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INFLUENCE OF TOLL ESTABLISHMENT IN CZECH REPUBLIC ON HAULERS PRICE'S

The paper deals with calculation of influence of toll establishment on carriage in Czech Republic for domestic and foreign haulers. The outcome is just first and not very precise, because of small number of nodes (towns). Further will be this volume put more precisely via add of nodes. This work is very time-consuming. This paper can be something like manual for haulers how to count influence of toll establishment.

1. Introduction

Since 1st of January 2006 we have in Czech Republic (further only CR) new system of toll drawings which is based on Dedicated Short Range Communication (DSRC). This system is obligatory for vehicles buses with total weight over 12tons and implemented on chosen sections of motorways and fast highways (see Picture 1). That ways were divided into toll stages which are bordered by toll points (toll gates).

The height of toll tariff depends on number of axles and volume of emissions (EURO standard). In the table 1 are those tariffs.

Table 1: View of tariffs used in CR [Kč]

Toll prices on highways and express ways					
EURO 0 – 2			EURO 3 – 5		
2	3	4+	2	3	4+
2,30	3,70	5,40	1,70	2,90	4,20

Source: www.premid.cz

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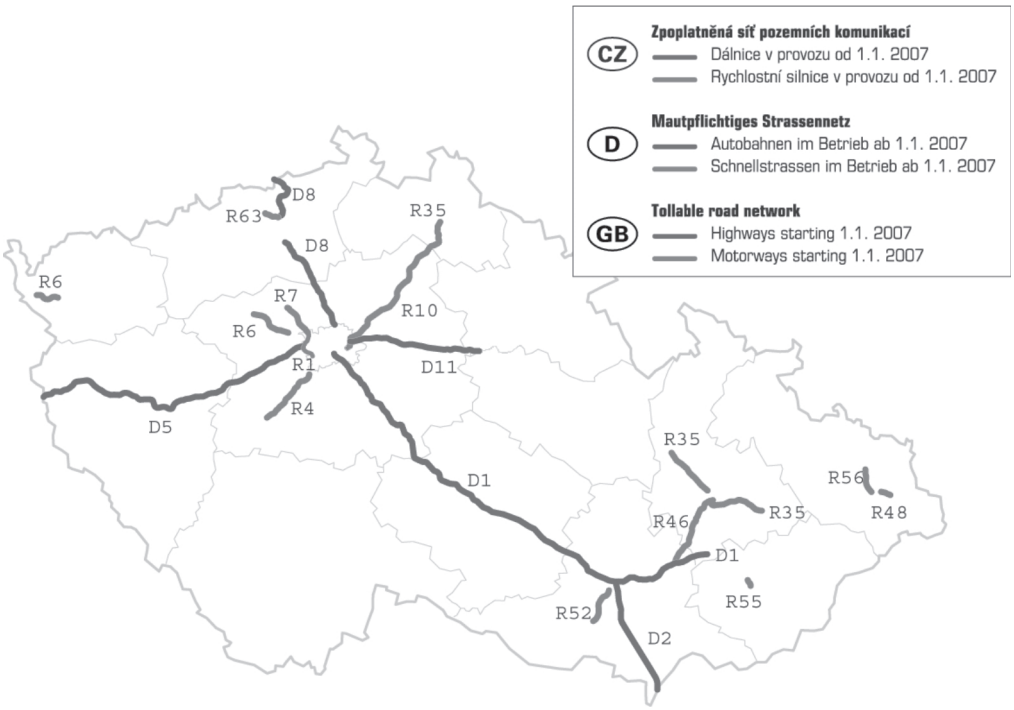
Picture 1: Map of road under toll in CR



Source: www.premid.cz

Each vehicle which is using paid route must have on board unit (OBU). The price of OBU is app. 1500 Kč and hauler can use 2 types of payment:

1.1.1 First of them (pre-pay) is advantageous to foreign haulers and to sporadic users. He is similar to credit recharging system of the cell phone. User will give money to the OBU and after each passage round toll gate is the credit lowered. Under 600 Crowns is driver informed that OBU needs another recharge,

1.1.2 Second way (post-pay) is similar to fixed payment tariff by cell phone. Payments are made in accounting periods for whole vehicles and whole kilometers traveled in previous period. Most important difference between cell phones and toll system is in non saving money using post-pay system.

