A TRANSPORT CLASSIFICATION OF SETTLEMENT CENTRES IN THE CZECH REPUBLIC USING CLUSTER ANALYSIS

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Abstract

An application of cluster analysis to road transport in studying the transport classification of the main settlement centres in the Czech Republic is presented in this paper. The aim of the applied cluster analysis is primarily to reveal those factors that co-determine the transport importance and the size of particular settlements. The principal role under these factors has the complex importance of the centre as measured by its population size and its location within the transport network. Based on the application of the cluster analysis, five typological groups of settlement centres were defined according to the inter-variability of all monitored components, which can be aptly used primarily in transport planning practice.

Shrnutí

Dopravní klasifikace středisek osídlení České republiky: využití metod shlukové analýzy

Příspěvek se zabývá aplikací shlukové analýzy při studiu dopravní klasifikace hlavních středisek osídlení České republiky na příkladě silniční dopravy. Smyslem aplikace shlukové analýzy je především hledání podmiňujících faktorů spoluutvářejících dopravní význam a velikost jednotlivých středisek, mezi nimiž zaujímají stěžejní úlohu především populační význam střediska a jeho poloha v dopravní síti. Na základě aplikace shlukové analýzy bylo vymezeno pět typologických skupin středisek podle vzájemné variability všech sledovaných komponent, které mohou být vhodně využívány především v dopravně-plánovací praxi.

Key words: *transport hierarchy, road transport, settlement centres, cluster analysis, Czech Republic*

1. Introduction

The assessment of the relationship between transport and the spatial organisation of society ranks among the fundamental research phenomena in current transport-geographical research. In this context, Marada et al. (2010) mention that the research of links between the resulting forms of geo-societal (complex) and transport (partial) systems should be focused on when seeking the relationship between transport and the spatial organisation of society. Both the current foreign (e.g. Derudder and Witlox, 2009) and Czech (Marada, 2008 or Kraft and Vančura, 2009a) studies demonstrated many times that there are very strong connections in the organisation of transport systems and complex systems. Hence, there is a reciprocal relationship between transport and the spatial organisation of society. However, the study by Rodrigue et al. (2006) points to the fact that the mutual reciprocity may be perceived in two ways. First, it is the reciprocity given by the location, which forms the separate transport system. This is because the transport interactions are strongly related to the deployment of transport nodes and transport links that form and determine the current shape and intensity of transport system interactions on the various hierarchical levels. The reciprocity driven by mobility is another manifestation, as the deployment of socioeconomic activities in the area is always linked to transport.

Thus, the above discussions may be summarized by concluding that there is a certain interdependence between transport and the spatial organisation of society as transport is affected by the settlement system, which is, in return, affected by transport and its spatial arrangement. Despite relatively satisfactory results of investigation into this matter, however, some serious objections may be presented, in a strictly critical perspective, to the essence and nature of the transport – society duality study. According to Keeling (2007), there are a number of issues still to be addressed in the current study of the relationship between transport and society, often without any adequate conceptualization (a similar position is also shared in the study by MacKinnon et al., 2008).

The main goal of this contribution is a transport classification of settlement centres in the Czech Republic using methods of cluster analysis based on road transport. This contribution follows up on previously published studies (Hůrský, 1978; Marada, 2008) in which the identical statistical characteristics were empirically proven between the transport system organisation and the societal system organisation. The study by Kraft and Vančura (2009b) has proven the existence of the correlation between the hierarchical organisation of the settlement and transport systems on the basis of studying the changes in the settlement centre transport hierarchy in the Czech Republic between 1990 and 2005. Methodically, there are, however, some questions determining the size-related important characteristics of individual settlement centres that have not been resolved yet. One can point especially to two essential problems that determine the transport importance of individual centres – identification of the transit transport impact and the influence of the transport infrastructure endowment of settlement centres on their final transport size. For instance, Viturka (1981) argues that the importance of individual settlement centres as to the transport is, in many cases, affected by especially two phenomena – a complex importance of the centre, usually expressed by its population number, as well, as the settlement centre location within the transport network. The "real" importance and tasks of these centres in the Czech Republic transport system can be identified after analysing the differentiation of the above components, which help to create the importance of individual settlement centres in the transport systems. Individual settlement centres can also be classified into relevant typological groups based on the similarity of all monitored components that determine their transport hierarchy. As a suitable tool for this process, a cluster analysis method can be used, as it enables us to grasp the variability of all affected components (transport importance, transport location, population) of the monitored centres. This article thus aims to answer especially the following questions: In what way does the transport hierarchy of settlement centres develop in the Czech Republic in the present period? How does the phenomenon of transport location and complex/population size of settlement centres affect the transport importance of the settlement centres? Which centres benefit from their appropriate location and, on the other hand, which centres are limited by their transport location? Which settlement centres show a high traffic level and are undersized in terms of their infrastructure? The above questions represent significant drivers for geographical research from the transport viewpoint, especially for strengthening the role of this research in transport planning. They may also contain some implications for the regional and transport policy of the Czech Republic, and, as a result, they are highly relevant and important for society.

