URBAN TRANSPORT ENERGY CONSUMPTION
Belgrade Case Study

by

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Original scientific paper
DOI: 10.2298/TSCI141106039J

More than half of the global population now lives in towns and cities. At the same time, transport has become the highest single energy-consuming human activity. Hence, one of the major topics today is the reduction of urban transport demand and of energy consumption in cities. In this article we focused on the whole package of instruments that can reduce energy consumption and transport demand in Belgrade, a city that is currently at a major crossroad. Belgrade can prevent a dramatic increase in energy consumption and CO_2 emissions (and mitigate the negative local environmental effects of traffic congestion, traffic accidents, and air pollution), only if it: (1) implements a more decisive strategy to limit private vehicles use while its level of car passenger km travelled is still relatively low, (2) does not try to solve its transport problems only by trying to build urban road infrastructure (bridges and ring roads), and (3) if it continues to provide priority movement for buses (a dominant form of public transport), while (4) at the same time developing urban rail systems (metro or light raid transit) with exclusive tracks, immune to the traffic congestion on urban streets.

Key words: *urban transport, energy consumption, Belgrade, world metropolises*

Introduction

In 2009 transport became the highest single energy-consuming human activity. It was responsible for 27.3% of world energy-consumption (compared to 23% in 1973) and finally managed to surpass industry, which dropped from 33% in 1973 to 27.3% in 2009 [1].

Since transport predominantly (95%) relies on a single fossil resource – petroleum, this sector is responsible for 24% of world energy-related greenhouse gas (GHG) emissions, with about three-quarters produced by road vehicles. Over the past decade, transport's GHG emissions have increased at a faster rate than any other energy-using sector.

Moreover, transport activity is expected to grow robustly over the next several decades, and by 2030 total transport energy use and carbon emissions are projected to be about 80% higher than current levels, doubling by 2050. It is estimated that approximately 75% of the projected total increase in world oil demand will ensue from the transport sector [2-4].

The Stern review expects transport to be one of the fastest growing sectors in the future and among the last sectors to bring its energy consumption and emissions down to below current levels [5].

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There are two main factors leading to such a huge increase in energy consumption and CO_2 emissions in transport:
- dependency on the internal combustion engine, with no wide-scale economically viable alternative available in the coming decades, and
- a sharp increase in vehicle kilometres travelled (VKT), which seems to be an inherent feature of economic growth [6], although in previous years there has been growing evidence that in many cities (especially in developed countries) VKT has decoupled from gross domestic product (GDP) [7, 8].

This technological and economic dependency presents a challenging energy efficiency issue.

As recent US National Academy of Sciences studies have clearly shown, energy consumption in transport can be reduced significantly only by a reduction in transport volume, focusing on those transport modes that consume less energy, and increasing the energy efficiency of different transport modes [9].

Joumard [10] rightfully stresses that *only 40% of the effort required should focus on technology, while the remaining 60% should focus on managing demand for transport and the adoption of more sustainable modes of transport*.

Unfortunately, as the intergovernmental panel on climate change (IPCC) clearly points out, transport activity is expected to grow robustly over the next several decades. Unless there is a major shift away from current patterns of energy use, projections foresee a continued growth in global transportation energy use by 2% per year, with energy use and carbon emissions in 2030 about 80% above 2002 levels [2].

Since more than half of the global population now lives in towns and cities, and UN-HABITAT research forecast that this figure will rise to two-thirds by the year 2050 [11], one of the main issues concerning energy consumption is how to limit rapidly rising urban transport energy consumption.

Vuchic [12] has pointed out that urban transport energy consumption estimates usually refer to direct consumption by transportation modes. However, in the longer run, energy consumption is also heavily influenced by urban form and intensity of land use activities, which are, in turn, strongly dependent on the composition of the modes used. For this reason, if in our analysis we include urban form and intensity of land-use activities, energy efficiency could be even greater in the long run.

Kenworthy [13] stresses that in high-income cities, 82% of the variance in car passenger kilometres (pkm) per capita and 78% of the variance in per capita private passenger transport energy use are linked to urban density. In low-income cities, where other factors such as extreme variations in income affect the outcome, still some 47% of the variation in per capita car use and 44% of the variance in per capita private passenger transport energy use are due to urban density.