In the toll system are nowadays registered app. 150 000 vehicles (90 000 in pre-pay mode and 60 000 in post-pay mode). Each hauler can also on web sites premid.cz on-line monitor instants of time when their vehicle is passing the toll gate and he can see set up of the OBU, time of pass and price of course. That was only short description of toll collecting system in Czech Republic. In the next lines will be reflection over system elements and set-up of the system.

2. Possibilities for Czech Republic

System, which is used in Czech Republic, uses principle of microwave transmission and that system was privileged before satellite systems. That system used to look suited for Czech Republic, because of small volume of highways. Nowadays we see that our system will be extended for 1st class roads, where is existing system uneconomic, because of large number of new toll gates and money for maintenance. In the table 2 is proposal of toll prices on 1st class roads.

Table 2: Expected toll prices on 1st class routes

Toll prices on 1st class routes						
Emission standard	EURO 0 – 2			EURO 3 – 5		
Number of axles	2	3	4+	2	3	4+
Rate Kč/km	1,10	1,80	2,60	0,80	1,40	2,00

Source: http://www.schenker.cz

Annotation of both systems:

- **DSRC** (Dedicated Short Range Communication): Transmission of information is between road facility and (RSE – Road Side Equipment) and on board unit (OBU). The communication is microwave band.
- **GNSS–CN** (Global Navigation Satellite Systems – Cellular Network): That system uses satellite navigation for positioning and measuring of distance run, transmission of information goes over telecommunication network.

Table 3: Advantages and disadvantages of both systems

DSRC

Advantages	Disadvantages
Extensive use in Europe	No compatibility with second system
Cheap OBU (app 1 500 Kč)	Expensive infrastructure
Easy implementation into praxis	Small perspectivity of other RTTT (Road-Transport and Traffic Telematics) applications

GNSS-CN

Advantages	Disadvantages
Cheap ground infrastructure	Expensive OBU (app 15 000 Kč)
High perspectivity of other RTTT applications	Necessity of special control points
References from EU	No practical experiences – system in Germany is first application

Source: author

Next elements, which have impact on prices for use of road infrastructure has been set by government. Those are emission standard and number of axles. In the first case were vehicles divided into 2 groups: EURO 0 – 2 and EURO 3 – 5. That division de-motivates haulers out from buying of new vehicles with EURO 4 or 5. Nowadays, they will pay the same toll for vehicle with EURO 3, 4 and 5. In the second case are vehicles divided into three groups according to number of axles (up to 3, 4 and 5), but the haulers motivation is similar to the first case (i.e. low), because semitrailer tractor has minimally two axles. The semitrailer has one, two, but most frequently three axles (one is retractable). So that 90 % of semitrailer units will pay the most expensive toll. Regardless of possible differences for full and empty semitrailers.

3. Financial impact on haulers

3.1. Selection of nodes (cities)

How was the impact of those changes on haulers? It depends on hauling distance and percentage of hauling distance on paid traffic route. Next lines will answer for the question about average hauling

