Carpooling as the other possibility of commuting in the Czech Republic

Igor Ivan[1]

[1]Institute of Geoinformatics, VSB – Technical University of Ostrava, 17. listopadu 15, 708 33, Ostrava – Poruba, Czech Republic
igor.ivan@vsb.cz

Abstract: The decline of public transport usage in the Czech Republic can bring a lot of traffic (congestions, public transport providers' sales), environmental and other problems. Carpooling can be defined as the shared use of a car by the driver and one or more passengers, usually for commuting. It seems to be very interesting alternative for people who prefers private car but who wants to save money. Carpooling is going to be very popular in the world, just because it saves money and it brings environmental positives. The more people commuter carpools the more money he saves. There is no statistic about carpooling use in the Czech Republic, but this paper would like to introduce the main positives of this type of commuting and compare it with other travel possibilities as public transport and individual transport. 95 main employers in three Regions were chosen as targets of commuting - two industrial Regions - Usti Region and the Moravian-Silesian Region and one agricultural Region - Vysocina Region. New special extension for the OpenJump software was developed and utilised. Randomly selected buildings were used as commuting origin and as street data-source the StreetNet was used. Based on results from almost 124 000 simulations there can be calculated distance a money saves with using carpooling with one, two or three passengers and compare these results with public transport and individual transport.

Keywords: carpooling, commuting, transport, distance, price

1 Introduction

The rate of individual car transport (next ICT) usage is rising and the usage of public transport (next PT) is continuously declining during last decades as it is written in the abstract. Compare to 1970 when only 5 % of people used the ICT for commuting out of the residential municipality, in 2001 it was more than 30 % [3] (the transport vehicle wasn't investigated in Censuses in 1980 and 1991). In case of rail transport, number of transported people declined about more than 22 % from 228.7 million (1994) to 177.4 million (2008). More significant decline is in case of bus transport where the decline is almost 40 % from 663.5 (1994) to 401.7 million (2008) of transported people per year [10], [10], [11]. So there is evident a need to compare general factors of these two transport modes. Price and distance of journey to chosen employees in particular Regions belong to these factors (see chapter 3). Carpooling is the third transport mode which was chosen for comparison with ICT and PT. It belongs to a group of new transport systems developed to reduce this increase of ICT against PT. It tends to increase the attractiveness of PT and to reduce the negative effects of ICT on the environment and even to reduce the number of cars in often overcrowded roads and streets mainly in urban areas [16].

As defined by the American geographer Rodrigue [13], carpooling is an agreement where two or more passengers share the use and cost of privately owned cars by travelling to and from pre-defined locations. The basic advantages of the two previous types of transport are combined in this type of transport. Price of journey is lower than in case of ICT, even though the journey distance is longer, because the financial costs are divided between all passengers. But the journey doesn't have to be so time-consuming and distance so long as in case of PT.

Carpooling should not be changed with car-sharing, which is organized and the providers are a professional private organizations who own car park just for this purpose (more [5] or [1]). The main difference is in the institutional guarantee – car ownership. These and related terms define in the Czech literature for example [5] or [16]. In terms of carpooling could be then conducted the ride-sharing (next R-S) or car-sharing (next C-S). R-S could be generally translated as shared journey. Its main aim is to achieve the maximal utilization of the vehicle to minimize the economic costs of the journey. At least two passengers must take part carpooling and the vehicle is usually owned by one of them. It is not important whether commuters use only the car owned by one passenger or they are changing the passengers' cars in regular intervals. It is important to share at least part of the journey.

This type of transport has to reduce at least one car journey in a similar direction and the passenger must have driving licence and under other circumstances he would use own car for commuting [6]. In addition, two types of R-S can be distinguished: formal (a provider for the R-S organization) and informal (two co-passengers commute together via private car) [16]. The main aim of C-S is the sharing of the vehicle in order to reduce the economic costs of using cars by as many participants as possible. For this mode of transport it is characteristic that the car is on loan or hired and the car owner doesn't have to travel at all. As an informal C-S can it be considered a car-sharing by family members within household, while as a formal C-S it can be considered a car rentals or taxi because the taxi driver can be considered as part of the car with some degree of generalization.