In this paper, we focus on a comparative analysis of energy use in the urban transport of Belgrade and different world metropolises.

Materials and methods

For Belgrade's urban values, we used raw material census data for 2002 and 2011 (level of statistical circles) and Urban Planning Institute of Belgrade surveys data [14, 15], while for the years 1960 and 1990 (for 41 world metropolises) we used Kenworthy and Laube's 1999 International Sourcebook [16] (given in tab. 1). For 1995 (for 62 world cities) we used UITP Millennium Cities Database [17] (tab. 2).

Table 1. International sample of 41 cities (for 1960 and 1990) [16]

US cities	Western European cities	Wealthy Asian cities	Third World metropolises	Australian cities	Canadian cities
New York Chicago Washington Boston San Francisco Los Angeles Denver Detroit Houston Phoenix	London Paris Stockholm Copenhagen Vienna Zurich Amsterdam Brussels Frankfurt Hamburg Munich	Hong Kong Singapore Tokyo Bangkok	Seoul Manila Jakarta Brisbane Kuala Lumpur Surabaya	Sydney Melbourne Perth Brisbane Adelaide	Toronto Montreal Vancouver Ottawa Calgary Edmonton

Table 2. International sample of 62 cities (for 1995) [17]

US cities	Western European cities		Wealthy Asian cities	Third World metropolises	Cities in transition	Chinese cities
Atlanta Chicago Denver Houston Los Angeles New York Phoenix San Diego San Francisco Washington	Graz Vienna Brussels Copenhagen Helsinki Lyon Nantes Paris Marseilles Berlin Frankfurt Hamburg Dusseldorf Munich Ruhr Stuttgart	Athens Milan Bologna Rome Amsterdam Oslo Barcelona Madrid Stockholm Bern Geneva Zurich London Manchester Newcastle Glasgow	Osaka Sapporo Tokyo Hong Kong Singapore Taipei	Manila Bangkok Mumbai Chennai K. Lumpur Jakarta Seoul HCM City	Prague Budapest Krakow	Beijing Shanghai Guangzhou

Since the gross (administrative) area was of no particular use to our analysis (because it includes an arbitrary amount of non-urban land, depending on how far out the boundaries are set, *etc*.), we used net-urbanised area based on land-use categories of urban and non-urban land given in tab. 3.

For the urban public transport mobility in Belgrade (year 2011) we used data collected from public transport operators (24 hours/7 days per week) and Statistical Yearbooks for Belgrade [18] for each mode: bus, trolley bus, tram, and urban rail. The VKT for different urban public transport modes in Belgrade for 2011 were: for buses 126,288,000, for trams 12,539,000, for trolley buses 5,781,000, and for urban rail (BG train) 740,000. The load factor (ratio of passenger kilometres to available seat kilometres) for buses was 32.7%, for trams 19.3%, for trolley buses 25.1%, and for urban rail (BG train) 35.1%.

Private car vehicle kilometres data were derived from major transport studies: *Belgrade transport model* [19] and *Study of the characteristics of transport demands, transport supply, efficiency and quality of the system of mass public transport of passengers in Belgrade* [20], and it was surveys conducted by authorities (assumed car occupancy was 1.31 passengers

Table 3. Assignment of the most common land use categories to urban and non-urban land [16, 17]

Land use category	Type*	Comment
Agricultural	n/u	
Meadows, pastures	n/u	
Gardens, local parks	u	These areas are not generally built up, but in their size they are generally too small and in their human recreational use are too intense to qualify as genuine non-urban land.
Regional scale parks	n/u	These are large, contiguous areas set aside within metropolitan areas for non-intensive or restricted recreational uses, water catchment functions, green belts *etc*.
Forest, urban forest	n/u	Urban forests are larger than parks and are often significant wildlife and forestry areas.
Wasteland (natural)	n/u	This includes flood plains, rocky areas and the like.
Wasteland (urban)	u	This includes derelict land, culverts *etc*.
Transportation	u	Road area, railway land, airports *etc*.
Recreational	u, n/u	Depending on the intensity of use, this group can belong partly in either category. Golf courses are urban, as their use is intense, while skiing areas for example are less intense in use and generally large and therefore non-urban. Mostly, however, recreational land is considered urban.
Residential	u	
Industrial	u	
Offices	u	
Commercial	u	
Public Utilities	u	
Hospitals	u	
Schools, Cultural uses	u	
Sports grounds	u	
Water surfaces	n/u	

* u = urban; n/u = non-urban

[19, 20]). Private car-fleet data were collected from the Ministry of Interior and major vehicle insurance companies.