Table 4: Unified nodes

Number of nodes	Final node	Unified nodes					
3	Františkovy Lázně	Aš	Františkovy Lázně	Cheb			
3	Tachov	Mariánské Lázně	Tachov	Rozvadov			
2	Karlovy Vary	Karlovy Vary	Sokolov				
3	Rokycany	Příbram	Rokycany	Plzeň			
2	Domažlice	Domažlice	Folmava				
3	Strakonice	Strakonice	Písek	Prachatice			
5	České Budějovice	České Budějovice	Český Krumlov	Dolní Dvořiště	Jindřichův Hradec	Tábor	
6	Jihlava	Pelhřimov	Třebíč	Havlíčkův Brod	Jihlava	Humpolec	Žďár nad Sázavou
5	Praha	Beroun	Praha	Kladno	Benešov	Rakovník	
4	Pardubice	Pardubice	Chrudim	Hradec Králové	Rychnov nad Kněžnou		
3	Náchod	Náchod	Trutnov	Královec			
4	Liberec	Liberec	Jabolonec nad Nisou	Habartice	Semily		
6	Chomutov	Chomutov	Hora Sv. Šebestiána	Žatec	Louny	Most	Kadaň
6	Ústí nad Labem	Ústí nad Labem	Česká Lípa	Litoměřice	Děčín	Teplice	Cínovec
4	Mladá Boleslav	Mladá Boleslav	Jičín	Mělník	Nymburk		
2	Kolín	Kolín	Kutná Hora				
2	Svitavy	Svitavy	Ústí nad Orlicí				
4	Jeseník	Jeseník	Mikulovice	Bruntál	Šumperk		
6	Ostrava	Ostrava	Karviná	Frýdek – Místek	Český Těšín	Chalupki	Opava
4	Vsetín	Vsetín	Horní Bečva	Zlín	Nový Jičín		
4	Olomouc	Olomouc	Kroměříž	Přerov	Prostějov		
3	Uherské Hradiště	Uherské Hradiště	Starý Hrozenkov	Hodonín			
2	Hatě	Hatě	Znojmo				
3	Brno	Brno	Blansko	Vyškov			
2	Břeclav	Břeclav	Mikulov				

Source: Author

distance. Authors' research came out from 91 largest cities and border checkpoints in Czech Republic [1]. First step of solution was reduction of nodes, cause matrix 91 to 91 has 8281 values (unreduced number of nodes), so that some cities were unified into one node. Therefore resultant value is just suboptimum which can be further improved. In the next table 4 are unified nodes.

After that reduction fairly good matrix 25 to 25 (225 values – reduced number of nodes) has been set. Next step was matrix of minimal distances from internet server www.mapy.cz. Whereas the difference between distances A – B and B – A is small, they are called equate. Whole table is in supplement 1.

3.2. Matrix of paid toll

Next step of the solution was matrix of paid toll. Those values are in matrix in supplement 2. Data were taken from web calculator on *www.premid.cz* for basic settings EURO 0-2 and 2 axles.

3.3. Matrix of rates of distances on paid routes to whole hauling distance

That step is very important for the solution, but without self predicative value. That table is in supplement 3. The mathematic formula for that matrix is in formula 1:

$$x_{ij} = \frac{\frac{p_j}{p_{km}}}{d_j} \times 100 \ [\%] \quad (1)$$

where: x_{ij} matrix of rates of distances on paid routes to whole hauling distance i – j,
p_{ij} matrix element from supplement 2,
p_{km} toll per kilometer (2,3 Kč/km),
d_{ij} matrix elements from supplement 1.

3.4. Calculation of average hauling distance with nodes rating

The next to the last step is calculating average distance hauled on paid route with nodes rating (that rating is first column from table 4. The formula 2 calculates new matrix with nodes rating. This matrix is in the table in supplement 4:

$$x^*_{ij} = x_j \times w_i \times w_j \qquad [-] \quad (2)$$

where: x^*_{ij} elements from matrix in supplement 4,
x_{ij} elements from matrix in supplement 3,
w_i, w_j rating of node i and j.

