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The energy consumption of public transit under rural and suburban conditions

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Abstract. The aim of paper is to investigate an energy consumption of public transit focused on regular commuting from suburban locations. Surveyed suburban settlements have become a part of 'urban sprawl' process in the suburbanized hinterland of Prague's city. The transport links are strongly influenced by the catchment area of Prague's city that has a dominant position in surveyed region and the most of the existing transport links are carried out in relation to the Prague's city on radially oriented roads. The traffic intensities are often on a roads' full capacity during peak hours or the roads are even congested alongside a ride to the city. The 10 suburban settlements were selected for the purpose of the fuel consumption investigation. Authors have focused on the journeys carried out during the morning peak hours of the ordinary working days when the transport demands are saturated. The fuel consumption investigation has involved the journeys by public transit (commuter bus) and by passenger car. Obtained results have proved possibilities of significant fuel consumption savings under condition that the bus transit preference would be effectively used. The energy efficiency of bus public transit allows to achieve the similar energy consumption per passenger as an ordinary passenger car has at a low occupancy rate of bus.

Key words: transit, passenger car, fuel consumption, peak hours, suburbanization.

INTRODUCTION

The paper points out the interplay between the transport energy consumption and the tasks of spatial planning with regards to support sustainable transport behaviour. The papers attempts to answer these questions: 'What is the actual energy consumption during the commuting from suburban settlements to the core city?' and 'Are there any possibilities to increase the energy efficiency during the daily commuting?'.

Nowadays, the society must pay attention to the issue of energy consumption, because this topic is important in the context of the sustainable development principles of land use and spatial planning, especially at the field of suburbanization. The process of suburbanization is one of the most significant phenomena in Europe and the extensive research and public debate are focused on that issue from the perspective of architectural and urban design. Suburbanization as a process can be perceived from the different perspectives that highlight the problematic factors in this process. Some authors point out the reduced availability of public amenities for residents within suburbanized area (Zolnik et al., 2010) and the consequences of the lack of public amenities in increased mobility needs of inhabitants.

Suburbanization has a sociological aspect, since there is a mix of the population between the natives (the original inhabitants of the former rural areas) and newcomers. (Špačková & Ouředníček, 2012). While original inhabitants retain their own lifestyle, the newcomers–inhabitants keep a high dependence on the core city (the dominant city of the region) in their every day's life. Demographic issues of their coexistence are discussed by Musil & Müller (2008), where the diverse population groups and their personal preferences are taken into account.

The changes of transport behaviour occur in connection with the previously mentioned factor. The newly built suburban settlements have a high private car dependency at modal split (Lukeš et al., 2014) to compare with the municipalities without suburbanization development. Transport demands of suburban settlement residents are carried out in relation to the core city. This situation contributes to the occurrence of traffic congestion and it increases the fuel consumption during the commuting from suburban settlements. Therefore, it is possible to observe increased energy consumption concerned with the suburban transport in comparison with the regional transport in rural areas (Marique & Reiter, 2012).

The legislative effort of the European Union was focused on the energy efficiency of buildings, until nowadays. The issued directive requires the construction of houses with energy consumption close to zero since 2020 (Directive of the European Parliament and of the Council, 2010). Energy efficiency of buildings has been taken into the strategic targets of energy savings at European level, but this effort is devalued in the context of fuel consumption in relation to commuting from the suburban settlement to the core city. The expended resources are devalued through energy demands associated with the location of suburbanized area.

Increased population mobility and transport accessibility have allowed factual development of suburbanization. The increased availability of private car transport and the passenger's demands to increased travel speed have caused the growth of traffic volume and an increase of travel distance (Boussauw et al., 2011). This kind of development has led to the preference of private car transport. On the other hand, this fact is also valid in the opposite meaning. Suburbanization and diffused forms of settlement have caused the need of increased mobility demands of inhabitants, and it creates a dependency on the accessible and cheap energy (da Silva et al., 2007). This fact creates interdependence of these factors.

