Przemyslaw Sekula, University of Economics, Katowice, Poland

Project Management Challenges in Road Infrastructure Development in Poland

Introduction.

Large investments in Poland's road transportation infrastructure began in 2007 and they are planned to continue till 2023. The scale of hitherto and forthcoming investments is presented in Figure 1.

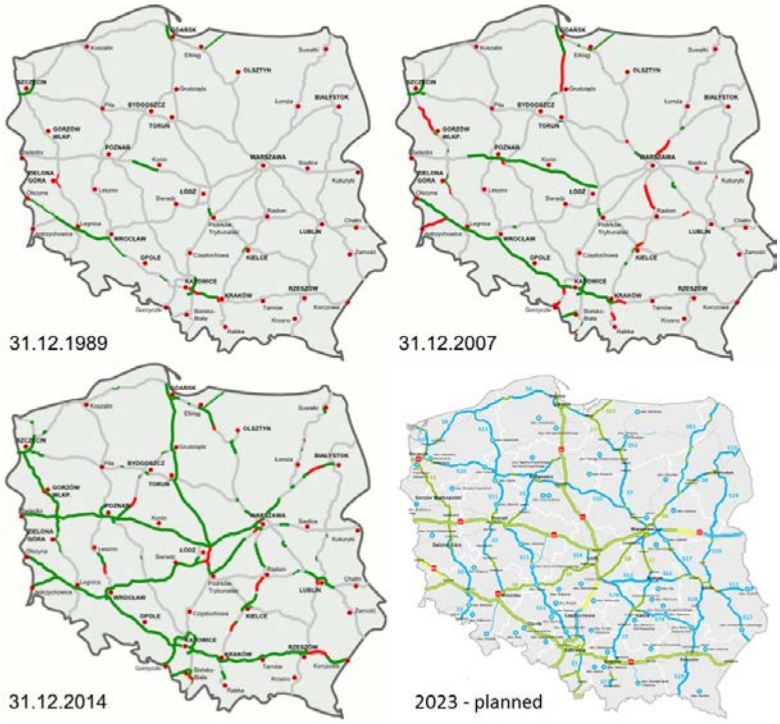

Figure 1: Motorways and highways in Poland in 1989, 2007, 2014 and 2023 (planned)[1]

Due to the scale and importance of road infrastructure investments in Poland, the decision support process in the field of road infrastructure management turns out to be very significant. This process may be supported by numerous tools and solutions. The most popular are economic models, financial analyses, multi-criteria evaluation methods, decision diagrams, risk sharing by cooperation in public-private partnership etc. They are described by numerous authors in numerous publications. For instance, the economic aspects of public investments planning and modeling were considered by D. Felstenstein, R. McQuaid, P. McCann and D. Cheltenham (2001)[2]. T. Zhao S. Sundararajan and C. Tseng (2004)[3] presented a model for decision making in highway development, operation, expansion, and

[1] Source: Based on Resolution No. 156/2015 of the Council of Ministers of Republic of Poland, 8 September 2015 - Establishing a multiannual program under the name "National Road Construction Programme for the years 2014 to 2023 (with the prospect of 2025)" and https://upload.wikimedia.org/wikipedia/commons/a/af/Historia_budowy_autostrad_i_dr%C3%B3g_ekspresowych.gif

[2] D. Felstenstein, R. McQuaid, P. McCann and D. Cheltenham (ed.), Public Investment and Regional Economic Development (2001), Edward Elgar Hardback, 271

[3] T. Zhao, S. Sundararajan, C. Tseng, Highway Development Decision-Making under Uncertainty: A Real Options Approach., J. Infrastruct. Syst., 10.1061/(ASCE)1076-0342(2004)10:1(23), 23-32.

rehabilitation. This model bases on Monte Carlo simulation method. E. Mongo (2008)[4] in his study about the decision-making process in road infrastructure development examined the problem that policy and planning decisions have led to limited navigable roads in Cameroon. W. Brauers, E. Zavadskas, F. Peldschus and Z. Turskis (2008)[5] presented a methodology for multi-objective optimization of multi-alternative decisions in road construction. This methodology bases on Multi-Objective Optimization on the basis of the Ratio Analysis (MOORA) method. A review of multi-criteria decision-making methods for infrastructure management was presented by D. Jato-Espinoa, E. Castillo-Lopezb, J. Rodriguez-Hernandeza and J. C. Canteras-Jordana (2013)[6]. The problems of decision support in road infrastructure are still up-to-date and are explored by numerous authors such as R. Haigh (2014)[7], L. Chen, T. Henning, A. Raith and A. Shamseldin (2015)[8] and others.