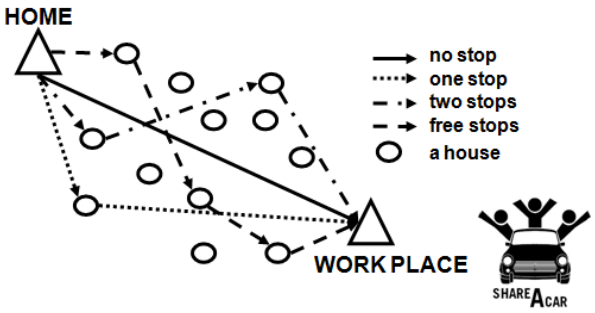

Fig. 1. Principal of carpooling

However, this still leads to an increase of ICT use and therefore it is not advisable [16]. Stimulating mechanisms for participation in C-S or R-S should not be based on favouritism of conditions for these types of driving. However, even CS or RS could reduce the car use more than the classical ICT. According to the results of the International Energy Agency from 2005, in case that each commute would be joined by another passenger, the potential benefits of using the R-S in OECD countries would lead to savings in overall oil consumption by 7.7 % or 2,223 barrels of oil per day and to reduce the number of kilometres travelled by a car by 12.5%, what implies a further numbers of advantages [2]. Based on the Census results in Ireland (2006), 4% of all commuters are using the R-S for daily morning commuting to Dublin [2].

First time, carpooling was officially used in the Czech Republic by Panasonic's office in Pilsen. This company has a guarded parking with limited capacity and with the growth of the employees' number its capacity wasn't sufficient. Therefore, carpooling helps to solve problems with parking and a parking place is always reserved for commuters who are using carpooling. Employees who participate in the system find it very positively and the company's management is therefore satisfied with the results and experiences from the operation of shared services and they support the whole system [16].

2 Routes generator for OpenJump

Extensions called Routes Generator was developed to simulate the distance and costs of commuting via carpooling, it was developed by Martin Prager. This is an extension of open source GIS software OpenJUMP. Extension is implemented as OpenJUMP ThreadedPlugin. Implementation of this class would be better able to cope with prolonged processes that occur by the carpooling simulations. In addition to basic components and JTS library (Java Topology Suite) which is one of the basic components of OpenJUMP, it is used other open-source library Jgrapht too. This library constructs weighted graph from the road network layer and it calculates the shortest route between the origin and destination (concretely the implementation of the class WeightedPseudograph). The entire process is performed in one thread without any persistence. So the number of calculations depends on computer memory. In general, this extension calculates the shortest path distance between the origin and destination, through defined number of randomly selected stops which are located in the x kilometres buffer area around the shortest path between the origin and the destination.

The main form of this extension can be divided into three main parts. The first part contains the definition of origins and target locations of commuting. These can be selected either randomly or can be specified by using the values of selected attributes. In case of this paper, origins were selected at random from all buildings within particular Districts or micro-regions. Destinations were selected

according to address of the chosen employer (see chapter 3). Attributes of the transport network are chosen in the second part of the form. In this case these are the node of origin and node of destination of particular transport segments and their length. The third part contains the details of the simulation. Firstly, the maximal time limit for each simulation is defined; in this case the limit is set to 60 seconds. If the duration of particular simulation exceeds this time limit, current calculation is interrupted and next simulation will start. Buffer size defines the width of the buffer zone around the shortest route between the origin and destination when particular stops for carpooling can be chosen. This area cannot be too large because the detour could be too significant and could even double the total length of journey and in this case the price reduction wouldn't bring any improvement compared to ICT. Number of stops is defined in the last text box of the main form. If random buildings selection is selected in form, it is possible to enter the minimum distance between the origin and destination in metres.

It is possible to monitor the progress of calculations during simulations in the output window; there is information about particular steps (Fig. 2). Input parameters are generated in the first step, the origin and destination is selected. Furthermore, it is found the shortest path between these two locations and selected a defined number of stops along this route. Next step is finding the shortest path between the origin and the first stop, then between the first stop and another stop or the destination. In the last step, all results are saved in four output layers.