2. Theoretical embedding – transport and settlement hierarchy

This paper is based on the methods of studying the transport hierarchy, which are further developed and brought closer to applied research. Transport hierarchies are among the fundamental geographical methods from the transport viewpoint, describing the differences in importance of transport nodes and their transport links. Theoretically, the transport hierarchy issue may be considered as a study of the correlations between the transport system organisation and the settlement system organisation. In this context, the methods and the procedures taken from settlement geography are frequently used in studying this correlation. According to Marada (2003), it is, however, necessary to distinguish between the hierarchical position of individual roads and that of the transport nodes. Transport hierarchy of settlement centres, as one of the basic structural and morphological features of transport networks, is very closely related to the transport node accessibility. The transport hierarchy issue is, however, of a relatively complex nature and it is studied using a variety of methods and procedures (for details see Ullman, 1980 or Mirvald, 1988). Of the currently determined study approaches to the transport hierarchy of transport nodes, three basic types of criteria used for the settlement centre hierarchy can be defined:

- *Hierarchization of transport centres by the road accessibility of their nodes* – a traditional transport-geographical method, originally based on graph theory (e.g. Ullman, 1980). It consists in the intentional transformation of the existing transport network and nodes into a graph where the availability of individual transport nodes is monitored upon the existence of direct links to the other network nodes. As this is a purely mathematized approach to studying the given issue, graph theory was frequently employed in the 1960s, in the period known as the quantitative revolution in geography. Garrison (1960) applied this theory to analyze highway system connectivity in the United States in 1957. Similarly, this mathematically modelled approach was employed by Yerra, Levison (2005) in studying the dynamics of transport network development. In the Czech environment, graph theory was used especially in connection with the application of quantitative approaches in transport geography in the 1970s and 1980s (e.g. Korec, 1981). However, graph theory

and the transport hierarchy analyzed thereby are of a rather descriptive nature and are frequently used to illustrate the historical development of individual transport networks (Rodrigue et al., 2006).

- *Hierarchization of transport centres by the degree of their infrastructure endowment* is based on a simple assumption that the transport importance of the centre is not primarily determined by its road accessibility, but also it is, in particular, based on the level of the centre endowment with various road types. Using the Czech Republic as an example, the study by Marada et al. (2010), however, indicates various groups of relatively important settlements lying in an inconvenient transport location and, on the other hand, of relatively less important centres located in an exposed transport location. This system was applied, for instance, in the study by Hůrský (1978) dealing with the attractiveness of centres in the former Czechoslovakia as to their location, in which the author applied a simple rating method (see below). A similar procedure was also used to evaluate the differentiation of regional towns by their level of transport infrastructure endowment in the study by Kraft (2009) or to assess the transport location and the traffic services of municipalities in the NUTS2 – South-East region, addressed in the study by Toušek et al. (2006).
- *Hierarchization of the transport centres by their size-relevant features* is currently the most frequently used approach to the transport hierarchy study. It is primarily based on distinguishing the monitored set of centres as to their importance on the basis of the intensity of transport relations between the centres themselves and between the centres and their transport hinterlands. Globally, attention is also given especially to the hierarchical position of the cities categorized as "world cities" as to the number of serviced passengers in international air passenger transport or the number of air flights with other international metropolises (e.g. Grubesic et al., 2009; and in the later study by Seidenglanz, 2008 or Grenčíková et al., 2011). An interesting view of the centre hierarchization by gateway functions within metropolitan areas in Germany is provided in the study by Jurczek (2008).

Another important question relating to the study of the transport hierarchization of centres is its relationship to the settlement hierarchy issue. It is beyond dispute that transport contributed to deepen the settlement hierarchy, as it had a significant impact on the concentration of industrial activities and inhabitants in towns especially during the industrialization era. This relation, however, can also be applied the other way round, as in the cases where the importance of the centres in their settlement system was also the main development factor of their importance in the transport perspective. The relationship between the settlement (complex) and transport (partial) hierarchies can be thus labelled as reciprocal, since the transport and transport connections determine the development of the settlement hierarchy, while the transport hierarchy development is influenced by the settlement centres and their interrelations (see similar comments by Nuhn, Hesse, 2006).

This issue of the transport hierarchy study has a relatively long tradition in the Czech and Slovak environments. Many pieces of work dealing with the transport hierarchy of transport links or their nodes were published by Hůrský (e.g. 1974, 1978). These traditional studies were primarily focused on analyzing the differentiation of transport hierarchization and their links upon the public transport or the transport infrastructure endowment of such centres, and were thus of a rather descriptive nature. In his studies, he arrived at a notable conclusion – that being preceded by service functions, transport plays the second most important role in the evaluation of town centrality and, therefore, it is necessary to primarily focus on the study of the settlement centre transport hierarchization in relation to the complex hierarchization. Newer studies addressing the issue of the settlement centre transport hierarchization in the Czech Republic were published by Marada (2008) who often applies methods that are close to settlement centre geography. His works are concerned with studying the features of the settlement and transport hierarchy, primarily focused on public transport, arriving at the conclusion that there is a relatively high association between the transport and settlement/complex hierarchies in the Czech Republic. Among other authors dealing with this issue, Viturka (1981) may be mentioned, since his works are directly addressing the relationship between the settlement structure and road transport.