The relationship between the affordable mobility of inhabitants and the character of settlements is evident from the spatial urban development in historical context. Muller (2004) points out an influence of transportation to the city's development in the example of American cities. There was implemented an urban tram and a suburban commuter train as an important elements of the population's mobility at the beginning of the 20th century. Development of settlements occurred alongside the corridor of tramway tracks and of commuter train tracks. Later (in the 30's during the advent of motorization), the settlements were located alongside the highway's or motorway's corridors (Newman & Kenworthy, 1992). There was a typical massive development of residential buildings and houses with the low population density (urban sprawl), during this period.

The similar development started in the Czech Republic, although a bit later. Residential suburbanization has been developed in relation to the radially oriented railways from the core city during the period between the World Wars (Hampl et al., 2007). After the 2nd World War, the residential suburbanization associated to the development of the automotive industry did not occur, as it was apparent in the U.S. (Pucher, 1999). Mainly it was caused by political and social changes during the period 1948–1989. The residential and commercial suburbanization has occurred since the 90's of the 20th century and the residential suburbanization is linked to the private car transport usage in the hinterland of large cities. The settlements were developed alongside the major road's corridors and also in a closer hinterland of large cities without adequate transport infrastructure. The first problems of increased traffic intensities have occurred with regards to the roads' capacity or the roads are even congested alongside the journey to the city centre. The competitiveness of public transport has been lost with the expansion of private car transport in the suburbanized city's hinterland.

The process of suburbanization and desurbanization is described as the most difficult stage of the residential development with regards to the public transport service (van den Berg et al., 1982). The transport demands are realized for a long travel distance and the passengers demand high accuracy of transit connections and sufficient transport capacity during peak hours. Public transport provides the population mobility in relation to the core city (radially oriented journeys) and also within micro–regions, where the intensity of transport demands is usually significantly higher in relation to the city to compare with micro–region relations. The scope of the public transport system is expanding further into the regional area due to growth of city's catchment area, as it is shown in example from the state of Maryland, USA (Chakraborty & Mishra, 2013). The commuter trains are needed to cover the most important transport links as a backbone of the transport system. Therefore, it is appropriate to integrate the commuter trains into an integrated transport system with including common tariff rules. It is appropriate to establish the tariff system on the base of travel distances instead of travel times, because the travel time is different for the same journey during peak hours and off–peak period. The off–peak tickets are offered in some transport systems at a reduced price as incentive to spread the peak hours onto longer period, but this kind of fare is not so useful for suburban residents and their daily commuting (Holmgren et al., 2008).

MATERIALS AND METHODS

The 10 localities of suburban settlements were chosen with the aim to describe suburban residents´ energy consumption during their commuting. The surveyed settlements are situated in newly built suburban localities with specific built up area also known as urban sprawl (or suburban sprawl) and these settlements are the only part of the original municipality. Some settlements are listed only administratively as part of municipality and they are built as a separate settlement far away from the original centre. The most of these settlements were built after the 2001 and the construction of new houses has gone on there up to nowadays. These surveyed settlements are influenced by catchment area of Prague's city that is dominant city of the region. The chosen settlements are localised by to 25 km from the Prague's city centre and up to 19 km from the nearest public transport terminal. These suburbs were chosen evenly in different directions from Prague's centre without direct commuter train connection, thus public transit is implemented as suburban bus transport only. Suburban settlements represent different type of buildings, level of public facilities etc.

