Multi-criteria evaluation of trolleybus transport transformations in Czech Republic, Poland and Slovakia in the period of the European Union accession

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Multi-criteria evaluation of trolleybus transport transformations in Czech Republic, Poland and Slovakia in the period of the European Union accession

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Why trolleybus transport

- Development of city landscape and increasing expectations of passangers regarding travel comfort
- Trolleybus transport plays significant role in Middle Eastern European countries
- Trolleybus transport is ecological and almost noiseless
- It referes to theses stated in Green Paper on the Municipal Environment, Action Plan on Urban Mobility and Transport White Paper
- Trolleybus transport has better possibilities at gaining EU funds due to its electrical character

Why do we need the synthetic index

- Urban transport is a phenomenom that can be described by using various indicators by multidisciplinary researchers
- Among research from the field of transport geography economic and technical aspects are also popular
- The synthetic index enables gathering one indicator describing trolleybus transport
- The synthetic index may be composed of various sub-indicators from diffrent fields of study

Why do we need the synthetic index

- The synthetic index is used in describing level of development of various subjects in diffrent fields of study and enanbles its linear arrangement
- The synthetic index is used during evaluation in the proces of gaining EU funds [an example: soft projects from EU Commission – Gdynia (PL) and Brno (CZ) in Central Europe Programme – Projects Trolley, Actuate, Dyn@amo] and in building propers schemes

Multi criteria decision analysis (MCDA)

- In many situations we have to deal with the description of objects using a number of unrelated criteria
- For comparative purposes, it is necessary to create a single index – Composed Indicator (CI)
- Rating of the transport development could be an example of using CI

TOPSIS method

- TOPSIS is one of the method of MCDA which allows to create composed indicator
- This method consists of 6 steps

Topsis – Step 1

- Variables describing level of trolleybus transport development are chosen on a basis of meritorical premises and on this ground matrix D is composed

$$\begin{matrix} DMU_1 \\ DMU_2 \\ \vdots \\ DMU_m \end{matrix} \begin{bmatrix} I_{11} & I_{12} & \cdots & I_{1n} \\ I_{21} & I_{12} & \cdots & I_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ I_{m1} & I_{m2} & \cdots & I_{mn} \end{bmatrix} \rightarrow \begin{bmatrix} CI_1 \\ CI_2 \\ \vdots \\ CI_m \end{bmatrix}$$

Topsis – Step 2

- **Normalize** the decision matrix. The values of sub-indicators are normalized to **scale 0-1**. As a result the normalized decision matrix *D'* is obtained .

Topsis – Step 3

- **Compute the weighted** normalized decision matrix: Elements of the normalized decision matrix D' **are multiplied by weight** vector W, which consist n weight factors w. These factors express the relative importance of criteria.

Topsis - Step 4
Identify the PIS and NIS

- The **positive ideal solution** A^+ and the **negative ideal solution** A^- can be expressed as:

$$A^+ = \left(\max_i \{v_{i,1}\}, \ldots, \max_i \{v_{i,n}\} \right) = \left(v_1^+, \ldots, v_n^+ \right)$$

$$A^- = \left(\min_i \{v_{i,1}\}, \ldots, \min_i \{v_{i,n}\} \right) = \left(v_1^-, \ldots, v_n^- \right)$$

Topsis - Step 5
Calculate the distance to PIS and NIS

- For each variable *i* the Euclidean distance d_i^+ to the positive ideal solution and distance d_i^- to the negative ideal solution is defined