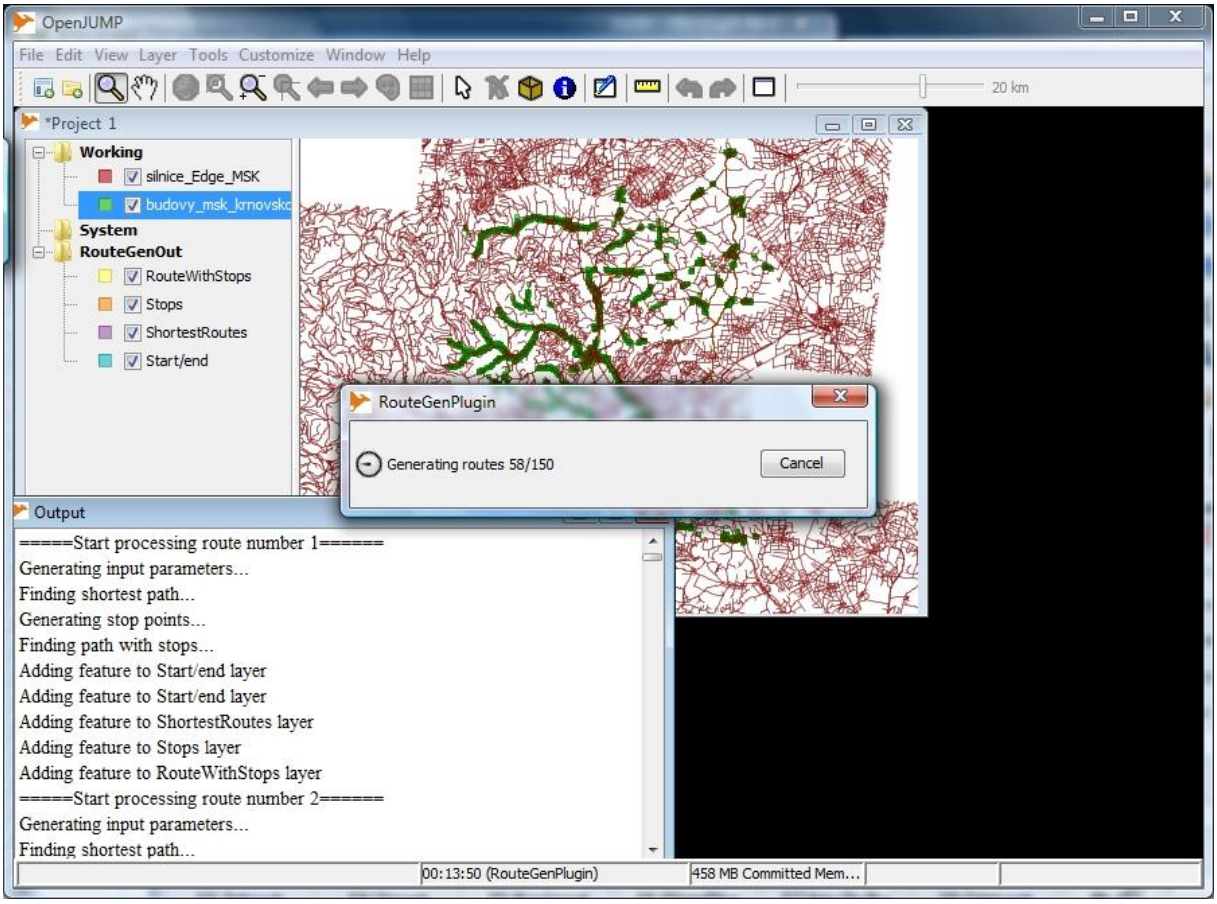

Fig. 2. Routes generator in use

3 Methodology

Three selected regions were chosen as case study areas – Moravian-Silesian Region (next MSK), Ústí Region (next ÚLK) and Vysočina Region (next VYS) and were analyzed on two spatial levels. In case of Regional level, results are evaluated and compared between particular Regions as units. The second spatial level is focused on particular employers within particular Districts within the Regions and in case of MSK within working micro-regions, which were created according to methodology of socio-economic regionalization of the Czech Republic in 2001 [7]. Two different administrative dividing

were chosen because of improper dividing of MSK into Districts (urban district of Ostrava-city without suburbs, large Districts Frýdek-Místek and Bruntál).
Districts are more homogeneous in both Regions and their size is generally very similar. Five employers were chosen in each district (LAU1) or in each micro-region in the case of MSK. These employers belong to the biggest in each Region. The selection of these employers was influenced by the number of employees, which had to be more than 250 (in February 2008) but finally more than half of the selected companies have more than 500 employees. Localization of the employer was another condition for employer selection; it should be located outside the influence of urban public transport, which is not included in the analysis of PT. This condition wasn't fulfilled in case of some significant employers, but employees of these big companies are also commuting from the areas without the urban public transport influence and so they depend only on the PT (or ICT). The last condition for employer selection was connected with an effort to maximize their spatial distribution. Overall, 95 employers were chosen within three Regions.