Based on the above discussion of empirical studies relating to the fundamentals of transport hierarchy, a few essential and generally applicable conclusions that form the needed "basis of inspiration" for further research may be formulated:

1. Despite some intermodal differences, we can point to the fact that the transport hierarchization of centres is relatively strongly related to the settlement hierarchy as transport has played and still continues to play an important role in distinguishing the importance of centres in the settlement system. This fact is also noted in the study by Marada (2006) that proves, from the vertical and horizontal transport location of settlement centres that *a)* there is a considerably

high degree of mutual association between the transport infrastructure endowment of settlement centres and the intensity of public transport and individual vehicle transport, and that *b)* all these indicators simultaneously go hand in hand with the importance of centres according to their complex significance value.

2. As to size-relevant features, the transport hierarchization of centres is particularly influenced, in line with Hůrský (1978), by their transport infrastructure endowment, transport location (similarly noted by Korec, 1996) and, to a certain degree, by other elements determining their settlement/regional importance such as population size, working size and the complex size. It is, however, necessary to note certain types of centres where a predominant occurrence of one of these features may unduly inflate their real transport importance (especially their transport location). As far as the overall differentiation of the transport centre hierarchization is concerned, the resulting transport hierarchy, determined by the size-relevant features, primarily depends on the cumulation of the above characteristics.

3. Research methods

As discussed above, current trends in the development of the settlement centre transport hierarchization in the Czech Republic (in relation to a previous evaluation – Kraft, Vančura, 2009b) are monitored in the first part of this work. The following second part classifies the settlement centres on the basis of their transport and complex characteristics using cluster analysis. Settlement centres were congruently defined on the basis of their complex size value ascertained by the latest available population census taken in 2001. The study thus evaluates 144 settlement centres of at least a micro-regional importance, i.e. centres that make up a framework of the current settlement system of the Czech Republic. The definition of the centres was adopted from the study by Hampl (2005).

In order to ascertain the transport size of individual centres, values of the annual average intensity of road vehicles driving through the census station located closest to residential areas of the monitored centres in 24 hours were allocated to each centre on the basis of data from the Road Transport Census. For each centre, real values were included from all census stations on motorways, expressways, and 1st and 2nd class roads leading through the residential area of the centres. Given this methodology for expressing the transport importance of individual centres, those centres with a certain exposure of their location were given an advantage, as also the high traffic intensity values from the motorways and expressways not always leading through the residential area of individual centres were included in the values of these centres. However, the nature of the data fails to enable separation of the transit transport that is in charge of traffic connections between individual centres from the "local" transport operating between the given centre and its transport facility. The transport importance of individual transport centres in the road transport system is evaluated using a relative transport size indicator, which is defined as a share of all road transport intensity values (incoming and outgoing vehicles) of the given centre in the road transport intensity of all centres (all centres = 10,000). These characteristics make it possible to monitor qualitative changes in the transport importance of the centres, especially changes in the transport importance of various hierarchical levels of settlement centres in the Czech Republic.

At the second stage of the research, all centres were, using cluster analysis, classified into individual typological groups upon the mutual differentiation and similarity of three main factors monitored – transport importance of the centres, transport location of the centres in the road network and population of the centres. The purpose of applying cluster analysis was to find those groups of centres that show an identical or very similar proportional structure of individual components being monitored. The cluster analysis method (hierarchical division clustering method) was used for classifying the centres (similar to Kladivo, 2011). This methodological procedure represents an important tool for studying the spatial homogeneity of data files, and, because of this, it can be aptly applied to the research of transport hierarchization of centres and their determining factors (McGrew and Monroe, 1999). It is evident that this procedure envisages the observed fact to be generalized to a certain degree. It is, however, relatively reliable in revealing certain regularities in the size and structural differentiation of the monitored centres. The transport importance of the centres as of 2010, expressed by an absolute total of all motor vehicles driving through the centre, was selected as a dependent variable for the centres. On the other hand, the population numbers of the centres and the qualitatively evaluated transport location were determined as independent variables. The qualitatively evaluated transport location is inspired by the approach of Hůrský (1978) to the transport classification of centres in the then Czechoslovakia. Based on the differentiation in the transport infrastructure endowment of individual centres, the qualitatively evaluated transport position of the centres was calculated as a sum of 10 × the number of motorways and expressways leading

through the centre, 3 × the number of 1st class roads and 1 × the number of 2nd class roads. This graduation is based on the proportionality of average values of the transport intensity as per individual road types based on the 2010 Road Transport Census.