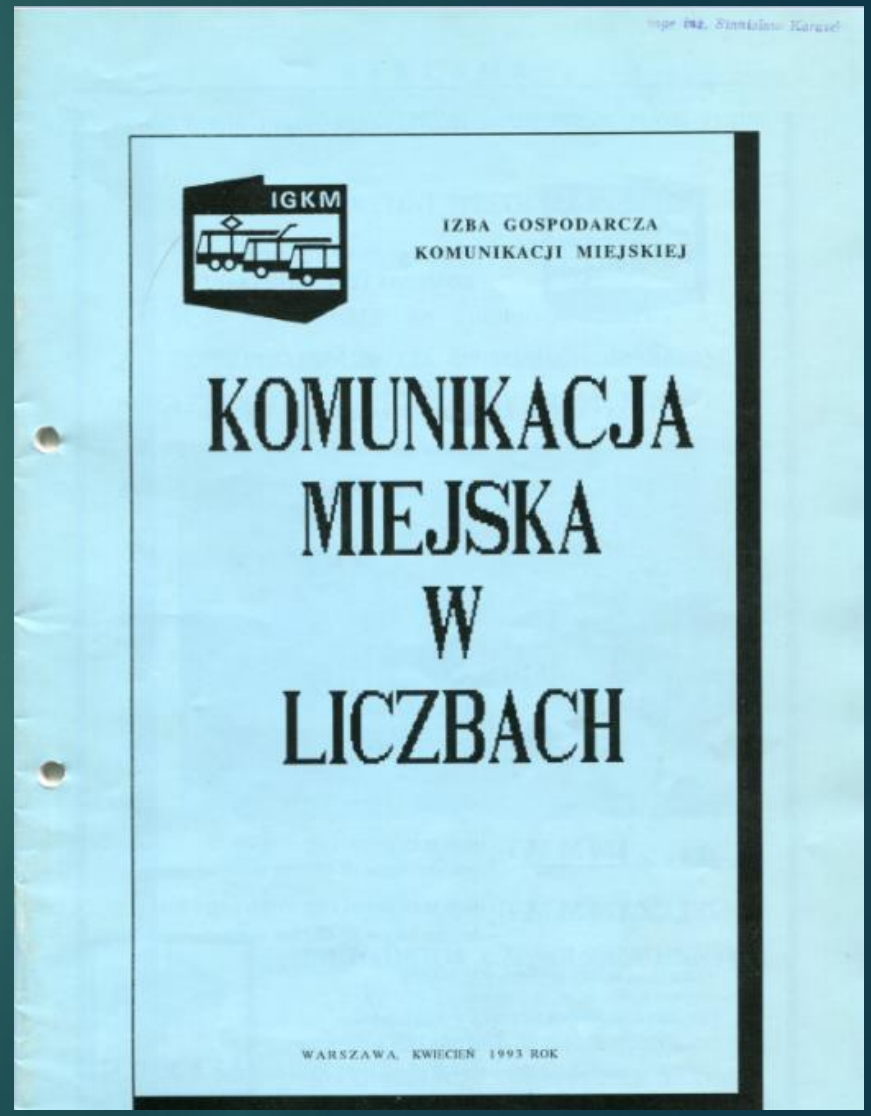
Topsis - Step 6
Compute the relative closeness data to CI

- Values d_i^+ and d_i^- are combined to relative closeness index C_i

$$C_i = \frac{d_i^-}{d_i^+ - d_i^-}$$

- The C_i is a composed indicator *CI* of variable *i*

Topsis – sources



Topsis – Step 1

X1 – Median age of vehicles

X2 – Low floor vehicles (%)

X3 – Vehicle kilometres per year

X4 – The trolleybus transport as a part of public transport in km (%)

X5 – The value of transport work per vehicle

X6 – Changes of the length of the network (routes) during last 10 years in km (%)