Experimental fuel consumption investigation of the journey (the fuel consumption survey) was carried out during morning peak hours (from 6 to 9 am) on ordinary working days in May. The survey's time covered uniformly the morning peak hours in all of surveyed settlements. The fuel consumption survey included an investigation of commuter bus fuel consumption and of passenger car fuel consumption. On base of these fuel consumption surveys, authors found out the total fuel consumption of the bus and of the passenger car to the journey from surveyed settlements to the nearest available underground station (public transit terminal), where the 'Park and Ride' parking lot is located as well. There was considered the journey to the best reachable public transit terminal with the 'Park and Ride' parking lot. The location of some surveyed settlements allowed to reach 2 equivalent public transit terminals, therefore it was distinguished at the 'Code of the bus journey'; for instance the journeys 'J 6a' and 'J 6b' (see Table 1) There was carried out at least 2 journeys for each of the 10 surveyed suburban settlements during the morning peak hour. An exception is the journey 'J 10' (Chýně–Zličín, see Table 1), there was found as a sufficient to carry out only 1 journey (short journey with no influence by surrounding traffic conditions). The journeys were carried out through the concurrent ride of the measuring bus and of the bus under the ordinary operation with passengers. Thus, the ride and the bus stops of the measuring bus were maintained under real conditions.

Table 1. The energy consumption related to 1 kilometre and to 1 passenger (bus and passenger car)

Code of the bus journey	Surveyed transport relation	Energy consumption per kilometre and per passenger			
		bus peak hours (kWh km^{-1})	bus off–peak hours (kWh km^{-1})	ordinary car peak hours (kWh km^{-1})	economy car peak hours (kWh km^{-1})
J 1a	Říčany–Depo Hostivař	0.07	0.06	0.49	0.51
J 1b	Říčany–Háje	0.11	0.06	0.59	0.64
J 2	Psáry–Budějovická	0.11	0.08	0.53	0.52
J 3	Sulice–Budějovická	0.09	0.07	0.56	0.56
J 4	Hostivice–Zličín	0.14	0.11	0.62	0.59
J 5	Bašť–Ládví	0.13	0.11	0.52	0.51
J 6a	Jenštejn–Letňany	0.11	0.10	0.61	0.57
J 6b	Jenštejn–Černý Most	0.11	0.09	0.58	0.55
J 7	Velké Přílepy 1–Dejvická	0.11	0.09	0.46	0.48
J 8	Velké Přílepy 2–Dejvická	0.11	0.09	0.46	0.47
J 9	Holubice–Dejvická	0.11	0.09	0.46	0.46
J 10	Chýně–Zličín	0.09	0.09	0.51	0.49

The investigation of the public transit fuel consumption was carried out to the off–peak journeys for the purpose of comprehensive comparison to the peak/off–peak journeys. Since many of the peak journeys were affected by traffic congestion, It was carried a fuel consumption survey of journeys during off–peak period. The off–peak journey was carried out during night hours (from 10 pm to 4 am). The similar time of the bus stops (the time spent on the bus stop during the journey) were kept for the peak journeys and for the off–peak journeys. Thus authors gained a comparable data to the peak/off–peak journeys. The authors get an overview of the real fuel consumption related to the transportation and the obtained data was not affected through surrounding traffic conditions. The emphasis was placed on traffic fluency during the off–peak journeys.

The measuring bus was not possible to occupy by ordinary passengers, therefore it was necessary to simulate the vehicle occupancy by ballast weight. The total weight (the ballast weight and the measuring equipment) corresponded to the occupancy by 31 passengers (all seats occupied).

Karosa B951E.1713 was used as a measuring bus; the engine: Iveco Cursor 8 F2B; the power of engine: 180 kW; the engine displacement: 7.8 litres; complying with Euro 3 emission standard; the fuel: diesel; fully automatic transmission Voith D 851.3. This type of bus is commonly deployed on the suburban bus lines nowadays.

Škoda Fabia 1.2 HTP was used as a measuring car (economy car); the engine: HTP (High Torque Performance); the power of engine: 40 kW; the engine displacement: 1.198 litres; complying with Euro 4 emission standard; the fuel: gasoline; manual transmission.

Škoda Octavia 2.0 TDI was also used as a measuring car (ordinary car); the engine: TDI (Turbo Direct Injection); the power of engine: 103 kW; the engine displacement: 1.968 litres; the fuel: diesel; manual transmission.