Despite efforts to include more independent variables in the research that would be relevant for the explanation of the differentiation of centres according to the share of freight transport, the author did not succeed in obtaining them. In this case, a criterion of the industrial production of individual centres could be used, but this is not statistically recorded in the Czech Republic.

4. Transport hierarchy of settlement centres in the Czech Republic – development and current trends

The previous evaluation demonstrated many times that there was a relative decrease in the transport importance of centres at medium and lower hierarchical levels between 1990 and 2005, while the largest centres were characterized by a definite increase in their importance (in absolute and relative values). This fact is basically affected by two factors. The first factor is that the largest transport centres are, as a general rule, the largest complex centres, too. Thus, their transport growth based on their size is caused by the general emphasizing of integration processes in the settlement system and strengthening of their importance within the regional systems. This can be exemplified by the increasing attractiveness of the largest towns from the viewpoint of commuting to work (more details can be found in Toušek et al., 2005, for example), resulting in an increased transport intensity, or the incoming suburbanization processes that require higher demands for car transport (as discussed in the studies by Urbánková and Ouředníček, 2006). Another important aspect is the fact that the largest transport centres also include centres of lower complex importance, the transport importance of which is especially given by their appropriate location within the transport network (for more details, see Kraft and Vančura, 2009b).

The results of the 2010 transport hierarchy analysis clearly demonstrate that the transport hierarchy has been further deepening, i.e. showing a growing asymmetry in the size relevant characteristics of the monitored set of centres (Tab. 1). The average transport intensity in the monitored centres already exceeded 44 thousand vehicles per 24 hour period in 2010 which represents a significant increase of this

Rank	Centre	Relative transport size	Rank	Centre	Relative transport size
1.	Praha	721.9	125.	Rumburk	24.1
2.	Brno	362.3	126.	Frýdlant	23.0
3.	Ostrava	245.0	127.	Blatná	22.4
4.	Olomouc	224.1	128.	Tanvald	22.2
5.	Plzeň	197.1	129.	Milevsko	21.7
6.	Jihlava	185.6	130.	Vimperk	21.4
7.	Frýdek-Místek	163.4	131.	Hořovice	21.4
8.	Hradec Králové	163.2	132.	Dvůr Králové n. Labem	20.7
9.	Beroun	157.8	133.	Semily	20.5
10.	Prostějov	151.0	134.	Nový Bydžov	20.1
11.	Velké Meziříčí	148.9	135.	Valašské Klobouky	20.1
12.	Brandýs n. Labem	146.5	136.	Sušice	19.9
13.	Humpolec	145.5	137.	Hlinsko	19.5
14.	Vyškov	133.8	138.	Dačice	19.3
15.	České Budějovice	133.6	139.	Podbořany	18.2
16.	Pardubice	132.8	140.	Tachov	16.3
17.	Kralupy n. Vltavou	127.3	141.	Bystřice n. Pernštejnem	16.1
18.	Poděbrady	121.7	142.	Chotěboř	16.1
19.	Ústí n. Labem	119.9	143.	Prachatice	16.0
20.	Mladá Boleslav	115.4	144.	Broumov	11.4

Tab. 1: The largest and smallest centres according to their relative transport size (2010)
Source: Road transport survey 2010, author's calculations
Note: Relative Transport Size = all transport volumes entering or departing the centre; all centres = 10,000

indicator in comparison to 1990 (21,997 vehicles). The maximum number of incoming and outgoing vehicles within 24 hours was registered in Prague (464,230 vehicles) and the minimum again in the Broumov centre (7,315 vehicles). The proportionality of the traffic flows continued to change as well. In 2010, the share of trucks in the centres was merely 18.8% of the total transport flow, while 80.5% was attributed to passenger cars and motorcycles accounted for the remaining percentage (0.7%). The last listed means of transport represented only a rather marginal part of the transport flow, though there was a tiny increase in the motorcycle transport in absolute and relative figures as compared with 2005. In comparison with 1990, there was also a further reduction of the freight transport by almost 9 percentage points in the centres, contrary to an increase of passenger transport by almost 10 percentage points. This trend again reflects the generally changing structure of the transport flows in the Czech road and motorway network during the monitored years.