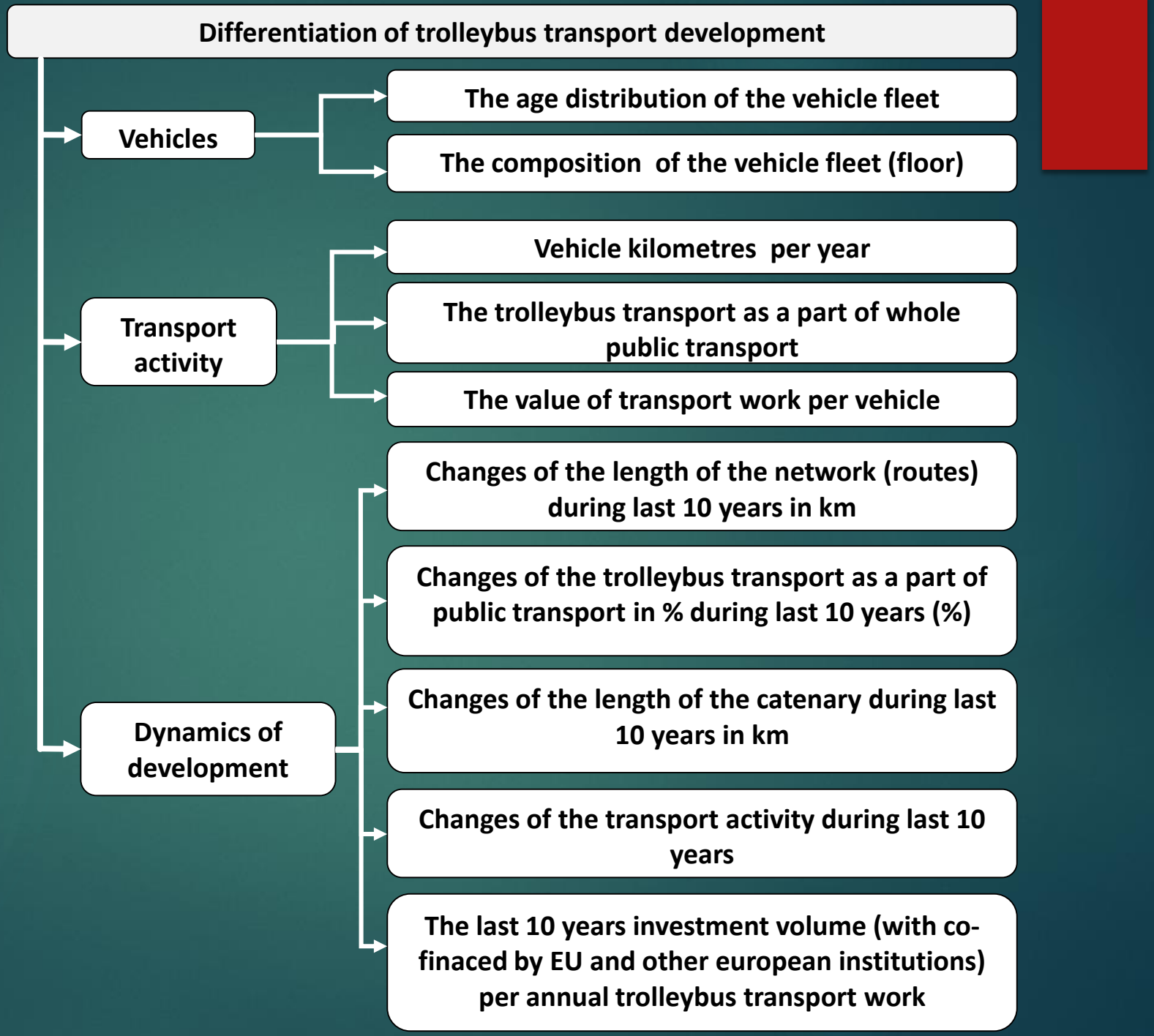
X7 – Changes of the lenght of the catenary during last 10 years in km (%)

X8 – Changes of the trolleybus transport as a part of public transport in % during last 10 years (%)

X9 – Changes of the trolleybus transport activity in km during last 10 years (%)

X10 – The last 10 years investment volume (with co-finaced by EU and other european institutions) per annual trolleybus transport work

Topsis – Step 1



Topsis – Step 1

City	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Brno	16,6	48	5855000	16,1	38520	27,3	0,00	-1,76	-16,74	0,00
C. Budejovice	10,6	55	2501000	44,6	41683	-6,0	0,04	4,46	4,34	0,41
Hradec Kralove	3,0	100	1746000	28,4	49886	0,0	0,00	0,57	1,58	1,24
Ch. Jirkov	14,4	33	698000	37,6	38778	0,0	0,00	-5,43	-32,95	0,00
Jihlava	4,3	100	1410000	49,3	44062	0,0	0,00	-2,98	-3,16	0,11
M. Lazne	8,9	78	326000	66,7	36222	8,5	0,00	20,39	63,82	0,98
Opava	10,9	67	1342000	44,8	49704	15,5	0,00	7,99	24,95	1,02
Ostrava	12,6	72	2765000	8,6	45327	30,5	0,04	-0,01	-13,27	0,47
Pardubice	10,4	67	2271000	39,8	41291	0,0	0,02	-2,58	-12,92	0,86
Plzen	5,4	80	4269000	28,3	49069	5,0	0,14	1,74	8,27	0,08
Teplice	10,3	59	1330000	23,3	32439	0,0	0,00	-20,41	-21,16	0,00
Usti n. Labem	19,0	20	3395000	47,0	48500	4,5	0,14	1,55	0,03	0,92
Zlin	9,5	58	3122000	65,2	56764	0,0	0,16	-0,63	-3,40	0,50
Gdynia	9,5	100	4950000	25,4	57558	49,3	0,19	3,68	21,00	1,62
Lublin	5,2	78	2850000	16,2	36075	4,4	0,17	3,25	2,00	9,43
Tychy	3,4	91	1330000	20,0	57826	0,0	0,00	3,62	7,00	4,65
Banska Bystrica	9,0	66	1134000	30,0	39103	0,0	0,00	44,00	1,98	2,64
Bratislava	16,2	0	5669000	13,0	47242	28,1	0,04	0,00	8,75	1,58
Kosice	19,7	0	1246000	8,0	46148	-15,1	0,00	2,00	27,40	0,00
Presov	13,0	38	1982000	44,0	41292	-17,0	0,00	-3,00	-17,03	0,00
Zilina	13,5	19	1828000	52,0	35843	-17,9	0,00	0,00	-8,09	0,00