One of the areas where the decision-making tools and solutions should be implemented concerns the cooperation between central and local governments. The process of building the new road infrastructure led to numerous expectations from Poland's local governments. On one hand, the communities crossed by motorways claimed negative impact of these roads on local businesses, on unemployment rates and on other economic performance factors. On the other, jurisdictions which have no direct access to the motorways need funds in order to ensure sustainable development. In Poland a significant amount of local government funds are derived not from property taxes or income tax from local residents, but from redistribution of central government tax revenues.

As a result, if the demands of local governments were met, the costs of economic development would have been charged to the central government budget and - in consequence - to the budgets of projects undertaken by the central government.

Due to the fact the expectations of local governments are not cohesive, it is necessary to determine objective criteria for funding allocation. To do this, it is essential to find the answers to the following questions:

- What is the nature (and spatial range) of impact of motorways on local municipalities?
- How to predict this impact in order to allocate the development funds?

Determining the impact

Preparing data

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[4] E. Mongo, The Decision-Making Process in Road Infrastructure Development in Cameroon Since 1980, Walden University, 2008

[5] W. Karel, M. Brauers , E. K. Zavadskas , F. Peldschus, Z. Turskis (2008) Multi-objective decision-making for road design, Transport, 23:3, 183-193

[6] D. Jato-Espinoa, E. Castillo-Lopezb, J. Rodriguez-Hernandeza, J. C. Canteras-Jordana, A review of multi-criteria decision-making methods for infrastructure management, Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance, 2013, 10.1080/15732479.2013.795978, 1176-1210

[7] R. Haigh , (2014) "Enhancing resilience of critical road infrastructure: bridges, culverts and floodways", International Journal of Disaster Resilience in the Built Environment, Vol. 5 Iss: 3

[8] L. Chen, T. Henning, A. Raith and A. Shamseldin, Multiobjective Optimization for Maintenance Decision Making in Infrastructure Asset Management, J. Manage. Eng., 10.1061/(ASCE)ME.1943-5479.0000371, 04015015., 2015

As an illustration of the premise of this study, Świecko - Nowy-Tomyśl section of A2 motorway was selected. This selection was made due to the following reasons:

- This section is relatively long (107 km), so it is easier to detect the spatial distribution of economic impact.
- The section was build in 2011, so in spite of being relatively new it is possible to obtain data necessary to assess its economic impact.
- The section is not in a close proximity to big cities. The proximity to a large economic center could skew the results.

The next step was to measure the distances from the motorway to all municipalities. The distances were measured to the centroids of municipalities, using QGIS software. The distances to the motorway and distances to the closest motorway intersection were both measured. The distances were put into MS Access database in order to combine them with data from the Polish Statistical Office. The database comprised the following data:

- change in the population of municipalities;
- change in the number of microenterprises (0-9 employees);
- change in the number of small enterprises (10-49 employees);
- change in the number of medium and big enterprises (50 employees and more);
- change in the unemployment level;
- change in the proceeds of individual income tax to local budgets;
- change in the proceeds of corporate tax to local budgets;
- distances to the motorway.

Each of the tested indicators is described as a change. The changes were calculated in "year on year" mode according to the formula:

$$\frac{v_y - v_{y-1}}{v_{y-1}}$$

Equation 1

where v_y is a value of an indicator in a year "y".

