Demand and Supply of Transport Connections for Commuting in the Czech Republic

Igor Ivan and Jiří Horák

Abstract The question of modal split or modal share for commuting is still very relevant topic in the studies of transport issues. This paper deals with evaluating of real demands for individual and public transport using for daily commuting between municipalities in the Czech Republic based on data from census 2011. Results discover a strong relationship between individual transport use and geographical location. The highest share of individual transport is in western areas and less populated municipalities. Concurrently the public transport supply is analysed based on data from the Database of public transport connections which has been developing by authors since 2007. Comparing evaluated transport demand and supply, all municipalities are divided into 12 categories. Various demographical (age, education, population) and geographical (altitude, area, distance to regional and national borders, x and y coordinates) factors including commuting time are studied and discussed in four most extreme groups. Typically small demand and small supply for public transport is correlated with high car ownership index, small number of residents, and closeness of regional borders (internal peripheries).

Keywords Commuting · Public transport · Individual transport · Modal split

1 Introduction

The decision of mode choice remains a crucial issue in studying transport geography. However some countries have been successful in shifting car users onto public transport, others are struggling despite their effort to make public transport

I. Ivan (✉) · J. Horák
Institute of Geoinformatics, VSB-Technical University of Ostrava, 17. Listopadu 15, 708 00 Ostrava, Czech Republic
e-mail: igor.ivan@vsb.cz

J. Horák
e-mail: jiri.horak@vsb.cz

I. Ivan et al. (eds.), *Geoinformatics for Intelligent Transportation*,
Lecture Notes in Geoinformation and Cartography,
DOI 10.1007/978-3-319-11463-7_10

more attractive. The modal split is related to numerous relevant more or less success factors, ranging from *individual mode choice*, which in turn depends on individual and mode characteristics, to *land use* and population density. But two of them are considered as the most important—the travel time and the level of variability of travel time [1]. Unlike price and other factors, time spent on travelling is an absolute constraint which cannot be increased infinitely [2, 3]. Particularly in case of regular short-distance trips, i.e. commuting to work, the commuter's behaviour minimises the economical and time costs needed for the trip. The preference of one of these two aspects—price and time—is crucial for the final transport mode selection.

It is not just about the time of transport (in-vehicle time), but also about the time for journey preparation (varying according to its length, purpose and frequency), walking to public transport stop, waiting for the vehicle (positive influence of regular time schedule), time for eventual vehicle changes and waiting for follow-up connection, walking to the final destination from stop. All of these parts create the out-vehicle time [3]. The same situation is valid also for the journey back to home after the end of the work-shift. Additionally the passengers are more sensitive to out-of-vehicle times than in-vehicle time (in range 1.5–2.3 times more). Particular phases of out-of-vehicle times are quite variable. The walking and waiting time is perceived mostly negatively (except very long journeys) and in case of commuting using public transport the walking times can make up 24–30 % the time of the whole journey (averagely 800 m) in the Czech Republic compared to individual car transport with distance about 50/160 m in rural/urban environment. All of out-vehicle time parts are generally more time consuming in case of mass public transport. Not only that out-vehicle and in-vehicle time is perceived differently, but also generally the time is perceived differently, and each individual has its own travel time budget. Its size is derived from how time is valued, which is in turn related to wages [4]. From the time point of view, it can be assumed that public transport is preferred if the in-vehicle and out-vehicle time of commuting meets the needs of the commuter, otherwise commuter must rely on individual transport.