Topsis – Step 2

City	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Brno	0,19	0,48	1,00	0,14	0,24	0,67	0,00	0,29	0,17	0,00
C. Budejovice	0,54	0,55	0,39	0,62	0,36	0,18	0,21	0,39	0,39	0,04
H. Kralove	1,00	1,00	0,26	0,35	0,69	0,27	0,00	0,33	0,36	0,13
Ch. Jirkov	0,32	0,33	0,07	0,50	0,25	0,27	0,00	0,23	0,00	0,00
Jihlava	0,92	1,00	0,20	0,70	0,46	0,27	0,00	0,27	0,31	0,01
M. Lazne	0,65	0,78	0,00	1,00	0,15	0,39	0,00	0,63	1,00	0,10
Opava	0,53	0,67	0,18	0,63	0,68	0,50	0,00	0,44	0,60	0,11
Ostrava	0,43	0,72	0,44	0,01	0,51	0,72	0,21	0,32	0,20	0,05
Pardubice	0,56	0,67	0,35	0,54	0,35	0,27	0,09	0,28	0,21	0,09
Plzen	0,86	0,80	0,71	0,35	0,66	0,34	0,73	0,34	0,43	0,01
Teplice	0,56	0,59	0,18	0,26	0,00	0,27	0,00	0,00	0,12	0,00
Usti n. Labem	0,04	0,20	0,56	0,66	0,63	0,33	0,73	0,34	0,34	0,10
Zlin	0,61	0,58	0,51	0,97	0,96	0,27	0,83	0,31	0,31	0,05
Gdynia	0,61	1,00	0,84	0,30	0,99	1,00	1,00	0,37	0,56	0,17
Lublin	0,87	0,78	0,46	0,14	0,14	0,33	0,89	0,37	0,36	1,00
Tychy	0,97	0,91	0,18	0,20	1,00	0,27	0,00	0,37	0,41	0,49
B.Bystrica	0,64	0,66	0,15	0,37	0,26	0,27	0,00	1,00	0,36	0,28
Bratislava	0,21	0,00	0,97	0,09	0,58	0,68	0,21	0,32	0,43	0,17
Kosice	0,00	0,00	0,17	0,00	0,54	0,04	0,00	0,35	0,62	0,00
Presov	0,40	0,38	0,30	0,61	0,35	0,01	0,00	0,27	0,16	0,00
Zilina	0,37	0,19	0,27	0,75	0,13	0,00	0,00	0,32	0,26	0,00

Topsis – Step 3

Median age	Low floor vehicles (%)	Vehicle kilometres per year	The trolleybus transport as a part of public transport in km (%)	The value of transport work per vehicle	Changes of the length of the network during last 10 years in km (%)	Changes of the length of the catenary during last 10 years in km (%)	Changes of the trolleybus transport as a part of public transport in % during last 10 years (%)	Changes of the trolleybus transport activity in km during last 10 years (%)	The last 10 years investment volume (with co-financed by EU or other european institutions) per 1mio vpk
0,25	1	0,5	1	1	1	0,5	1	0,5	1