[1] Aš, Benešov, Beroun, Blansko, Brno, Bruntál, Břeclav, Cínovec, Česká Lípa, České Budějovice, Český Krumlov, Český Těšín, Děčín, Dolní Dvořiště, Domažlice, Folmava, Františkovy Lázně, Frýdek – Místek, Habartice, Hatě, Havlíčkův Brod, Hodonín, Hora Sv. Šebestiána, Horní Bečva, Hradec Králové, Humpolec, Chalupki, Cheb, Chomutov, Chrudim, Jabolonec na Nisou, Jeseník, Jičín, Jihlava, Jindřichův Hradec, Kadaň, Karlovy Vary, Karviná, Kladno, Kolín, Královec, Kroměříž, Kutná Hora, Liberec, Litoměřice, Louny, Mariánské Lázně, Mělník, Mikulov, Mikulovice, Mladá Boleslav, Most, Náchod, Nový Jičín, Nymburk, Olomouc, Opava, Ostrava, Pardubice, Pelhřimov, Písek, Plzeň, Praha, Prachatice, Prostějov, Přerov, Příbram, Rakovník, Rokycany, Rozvadov, Rychnov nad Kněžnou, Semily, Sokolov, Starý Hrozenkov, Strakonice, Svitavy, Šumperk, Tábor, Tachov, Teplice, Trutnov, Třebíč, Uherské Hradiště, Ústí nad Labem, Ústí nad Orlicí, Vsetín, Vyškov, Zlín, Znojmo, Žatec, Žďár nad Sázavou

The formula 3 is for calculation of average hauling distance hauled on paid route:

$$, = \frac{\sum_{i,j=1}^{n_r} x_j^*}{\frac{n^2}{2} - n} \times 100 \ [\%] \quad (3)$$

where: d_p average hauling distance hauled on paid routes,
x^*_{ij} elements from matrix in supplement 4,
n_r reduced number of nodes,
n unreduced number of nodes.

That way was calculated value 44 %. That means that during haul users goes approximately 44 % on paid roads. So that we have to calculate average hauling distance for calculation of price rising.

3.5. Monetary value of toll implementation

The last step is only calculation of average hauling distance from matrix in supplement 1 according to formula 4:

$$\Delta = \frac{\sum_{i,j=1}^{n_r} d_{ij}}{\frac{n^2}{} - n} \ [\text{km}] \quad (4)$$

where: d_Δ average hauling distance,
d_{ij} elements from matrix in supplement 1,
n_r reduced number of nodes,
n unreduced number of nodes.

Resultant value of the calculation is 223,05 km. So that we haul on paid route at a medium: $d = d_\Delta \times d_p = 98km$. The monetary value of toll implementation is in the table 5.

Table 5: Average paid toll

Average paid toll [Kč]					
EURO 0 – 2			EURO 3 – 5		
2	3	4+	2	3	4+
225	363	529	167	284	412

Source: Author

4. Conclusion

As mentioned about, calculated values are just a suboptimum, which will be further improved by adding of nodes. However we can say that impact of toll implementation isn't negligible and haulers will count the toll towards their prices.

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Recenzent: doc. Ing. Vaclav Cempirek

Supplement 1: Matrix of minimal distances [km]