This general modal split based only on travel time is further influenced by price of travel. The individual car transport is more monetary expensive than the commuting by public transport. Each individual has also own money budget, similarly as in case of time. If the prize exceeds the individual's budget, commuter has the only possibility to use public transport even the commuting time is partly over the time budget. In the worst case, the people cannot commute at all and either they have to move closer or to prefer a job in better accessible areas. For regular travelling between two places, public transport providers offer cheaper seasonal ticket in order to increase the share of public transport in commuting trips to work [4]. The owning such seasonal ticket increases the probability that an individual will use public transport and create larger resistivity to new cheaper opportunities (such as ridesharing with colleague, purchase of a new car). On the other hand, White [5]

has noted that owning a car makes the probability of using it for daily activities (including commuting) much higher, even if it does not provide any economic benefits and an appropriate public transport connection exists. Then, the public transport will be used only under rare circumstances (journey to the city centre, to a party etc.). Additionally the car is shared also by other members of the family, either as passengers for journeys to work, school (ridesharing) or as drivers for their own needs (carsharing). So, the decrease of public transport use is higher than the average for one person. Each new car in a family substitutes about 200–250 local journeys by public transport per family and year. This effect is more significant in case of the first car and smaller for additional cars. Therefore, policies aimed at discouraging car ownership with activities such as high registration fees or annual excise duties, hoping to reduce the share of car use for trips to work. Unsurprisingly, GDP per capita is also positively correlated with car share. Also other more or less significant individual factors have influence on final mode choice such as ecological lifestyle, subjective perception of public transport, personal image, comfort of travelling etc.

Socio-economic and other subjective factors have been found to be very important in explaining commuting behaviour. Nevertheless, land use is considered as equally important factor for final mode choice and has a clear relationship with travel behaviour [4]. Following seven main dimensions of land use factors have been identified: (1) density; (2) diversity/mixed use; (3) design and infrastructure (including parking, and conditions for walking and cycling), (4) destination accessibility; (5) accessibility to public transport; (6) demand management; and (7) demographics [6, 7].

In this paper, we compare the demand and supply of two transport modes—public and individual—in relation to commuting in the Czech Republic. The goal is to answer three questions: (1) Where are the main areas/flows using individual transport? (2) What kind of commuters is travelling here? (3) Do they have any alternative in public transport use? The demand is based on the data from census 2011 and characterized as real modal-split used for commuting between a pair of municipalities. By contrast, the majority of the existing Czech geographical studies on commuting mode choice have been conducted based on data from census 2001 without consideration whether any alternative exists, i.e. [8–14]. We add another perspective and utilise our data from the database of public transport connections (described below). Combining these two data sources we classify municipalities into several categories based on the level of real public transport use for commuting (demand) and the number of municipalities accessible by public transport (supply). Additionally we select the typical members of the most extreme groups considering various aspects. The remainder of this paper is organised as follows: Sect. 2 describes the data used; Sect. 3 presents the commuting modal-split; Sect. 3.1 describes the supply of public transport connections; Sect. 4 presents the results of combining both data sources and finally; Sect. 4 summarises the main findings.

2 Data

Commuting flow data comes from census 2011 with the decisive moment at midnight from 25 to 26 March 2011. It provides information about all commuting flows with the origin municipality within the Czech Republic (destination can be in foreign country). The commuter is defined as an employee or a student (commuting to school and to work is distinguished in data) who has the job or school out of the residential municipality (this can differ from official address in the ID card). The commuting within the same municipality is not considered by statistics as commuting. Altogether, the table contains 178,171 records and 1,551,918 commuters are travelling between these pairs of municipalities (general volume of data are summarised in Table 1). Standard list of parameters has been further extended about the modal share between seven analysed transport modes for all of 178,171 records—car (driver); car (passenger); train; bus; urban public transport (some transport links operate also outside the municipality area); motorcycle; and bicycle. The frequency of transport mode use within one municipality combination is often higher than number of commuters. This is caused by the possibility of respondents to choose more options if they are using a combination of them. Due to all possible combinations, this inconsistency causes only small problem in case of individual and public transport combination. Only 0.5 % of all respondents selected this combination as the used transport way for commuting what makes it irrelevant. Combination of public and individual transport such as park and ride, bike and ride play only negligible role in the Czech Republic.