Topsis – Step 3 and 4

City	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Brno	0,05	0,48	0,50	0,14	0,24	0,67	0,00	0,29	0,08	0,00
C. Budejovice	0,14	0,55	0,20	0,62	0,36	0,18	0,10	0,39	0,19	0,04
H. Kralove	0,25	1,00	0,13	0,35	0,69	0,27	0,00	0,33	0,18	0,13
Ch. Jirkov	0,08	0,33	0,03	0,50	0,25	0,27	0,00	0,23	0,00	0,00
Jihlava	0,23	1,00	0,10	0,70	0,46	0,27	0,00	0,27	0,15	0,01
M. Lazne	0,16	0,78	0,00	1,00	0,15	0,39	0,00	0,63	0,50	0,10
Opava	0,13	0,67	0,09	0,63	0,68	0,50	0,00	0,44	0,30	0,11
Ostrava	0,11	0,72	0,22	0,01	0,51	0,72	0,10	0,32	0,10	0,05
Pardubice	0,14	0,67	0,18	0,54	0,35	0,27	0,04	0,28	0,10	0,09
Plzen	0,21	0,80	0,36	0,35	0,66	0,34	0,36	0,34	0,21	0,01
Teplice	0,14	0,59	0,09	0,26	0,00	0,27	0,00	0,00	0,06	0,00
Usti n. Labem	0,01	0,20	0,28	0,66	0,63	0,33	0,36	0,34	0,17	0,10
Zlin	0,15	0,58	0,25	0,97	0,96	0,27	0,42	0,31	0,15	0,05
Gdynia	0,15	1,00	0,42	0,30	0,99	1,00	0,50	0,37	0,28	0,17
Lublin	0,22	0,78	0,23	0,14	0,14	0,33	0,45	0,37	0,18	1,00
Tychy	0,24	0,91	0,09	0,20	1,00	0,27	0,00	0,37	0,21	0,49
B.Bystrica	0,16	0,66	0,07	0,37	0,26	0,27	0,00	1,00	0,18	0,28
Bratislava	0,05	0,00	0,48	0,09	0,58	0,68	0,10	0,32	0,22	0,17
Kosice	0,00	0,00	0,08	0,00	0,54	0,04	0,00	0,35	0,31	0,00
Presov	0,10	0,38	0,15	0,61	0,35	0,01	0,00	0,27	0,08	0,00
Zilina	0,09	0,19	0,14	0,75	0,13	0,00	0,00	0,32	0,13	0,00

Topsis – Step 5 and 6

	S+	S-	C
Brno	1,92	1,05	0,35
Ceske Budejovice	1,75	1,05	0,38
Hradec Kralove	1,66	1,38	0,45
Chomutov Jirkov	2,03	0,75	0,27
Jihlava	1,72	1,39	0,45
Marianske Lazne	1,61	1,57	0,49
Opava	1,48	1,37	0,48
Ostrava	1,78	1,22	0,41
Pardubice	1,76	1,04	0,37
Plzen	1,60	1,33	0,45
Teplice	2,21	0,72	0,25
Usti nad Labem	1,68	1,16	0,41
Zlin	1,51	1,63	0,52
Gdynia	1,28	1,94	0,60
Lublin	1,60	1,49	0,48
Tychy	1,53	1,56	0,51
Banska Bystrica	1,63	1,36	0,46
Bratislava	1,88	1,11	0,37
Kosice	2,25	0,72	0,24
Presov	2,01	0,87	0,30
Zilina	2,12	0,87	0,29

Composed-indicator CI			Hierarchy class	
Gdynia	PL	0,60	I	High development
Zlin	CZ	0,52		
Tychy	PL	0,51		
Marianske Lazne	CZ	0,49	II	Mid-High development
Lublin	PL	0,48		
Opava	CZ	0,48		
Banska Bystrica	SK	0,46		
Plzen	CZ	0,45		
Hradec Kralove	CZ	0,45		
Jihlava	CZ	0,45		
Usti nad Labem	CZ	0,41		
Ostrava	CZ	0,41	III	Mid-Low development
Ceske Budejovice	CZ	0,38		
Bratislava	SK	0,37		
Pardubice	CZ	0,37		
Brno	CZ	0,35		
Presov	SK	0,30	IV	Low development
Zilina	SK	0,29		
Chomutov Jirkov	CZ	0,27		
Teplice	CZ	0,25		
Kosice	SK	0,24		