The measuring bus was equipped with differential flowmeter DWF as a fuel gauge with two independent measuring sections. This type of fuel gauge works on the principle of flowmeter with oval gear wheels including Hall sensor as a speed encoder of oval gear wheels. The fuel gauge was connected to the suction pipe (from the tank to the unit injector) and to the return pipe of bus fuel system from the unit injector back to the tank (Fig. 1).

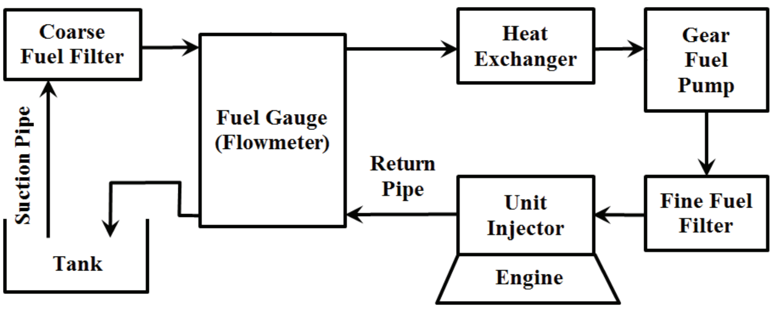

Figure 1. The schema of the bus fuel system including fuel gauge, Ed. the arrows indicate direction of the fuel flow.

The output signal of fuel gauge was a pulse with the transmission through the Hall sensor. Each pulse obtained from Hall sensor represented 0.0025 litre of fuel. This volume is determined by the flowmeter construction that provides a resolution of 400 pulses per litre. The instantaneous fuel consumption was represented as a difference between the number of pulses on the suction pipe and the number of pulses on the return pipe of fuel system. Fuel gauge provided data continuously, because it was fully implemented into the fuel system of the bus and cannot be so easily installed or removed before/after the measurement period. Fuel gauge was connected to the datalogger (see Fig. 2) that recorded each pulse of fuel gauge, for the purpose of data evaluation. These data was transmitted further to the processing device (notebook). The external GPS receiver was also connected to the processing device. The GPS receiver was fixed by a magnet on the measuring bus roof and it provided data about position, speed, azimuth, number of available satellites and the magnetic declination.

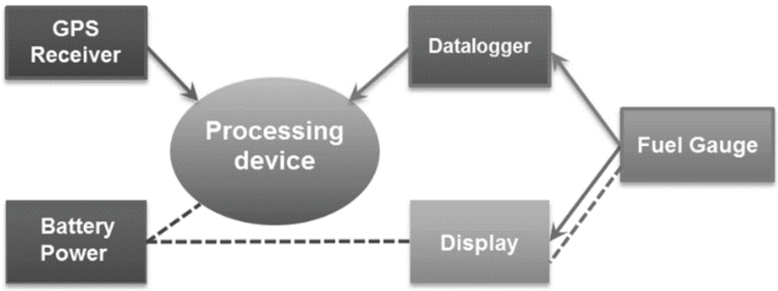

Figure 2. The schema of the measuring system, Ed. the arrow of solid lines indicate the directions of data flow, the dashed lines indicate power supply.

The processing software was implemented to the notebook and all of measured data were converted into database file (*.dbf). Thus, it was possible to process the data in any spreadsheet. The data was aggregated and synchronized in the frequency of one second. The database record included time data, data of fuel gauge (fuel flow to the suction pipe and to the return pipe) and information about the position and speed provided by GPS receiver. The battery power was used as a source of electrical supply for the fuel gauge through the display.

The data of passenger cars fuel consumptions was gained in standardized way through the OBD connector (On–Board Diagnostics) during the surveyed journey.