For public transport energy consumption, we collected actual litres of diesel, petrol, and kWh of electricity from the operators (traction only). For private transport car energy consumption we made calculations based on the (estimated) car VKT data found in surveys and major transport studies.

Conversion factors from fuel types to energy are given in tab. 4.

Table 4. Conversion factors from fuel types to energy [16]

Fuel type	Conversion factor
Motor spirit (petrol/gasoline)	34.69 MJ/l
Automotive distillate (diesel)	38.29 MJ/l
Liquefied petroleum gas	26.26 MJ/l
Electric power	3.60 MJ/kWh

For the comparative analysis of the different scenarios of Belgrade's future urban transport energy consumption, we used the mobility levels of metropolises in countries in transition and in West European metropolises from the Millennium Cities Database [17]. For the calculation of Pearson's correlation coefficient we used statistical SPSS software.

Belgrade's spatial development

Belgrade can be divided into four concentric zones: central, middle, outer, and edge (tabs. 5. and 6, figs. 1 and 2).

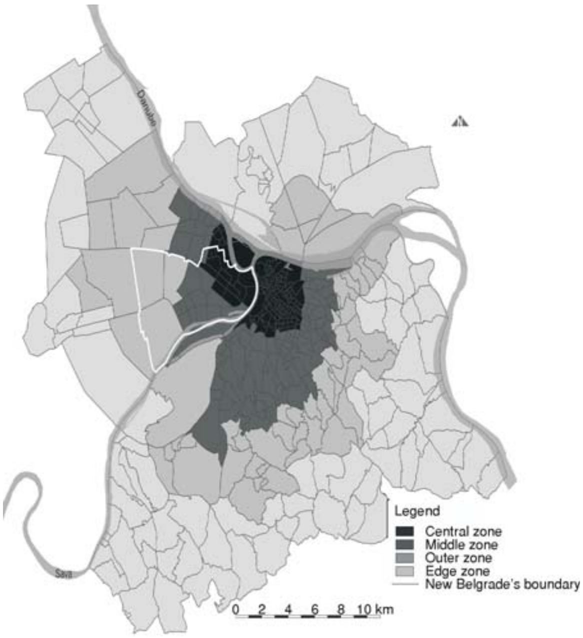

Figure 1. Zones (and statistical circles) of Belgrade

Table 5. Spatial distribution of population and densities of Belgrade's zones [14, 15]

Zone	Net-urbanised area [km^2]		Population		Population densities [inhabitants per km^2]	
	year 2002	year 2010	year 2002	year 2011	year 2002	year 2011
CBD	3.640	3.640	50,447	43,697	13,841	11,989
Central zone	24.754	24.825	298,559	276,635	12,061	11,143
Middle zone	57.064	57.665	533,401	542,859	9,347	9,413
Outer zone	65.059	71.184	257,657	314,319	3,960	4,415
Edge zone	79.935	87.526	174,810	205,052	2,186	2,342
Master plan (MP)	226.812	241.20	1,264,427	1,338,865	5,575	5,551
Continuously built-up area (CBA)	146.877	153.674	1,089,617	1,133,813	7,419	7,378

Source: Author's calculation (explained in the section *Materials and methods*)

Table 6. Spatial distribution of jobs through Belgrade's zones [14, 15]