Finally the data set has been reduced based on two criterias (1) both, origin and destination of commuting must be within the Czech Republic (commuting to foreign country has been excluded); (2) in case we compare the real modal share with existing public transport connection, we work only with commuting flows within 100 km (Euclidean distance). This distance selection is important to make this data consistent with the second data source (see text below).

The final number of records and commuters is in Table 1.

The second data used in this paper are from the Database of transport connections which has been developed and three times a year updated since 2007. This database contains all combination of municipalities within 100 km (Euclidean distance) with

Table 1 Number of records and commuters in data set from census 2011

	Number of records	Number of commuters	Commuting to work		Commuting to school	
			Total	On daily basis	Total	On daily basis
Domestic and foreign commuting	178,171	1,551,918	1,125,337	953,190	426,581	302,955
Domestic commuting	165,347	1,508,711	1,089,876	935,186	418,835	299,324
Domestic commuting within 100 km	143,591	1,427,475	1,050,933	921,010	376,542	291,719

information about public transport connections between each pair. A municipality is defined by the main public transport stop suggested by the valid time tables. The database contains travel time, number of changes, price and existence of return connection for each combination of municipalities and five time intervals (to 6, 7, 8, 14 and 22 o'clock) which define the beginnings of three work shifts. Each public transport connection must fulfil these criterias: (1) the Euclidean distance between municipalities is less than 100 km; (2) the duration is less than 90 min; (3) number of changes is 5 and smaller; (4) arrival time cannot be earlier than 60 min before; and (5) departure time from commuter's residence cannot be earlier than 120 min before arrival (more in [15, 16]).

Valid timetables have been used to search all public transport connections using buses and trains (no urban transport) for the 8 March 2011 (similar date as the decisive moment of census). For the municipality level, the database contains 12,579,133 combinations with further information of transport connections to 6, 7, 8, 14 and 22 o'clock. From this volume, 721,826 combinations have at least one connection for at least one commuting time.

3 Modal Split of Commuting

Following Rodrigue et al. [17] we define modal split or mode share as the proportion of trips that is made by each transport mode. Compared to the modal options in our data set, census results in general distinguish 14 different modal options including their combinations. From the public transport modes bus is used for commuting with 18.8 %, following by urban transport with 6.6 % and train with 6.2 %. The most often, commuters are using car as drivers with 36.3 % and as passengers as 7.6 %. The other individual transport modes have only negligible usage—motorbikes with 0.1 %, bicycle with 1.4 %. Combination of different transport modes are not as common as was expected with the highest share of bus and urban transport combination (3.3 %) and train and urban transport with 2.6 %. Other combinations have the share below 2 % and about 10 % of commuters did not respond this answer.

For the needs of this paper, we work with modified data set from census as specified above and only domestic daily commuting is analysed. For all of 935,186 daily commuters, 1,283,421 cases of transport option uses are stored in the data set. This inconsistency is explained above. Transport options have been aggregated to two groups. First group consists of 803,601 users (63 %) of cars as driver; cars as passenger; motorcycles and bicycles and is named as individual transport and the second group is named as public transport and consists of 479,820 users (37 %) of trains; buses and vehicles of urban public transport. Daily commuters prefer individual transport compared to general commuting with the share about 51 %.

The spatial variability of individual transport share is high with east-west gradient as it is portrayed in the map (Fig. 1). The spatial variability in case of public transport share is inverted. No employee is commuting or no given transport option is in case of 561 municipalities from 6,251 of municipalities in the Czech Republic.