Data analysis

The next stage was to determine whether the dependence between the selected factors and the distances to motorway exists. To determine this dependence, the Pearson correlation coefficient was used. The data were sorted out by distance to the motorway. Then, for each municipality, Pearson correlation coefficient was calculated, including the calculations for all the municipalities, which are at least as close to the motorway as the selected municipality. For instance, if municipality of Buk is situated 29.5 kilometers away from the motorway, to calculate the Pearson correlation coefficient one included all the communes, which are no more distant from motorway than the municipality of Buk. It was done in order to assess the character and spatial range of the impact on the tested factor. The example charts which present correlations between the distances from motorway and changes of various parameters are presented in Figure 2.

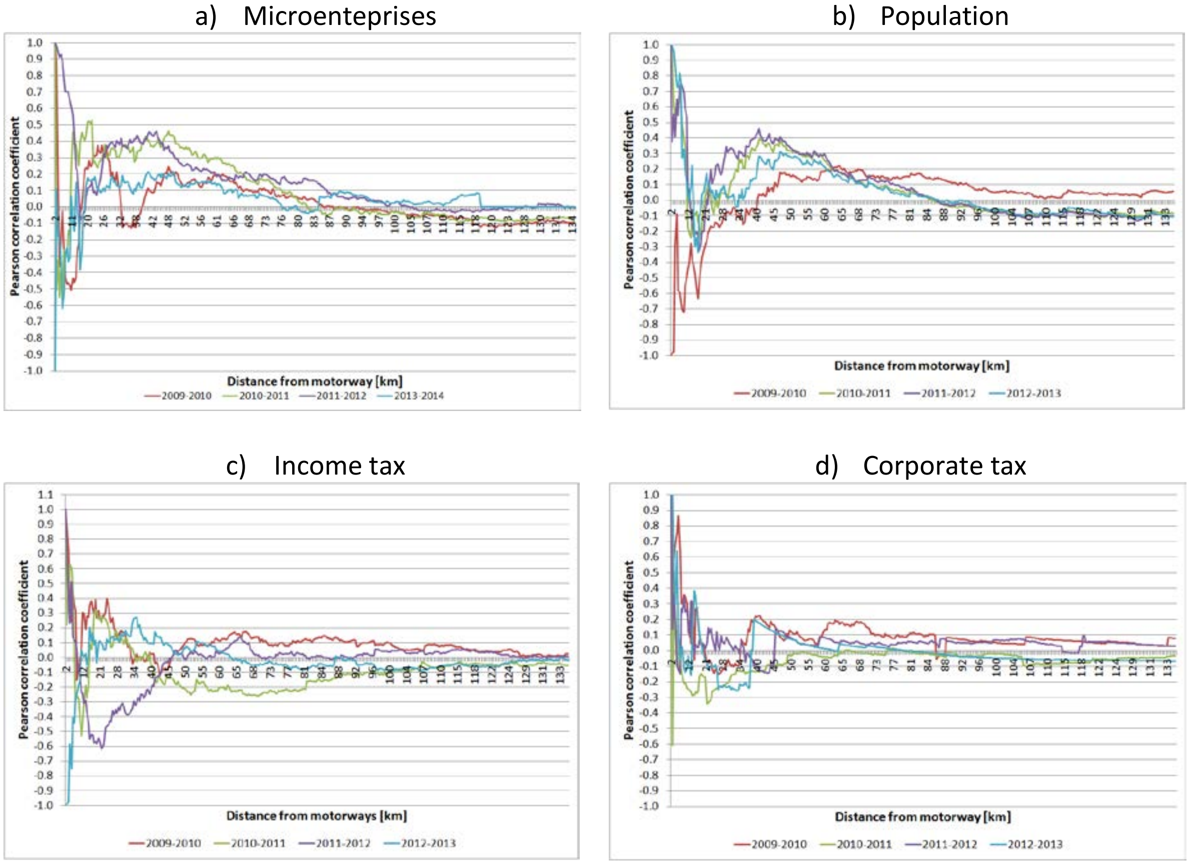

Figure 2: Correlations between distances from motorway and changes in number of microenterprises, population and proceeds of income and corporate tax