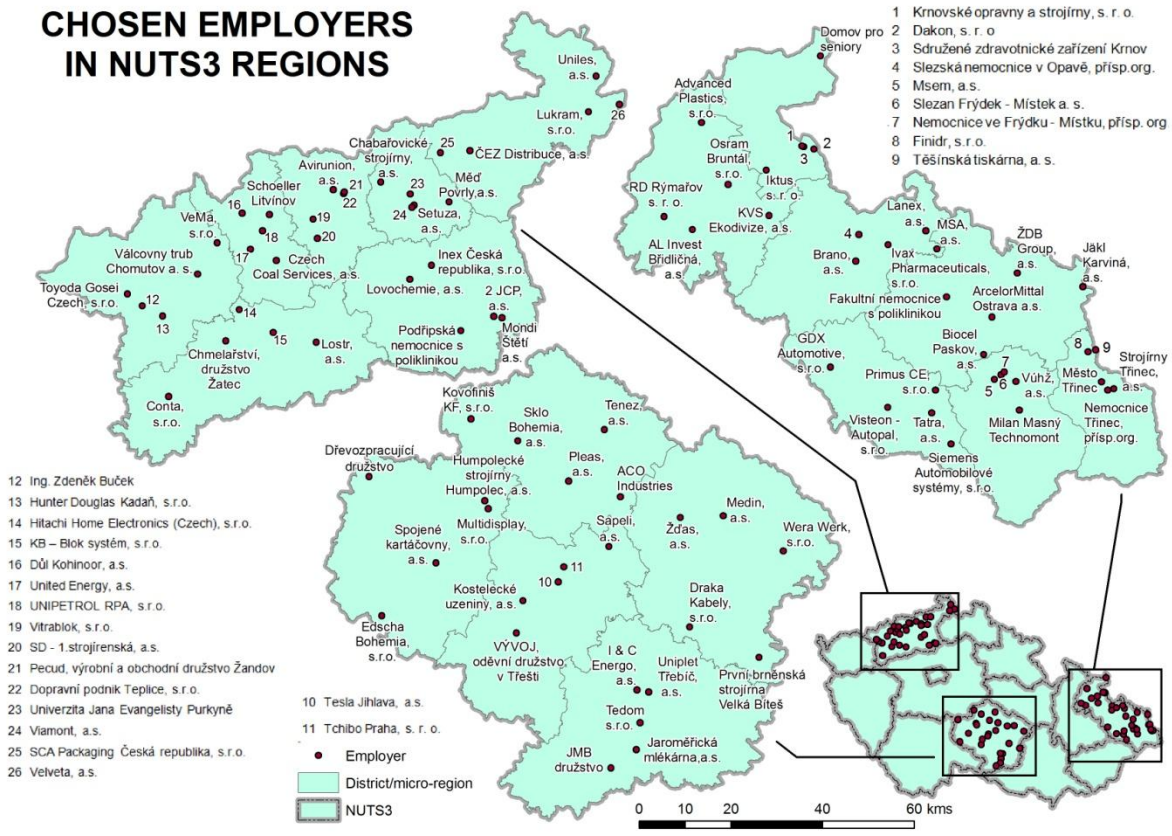

Fig. 3. Chosen employers

Methodology for calculation of commuting cost of PT and ICT is described in [8]. Shortly, in the case of IAD commuting distances are calculated with evaluated road network between all the buildings in the District/micro-region and each employer in the same District/micro-region. In case of PT, commuting distances were found out from valid timetables. Commuters have the possibility to choose one of the five nearest PT stops near the residence as well as near the workplace. So the final commuting distance includes also walking distance to or from the chosen stops (door-to-door approach, more in [9]). The carpooling simulations were done in the series of groups. Overall, 285 possible cases of journeys were simulated, ie. three carpooling types were simulated to all 95 employers - with one stop (commuter shares the car with one passenger), with two stops (the driver stops at two different places and shares the journey with two passengers) and with three stops (car occupy by 4 people and the driver stops at three different locations). Buffer zone was defined as 3,000 meters along each side of shortest path between the residence and employer and commuter can travel only within this area. This size seems to be appropriate large to use the advantages of carpooling – bigger price reduction than length enlargement. Similar simulations of carpooling have been already made in the MSK [8] and so minimal number of simulations was stated as 300 for each employee and type of carpooling. This is three times bigger number than in [8], where the number of simulations was stated

as 100 and it brought many problems and it even happened that results did not correspond to reality. In some cases the distance of carpooling with one stop was even shorter than the distance via ICT, due to most of randomly selected origins were close to the employer. However finally, it was simulated mostly more than 400 simulations for each variant. It was done more than 45,000 simulations in ÚLK and MSK and 32,000 simulations in VYS, so overall 123,437 simulations. The picture below (Fig. 4) describes an example of results in the Decin District, where it is shown the straight commuting route, shortest commuting route and commuting route with three stops commuting.

A hypothesis was accepted to define the commuting price that passengers will share the commute price equally. The commuting price is equal to the half the normal price via ICT in case of one stop carpooling. In case of two stops carpooling it is one-third and in case of the three stops carpooling it is one quarter of the price via ICT.