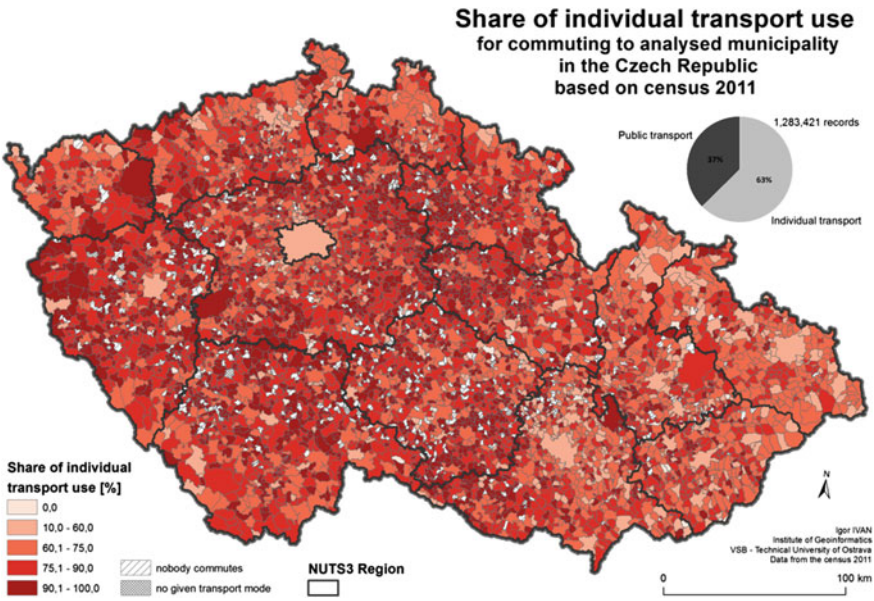

Fig. 1 Share of individual transport use for daily commuting in the Czech Republic (2011)

Nevertheless these are only low-populated municipalities. The most populated cities have the share of individual transport between 40 and 60 % what is significantly below the average. This confirms the Pearson correlation coefficient between the population (aged 15–64) and frequency of individual or public transport use which is slightly higher in case of public transport mode (0.987 and 0.975). If we analyse the correlation between the population (15–64) and share of individual or public transport use, the correlation coefficient is negative in case of individual transport ($R = -0.084$). This is even more evident if only municipalities above 10,000 residents are included ($R = -0.452$ for individual transport). The more populated is the city the smaller is the share of individual transport use and this relationship is getting stronger.

The level of individual transport use is getting higher in the direction from the eastern to the western parts of the Czech Republic (see Fig. 1). This general spatial trend is also confirmed by negative Person correlation coefficient between the share of individual transport use and the x coordinates ($R = -0.195$). Also the correlation between the population (15–64) and the x coordinates has been analysed to exclude the influence of relationship between the population size and individual transport share. Nevertheless, this correlation is very small, not statistically significant and even positive ($R = 0.009$). So there may play an important role some different influences and the supply of public transport connections (Fig. 2) can be the one with the biggest importance.

It has been discussed that the mode decision is influenced by many more or less important factors which significantly depend on individual's subjective opinion.

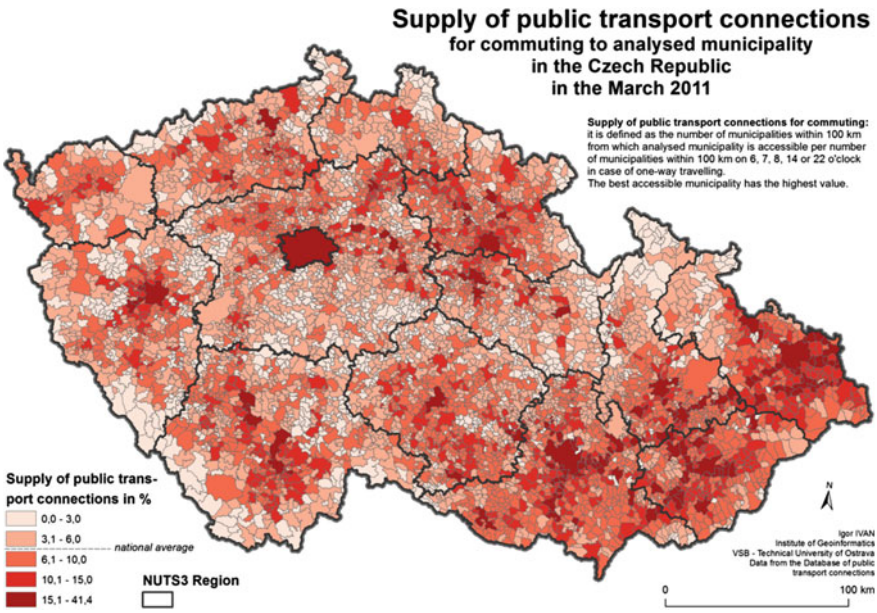

Fig. 2 Supply of public transport connections to analysed municipality in the Czech Republic (2011)