	Ta-chov	Karlovy Vary	Roky-cany	Domaž-lice	Strako-nice	České Budějo-vice	Jihlava	Praha	Pardu-bice	Náchod	Liberec	Cho-mu-tov	Ústí nad Labem	Mladá Bole-slav	Kolín	Svitavy	Jeseník	Ostra-va	Vsetín	Olomo-uc	Uher-ské Hradi-ště	Hatě	Brno	Břeclav
Františko-vy Lázně	60	48	133	110	185	245	306	178	291	333	265	104	166	225	253	373	446	558	540	462	460	394	388	437
Tachov		68	82	59	135	195	281	158	267	308	268	124	192	223	229	348	422	534	516	438	436	369	364	413
Karlovy Vary			105	121	169	229	259	131	244	286	219	56	120	179	207	326	399	511	494	416	413	347	341	391
Rokycany				81	87	147	206	83	191	233	193	103	170	148	154	273	346	458	441	363	360	294	288	338
Domažlice					83	141	279	156	264	306	265	161	243	220	227	346	419	531	513	435	433	296	361	410
Strakonice						57	157	115	218	260	219	182	203	174	180	231	373	410	392	314	312	213	237	289
České Budějovice							139	148	202	292	251	251	239	206	186	214	326	392	375	297	295	159	220	272
Jihlava								125	91	154	228	228	216	183	83	103	217	264	247	169	167	88	92	144
Praha									107	150	109	98	91	64	69	190	264	381	363	286	283	213	204	260
Pardubice										65	120	217	184	99	45	73	179	243	229	139	217	183	139	193
Náchod											132	258	225	118	97	92	111	218	246	160	239	238	160	227
Liberec												165	97	51	104	174	246	347	329	243	385	318	243	362
Chomutov													64	144	175	294	367	482	465	387	384	319	312	362
Ústí nad Labem														85	143	262	336	466	448	370	368	301	296	345
Mladá Boleslav															59	159	231	330	312	226	337	270	262	314
Kolín																120	209	290	272	186	238	171	163	215
Svitavy																	112	176	158	72	146	146	67	134
Jeseník																		116	195	97	187	257	177	236
Ostrava																			74	100	140	250	180	229
Vsetín																				82	60	233	163	130
Olomouc																					75	156	81	132
Uherské Hradiště																						153	80	66
Hatě																							79	94
Brno																								61

Supplement 2: Matrix of paid toll [Kč]

	Tachov	Karlovy Vary	Rokycany	Domažlice	Strakonice	České Budějovice	Jihlava	Praha	Pardubice	Náchod	Liberec	Chomutov	Ústí nad Labem	Mladá Boleslav	Kolín	Svitavy	Jeseník	Ostrava	Vsetín	Olomouc	Uherské Hradiště	Hatě	Brno	Břeclav
Františkovy Lázně	15	27,9	169,4	15	146,2	146,2	586,9	311,3	491	491	527,1	27,9	53,6	439,6	425,3	491	491	1038,3	894,7	950,2	813	586,9	775	892,8
Tachov		0	154,4	0	131,2	131,2	571,9	296,3	476	476	512,1	0	431,7	424,6	410,3	476	476	1023,3	879,7	935,2	798	571,9	760	877,8
Karlovy Vary			9,4	0	16,1	16,1	333,1	48,8	237,2	237,2	273,3	0	25,7	185,8	171,5	237,2	237,2	784,5	640,9	696,4	559,2	333,1	521,2	639
Rokycany				69,2	0	0	417,5	141,9	321,6	321,6	357,7	0	277,3	270,2	255,9	321,6	321,6	868,9	725,3	780,8	643,6	417,5	605,6	723,4
Domažlice					0	0	486,7	211,1	390,8	390,8	426,9	0	346,5	339,4	325,1	390,8	390,8	938,1	794,5	850	712,8	486,7	674,8	792,6
Strakonice						0	49,4	73,5	236,1	236,1	272,2	113,1	194,7	184,7	170,4	0	236,1	500,8	357,2	412,7	275,5	0	237,5	355,3
České Budějovice							0	60,1	0	222,7	258,8	125,5	181,3	171,3	0	0	0	500,8	357,2	412,7	275,5	0	237,5	355,3
Jihlava								258,5	0	0	457,2	323,9	379,7	369,7	0	0	347,2	435,3	291,7	347,2	210	0	172	289,8
Praha									162,6	162,6	198,7	34,1	121,2	111,2	96,9	162,6	162,6	709,9	566,3	621,8	484,6	258,5	446,6	564,4
Pardubice										0	25,2	279,6	279,6	74,2	41,5	0	0	110	81,1	52,5	160,4	0	122,4	240,2
Náchod											25,5	279,6	279,6	0	41,5	0	0	110	81,1	52,5	59,4	0	0	112,5
Liberec												25,7	0	87,5	96	25,5	25,5	135,5	106,6	78	666,5	440,4	25,5	746,3
Chomutov													25,7	224,6	213,9	279,6	279,6	775,3	631,7	687,2	550	323,9	512	629,8
Ústí nad Labem														0	213,9	279,6	279,6	831,1	687,5	743	605,8	379,7	567,8	685,6
Mladá Boleslav															8,5	0	0	145,6	660,7	52,5	579	352,9	541	658
Kolín																0	41,5	451,4	307,8	363,3	226,1	0	188,1	305,9
Svitavy																	0	110	81,1	52,5	15,2	46,8	0	112,5
Jeseník																		0	28,6	0	6,9	222	152,4	282,4
Ostrava																			28,9	57,5	28,9	310,1	240,5	370,5
Vsetín																				28,6	0	166,5	96,9	0
Olomouc																					6,9	222	152,4	282,4
Uherské Hradiště																						84,8	15,2	0
Hatě																							46,8	0
Brno																								112,5