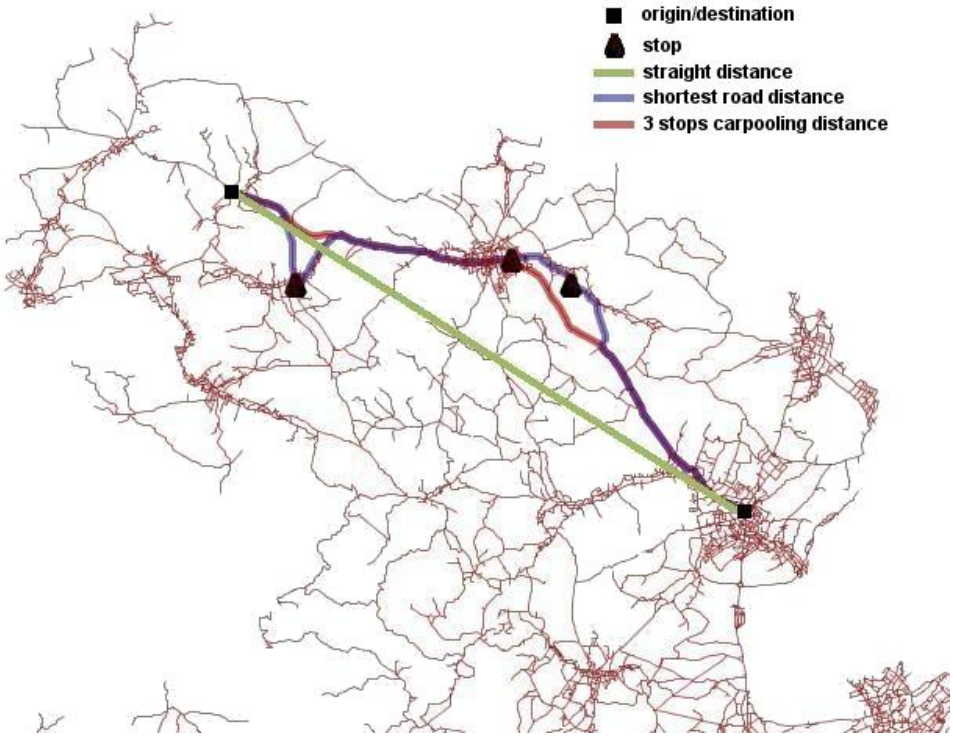

Fig. 4. Example of three stops carpooling

The following table summarizes the total number of simulations in the Regions for each type of travel, according to the number of stops. More than 40,000 routes were simulated for each type of carpooling (based on number of stops). There is evident enlargement of the carpooling journey with each other stop, enlargement size is approximately 2 kilometres in case of all Regions. Comparison with ICT and PT will be part of the next chapter.

Table 1. Number of simulations and average distance of the carpooling journeys in Regions

Region	Number of simulations			Average distance of commuting [m]		
	1 stop	2 stops	3 stops	1 stop	2 stops	3 stops
Moravian-Silesian	15,611	15,416	15,173	17,332.8	19,157.5	21,279.7
Ústí	15,061	15,195	15,037	16,939.5	19,378.3	21,413.7
Vysočina	10,913	10,583	10,448	23,453.0	25,282.9	27,152.1
Total	41,585	41,194	40,658	18,796.4	20,812.6	22,838.3

4 Commuting quality via particular transport modes

In the following chapters, the results of carpooling simulations will be compared with results of commuting via PT and ICT from the distance, price and time point of view. Area is identical for all transport modes; workers can commute only within the District/micro-region. This territorial limitation was chosen according to results of a questionnaire survey in MSK and VYS [14]. Respondents were asked whether they would work outside their residence and if so, how close due to administrative boundaries crossing. Always around 80% of respondents were willing to work only within the District. All results are Regional averages of commuting performances to particular companies.

4.1 Commuting distance

The smallest commuting distances are in the case of ICT. The smallest values for ICT and one stop carpooling are evident in case of the MSK, however the shortest average distance of PT is in case of the ÚLK. The longest commuting distances are in the VYS. Generally, the second longest mode of transport is carpooling with one stop. The average distance is smaller than in case of PT in all Regions. In absolute numbers the smallest enlargement compared to ICT is in the MSK, in percentage it is less than 2% (hundreds of metres). In other Regions the enlargement against ICT is more than 1 kilometre (in ÚLK about 6.4% and in VYS about 8.2%). This small enlargement in this mode is understandable because the driver doesn't have to leave the shortest route significantly and after he has picked up the passenger he can follow the shortest route. However, in each Region the size of maximal enlargement is bigger than 30 % (compared to ICT) and in absolute numbers the commuting distance may also increase up to 60 kilometres (ÚLK and VYS).