Zone	Jobs 2002	Net-urbanised area 2002	Job densities 2002.	% share of jobs (in MP)	% share of jobs (in CBA)
CBD	121,941	3.640	33,457	28.20	29.69
Central zone	236,046	24.754	9,535	54.65	57.46
Middle zone	136,534	57.064	2,392	31.61	33.24
Outer zone	38,186	65.059	586	8.84	9.30
Edge zone	21,183	79.935	265	4.90	–
Master plan (MP)	431,949	226.812	1,904	100	–
Continuously built-up area (CBA)	410,766	146.877	2,797	–	100

Source: Author's calculation (explained in the section *Materials and methods*)

In the last twenty years, a distinctive feature of Belgrade has been the rapidly developing new business district (NBD) of New Belgrade, in the vicinity of and spatially inter-connected with the old city core, central business district (CBD) [21]. Hence, Belgrade's highly monocentric structure has become even more pronounced, since 28.2% of all MP work places are concentrated in the traditional CBD with an additional 7.4% in New Belgrade's NBD (just across the river) (tab. 7 and fig. 2).

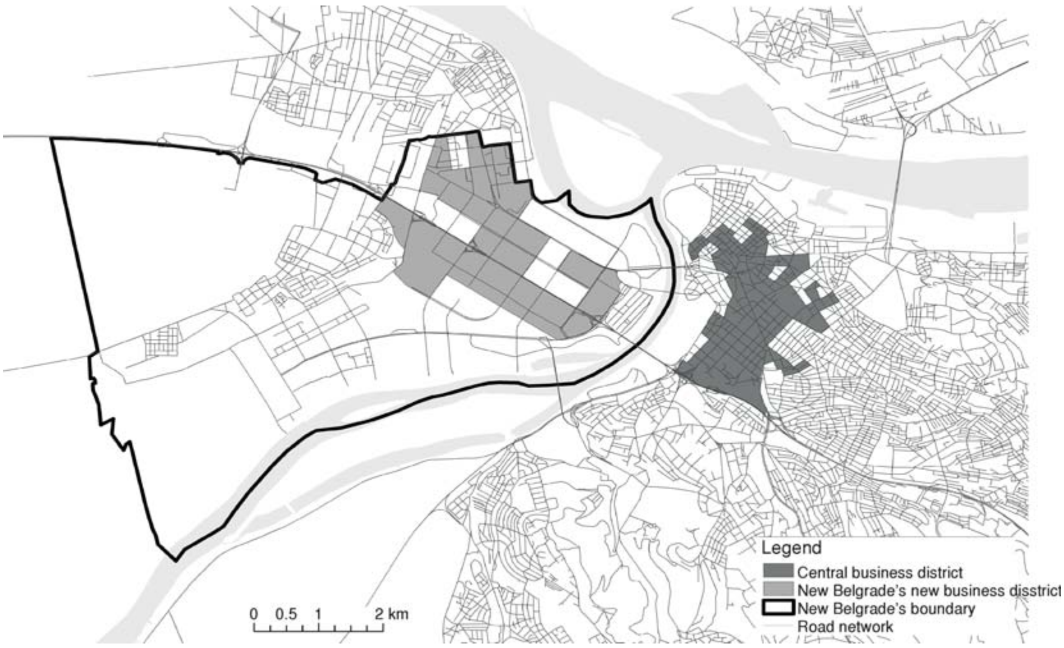

Figure 2. Belgrade's CBD and New Belgrade's NBD [21]

Table 7. Share of jobs of old CBD and New Belgrade's NBD of all Belgrade's MP area jobs, in 2002 (in %) [21]

Area	Work places (in %)	Net-urbanised area [km^2]	Job densities	% share of jobs (in MP)	% share of jobs (in CBA)
CBD – old Belgrade	28.2	3.640	33,457	28.20	29.69
NBD – New Belgrade	7.4	4.730	6,738	7.41	7.76
Total	35.6	8.370	18,379	35.61	37.45

It is evident that the average population density of the CBA of Belgrade (that consists of central, middle, and outer zones) is rather high (7,419 inhabitants per km^2) and that during 2002-2011, major changes occurred in the outer and edge zones – with an increase of 87,000 inhabitants and 13.7 km^2 of net-urbanized area (whereas the middle zone gained only 9,500, the central zone lost 22,000 and the CBD lost 16,191 inhabitants) (tab. 5).

