 where ARTI is average road traffic intensity. It was the tool, which showed us differences among individual time spans.

Table 4. Multiple regression models explaining average road traffic intensity

Models explaining the ARTI			
Year	$R_a^2$ [%]	Items (sum) Type of attributes	Explaining variable
1970	15,3	25 (25) P+E+L	Population
1980	47,4	23 (25) P+E+L	Population Recreational areas
1990	53,6	23 (25) P+E+L	Population Recreational areas
1995	80,4	18 (25) P	Population aged 0-14 Immigrants
2000	47,3	25 (25) P	Population Population aged 0-14
2005	60,4	25 (25) P	Population Population aged 0-14
2005	99,1	10 (25) P+L	Population Population aged 0-14 Female residents Total population growth Traffic areas
<i>P = Population, E = Economic situation, L = Land use</i> Opposite contribution			
70-80-90	49,0	67 (75) P+E+L	Population Births Economically act. population Recreational areas
95-00-05	60,3	68 (75) P	Population Population aged 0-14
00-05	94,2	15 (75) P+L	Population Population aged 0-14 Total population growth Traffic areas

## CONCLUSION

This analysis showed the impact of particular indicators on the average road traffic intensity. It is a step to the next analysis, where some of the indicators (for example E, A, Q) can be analysed deeper. It means the analysis of cities regarding the comparison of particular indicators from the point of view of their influence. It should answer the question, what is the difference among cities which makes the indicators influence differently.

Indicator R (Dust emissions from large sources) has the highest absolute influence (Fig. 2) and it is in the middle of average values of CCAI (Fig. 5). It is interesting that indicator Q (CO<sub>2</sub> emissions from large sources), N (Population growth) and R (Dust emissions from large sources) are the most important indirect indicators having only negative correlation values. Indicator F (Traffic areas in the core area) was the most important indicator in the table of average CCAI. The credibility of this indicator is emphasized, because this indicator was monitored in 36 cities (Table 1) (even in all 49 cities analysed in the project). A negative result of this indicator was only in Chomutov (a transit city). The second most important indicator is Q (CO<sub>2</sub> emissions from large sources). This indicator belongs to a group with a lower positive sum of CCAI and a higher negative sum of CCAI. It seems to be an un-expected result. However, traffic is a significant source of CO<sub>2</sub> emissions. This can be shown in all big cities not only in the Czech Republic; road traffic intensity is a great source of CO<sub>2</sub> emissions in centres of these cities. Therefore it is obvious that the road traffic in core city areas has a strong influence to the overall volume of CO<sub>2</sub> emissions.

On the other side, one of the lowest value indicator among all categories is the Population of the city (L). There are four cities (Děčín, Chomutov, Mělník a Litvínov) with the lowest correlation coefficient in this indicator which is - in the absolute value - lower than 0.1. The prevailing part of their traffic is created by transit, which affects resulting average value of CCAI. There are two indicators, which have no negative correlation coefficient value in 8 cities processed in this analysis – C (The area of water bodies in the administrative city area) and D (Built-up areas and courtyards in the administrative city area).

Results of MLR taking into account the more detailed data about population proved a high complexity of the dependence and ambiguity of results from two different evaluations. They highlighted influence of population data and suppressed spatial data showing significant influence of recreational and traffic areas differently in three analysed periods.

This part of the project confirmed the results published already in Halounová (2013) that urban development and its impact on the road traffic (analysed here as average road traffic intensity in cities) of individual cities substantially differs among cities. The difference was found in unequal value of correlation coefficients of individual indicators of individual cities. It was found that each indicator has both direct and indirect impact in the whole group of cities. These correlation coefficients proved that the functional classes and their areas describing residential areas in core city areas, traffic and productive areas have the strongest direct impact to the road traffic intensity from the whole group view. It was also determined by other authors (see Chapter 2 - e.g. Barla 2011, Ewing *et al.* 2007, Ewing and Cervero 2010).

All indicators used can be derived or found for all cities at least in the several previous years. Results of this part of the project showed that prediction of the impact of the future development of a city on road traffic intensity should be analysed rather from the historical development of the last 25 years than from the a model made from many cities. The analysis should take into account not only spatial indicators, but also the number of inhabitants, economically active population, and number of inhabitants commuting to work.

The future work will be focused on spatial distribution, fractionalisation, road network density, GDP, etc., in the cities. These phenomena were not taken into account in this phase of the research.

## REFERENCES

- Banister, D. (2011). Cities, mobility and climate change. *Journal of Transport Geography*, 19, 1538-1546.
- Banister, D. (2011). The trilogy of distance, speed and time. *Journal of Transport Geography*, 19, 950-959.

- Banister, D., Anderton K., Bonilla D., Givoni M. and Schwanen T. (2011), Transportation and the Environment. Annual review of environment and resources, 36, 247-270.
- ESRI. (2011) ArcGIS Help Library: Regression analysis basics. [online]. [quoted 2011-11-15]. Accessible from:  
<[http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Regression\\_analysis\\_basics/005p00000023000000/](http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Regression_analysis_basics/005p00000023000000/)>
- Fan F., Wang Y., Qiu M. and Wang Z. (2009). Evaluating the Temporal and Spatial Urban Expansion Patterns of Guangzhou from 1979 to 2003 by Remote Sensing and GIS Methods. I Journal of Geographical Information Science, 01/2009.
- Halounová, L. (2013). Relation between road traffic intensity and urban development in cities of the Czech Republic, GIS Ostrava 2013.
- Halounová, L., Holubec V., Těhle M., Řehák M. and Vepřek K. (2013). Atlas of urban development in Czech cities (since 60-ies of the 20th century). FCE CTU in Prague, Prague. ISBN: 978-80-01-05177-1.
- Holubec, V. (2013). Processing of COST project (master thesis in Czech). FCE CTU in Prague, Prague.
- Hornik, D. (2013). Spatial changes in selected urban areas of the Czech Republic (master thesis in Czech). FCE CTU in Prague, Prague.
- Jacobson, E. (2003). The Transportation-Land Use Connection. Transportation and Growth Management, School of Urban Studies and Planning, College of Urban and Public Affairs, Portland State University.
- Litman, T. A. and Steele, R. (2013). How Land Use Factors Affect Travel Behaviour. Land Use Impacts on Transport, Transport Policy Institute; available in pdf at: <http://www.vtpi.org/landtravel.pdf>, cited 18 October 2013.
- Ma KR., Banister D. (2007). Urban spatial change and excess commuting. Environment an planning, 39, 630-646.
- Ristimäki, M. and Kalenoja, H. (2011) .Travel-related Zones of Urban Form in Urban and Peri-Urban areas. Track 11, 3rd World Planning School Congress, Perth
- Stolbenková, P. (2012). Analysis of various indicator influences in road traffic in GIS (master thesis in English). FCE CTU in Prague, Prague.
- de VAUSS, David. (2002) Analysing Social Science Data. London: SAGE.
- Vepřek, K. (2000). Požadavky na jednotný způsob zpracování a hodnocení analýzy vývoje funkčních ploch a českých měst v konfrontaci s vývojem infrastruktury silniční dopravy/Demands on the unified way of processing and evaluation of analysis of functional areas in the Czech Republic vs the development of the road traffic infrastructure (in Czech only). Prague.
- Vepřek, K. (2009). Metodika hodnocení efektivity rozvoje silniční sítě z hlediska urbanizace/Methodology of evaluation of affectivity of the road traffic development from the urbanisation point of view. (in Czech only). Prague.