The hierarchization level of the set of centres proved that the dominance of large transport centres is continuously growing at the expense of smaller and medium-sized centres. This can be documented also by the data in Table 1, in which twenty largest and smallest centres are compared according to relative transport importance in 2010. Primarily, it is necessary to highlight the growing dominance of Prague, which increased its relative transport importance from 527.3 in 1990 to 721.9 in 2010. The relative increase can also be seen in the remaining transport centres at the highest hierarchy levels (primarily Brno, Ostrava, Olomouc, Plzeň, Jihlava), which demonstrates the trends listed above showing the strengthening of the principal transport centres and therefore also a higher concentration of traffic flows in a smaller number of centres. As a result, we found most Czech regional capitals among the most significant transport centres in 2010. Karlovy Vary (31st position), Liberec (26th position) and newly also Zlín (25th position), the transport importance of which is weakened primarily by the lack of superordinate roads, can be seen as an exception. The opposite case with an increased importance would be for example the area of Ústí nad Labem, the transport importance of which was raised by the construction of the D8 motorway, which resulted in certain traffic redirection from the main flow Prague–Dresden. In this case, too, the centres of lower complex importance are to be found among the top 20 of most significant centres. However, their transport location is very exposed, adding value to their overall transport importance. What is meant by that is primarily the effect of the D1 motorway (Velké Meziříčí, Vyškov), R10 expressway (Brandýs n. Labem, partially Mladá Boleslav) or D5 motorway (Beroun) etc. Again, we can thus document the correlation between the transport importance of the centres themselves, which is determined by their complex importance in the settlement and regional system of the Czech Republic and their transport location. At the opposite end of the monitored set, we can again find centres the low transport importance of which is given by the joint influence of their low complex transport importance and the peripheral transport location in the road network (as analogously described in the study by Zapletalová, 1998).

The concentration of these centres is again remarkable in the less populated areas of the Czech Republic with low industrialization. From the viewpoint of size-relevant characteristics, it is nevertheless necessary to highlight the continuous weakening of the importance of these centres (e.g. the relative transport size of Broumov decreased from 15.7 to 11.4 during the monitored period). Considering the weakening importance of small centres and the increasing importance of large centres, we can prove the growing asymmetry in the spatial distribution of traffic flows and the gradually deepening hierarchization of the set of centres as per transport indicators. In 2010, we could also define clear lines of centres with higher transport importance and higher share of freight road transport in the Czech road and motorway network: Praha (Prague) – Beroun – Rokycany – Plzeň; Praha – Benešov – Tábor – České Budějovice; Cheb – Karlovy Vary – Most – Teplice – Ústí n. Labem – Děčín; Praha – Roudnice – Lovosice – Teplice; Praha – Mladá Boleslav – Turnov – Jičín/Liberec; Praha – Poděbrady/Kolín – Hradec Králové/Pardubice; Hradec Králové – Litomyšl – Svitavy – Brno/Olomouc; Brno – Vyškov – Prostějov – Olomouc – Hranice – Ostrava; Hodonín – Uherské Hradiště – Zlín/Kroměříž – Přerov. These highly exposed axes can be deemed the main international/supraregional transport lines created by automobile transport. The overview of all centres, structured by their relative transport size, is shown in Fig. 1.

5. Transport classification of settlement centres – using cluster analysis

It was clearly stated in the above analysis of the hierarchy of transport centres that the transport hierarchization, or more precisely the transport importance, of individual centres is influenced primarily by two key factors – a centre's transport location within the road network and its complex importance expressed by its population size. Based on this finding, attention is paid to this phenomenon, namely to the influence of these key determinants on the transport size of

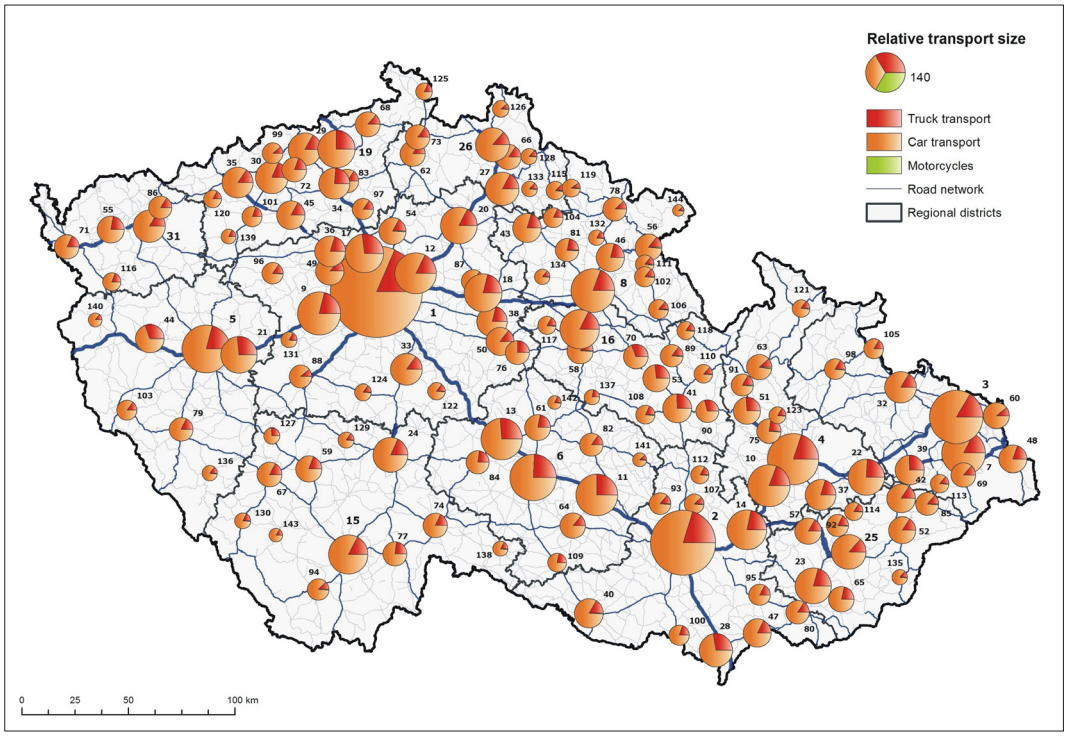

Fig. 1: Transport hierarchy of Czech settlement centres by relative transport size (2010)
Source: Hampl 2005, Road transport survey 2010, author's calculations