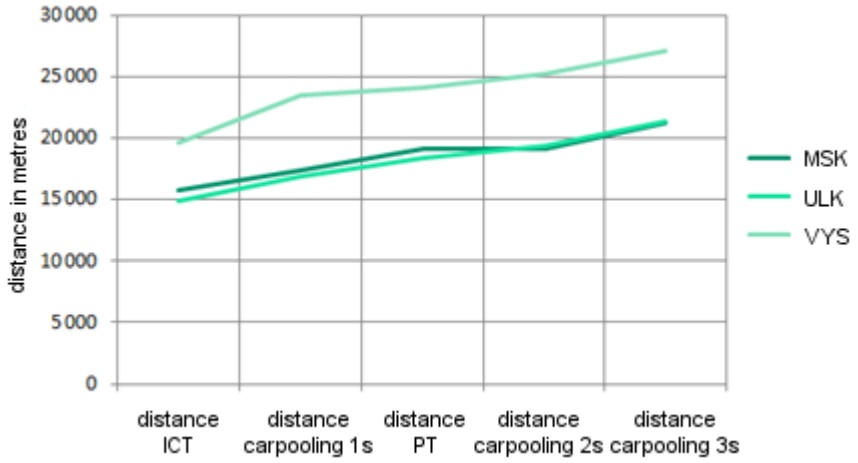

Fig. 5. Comparison of commuting distance according to used transport mode

In terms of commuting distance, the situation is similar in case of PT and one stop carpooling in the ÚLK, where the increase is about 6, respectively 7 % (about 150 metres). So the PT use is very useful in this Region and the PT routes are very similar to the smallest route and so the average commuting distance is less than 20 kilometres. But the difference between carpooling with two stops and PT is relatively significant (almost 2 kilometres) and the enlargement against ICT is the biggest from all Regions (more than 20 %). The same situation is in case of three stops carpooling when the distance is about 32 % longer then in case of ICT. By contrast in the MSK, the distance of PT and carpooling with two stops is very similar and the enlargement is about 12.5 %. The situation is very similar even in maximum of commuting distances of both transport modes; these are the smallest from all Regions and the size is almost 60 kilometres. But the enlargement of PT against ICT and one stop carpooling is the longest in comparison with all other Regions.

Table 2. Percentage distance enlargement according to used transport mode

Region	Carpooling (1 stop)	Public transport	Carpooling (2 stops)	Carpooling (3 stops)
Moravian-Silesian	9.9	21.4	21.5	34.9

Ústí	13.5	23.3	29.8	43.5
Vysočina	19.4	22.5	28.7	38.2

distance of ICT = 100 %

4.2 Commuting price

Many commuters find the price of transport as the most important parameter of their transport mode choice and especially in case of socially deprived people, who commute to low-paid jobs. Actual timetables were used as the source of the PT price and it contains the fares discount for rail transport. Financial costs of ICT were calculated according to the average fuel price based on the legislative of the Ministry of Labour and Social Affairs from the 1st of January 2009 (No 451/2008). So the average price of petrol is 26.8 CZK and this price will be increased by amortization of the vehicle. The same legislative states this amount to 3.9 CZK per 1 kilometre but this amount is not realistic in case of voluntary commuting, so the half amount was used as the costs of the vehicle amortization. With an average consumption of 8 litres per 100 kilometres the price of 1 kilometre is equal to 4 CZK. In comparison with commuting distance, where the ICT was the best transport mode, in case of commuting price is the situation opposite. The price of commuting via ICT is the most expensive mode. The average amount of commuting is about 70 CZK in the MSK and ÚLK and in case of VYS it is almost 87 CZK.

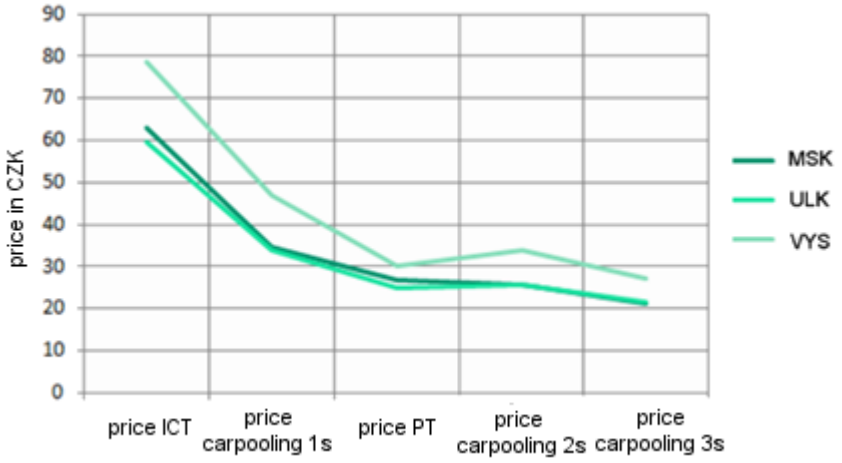

Fig. 6. Comparison of commuting price according to used transport mode

The development of transport price according to the transport mode is similar in all three Regions. The second most expensive mode transport is carpooling with one stop, but this mode is still about 50 % cheaper than the commuting via ICT and the biggest price decline is in the MSK. The commuting prices via PT and two stops carpooling are very similar and both reduce the ICT price about more than 60 % (averagely about 25 – 34 CZK). From the decreasing trend of commuting prices, it is evident that the biggest price declines against ICT occurred in case of one stop carpooling. Another significant price decrease is between carpooling with one and two stops. The price declines between the remaining modes of transport are not so significant and they differ in the range of 9 %.