In short, the main characteristics of Belgrade's spatial development are high levels of population density (9,500-12,000 inhabitants per km^2 in its central and middle zone), and a very high level of centralization (28.2%) of employees in the CBD (tab. 6 and tab. 7) [21]. This is fertile ground for introducing high capacity rapid rail rapid transit systems (light rail transit (LRT) or metro systems) [12]. Newman and Kenworthy [22] point out that long-term data from cities around the world show that there is a fundamental threshold of urban intensity (residents and jobs) of around 35 per hectare to support public transit – a threshold Belgrade evidently exceeds (tabs. 5 and 6).

Belgrade's urban transport energy consumption from an international perspective

The degree of energy consumption in urban transport, resulting from the rapid increase in automobile passenger kilometres (tabs. 8 and 9), is, unfortunately, usually neglected [23].

Table 8. Passenger kilometres per capita in 24 cities (1960 and 1990) [16, tab. 1]

Cities	Automobile (pkm/per capita)		Public urban transport (pkm/per capita)	
	1960	1990	1960	1990
USA*	8,289	14,981	666	620
Australia	5,489	10,797	1,409	882
Western Europe	2,503	6,602	1,472	1,895

* Data for 1960 are not available for Washington, Detroit, and Houston

Both load factors and the degree of mobility of different urban transport modes directly depend on:
- income changes and economic development,
- transport infrastructure investments and the choice of transport technology,
- prices and economic instruments, and
- interdependence of transport and urban form, and the influence of urban planning policy [24].

Table 9. Urban transport in 63 cities (in passenger kilometres) (1995) [17, tab. 2]

Cities	Urban transport – total [pkm]	Private transport (automobile + motor-cycle) [pkm]	Urban public transport (total) [pkm]	Urban public transport share in total pkm [%]
USA	18,743	18,200	544	2.9
W. Europe	7,804	6,321	1,483	19.0
Wealthy Asian	7,340	3,971	3,369	45.9
Developing	4,303	2,539	1,764	41.0
China	2,451	1,103	1,348	55.0
In transition	6,225	2,926	3,299	53.0
Belgrade*	6,066	1,502	4,563	75.2

* Author's calculation for Belgrade for 2011

As Kenworthy [25] points out: *Meaningful results can be obtained from energy use per passenger km because this takes into account vehicle loadings. It is also the only way to fairly compare public and private transport energy efficiency*. Taking into account these different load factors of urban transport modes, comparative analysis of the indicators of energy consumption per passenger kilometre of urban transport in world metropolises is given in (tab. 10) [16, 24].

Table 10. Energy consumption of urban transport in 63 cities (in MJ per passenger km) (1995) [17, tab. 2]

Cities	Private transport (automobile + motor cycle) [MJ/pkm]	Bus [MJ/pkm]	Tram [MJ/pkm]	Metro [MJ/pkm]	Energy use ratio of different transport modes		
					Private tr./Bus	Bus/Metro	Private tr./ Metro
USA	3.25	2.85	0.99	1.65	1.1	1.7	1.97
W. Europe	2.49	1.17	0.72	0.48	2.1	2.4	5.2
Wealthy Asian	2.33	0.84	0.36	0.19	2.9	4.4	12.3
Developing	1.78	0.66	–	0.46	2.7	1.4	3.9
China	1.69	0.26	–	0.05	6.5	5.2	33.8
In transition	2.35	0.56	0.74	0.21	4.2	2.7	11.2
Belgrade*	2.10	0.44	0.375	0.16**	4.8	2.75*	13.1*

* Author's calculation for Belgrade for 2011; ** Urban rail (BG train)

In Belgrade, automobiles consume 4.8 times more energy than buses (the main transport mode with an 87.3% share of public transport passenger kilometres) and 13 times more than urban rail (BG train). In the USA, private transport (automobile and motorcycle) consumes 14% more energy than buses and 2 times more than the metro system, in Western Europe, it consumes 2 times more energy than buses and 5 times more than the metro system, in wealthy Asian cities, 3 times more than buses and 12 times more than the metro system, in Third World metropolises private transport consumes 3 times more than buses and 4 times more energy per passenger kilometre than the metro system, and in countries in transition and China, 4-6.5 times more energy than buses and 11-34 times more than the metro.