The crucial aspect in this choice is existence of an alternative. If no public transport connection exists the commuter must rely on individual transport. It is not an easy task to evaluate the supply of public transport connection at the municipality level. Commonly used indicator for such evaluating is the number of links servicing the municipality. But this indicator suffers several problems, i.e. there can be only one or a few frequent links connecting only several and still the same municipalities, these links can arriving and departing at wrong time for commuting needs. We have developed a new indicator for evaluating the supply of public transport connections and defined it as the number of municipalities within 100 km from which analysed municipality is accessible per number of municipalities within 100 km on 6, 7, 8, 14 or 22 o'clock in case of one-way travelling. The map (Fig. 2) shows spatial distribution of supply and on the first look it is clear that the general distribution is opposite to that in the previous map (Fig. 1). So the best accessibility by public transport is in case of the biggest cities what is again confirmed by positive and statistically significant ($p = 0.01$) correlation ($R = 0.257$). If only cities above 10,000 residents are analysed, the correlation is even 0.621.

Similarly also the spatial trend from west to east is evident and confirmed by positive and statistically significant ($p = 0.01$) correlation ($R = 0.277$) which is even bigger than in case of the population size. Also in this case correlation is higher without municipalities below 10,000 residents but the increase is not as high as in the previous case ($R = 0.336$).

3.1 Demand and Supply of Transport Connections for Commuting

The share of individual transport use and level of public transport services are mutually interlinked. If the share of individual transport use goes higher the provider of public transport should react on such decrease of passengers and reduce provided transport services. On the other hand, the share of individual transport can decrease when the number of accessible municipalities is higher in correct commuting times. The map (Fig. 3) describes the relationship between previously defined supply of public transport services and demand for public transport services defined as the share of public transport use for commuting. All municipalities have been divided into 12 categories depending on the size of both indicators. The first three categories (shadow colours) contain only 38 municipalities with no use of public transport for commuting. The median of commuting employees to these municipalities is equal to 1 so they have only negligible impact (47 commuters). All remained municipalities have been divided into 3 × 3 categories corresponding to three quantiles of these two distributions.

Several geographical (x, y coordinate; distance to national and regional border; area; altitude) and demographical (age end education of commuters; number of residents aged 15–64) aspects and commuting time have been analysed to find typical members of the most extreme four categories. All analysed factors are