RESULTS AND DISCUSSION

Overall, the fuel consumption investigation was carried out to the suburban bus lines (422 km of measured journeys) and to the passenger cars (304 km of measured journeys). Another overview represents a comparison of the involved journeys during the peak hours (240 km) and during the off–peak hours (182 km). The off–peak journeys were not affected significantly by the surrounding traffic conditions and therefore the variation of fuel consumption was lower than during peak journeys. Thus the range of fuel consumption investigation might be smaller during off–peak journeys.

The summary of the distribution of speed intervals into the travel time (see Fig. 3) points out the fact that the most of the congested journeys have the highest proportion of low speeds during 7–8 am. It is mainly caused by the saturation of the transport demands linked to home–to–school journeys (pupils and students) during this period. These transport demands are complemented by transport demands of the ordinary commuters (home–to–work journeys). Therefore, the total transport demands are saturated during this period. There is evident that the most congested transport relations come from the southeast of Prague (the journeys ‘J 1’, ‘J 2’ and ‘J 3’) – the strongly influenced area through the uncoordinated development of suburbanization as it is presented in Ouředníček (2007). The position of public transit is hardly competitive in these journeys. For instance, the passengers of public transit have to spend app. 56% of travel time under the travel speed 10 km h^{-1} (see journey 'J 1b'). It is equivalent to spend app. 56% of travel time by walk. On the other hand, there were included the fast and comfortable journeys ('J 6b' see Fig. 3) as well.

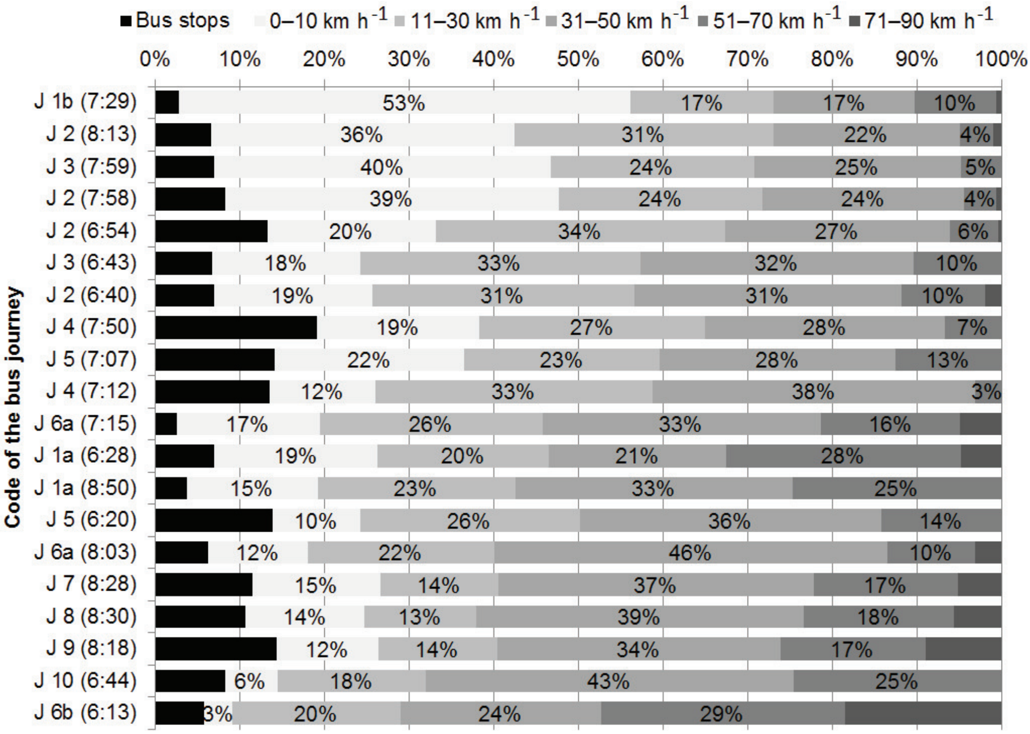

Figure 3. The distribution of speed intervals into the travel time of bus journeys during the peak hours, Ed.: the time in the brackets indicates the time of departure from the bus stop of surveyed settlements.