As one can see from Figure 2a, example on the chart with microenterprises, the correlations were quite high in close proximity from the motorways and then they started to decrease. In the beginning the charts are serrated. This variety is caused by a small amount of data (there are not many municipalities in such proximity of the motorway). Analysis of all the charts and previous research[9] shows that if impact of the motorways on the examined factors exists, it has a range of about 40 kilometers. However, one can notice the vast variety of correlations calculated for particular municipalities. That means that it is necessary to introduce additional conditions in order to ensure that the calculated correlations are statistically significant. For each factor all the correlations for communes which are between 30 and 35 kilometers from motorway were taken, and then the average, median and standard deviation of these data were calculated. The average value of correlation coefficients allows to flatten the serrated charts. The median value of correlation coefficients helps to eliminate the cases, when a few large values significantly overstate the average. Standard deviation, if it is too large, testifies that the chart is excessively serrated, and the correlations are changing too fast to become a creditable source of information. These three measurers were used to determine the existence and character of

[9] Results of previous research presented in report "Wpływ projektów infrastrukturalnych na rozwój lokalnej tkanki gospodarczej" (the Impact of Infrastructure Projects on Development of Local Economies), University of Economics, Katowice, 2014, unpublished

impact of motorways on the examined factors. To recognize an impact as being of significance the following conditions should be fulfilled:

- average correlation ≥ 0.2
- median of correlations ≥ 0.2
- standard deviation < 0.1

The same procedure was repeated for correlations between selected factors and distances from motorway intersections, and for the data taken from all communes between 25 and 40 km. The results are presented in Tables 1 and 2.

Table 1: Results of calculations for frame 30-35 km

	For range 30 - 35 km									
	For distances from motorways					For distances from intersections				
Dates	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014
	Microenterprises					**Microenterprises**				
Average	-0.09	**0.37**	**0.29**	-0.04	0.14	-0.01	**0.35**	**0.38**	0.10	0.14
Median	-0.12	**0.38**	**0.29**	-0.06	0.15	-0.10	**0.36**	**0.38**	0.08	0.15
Std. dev.	0.08	**0.03**	**0.04**	0.06	0.04	0.13	**0.03**	**0.02**	0.04	0.02
	Small enterprises					**Small enterprises**				
Average	-0.10	0.14	0.13	0.16	-0.16	-0.13	0.14	0.12	0.22	-0.16
Median	-0.09	0.14	0.13	0.16	-0.16	-0.15	0.13	0.13	0.24	-0.15
Std. dev.	0.10	0.03	0.04	0.02	0.02	0.03	0.03	0.05	0.03	0.03
	Medium and large enterprises					**Medium and large enterprises**				
Average	-0.08	0.04	0.17	-0.14	-0.02	-0.09	0.04	0.08	-0.11	-0.12
Median	-0.09	0.03	0.16	-0.13	-0.02	-0.08	0.04	0.07	-0.13	-0.14
Std. dev.	0.06	0.02	0.05	0.02	0.08	0.06	0.02	0.04	0.03	0.07
	Unemployment					**Unemployment**				
Average	0.15	0.08	0.11	-0.18	No data	0.15	0.00	0.05	-0.14	No data
Median	0.14	0.09	0.10	-0.18	No data	0.15	-0.01	0.05	-0.14	No data
Std. dev.	0.06	0.02	0.03	0.04	No data	0.02	0.03	0.02	0.05	No data
	Corporate tax					**Corporate tax**				
Average	-0.10	-0.12	-0.02	**-0.23**	No data	-0.06	-0.14	0.02	**-0.24**	No data
Median	-0.09	-0.13	0.00	**-0.23**	No data	-0.09	-0.13	0.01	**-0.25**	No data
Std. dev.	0.01	0.02	0.04	**0.02**	No data	0.07	0.01	0.02	**0.02**	No data
	Income tax					**Income tax**				
Average	-0.01	0.01	**-0.27**	0.23	No data	0.04	0.06	**-0.35**	0.20	No data
Median	0.00	0.01	**-0.27**	0.25	No data	0.02	0.07	**-0.36**	0.18	No data
Std. dev.	0.04	0.04	**0.05**	0.05	No data	0.06	0.06	**0.04**	0.06	No data
	Population					**Population**				
Average	-0.10	0.15	**0.24**	-0.06	No data	-0.09	0.19	**0.31**	0.01	No data
Median	-0.09	0.13	**0.23**	-0.06	No data	-0.09	0.18	**0.31**	0.02	No data
Std. dev.	0.02	0.07	**0.05**	0.07	No data	0.03	0.06	**0.02**	0.04	No data