In tab. 11 indicators of mobility (expressed in passenger km per capita) and energy consumption in urban transport of different world metropolises (expressed in MJ per capita) [23, 24] are given.

Table 11. Energy consumption in urban transport (in MJ/ per capita) and the average daily motorized mobility in 63 cities (in pkm per capita) (1995) [17, tab. 2]

Cities	Average daily motorized mobility		Daily private mobility (automobile + motorcycle)			Urban transport energy use	
	pkm per capita	Ratio world metropo-lises/USA cities (=1)	pkm per capita	Ratio world metropo-lises/USA cities (=1)	Private mobility share in pkm per capita (%)	MJ per capita	Ratio world metropolises/ Belgrade (=1)
USA	51.3	1	49.9	1	97.2	60,843	12.0
W. Europe	21.4	2.4	17.3	2.9	80.8	16,793	3.3
Wealthy Asian	20.1	2.55	10.9	4.6	54.2	10,979	2.2
Developing countries	11.8	4.36	7.0	7.1	59.3	6,635	1.3
China	6.7	7.65	3.0	16.6	44.8	2,917	0.6
In transition	17.1	3.01	8.0	6.2	46.8	7,903	1.6
Belgrade*	16.6	3.09	4.1	12.2	24.8	5,083	1

* Author's calculation for Belgrade for 2011

The high value of Pearson's correlation coefficient (0.963) for automobile passenger kilometres per capita and total energy consumption of urban transport (for our sample of 41 metropolises (see tab. 1) illustrates the importance of automobile mobility in the total energy consumption in urban transport (fig. 3).

Thus, it is apparent that the increase in the efficiency of motor vehicle fuel consumption – a thesis frequently promoted by supporters of an auto-dependent transport policy, such as Dunn [26] – does not save energy in urban transport. The most important role in this process is clearly played by the rapid rise in level of mobility, and the sharply increasing share of automobiles use in urban transport.

These are the main reasons why US cities, with their highest level of motorized mobility in the world, also have the highest energy consumption per capita ever registered in urban transport [23, 24].

At the same time, urban transport energy consumption in developing world metropolises is almost insignificant today. Their energy consumption is 9.2

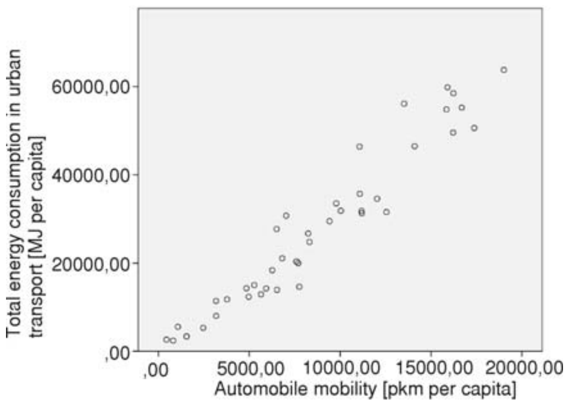

Figure 3. Correlation between automobile mobility and total energy consumption in urban transport

times lower than that of US cities. However, due to the fact their populations will be 4 times larger than the population of the developed world metropolises by 2025 (doubling within the 2000-2025 period from 735,000,000 to 1,413,000,000) [27]), a further increase in motor vehicle use in developing countries will have devastating effects on global energy consumption (and CO_2 emissions). If the developing metropolises follow the example of the auto-dependent, low-density suburban development, unforeseeable consequences in the succeeding decades will ensue, with energy consumption in their urban transport 18 times higher!

In short, it is obvious that major savings in the energy consumption of Belgrade urban transport are to be made in stopping its further increase in automobile mobility.

Results and discussion – different scenarios for Belgrade's future urban transport energy consumption

Compared to other world metropolises, Belgrade has a relatively low level of total energy consumption in urban transport today. Belgrade is now at major crossroad, whether to follow the current unsustainable transport trajectory, or to shift towards a more sustainable urban transport policy.