The peak journeys by commuter bus were taken into compared with the off–peak journeys with a fluent ride (see Table 2). There was statistically proven the difference of energy consumption between peak journeys of public transit and off–peak journeys of public transit (t–test, n = 12, P > 0.05). The energy consumptions savings of bus operation varies from 0% to 41% of energy consumption or fuel consumption consequently (0% = no difference between peak and off–peak consumption of bus). The off–peak journeys have represented conditions under which the bus transit is not negatively influenced by passenger car transport. The variety of energy saving provides the awareness of energy consumption impacts if effort would have been focused on traffic fluent flows and congested parts of the journey would be preferred to bus transit operation (bus lanes, bus turning lane at intersections, traffic lights preference, etc.). These practical results have shown the potential benefits of bus service traffic fluency in energy consumption context and there is shown here that the benefit could be found not only at the field of travel time reductions. This approach is in accordance with the transport policy principles concluded by Stopher (2004) 'busways represent probably a much more efficient way for buses to serve their optimum markets–suburb to downtown movements of workers'. But these principles are often not practically implemented into reality of suburbanized area and it is only implicitly declared in transport policy released by administrative authority. The journeys that are congested during the peak hours have shown a higher energy consumption savings than others. On the other hand, there was not statistically proved the difference of energy consumption between the economy car and the ordinary car (t–test, $n = 12$, $P > 0.05$). The economy car usage has proved higher energy consumption than ordinary car under congested journeys, but the economy car has shown lower energy consumption than ordinary car under fluent traffic conditions (see Table 1). This fact points out that the benefit of economy car is not unambiguous at the field of fuel consumption during daily commuting. These practical results provide a different perspective to fuel consumption of cars with the lower engine displacement and it offers a complementary view on the issue that has been studied by Ntziachristos et al. (2014). The public transit usage has proved to be an important element of reducing energy consumption of the transportation.

The difference between the energy consumption of public transit and the passenger car varies in a range from 74% to 86%, as it is presented in Table 2 (0% = energy consumption of bus; data are related per one passenger and to one kilometre).

Table 2. The energy consumption savings and energy consumption equilibrium

Code of the bus journey	Travel distance of bus journey	Travel distance of passenger car journey	Energy savings		Energy consumption equilibrium	
			bus (P hours) vs. bus (OP hours)	bus vs. passenger car (P hours)	bus vs. passenger car (P hours)	bus (OP hours) vs. passenger car (P hours)
	(km)	(km)	(%)	(%)	(passengers)	(passengers)
J 1a	16,6	16,6	13%	86%	4	3
J 1b	14,4	14,4	41%	82%	5	3
J 2	15,2	15,0	25%	79%	6	4
J 3	15,1	14,7	26%	84%	4	3
J 4	7,8	8,4	21%	77%	6	5
J 5	11,8	12,6	16%	74%	7	6
J 6a	9,4	9,2	7%	81%	5	5
J 6b	7,7	7,6	16%	80%	5	4
J 7	12,5	12,2	16%	77%	6	5
J 8	11,8	11,3	17%	77%	6	5
J 9	18,5	17,2	17%	76%	6	5
J 10	6,9	7,0	0%	82%	5	5

Note: P hours – peak hours; OP hours – off–peak hours.

The energy density of fuels was considered as 32.18 MJ per litre of gasoline and as 35.86 MJ per litre of diesel (Kubička & Kubičková, 2007) for the purpose of energy consumption calculation.

As was mentioned above, passenger car transport has caused delays by itself as well as it has induced delays on a bus public transit. The position of bus public transit is different. Due to the delays it is perceived as an uncompetitive, because there is no offer of higher travel speed and even the price level of fare is not sufficiently motivating factor

(Lukeš et al., 2014). These facts probably have led to the domination of private car transport at the modal split. On the other hand the low energy efficiency of passenger car transport in comparison with public transit is often caused by low rate of car occupancy.