Supplement 3: Matrix of rates of distances on paid routes to whole hauling distance [%]

	Ta-chov	Karlovy Vary	Roky-cany	Doma-žlice	Strako-nice	České Budějo-vice	Jihlava	Praha	Pardu-bice	Náchod	Liberec	Cho-mutov	Ústí nad Labem	Mladá Bole-slav	Kolín	Svitavy	Jeseník	Ostra-va	Vsetín	Olomo-uc	Uher-ské Hradi-ště	Hatě	Brno	Břeclav
Františko-vy Lázně	11	25	55	6	34	26	83	76	73	64	86	12	14	85	73	57	48	81	72	89	77	65	87	89
Tachov		0	82	0	42	29	88	82	78	67	83	0	98	83	78	59	49	83	74	93	80	67	91	92
Karlovy Vary			4	0	4	3	56	16	42	36	54	0	9	45	36	32	26	67	56	73	59	42	66	71
Rokycany				37	0	0	88	74	73	60	81	0	71	79	72	51	40	82	72	72	94	78	62	91
Domažlice					0	0	76	59	64	56	70	0	62	67	62	49	41	77	67	67	85	72	71	81
Strakonice						0	14	28	47	39	54	27	42	46	41	0	28	53	40	40	57	38	0	44
České Budějovice							0	18	0	33	45	22	33	36	0	0	0	56	41	41	60	41	0	47
Jihlava								90	0	0	87	62	76	88	0	0	70	72	51	89	55	0	81	88
Praha									66	47	79	15	58	76	61	37	27	81	68	95	74	53	95	94
Pardubice										0	9	56	66	33	40	0	0	20	15	16	32	0	38	54
Náchod											8	47	54	0	19	0	0	22	14	14	11	0	0	22
Liberec												7	0	75	40	6	5	17	14	14	75	60	5	90
Chomutov													17	68	53	41	33	70	59	77	62	44	71	76
Ústí nad Labem														0	65	46	36	78	67	87	72	55	83	86
Mladá Boleslav															6	0	0	19	92	10	75	57	90	91
Kolín																0	9	68	49	85	41	0	50	62
Svitavy																	0	27	22	32	5	14	0	37
Jeseník																		0	6	0	2	38	37	52
Ostrava																			17	25	9	54	58	70
Vsetín																				15	0	31	26	0
Olomouc																					4	62	82	93
Uherské Hradiště																						24	8	0
Hatě																							26	0
Brno																								80

Supplement 4: Matrix of rates of distances on paid routes to whole hauling distance with nodes rating