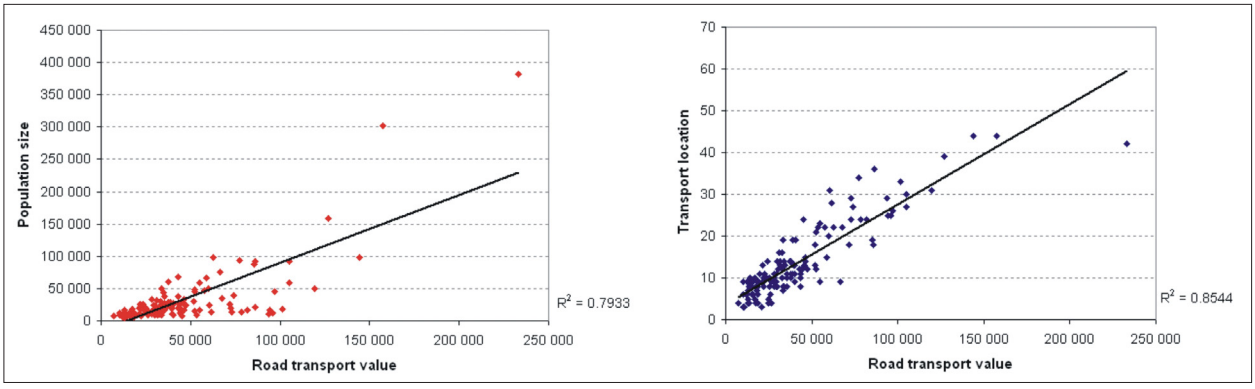

Fig. 2: Relation of the population number (a) and the qualitatively evaluated transport location (b) to the overall transport importance of centres (2010)
Source: Road transport survey 2010, author's calculations

the centres. Therefore, we monitored the transport hierarchization of settlement centres in the Czech Republic in 2010 in relation to both determining factors as stated above. Generally, it can be confirmed that there is a linear relation between the growing population sizes of individual centres and their relative transport importance. Put in a simple way, if the population number in a centre increases, its transport importance grows as well. Even though there are certain outliers in this simple relation that are caused by the exposed/peripheral transport location of the centres (the exposed position of centres such as Velké Meziříčí, Humpolec, Stříbro or, the other way round, the peripheral position of Tachov or Jeseník can be taken as examples), it can be stated that the population size of individual centres is one of the key factors in the differentiation of this transport importance. As demonstrated earlier (Kraft, Vančura, 2009b), the population size of individual centres correlates more with the importance of the centre according to passenger car transport rather than according to freight road transport importance. The freight road transport is, however, in the closest relation with the transport location phenomenon, as it can be confirmed that the highest share of freight transport is documented to occur in centres with the most exposed location. Also in the case of qualitatively evaluated transport location, we can highlight a remarkable linear relation between the quality of transport location and the overall transport importance of the centre (highest coefficient of determination R2). Nevertheless, the centres in a relatively worse transport location the high transport size of which is determined

primarily through their complex importance (for example Zlín or České Budějovice) or their – though exposed – transport position, however, without a quality transport infrastructure (Benešov) occur even there. The high linear interdependence between the transport importance of centres and their population size or their transport location is documented also in Fig. 2.

Therefore, attention will be now given to searching for the main factors determining the importance and the hierarchical position of individual centres according to automobile transport. It will be primarily the search for centres, the transport importance of which is given rather by their population number and centres with the transport importance primarily determined by their exposed transport location. The overall transport importance of these centres is certainly often caused by an interaction of the two (possibly more) factors. The result of the identification of the determining factors of the transport importance of individual centres is the typology of individual centres exactly according to the weight and share of each of the stated factors in the overall importance of the centre in the transport system. The purpose was to look for such types (clusters) of the centres whose transport importance would most correspond with the transport location of top quality and with their complex importance, expressed in this case through the mere population size by the method of hierarchical clustering (based on the maximum possible similarity within a cluster and the maximum differentiation of this cluster from other clusters). Based on the k-diameter method, five typological groups of centres were determined which have the most similar components of transport importance, transport location and population number, i.e. which showed the highest correlation. Tab. 2 shows the essential structural characteristics of the individual cluster groups of centres indicating their mutual differentiation.