TOPSIS analysis results
Linear arrangement

Class I – High development

$$x_i \geq \bar{x} + \sigma_x$$

Class II – Mid-High development

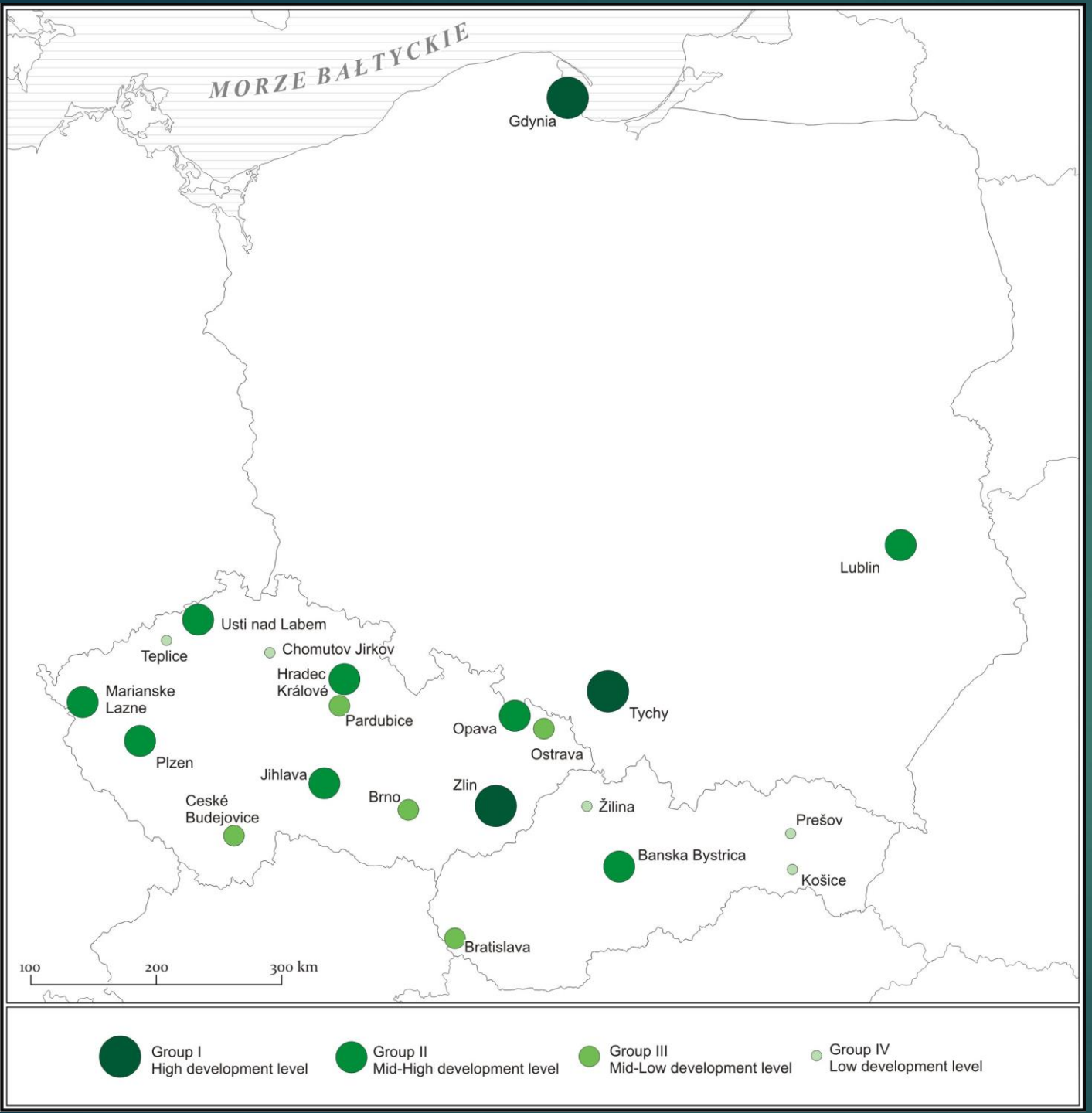
$$\bar{x} \leq x_i < \bar{x} + \sigma_x$$

Class III – Mid-Low development

$$\bar{x} - \sigma_x \leq x_i < \bar{x}$$

Class IV – Low development

$$x_i < \bar{x} - \sigma_x$$



Spatial aspects of the results

- The **highest level** of development in **Polish** trolleybus transport cities
- The **worst level** of development in **Slovakian** trolleybus transport cities

Conclusions

- The population of 21 trolleybus networks in Czech Republic, Poland and Slovakia were analised
- Results indicate that trolleybus networks from Poland – Gdynia and Tychy, and Czech Rep. – Zlin are the ones closesed to positive ideal solution
- Trolleybus networks from Slovakia – Kosice, Presov and Zilina and Czech Rep. – Teplice and Chomutov Jirkov reached the lowest results
- Results reflect political atmosphere among local authorities (plans of dismantling trolleybus transport in Kosice and Chomutov Jirkov)
- In comparison with Czech and Slovakian trolleybus networks development of polish trolleybus transport reached more significant results after joining the EU
- The results obtained show the possibility of building the ranking based on heterogeneous features

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Thank you

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