The average vehicle occupancy rate was found out 1.41 persons per ordinary car and 1.35 per economy car during the journeys from surveyed settlements (Lukeš et al., 2014). Thus, the presented values – see Table 1 and Table 2 where the occupancy of passenger car was considered as a 1 passenger (driver) – occur at the most cases of all journeys made from the surveyed settlements. The weighted arithmetic mean of bus occupancy was found out 21 passengers (the travel time was considered as a weighted value) across all investigated journeys, but this value differs under surveyed transport relation. For instance, the transport relation 'J 10' is used by passengers quite weakly to compare with another transport relations.

Of course, the energy efficiency of public transit declines with the decreasing of bus occupancy. The energy consumption equilibrium between passenger car and public transit occurred when the both surveyed transport modes have the similar energy consumption per one passenger under the same traffic conditions. The energy consumption equilibrium has occurred when the occupancy of bus varies from 4 to 7 of bus passengers, while the passenger car stays occupied by driver only (see Table 2). The decrease of fuel consumption linked with the lower occupancy rate of bus was included into calculations. The occupancy level of energy consumption equilibrium is even lower in case of off–peak journeys by bus (from 3 to 6 of bus passengers) and it confirm a presumption of better public transit profitability under fluent traffic flow of bus operation. This equilibrium depends on the journey from surveyed settlements, as it is presented in Table 2, regardless if the economy car or ordinary car was used, because there is no difference between those kinds of car at the surveyed journeys (t–test, $n = 12$, $P > 0.05$). Any higher occupancy of the bus has had energy consumption benefit on the side of public transit to compare with passenger car transport. There should be pointed out, that this statement is valid for used type of bus. It is possible to assume that newer buses or low–capacity vehicles (minibuses or midibuses) have a better economical operation. Therefore, the energy consumption equilibrium between passenger car and transit could be expected at the lower end of occupancy interval from 3 to 7 passengers.

The offered capacity of bus transit was recognized as a sufficient to cover public transit demands as for a long–travel journeys as the short–travel ones. Furthermore it was possible to travel as passenger with his own seat from all surveyed suburbs during morning peak. According to the above mentioned conclusions, there is no assumption that the next increasing of transit offer should lead to increase of transit ridership as well. This statement is suggested by determination coefficients and it was not found any statistical relation between a transit offer (represented as a number of bus departures per peak hour) and a transit ridership or total number of outgoing persons ($R^2 = 0.020$ respectively $R^2 = 0.202$) in surveyed settlements. This declaration points out the limits of transit demands in suburbanized area (Næss, 2006) and it is possible to assume that the modal split is saturated in a favour of transit under current conditions which are determined by distribution of travel time, reliability of transit, fare, etc.

Usually, the energy efficiency of transportation is not taken into account by passengers. It is a task for the concerned administrative authorities to set up the appropriate transport policy and for the organisers and designers of public transit to ensure the fulfilment of this transport policy practically.

CONCLUSIONS

The analyses have proved that the potential of energy consumption savings are not fully exploited in public transit. It is possible to save more than 40% of fuel consumption during the congested journeys, if the tools of bus transit preference would be effectively used. As it is evident, there is another way to streamline the operation of public transit in the context of energy consumptions savings, among of commonly accepted decreasing of travel time. The public transit has no likelihood perspective that the railroads could be implemented into surveyed settlements. Therefore the alternative variant of public transit system is the Bus Rapid Transit system (BRT system) or Metrobus system. The energy efficiency of bus public transit allows achieve the similar energy consumption per passenger as an ordinary passenger car has at a low occupancy rate of bus (from 3 to 7 passengers). This finding suggests that the endeavour to 'overcrowd' buses, to increase of economic profitability, is not justified in the energy consumption context.