The first group of centres (Cluster 1) largely consists of large transport centres with high values of transport location but with low values of complex importance. Therefore, it includes significant and medium significant centres whose transport importance is primarily determined by the exposure of their location within the transport network. The statement is proven also by the list of centres with the lower complex importance in this category situated on the main routes in the Czech Republic (Rokycany, Stříbro, Beroun, Slaný, Humpolec, Vyškov, Velké Meziříčí, Hranice, etc.). The second fundamental feature of this category of centres is represented by the presence of centres lying outside the reach of expressways, which however

	Number of centres	Average transport importance	Average complex importance	Average transport location	Average truck transport share (%)	Average car transport share (%)	Basic features of cluster
Cluster 1	32	46,725.9	13,092.8	18.4	21.6	69.2	Mainly transport and transport-location exposed centres with lower complex size
Cluster 2	20	26,140.1	11,325.8	9.6	16.6	70.1	Centres with lower complex and transport size with peripheral transport location
Cluster 3	35	72,379.0	83,931.3	20.7	17.4	70.9	Centres with highest complex and transport size with exposed transport location
Cluster 4	27	34,268.3	28,132.9	11.5	16.3	70.4	Centres with average value of transport and complex size with lower transport location
Cluster 5	30	41,236.0	28,630.6	¨ 7.7	14.8	72.5	Larger transport and complex centres with peripheral transport location

Tab. 2: Basic structural characteristics of cluster groups of the centres (2010)
Source: Road transport survey 2010, Czech Statistical Office 2010, author's calculations

have clearly the character of supraregional or regional transport nodes (Blatná, Milevsko, Čáslav, Jaroměř, Moravské Budějovice, Svitavy, Mohelnice, Litovel, etc.). It can be justly stated that this category includes important centres with a high share of transit/freight transport. It is exactly the remarkably above average share of freight transport in these centres that proves their transport importance being strongly influenced by their location exposure.

By contrast, the second group of centres (Cluster 2) includes centres of low transport importance, low complex importance and rather low value of transport location, i.e. less significant transport centres the low transport importance of which results from the combined effect of a rather peripheral transport location and low population size. In this group of centres we can find centres lying as a rule on less important roads that do not have any major transit role in the transport system of the Czech Republic (Dačice, Hlinsko, Podbořany, Dobruška, Žamberk, Jeseník, Valašské Klobouky etc.). Conspicuous is a relatively low share of freight transport, as demonstrated by their rather marginal importance as to the generation of supra-regional traffic flows.

Fully developed centres of high transport and complex importance and favourable transport location form the basis of the third group (Cluster 3). In this category, we can find most regional and former district towns of the Czech Republic, which proves their relatively complex character. In the case of these centres we can observe the accumulation of all variables mentioned above, hence it is not possible to ascertain whether the transport importance of the respective towns is determined by their complex importance as opposed to their transport location. Centres belonging in this cluster group include both the important transport centres in which the high share of freight transport is influenced by the high individual automobilization of their hinterlands (Praha, Plzeň, Ústí nad Labem, Brno, Olomouc etc.) and the centres situated on more important supra-regional flows from where a part of the freight transport is taken away by the near motorways (Havlíčkův Brod, Žďár nad Sázavou, Nový Bydžov, Tábor, Kroměříž etc.). The high share of passenger car transport in this group can be attributed to the existence of large and strongly automobilized settlement centres.

In the fourth group of centres (Cluster 4), the complex importance of centres combined with rather average values of transport location starts to play a more pronounced role. The transport importance of these centres is thus influenced by their population size rather than by their transport location. This group therefore includes mainly smaller transport centres in less favourable transport locations as to the main transport flows of the Czech Republic (Domažlice, Sušice, Vlašim, Mariánské Lázně, Kyjov etc.). This fact is also reflected in a relatively low share of freight transport in these centres, which again indicates their lower transport importance as based on the generation of more significant transport intensities. Certain exceptions in this category can be considered the towns Pardubice, Znojmo, Teplice or Liberec, which on the contrary play a relatively important part in the distribution of supra-regional traffic flows but are affected by their not entirely favourable position within the road network.

Finally, the fifth group of centres (Cluster 5) is characterized by the high transport importance and to a certain extent also by their complex importance – however, with an unfavourable transport location. It includes primarily large centres situated on important routes, yet with a relatively peripheral transport location caused usually by the absence of higher road infrastructure (Zlín, České Budějovice, Benešov, Chomutov, Příbram, Šumperk, Hodonín, Vsetín etc.) and smaller centres with an unfavourable transport location (Tachov, Prachatice, Český Krumlov, Boskovice etc.). It is the high complex importance and the low transport location that are the determining characteristics for this group of centres. The set of all centres including their classification in the individual typological groups and brief characteristics of the cluster groups is provided in Fig. 3.