Table 3. Percentage price enlargement according to used transport mode

Region	Carpooling (1 stop)	Public transport	Carpooling (2 stops)	Carpooling (3 stops)
Moravian-Silesian	45.0	57.8	59.6	66.2
Ústí	43.2	58.3	56.8	64.2
Vysočina	40.3	61.7	57.1	65.4

price of ICT = 100 %

5 Accessibility of employers according to used travel mode

The deviality of particular travel modes was used as the main criteria for evaluation of the accessibility of each employer. The transport network deviality is defined as the deviation from the straight distance between identical origins and destinations [4]. The main causes of deviality could be divided into physical geographical factors like elevation, moors, rivers, etc. and socio-economical factors like location and area of cities, recreational areas, private property, etc. Deviality was calculated for each employer and for all analyzed transport modes. It is equal to:

$$D = \sum_{i=1}^{n} \frac{k_i}{p_i}, \qquad (1)$$

where *k* is the distance of particular road segment, *p* is the straight distance between both nodes [4].

The table below contains the average deviality of commuting to employers for each Region. The smallest values of deviality for all transport modes are in case of the VYS. On the other hand, the worst situation is in the ÚLK, where all values of deviality are big and all types of carpooling are even very big compared to other regions.

Table 4. Average deviality of commuting according to used transport mode

Region	ICT deviality	PT deviality	Carpooling (1S) deviality	Carpooling (2S) deviality	Carpooling (3S) deviality
Moravian-Silesian	1.28	1.49	1.39	1.55	1.73
Ústí	1.30	1.52	1.53	1.77	1.97
Vysočina	1.24	1.41	1.36	1.46	1.58
Total	1.28	1.48	1.43	1.60	1.78

Based on the deviality of commuting distances to employers via particular transport modes, three homogenous clusters we created with the k-means cluster method. Significant majority of employers (65) were assigned to the first cluster which could be described as very well accessible employers via all analyzed transport modes, because these employers have the smallest values of deviality. The second group consists of employers who are well accessible via ICT and via all types of carpooling, but the accessibility via PT is the worst with very high values of deviality. This cluster is represented by 26 employers. The third cluster contains those employers, who have better accessibility via PT than in case of previous cluster, but the deviality of ICT has big values and all types of carpooling significantly enlarged the commuting distances to employers. But only 4 employers belong to this group.

Table 5. Cluster centres

Transport mode	Cluster number		
	1	2	3
ICT deviality	1.26	1.31	1.39
PT deviality	1.40	1.64	1.62
Carpooling (1S) deviality	1.36	1.54	1.97
Carpooling (2S) deviality	1.48	1.79	2.45
Carpooling (3S) deviality	1.60	2.04	2.95

Interesting situation is in case of employers in the VYS, all these companies belong to the first cluster. Values of deviality of commuting via all transport modes are the smallest from all Regions. If the price of commuting was analyzed, there would be one exception – Medin, Inc. Different situation is in the ÚLK. Differences are evident mainly in the District of Ústí nad Labem, where the four employers belong to the third cluster as its only participants and so the commuting distances are affected by big deviality of ICT and all types of carpooling, PT is only slightly better. The only exception in this District is Chabařovické strojírny which belongs to the second cluster. So the deviality of carpooling and ICT is relatively small, but in the case of PT it reaches bigger values. This cluster also includes all employers in other smaller Districts - Teplice and Most, what is mostly caused by an influence of urban transport. But also some companies from Chomutov and Litoměřice belong to the second cluster. Completely without any problem is the situation in the Děčín and Louny Districts where all

employers belong to the first cluster. In the case of MSK, positive situation is evident in case of companies from Krnov and Nový Jičín micro-regions, where all employers fall into the first cluster. But in the MSK there are some members of the second cluster too. Again possible impact of urban transport may influence results for some companies in all others micro-regions. But there are some exceptions. In Frýdek-Místek micro-region where four employers belong to the second cluster but one employer is member of the first cluster and it is located within the city and so there definitely exists some impact of urban transport.