Table 2: Results of calculations for frame 25-40 km

	For range 25 - 40 km									
	For distances from motorways					For distances from intersections				
Data	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**
	Microenterprises					**Microenterprises**				
Average	0.06	**0.32**	**0.30**	0.03	0.12	0.06	**0.34**	**0.38**	0.09	0.13
Median	-0.03	**0.33**	**0.30**	0.04	0.14	0.00	**0.34**	**0.38**	0.09	0.13
Std. dev.	0.19	**0.05**	**0.06**	0.07	0.05	0.18	**0.03**	**0.04**	0.04	0.03
	Small enterprises					**Small enterprises**				
Average	-0.08	0.13	0.10	0.11	-0.17	-0.08	0.11	0.12	0.19	-0.17
Median	-0.09	0.14	0.12	0.14	-0.16	-0.10	0.13	0.13	0.23	-0.16
Std. dev.	0.13	0.09	0.08	0.08	0.04	0.09	0.10	0.07	0.08	0.04
	Medium and large enterprises					**Medium and large enterprises**				
Average	-0.11	0.05	0.15	-0.11	-0.04	-0.13	0.06	0.15	-0.08	-0.07
Median	-0.14	0.03	0.15	-0.13	-0.02	-0.16	0.04	0.16	-0.07	-0.05
Std. dev.	0.08	0.04	0.06	0.04	0.07	0.08	0.05	0.07	0.03	0.09
	Unemployment					**Unemployment**				
Average	0.16	0.12	0.08	-0.12	No data	0.15	0.05	0.02	-0.14	No data
Median	0.14	0.12	0.08	-0.13	No data	0.15	0.03	0.04	-0.14	No data
Std. dev.	0.06	0.05	0.06	0.06	No data	0.05	0.06	0.05	0.05	No data
	Corporate tax					**Corporate tax**				
Average	-0.05	-0.14	-0.01	-0.16	No data	-0.01	-0.17	0.01	-0.17	No data
Median	-0.09	-0.13	0.00	-0.23	No data	-0.08	-0.15	0.01	-0.23	No data
Std. dev.	0.10	0.04	0.07	0.16	No data	0.13	0.04	0.06	0.14	No data
	Income tax					**Income tax**				
Average	0.05	0.02	**-0.27**	0.20	No data	0.08	0.06	**-0.32**	0.16	No data
Median	0.00	0.03	**-0.28**	0.20	No data	0.03	0.07	**-0.32**	0.14	No data
Std. dev.	0.10	0.09	**0.06**	0.06	No data	0.09	0.06	**0.06**	0.05	No data
	Population					**Population**				
Average	-0.11	0.12	**0.26**	-0.02	No data	-0.10	0.17	**0.30**	0.05	No data
Median	-0.12	0.13	**0.27**	-0.04	No data	-0.09	0.18	**0.31**	0.04	No data
Std. dev.	0.05	0.15	**0.08**	0.09	No data	0.04	0.12	**0.07**	0.05	No data

For both, the distances from motorways and distances for intersections the results were similar. For both frames (30-35 and 23-40 km) the requirements necessary to recognize the impact as significant were fulfilled for the following factors:

- change of number of microenterprises in 2010-2011 (just after the opening the motorway to use);
- change of number of microenterprises in 2011-2012 (a year after opening the motorway to use);
- change of population of communes in 2011-2012;
- change of proceeds of income tax for individuals to local budgets in 2011-2012.

In the case of 'Change of corporate tax in 2011-2012' the requirements where fulfilled while calculated in the frame of 30-35 km, but not in the frame of 25-40 km.