6. Conclusions

From the viewpoint of the vertical organization of the transport system in the Czech Republic, it was clearly demonstrated that the two monitored systems (transport and residential/complex) are strongly interlinked. Similarities and interconnections of their hierarchical organization are to a certain extent logical since the system of settlements is one of basic determinants forming transport links in the territory (as discussed in Řehák, 1982). Thus, we can corroborate the trivially formulated hypothesis about the high association of transport and complex centre hierarchization (similarly for public transport – see Marada et al., 2010). The fact was also confirmed that the centres are far less hierarchically developed according to transport indicators than according to complex indicators. Nevertheless, some essential changes that have resulted in the deepening of hierarchization tendencies in the vertical organization of the transport system occurred in the period 1990–2010 also in the transport characteristics. This deepening was caused by the weakening significance of smaller transport centres and by the progressive growth of the size-

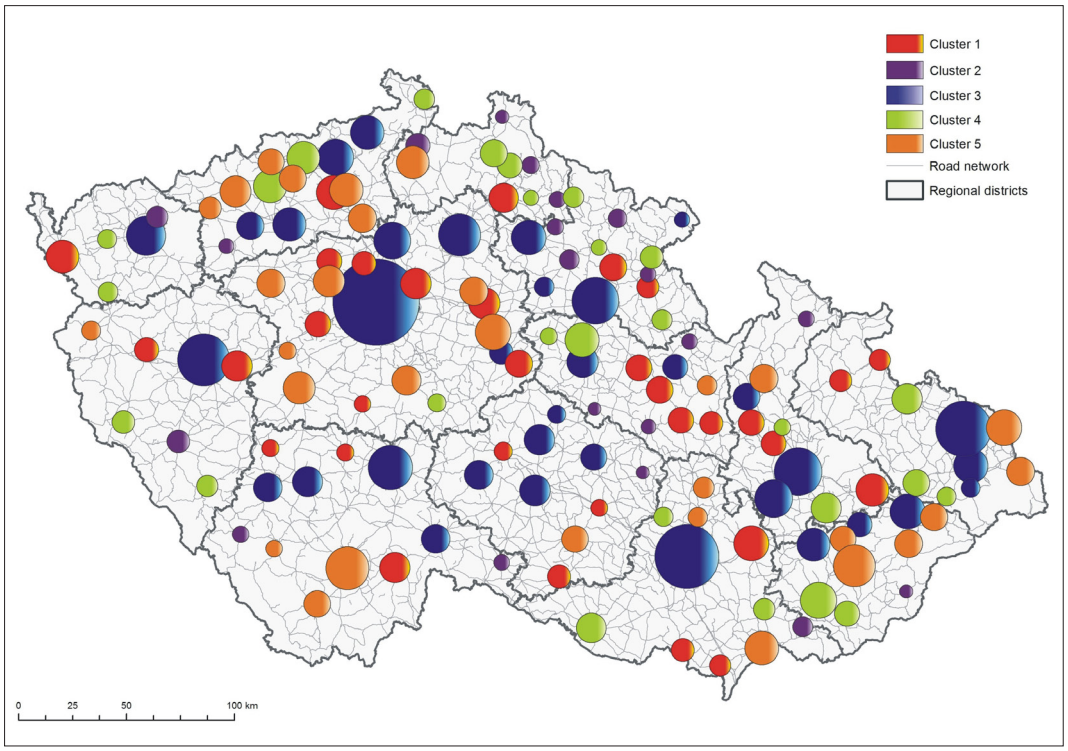

Fig. 3: Cluster groups of settlement centres according to their relative transport size (2010)
Source: Hampl 2005, Road transport survey 2010, author's calculations
Note – the size of the circles corresponds to relative transport size of centres in 2010

relevant characteristics of the largest centres. However, a conspicuous sign of the transport hierarchization of centres is the fact that the deepening of hierarchization tendencies is influenced to various extents by different road transport modes. Currently, we can therefore consider freight transport to be primarily the most hierarchically developed transport mode. As to road transport development in the Czech territory, we can consider as positive namely the fact that the intensity of freight road transport in urban areas of Czech towns shows in general a relative (in some cases even absolute) decrease. Freight road transport has been moved gradually to bypass/motorway communications and its the unfavourable consequences following out from the operation of this transport mode represents a relatively lower impact on Czech towns.

The principal outcome of our study into the transport hierarchy of settlement centres can be considered results of analysis generalizing some broader relations of the transport hierarchy of settlement centres including setting the issue into a broader context. Following from this are some facts that had been formulated already several times but not verified so far (e.g. Viturka, 1981; Marada, 2003), namely that the transport importance of centres always results from the interaction of the vulnerability/peripheral character of the transport location and more complex indicators, particularly the centre's population size or attractiveness for commuting to work. It is also important to note that some centers (e.g. Český Těšín or Břeclav) are severely affected by freight transport. Their importance in the transport system of the Czech Republic is primarily supported by the proximity of the state border. These examples are therefore part of the cross-border urban complexes and their position cannot be definitely perceived as purely peripheral (similarly for Slovakia in Horňák, 2006).

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