Conclusions have proven the meaningfulness of efforts to improve the fluency of public transport in suburbanized area. The presented approach has shown that the discussion with the responsible authorities could be supported by exact data of fuel consumption and possibility of fuel savings that are often neglected.

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REFERENCES

Boussauw, K., Derudder, B. & Witlox, F. 2011. Measuring Spatial Separation Processes through the Minimum Commute: the Case of Flanders. *European Journal of Transport and Infrastructure Research* **11**, 42–60.

Chakraborty, A. & Mishra, S. 2013. Land Use and Transit Ridership Connections: Implications for State–Level Planning Agencies. *Land Use Policy* **30**, 458–469.

da Silva, A.N.R., Costa, G.C.F. & Brondino, N.C.M. 2007. Urban sprawl and energy use for transportation in the largest Brazilian cities. *Energy for sustainable development* **11,** 44–50.

Directive of the European Parliament and of the Council 2010/31/EU. Energy Performance of Buildings (revised version). Acceessed 19/05/2010

Hampl, P., Dostál, P. & Drbohlav, D. 2007. Social and cultural geography in the Czech Republic: under pressures of globalization and post–totalitarian transformation. *Social & Cultural Geography* **8**, 473–495.

Holmgren, J., Jansson, J. & Ljungberg, A. 2008. Public transport in towns–Inevitably on the Decline. *Research in Transportation Economics* **23**, 65–74.

Kubička, D. & Kubičková, I. 2007. The Influence of motor fuels containing bio–components on operation and emissions of diesel and gasoline engines in the fleet of the Czech Republic. Research report of the project FT–TA4/066 VZ–S–1791. Litvínov (in Czech)

Lukeš, M., Kotek, M. & Růžička, M. 2014. Transport Demands in Suburbanized Locations. *Agronomy Research* **12**, 351–358.

Marique, A.–F. & Reiter, S. 2012. A method for evaluating transport energy consumption in suburban areas. *Environmental Impact Assessment Review* **33**, 1–6.

Muller, P.O. 2004.Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis. *The Geography of Urban Transportation*. Third Edition. The Guilford Press New York. 59–85.

Musil, J. & Müller, J. 2008. Inner Peripheries of the Czech Republic as a Mechanism of Social Exclusion. *Czech Sociological Review* **44**, 321–348. (in Czech)

Næss, P. 2006. *Urban Structure Matters. Residential location, car dependence and travel behaviour*. Routledge. London. 344 pp.

Newman, P. & Kenworthy, J.R. 1992. Cities and Automobile Dependence: A Sourcebook. Avebury Technical. Avebury. 388 pp.

Ntziachristos, L., Mellios, G., Tsokolis, D., Keller, M., Hausberger, S., Ligterink, N.E. & Dilara, P. 2014. In-use vs. type-approval fuel consumption of current passenger cars in Europe. *Energy Policy* **67**, 403–411.

Ouředníček, M. 2007. Differential Suburban Development in the Prague Urban Region. *Geografiska Annaler: Series B, Human Geography* **89**, 111–126.

Pucher, J. 1999. The Transformation of Urban Transport in the Czech Republic, 1988–1998. *Transport Policy*, **6**, 225–236.

Stopher, P.R. 2004. Reducing road congestion: a reality check. *Transport Policy* **11**, 117–131.

Špačková, P. & Ouředníček, M. 2012. Spinning the web: New social contacts of Prague's suburbanites. *Cities* **29**, 341–349.

van den Berg, L, Drewett, R., Klaasen, L.H., Rossi, A. & Vijverberg, CH.T. 1982: Study of Growth and Decline. *Urban Europe*. Pergamon Press England, 162 p.

Zolnik, E., Minde, J., Das D.G. & Turner, S. 2010. Supporting planning to co–locate public facilities: A case study from Loudoun County, Virginia. *Applied Geography* **30**, 687–696.