The positive sign of standard deviation means that the examined values are growing with the distance from the motorway. So the impact on motorway on the number of microenterprises and population is negative. These factors are decreasing (or the rate of increase is diminishing) when the distance from motorway decreases. The negative value of correlation coefficient in case of income tax indicates the positive impact of the motorway. This also means that the motorway has a positive impact on the income tax in general and, in consequence on the income level of citizens. In summary, both positive and negative impact of the highway has been detected.

Predictions

The next question formulated in the goal of research was "how to predict the economic impact in order to allocate the development funds?". The first attempt to arrive at an answer based on computing linear regression using the least-square method. As the dependent variables, the distances to motorways, the distances to intersections and both (multiple regression) consecutively were taken. To assess the results the coefficient of residual variation V_e was used.

$$V_e = \frac{S_e}{Y_{av}} * 100\%$$

Equation 2

where:

$$S_e = \left[\frac{1}{n-m-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\right]^{0.5}$$

Equation 3

Y_{av} – average independent value

n – number of observations (communes)

m – number of dependent values

y_i – real independent value

$\hat{y}_i$ – estimated value

The values of coefficient of residual variation are presented in Table 3.

Table 3: Linear regression - coefficients of residual variation of values predicted by linear regression.

Dependant variables (distances from)	Microenterprises 2010-2011	Microenterprises 2011-2012	Income tax 2011-2012	Population 2011-2012
Motorway	-557.91%	82.20%	109.52%	333.09%
Intersection	-560.69%	82.42%	110.06%	333.31%
Both	-557.14%	80.79%	110.02%	331.02%

The value of the coefficient of residual variation indicates how strong is the impact of factors omitted in the model (including random error) on the independent value. In every case, even in analyses of changes of number of microenterprises in 2011-2012, this coefficient is relatively high. This means that the proposed models are insufficient to predict the real outputs. The possible reasons of poor fit of models to reality may be as follows:

- *Phenomena are not linear*. To increase the fit, non-linear models should be used.
- *Initial conditions should be taken into account*. For instance it is possible that the communes with strong economic base are getting stronger while the weak communes are getting weaker. It is also possible that for the weak communes the positive impacts are large while for the stronger ones they are weaker.
- *Some spatial information should be taken into account*. The results may be disfigured by big factories, economic centers etc. The results may be also distorted by the road infrastructure, which is not included in this research. If this problem occurs, it may be partially solved by including information about mutual proximity of communes into model.
- Lack of data or lack of data accuracy. It is also possible that the data are insufficient or to general to obtain better results. The data about communes are focused in points (centroids) and all the information about the spatial deployment of this data inside the communes are not taken into account. Moreover it is possible that the data such as traffic information should be included in model too.

If the first three reasons occurs it is possible to improve the quality of the model by using machine learning computations and a locally weighted linear regression method.

Locally weighted linear regression.

Locally weighted linear regression algorithm is a modification of Least Mean Squares (LMS) rule. Let us assume that we have values x_1, x_2, …, x_n included in a model. If the model is linear, it can be represented as in Equation 4:

$$h(x) = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \ldots + \theta_n x_n$$

Equation 4

The θ's are the parameters (or weights) of model. Function $h(x)$ is called hypothesis. To simplify the notation the value x_0 = 1 is introduced, so the hypothesis may be written as in Equation 5.

$$h(x) = \theta_0 x_0 + \theta_1 x_1 + \theta_2 x_2 + \ldots + \theta_n x_n = \sum_{i=0}^{n} \theta_i x_i = \vec{\theta}^T \vec{x}$$

Equation 5

The training set which X and Y is given. The goal is to pick (learn) the parameters θ in order to minimize the errors of hypothesis. To formalize it the cost function J(θ) is defined:

$$J(\theta) = \frac{1}{2} \sum_{i=1}^{m} \left(h_\theta(x^{(i)}) - y^{(i)}\right)^2$$

Equation 6

Where:

m	– number of training examples
$x^{(i)}$	– the dependent values in row i
$y^{(i)}$	– the independent value in row i
$h_\theta\left(x^{(i)}\right)$	– hypothesis (now $\vec{x}$'s are known and $\vec{\theta}$ is searched).