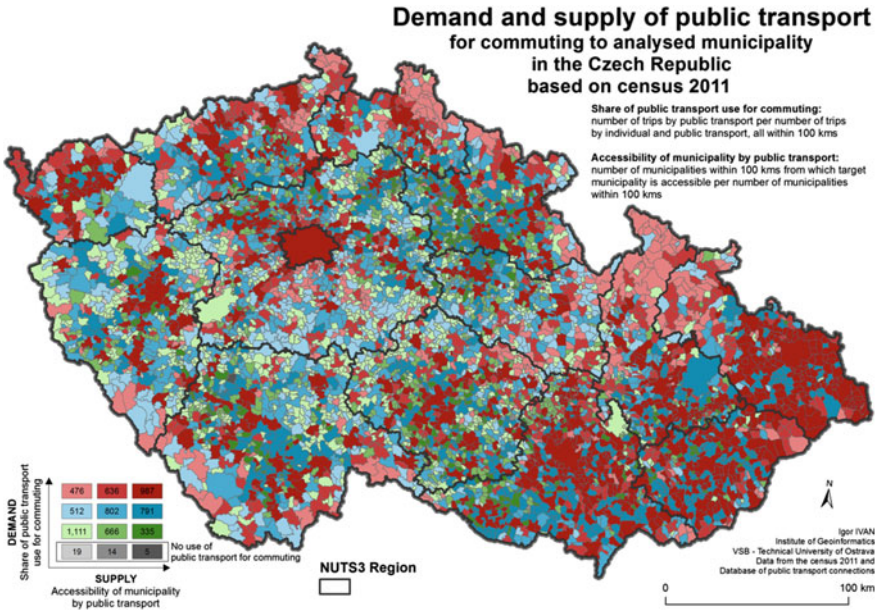

Fig. 3 Demand and supply of public transport for commuting to analysed municipality in the Czech Republic (2011)

statistically significant between groups except commuters with basic education and aged 30–49. The light green category consisting of 1,111 municipalities (18 %) is typical due to small demand for public transport and also small supply of such services. Its members are destinations most often for older commuters (above 50 years) with secondary education without final exam and lower who commute typically up to 15 min. Typical aspects of these municipalities are very high car ownership index, so these people rely on cars and more than 60 % people (aged over 18) own private car. These municipalities have the smallest average number of residents (138) and are located typically in higher altitudes in western areas, significantly more distant from national and closer to regional borders—internal peripheries. These facts are proved also in the map (Fig. 3) where the group members are located along regional borders of Bohemian regions (western parts).

The dark red group consists of 987 municipalities which are typical by high supply and demand for public transport for commuting to analysed municipality. According to current trends in transport policy this is an ideal case. These commuters use to be younger with the highest levels of education (complete secondary and tertiary) and commuting for longer time (above 15 min but also above 60 min). Residents show very small car ownership index. The municipalities of this group belong to the biggest and largest, located more often in the eastern and northern parts of the country, closer to national borders and far from regional borders. Based on the map, they are concentrated in the Moravian part of the country (east) and in the northern parts of Bohemia (similarly as members of dark blue group).

The smallest number of municipalities (335) belongs to dark green transitional group and they have high supply of public transport, but the commuters are rarely using it for daily commuting. Employees commuting to these municipalities are usually younger 30 years, with full secondary education. Compared to the next group, commuters to these destinations commute for shorter time, rarely above 15 min. So, residents do not use public transport despite a good level of public transport accessibility because their travel time is very short. These municipalities are small (both by population and area), in lower altitudes, in southern areas, closer to national border and more distant from regional borders. Indicated spatial influences seem to be confirmed in the map with the increased occurrence of such municipalities in the Vysocina Region and South Bohemian Region.

Municipalities with high demands for public transport but with low supply of these services belong to the light red group (476 municipalities). Residents are usually older with various levels of education. A typical attribute of commuters is longer time spent by journey to work. They have the highest share of trips between 30 and more minutes. The accessibility of public transport is low but the commuters probably do not have any other option and they rely on this mode of transport. These municipalities are located more in eastern and northern areas and in areas with higher altitude. They are close to national and regional borders, large but sparsely populated. The map proves these geographical findings—two main clusters of such municipalities are Jeseniky mountains (N-E part) and Krkonoše and Jizerské mountains (N part).

4 Conclusion

The study is based on data from census 2011 (daily commuting between municipalities, demographical attributes), the register of cars (car ownership), and the Database of public transport connections (description of public transport conditions in municipalities).