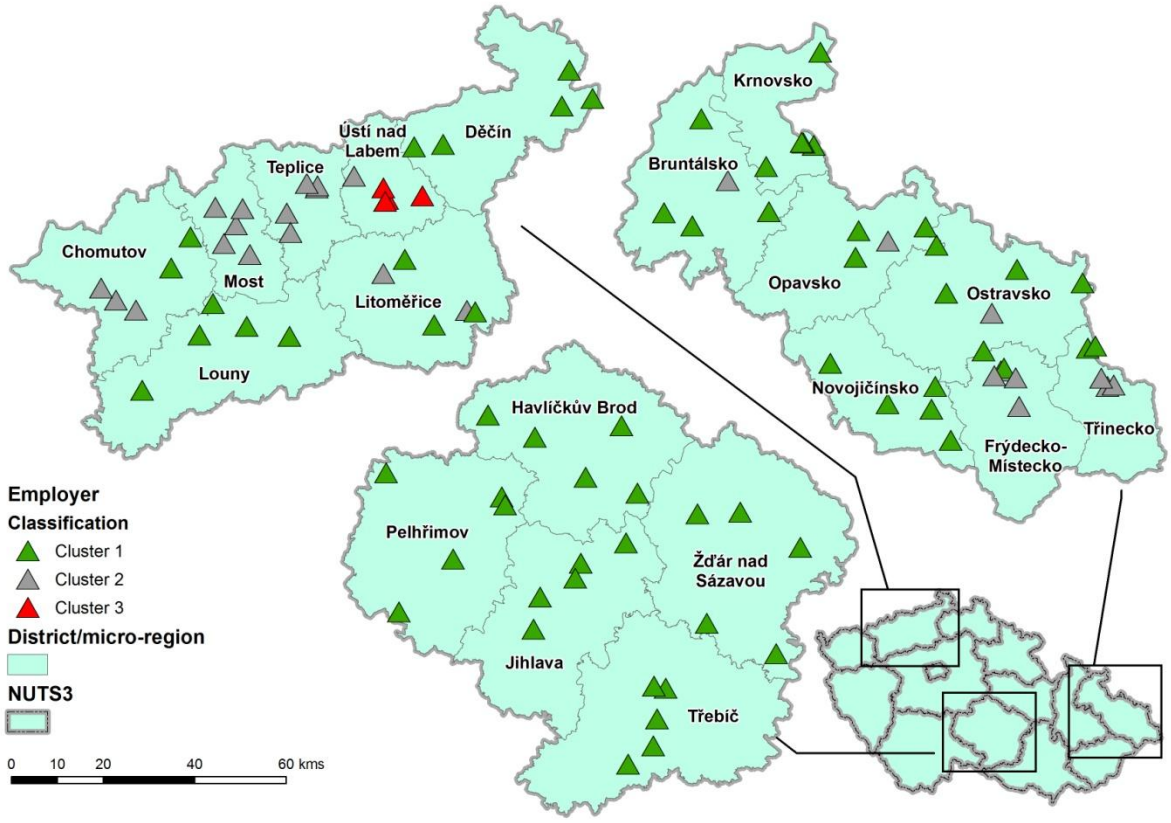

Fig. 7. Classification of employers into three clusters

Conclusions

Although there is no database in the Czech Republic that would monitor the use of carpooling, it would be certainly interesting to make a questionnaire survey to quantify the use of this transport mode for real commuting. Based on interviews with personnel officer of two companies in Opava mico-region (Lanex, Inc. and MSA, Inc.) it results that their employees are normally using carpooling for commuting and they mostly share a car with two or three other employees. They note that the size of carpooling use would be bigger, but the significant problem is in different shift schedule of particular workers [15]. Carpooling with one stop enlarges the distance against ICT averagely (three analyzed regions) about 5.5 %, but the price of commuting is reduced by almost half. In case of the MSK the enlargement is even less than 2 % and the discount is more than 49 %. Two stops carpooling is averagely about 2 kilometres longer and another 2 kilometres have to be added in case of three stops carpooling. But the enlargement of the distance against ICT is more significant, about 16.5 % (2 stops carpooling) and 27.5 % (3 stops carpooling). Contrary the price discount is really significant and exceeds 50 % of ICT price. But the difference between two and three stops carpooling is not so significant and distance enlargement is bigger.

Three clusters were created based on the deviality of commuting distances via particular transport modes. Most companies have small deviality in case of ICT, PT and carpooling, but there are some employers in the ÚLK where the commuting via PT enlarges significantly the distance (Districts like Chomutov, Most or Teplice). Some companies from the MSK belong to this cluster too. Mostly this is

caused by the impact of urban transport. Only 4 employers are members of the third cluster and all are located in the Ústí nad Labem District. These companies have big deviality for all transport modes except PT.

From all these results there are evident the main advantages of carpooling. Results are affected by the simulations settings in case of larger buffer area the results would be different but it is question whether the driver is willing to drive for passengers to the more remote areas. The impact of the buffer area size on the performance of carpooling could be further tested.

Generally, each type of carpooling can significantly reduce the price of commuting against the ICT and the distance is not so significantly enlarged. Applicability of this transport mode was proved for more than 95 % of all analyzed employers.

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