To minimize the cost function it is possible to use gradient descent algorithm. In this algorithm the subsequent values of θ are computed using the formula:

$$\theta_j := \theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\theta)$$

Equation 7

$$\theta_j := \theta_j + \alpha \sum_{i=1}^{m} \left(y^{(i)} - h_\theta(x^{(i)})\right) x_j^{(i)}$$

Equation 8

where:

α – learning rate: relatively small value responsible for speed and accuracy of algorithm.

Using this formula each θ is calculated repeatedly until obtaining convergence (the changes of θ are negligible).

In the locally weighted linear regression (LLWR) algorithm the entire calculations are made not to find the general function, but to find the predicted independent value for one particular x. The intuition is to reduce non-linear effects by paying attention mostly to these data examples, which are in the proximity of x. This is presented in Figure 3.

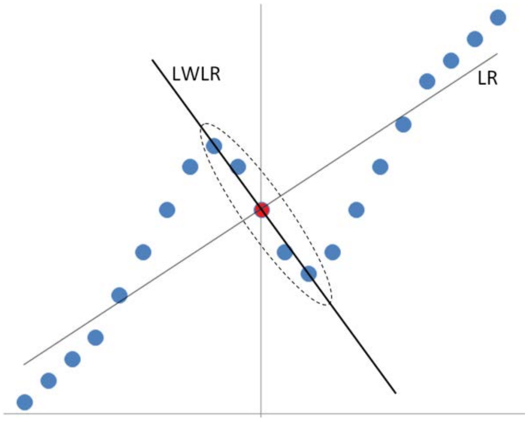

Figure 3: Locally weighted linear regression

LLWR adds weights to the cost function.

$$J(\theta) = \frac{1}{2}\sum_{i=1}^{m} w^{(i)}\left(h_\theta(x^{(i)}) - y^{(i)}\right)^2$$

Equation 9

A standard choice of "w" is:

$$w^{(i)} = \exp\left(-\frac{\left(x^{(i)} - x\right)^2}{2\tau^2}\right)$$

Equation 10

And if x is a vector:

$$w^{(i)} = \exp\left(-\frac{\left(x^{(i)} - x\right)^T\left(x^{(i)} - x\right)}{2\tau^2}\right)$$

Equation 11

τ is the parameter responsible for the behavior of algorithm. For a small values of τ the algorithm pays attention mostly on the data in proximity of searched value. For a big τ the algorithm tends to behave like Linear Regression.

The entire algorithm to find predicted value for a single data example is presented as follows:

Repeat until convergence { For each j { $\theta_j := \theta_j + \alpha \sum_{i=1}^{m} w^{(i)}\left(y^{(i)} - h_\theta(x^{(i)})\right)x_j^{(i)}$ } }

Calculations and results

Originally, the LWLR algorithm was supposed to deal with the nonlinearity of analyzed functions. However, the possibilities delivered by this algorithm are wider. The weights do not have to base on the distances of dependent values, but they may be selected due to other reasons. For instance - if we assume that the results should depend on the initial income of commune per capita, the weights could represent this income. Predicting the results, algorithm will take account mostly on this communes, which have similar level of income per capita.

During the research three different types of weights were taken into account. In the first type the "classical" weights, based on the dependent values (distances from motorway and closest intersection), were calculated. By using these weights it was possible to check, whether the searched function is significantly non-linear. The second type of weights were based on the initial values of searched variables. The data used to calculate the weights were as follows:

- population
- number of microenterprises per 1000 inhabitants
- communes budgets revenues from the income tax per capita

The third type of weights comprises spatial information - the data about mutual distances of communes. The distances were calculated using QGIS. This time, weights were used to check whether the spatial information about mutual position of commune can influence the accuracy of predictions.

Before calculating the weights, data were normalized in columns to scale [0..1]. For the second type of weights the normalization was necessary in order to make the different types of data comparable. The first and third type of data may be used to calculate weights without normalization, but normalization facilitated adjusting the proper value of τ.