The strong relationship between individual transport use and geographical location has been proved. The highest share of individual transport is in western areas and less populated municipalities. According to the local transport demand and supply, municipalities are divided into 12 categories. A correlation analysis with many demographical (age, education, population) and geographical (altitude, area, distance to regional and national borders, x and y coordinates) factors including commuting time enable to characterize following groups of municipalities by selected attributes:

- 1st group with small demand and small supply for public transport indicates high car ownership index, small number of residents, high altitude, and closeness of regional borders (internal peripheries).
- 2nd group with high supply and demand for public transport shows very small car ownership index, closeness to country border (external peripheries), younger population with higher education (complete secondary and tertiary) and longer commuting time. These municipalities are located very often in eastern parts of the country.
- 3rd group with high supply of public transport but low utilisation in commuting is probably interlinked with short commuting time, young and middle educated population in smaller municipalities.
- 4th group with high demands for public transport but with low supply of such services is typical by longer commuting time (above 30 min), in peripheral mountain areas, with older population. These municipalities are mostly clustered in two larger areas.

The result shows typical features of transport choice conditions in the country. Further research should focus more on regional differences to deliver adjusted recommendations to regional transport decision makers.

Acknowledgments Application has been developed as a part of higher education development fund—frvš 956/2013/b1. Authors thank the agency for financial support.

References

1. van Vugt M, van Lange PAM, Meertens RM (1996) Commuting by car or public transportation? A social dilemma analysis of travel mode judgements. Eur J Soc Psychol 26 (3):373–395
2. Bhat C, Koppelman FS (1999) A retrospective and prospective survey of time-use research. Transportation 26(2):119–139

3. Vande Walle S, Steenberghen T (2006) Space and time related determinants of public transport use in trip chains. Transp Res Part A Policy Pract 40(2):151–162
4. Vale DS (2013) Does commuting time tolerance impede sustainable urban mobility? Analysing the impacts on commuting behaviour as a result of workplace relocation to a mixed-use centre in Lisbon. J Transp Geogr 30:38–48
5. White P (2002) Public Transport. Spon Press, London. ISBN 0-415-25772-7
6. Banister D (2011) Cities, mobility and climate change. J Transp Geogr 19:1538–1546
7. Litman T (2011) Land use impacts on transport—how land use factors affect travel behavior. Victoria Transport Policy Institute, Vitoria, p 80
8. Čermák Z (1993) Geografické aspekty prostorové mobility obyvatelstva. [kandidátská disertační práce], přírodovědecká fakulta univerzity Karlovy, katedra sociální geografie a regionálního rozvoje, Praha
9. Čtrnáct P (1983) Dojížďka do zaměstnání podle výsledků sčítání 1980. Demografie 25(3): 221–233 (FSÚ, Praha)
10. Hampl M (2004) Současný vývoj geografické organizace a změny v dojížďce za prací a do škol v Česku. Geografie - Sborník ČGS 109(3):205–222
11. Hůrský J (1969) Metody grafického znázornění dojížďky do práce. Rozpravy ČSAV, řada matematických a přírodních věd, 79 (3). Academia, Praha
12. Macka M, Králová M (1977) Kvalitativní změny ve vývoji dojíždění do zaměstnání v ČSR. Studia geographica 61:67–74 (GÚ ČSAV, Brno)
13. Řehák S (1988) Dojížďka do zaměstnání v ČSSR. Sborník prací 19, Současný stav a dynamika prostorových struktur měst a regionů v PLR a ČSSR. GGÚ ČSAV, Brno, pp 83–95
14. Szczyrba Z, Toušek V (2004) Vyjížďka a dojížďka do zaměstnání v České republice; Změny v období transformace. In: Przeksztalcenia regionalnych struktur funkcjonalno-przestrzennych, VIII/2, Wroclaw, 21–31
15. Fojtík D, Ivan I, Horák J (2011) Database of public transport connections—its creation and use. In: Proceedings of the 2011 12th international carpathian control conference, ICCC'2011, pp 115–119
16. Ivan I, Horák J, Fojtík D, Inspektor T (2013) Evaluation of public transport accessibility at municipality level in the Czech Republic. In: GeoConference on informatics, geoinformatics and remote sensing, conference proceedings 1, ISBN:978-954-91818-9-0, p 1088
17. Rodrigue JP, Comtois C, Slack B (2009) The geography of transport systems. Routledge, New York, p 368