	Ta-chov	Karlovy Vary	Roky-cany	Domaž-lice	Strako-nice	České Budějo-vice	Jihlava	Praha	Pardu-bice	Náchod	Liberec	Cho-mutov	Ústí nad Labem	Mladá Bole-slav	Kolín	Svitavy	Jeseník	Ostrava	Vsetín	Olomo-uc	Uher-ské Hradi-ště	Hatě	Brno	Břeclav
Františko-vy Lázně	58,7	72,8	662,9	39,1	572,1	953,5	4593,1	2030,2	2561,7	1921,3	2750,1	218,3	419,5	2293,6	1109,5	1280,9	2561,7	8125,8	4668,0	4957,6	3181,3	1531,0	3032,6	2329,0
Tachov		0,0	604,2	0,0	513,4	855,7	4475,7	1932,4	2483,5	1862,6	2671,8	0,0	3378,5	2215,3	1070,3	1241,7	2483,5	8008,4	4589,7	4879,3	3122,6	1491,9	2973,9	2289,9
Karlovy Vary			24,5	0,0	42,0	70,0	1737,9	212,2	825,0	618,8	950,6	0,0	134,1	646,3	298,3	412,5	825,0	4093,0	2229,2	2422,3	1458,8	579,3	1359,7	1111,3
Rokycany				0,0	0,0	0,0	2331,6	2296,9	729,1	1031,6	2253,1	0,0	1314,9	1619,3	641,6	473,3	1323,9	5137,2	3930,0	3784,2	3055,3	1679,0	1633,7	1579,8
Domažlice					0,0	0,0	1283,3	1641,5	803,2	879,5	1714,6	0,0	1197,8	1303,9	548,0	445,9	1122,5	3862,1	2860,4	2763,5	2217,4	1239,7	1269,7	1173,6
Strakonice						0,0	140,4	654,4	649,8	774,6	1686,1	1065,1	1366,1	1124,3	429,7	0,0	762,9	3565,6	1949,2	1863,7	1614,9	718,7	0,0	619,6
České Budějovice							0,0	613,5	0,0	1004,7	2618,0	1637,0	2483,5	1728,2	0,0	0,0	0,0	5432,4	3246,9	3106,1	2691,5	1197,8	0,0	1032,6
Jihlava								3371,7	0,0	0,0	4770,8	5069,7	5943,1	3857,7	0,0	0,0	3623,0	6813,4	3043,8	3623,0	1643,5	0,0	1346,1	1512,0
Praha									1413,9	1060,4	1727,8	444,8	1580,9	967,0	421,3	707,0	1413,9	9259,6	4924,3	5407,0	3160,4	1123,9	2912,6	2453,9
Pardubice										0,0	175,3	2917,6	2917,6	516,2	144,3	0,0	0,0	1147,8	564,2	365,2	836,9	0,0	638,6	835,5
Náchod											133,0	2188,2	2188,2	0,0	108,3	0,0	0,0	860,9	423,1	273,9	232,4	0,0	0,0	293,5
Liberec												268,2	0,0	608,7	333,9	88,7	177,4	1413,9	741,6	542,6	3477,4	1531,8	133,0	2595,8
Chomutov													402,3	2343,7	1116,0	1458,8	2917,6	12135,1	6591,7	7170,8	4304,3	1689,9	4007,0	3285,9
Ústí nad Labem														0,0	1116,0	1458,8	2917,6	13008,5	7173,9	7753,0	4741,0	1981,0	4443,7	3577,0
Mladá Boleslav															29,6	0,0	0,0	1519,3	4596,2	365,2	3020,9	1227,5	2822,6	2288,7
Kolín																0,0	144,3	2355,1	1070,6	1263,7	589,8	0,0	490,7	532,0
Svitavy																	0,0	573,9	282,1	182,6	39,7	81,4	0,0	195,7
Jeseník																		0,0	199,0	0,0	36,0	772,2	795,1	982,3
Ostrava																			301,6	600,0	226,2	1617,9	1882,2	1933,0
Vsetín																				199,0	0,0	579,1	505,6	0,0
Olomouc																					36,0	772,2	795,1	982,3
Uherské Hradiště																						221,2	59,5	0,0
Hatě																							122,1	0,0
Brno																								293,5