The entire algorithm used to calculate the predicted values looked as follows:

```
For each type of weights and for each independent value {

        For each data example {

                Remove data example from data set;

                Normalize the data_for_weights set;

                calcualate the weights;

                Predict independent value using LWLR;

        }

}
```

The calculations were implemented in c++[10]. Due to the fact that the real values of the independent variables were known, it was possible to calculate the coefficient of residual variation in order to assess the improvement of employing LWLR algorithm with various sets of weights. The values of coefficient of residual variation are presented in Table 4.

[10] Source code on http://przemeksekula.eu/motorways2015/, (access: 2016/03/15)

Table 4: Locally weighted linear regression - coefficients of residual variation

Type of weights	Tau	Dependant variables (distances from)	Microenterprises 2010-2011	Microenterprises 2011-2012	Income tax 2011-2012	Population 2011-2012
Based on independent values	0.5	**Motorway**	-575.82%	84.33%	111.66%	339.70%
		Intersection	-582.08%	84.57%	113.03%	336.95%
		Both	-607.77%	90.01%	119.54%	341.07%
	1	**Motorway**	-573.60%	83.99%	112.98%	340.18%
		Intersection	-579.45%	84.43%	113.60%	339.09%
		Both	-594.44%	90.35%	117.59%	347.06%
Based on initial conditions	0.5	**Motorway**	-577.06%	83.45%	113.98%	340.90%
		Intersection	-583.24%	83.83%	114.21%	339.60%
		Both	-593.46%	90.78%	119.00%	351.35%
	1	**Motorway**	-574.24%	83.70%	113.82%	340.65%
		Intersection	-580.10%	84.16%	114.09%	339.98%
		Both	-589.81%	90.62%	117.95%	351.87%
Based on distances between communes	0.5	**Motorway**	-591.57%	84.61%	126.27%	345.86%
		Intersection	-598.25%	85.20%	126.33%	342.01%
		Both	-593.50%	90.28%	119.49%	347.47%
	1	**Motorway**	-590.86%	85.26%	125.20%	346.42%
		Intersection	-597.28%	85.73%	125.38%	343.59%
		Both	-590.10%	90.44%	117.67%	351.89%

None of the coefficients has a satisfactory value. Moreover, in any case the value of coefficient of residual variation has not improved (decreased). This leads to the following conclusions:

- Simple non-linear models cannot predict the searched values better than linear ones.
- Inclusion of information about the initial values of searched variables does not improve the accuracy of the model.
- Inclusion of information about the relative position of communes does not improve the accuracy of the model.

Taking into account the conclusions from the subsection "predictions" the biggest obstacle in acquiring the accurate predictions is insufficiency of data. The most obvious, and probably the only possible, way to ensure the satisfactory level of predictions is inclusion into the model more data, especially data connected with particular geographic locations, instead of data aggregated to centroids of municipalities.

Conclusions

The presented approach allowed the research undertaken herein to find answers to some of the questions formulated in the goal of the research.

1. The impact of motorways has not only a national character, but also a local one. For the examined section of the motorway the following phenomena were found:

a. The motorway had negative impact on a change of number of microenterprises. This impact took place both in the year of finishing the motorway construction (2011) and in the subsequent year.
b. The motorway had negative impact on the change of population in municipalities. This impact took place one year after the completion of the motorway construction project (2012).
c. The motorway had positive impact on a change of incomes of society (measured by change of income taxes). This impact took place one year after completion the motorway construction project (2012).

2. The local impact of motorway projects after lasted no longer than 2 years. After this time the local character of impact on local economic was not possible to detect.
3. The local scale impact is discernible at a distance of about 40 km from the motorway.
4. The simple linear regression is insufficient to predict the impact in particular communes.
5. The usage of LWLR algorithm in order to include non-linearity in a model did not improve the results.
6. The local-scale impact does not depend on the initial level of independent values.
7. Inclusion of distances among communities into model did not improve the accuracy of predictions.
8. It is most likely that to make the predictions sufficiently accurate one has to use more detailed data. The assignment of data to the centroids of communes turned out to be sufficient to estimate the nature of impact, but it did not allow to make accurate predictions.

According to presented conclusions the next step of research should be focused on including the detailed data (associated with particular places) in the prediction process.

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