Unlike other Eastern European countries, where (due to economic restructuring, *etc*.) during the mid-1990s the level of private motorization rose quickly, but was not accompanied by a significant rise in automobile passenger kilometres travelled (PKT) [28], in Belgrade (due to the economic crisis) neither the level of private motorization (300 cars per 1,000 people), nor automobile passenger kilometres have changed much during the last 15 years (the only change being that old vehicles were replaced with second-hand cars, imported from Western Europe). Nevertheless, although the level of automobile energy consumption in Belgrade is still very low – 3,162.2 MJ per capita, due to the low volume of automobile passenger kilometres (1,502 pkm), the fact must not be overlooked that automobile mobility is of major importance to total level of energy consumption in urban transport, and it can change surprisingly quickly. In tab. 12, we gave different scenarios of Belgrade's future urban transport energy consumption: (a) current energy consumption, (b) energy consumption when Belgrade reaches the automobile mobility level of cities in countries in transition, and (c) energy consumption when Belgrade reaches the automobile mobility level of cities in Western Europe.

Belgrade's urban transport energy consumption will be 1.72 times higher when the city reaches the automobile mobility level of metropolises in countries in transition recorded in 1995 (tabs. 10 and 11). When the automobile mobility level of metropolises in West European countries recorded in 1995 is reached (tabs. 10 and 11), it will be 3.5 times higher. Hence, traffic limi-

Table 12. Different scenarios of Belgrade's future urban transport energy consumption [17, tab. 2]

	Automobile [pkm]	Urban public transport [pkm]	Total [pkm]	Automobile [MJ per capita]	Urban public transport [MJ per capita]	Total [MJ per capita]
Belgrade today	1,502	4,563	6,066	3,162.18	1,921.02	5,083.21
Belgrade – "East EU" scenario	2,907	4,563	7,470	6,831.45	1,921.02	8,752.47
Belgrade – "West EU" scenario	6,202	4,563	10,765	15,675	1,921.02	17,596.02

Source: Author's calculation according to tab. 2 [17] tation strategies (like those applied in Singapore, Hong Kong, London, *etc*.) are of the utmost importance.

Belgrade's urban public transport share in total urban transport energy consumption (approximately 38%) is the highest in our sample of cities. Due to its extremely high share of regular buses, urban public transport of Belgrade is not as energy-efficient as it could be (tabs. 13 and 14). As our comparative analysis of urban transport energy consumption of world metropolises showed (tab. 10), if urban form (high population densities and concentration of jobs in the CBD) supports rail use, it is much more energy efficient than regular buses – even the old Russian urban rail proved to be three times more energy efficient (tab. 10), with the recently imported and tested Swiss (Flirt) urban train even 7.6 times more energy efficient, than buses in Belgrade.

Table 13. Urban public transport share in total urban transport energy consumption (in %) (1995) [17, tab. 2]

Cities	Urban transport energy consumption [MJ/per capita]			Urban public transport share in total urban transport energy consumption (in %)
	Total [MJ per capita]	Private (automobile + motorcycle) (MJ per capita)	Urban public transport [MJ per capita]	
USA	60,843	60,034	809	1.3
W. Europe	16,793	15,675	1,118	27.6
Wealthy Asian	10,979	9,556	1,423	13.0
Developing	6,635	5,523	1,112	16.8
China	2,907	2,498	419	14.4
In transition	7,903	6,661	1,242	15.7
Belgrade*	5,083.2	3,162.2	1,921	37.8

* Author's calculation for Belgrade for 2011

Table 14. Belgrade's urban public transport energy consumption for 2011 (% share)

	Bus	Tram	Trolley-bus	Urban rail (BG train)
% share	90.7%	6.8%	1.5%	1%

Source: Author's calculation (explained in the section Materials and methods)

Unfortunately, Belgrade has not been doing much in this respect. For example, another serious transport issue is the lack of valid urban public transport strategy (Belgrade can be defined as a typical *public transport city*; see classification in [29,30]. So far, the public transport strategy has concentrated on buses, incapable of accommodating the rapidly rising transport demand, and on the introduction of parking zones in the central area of the city.

Although express-buses are strongly promoted lately [31], Belgrade is completely unsuitable for this type of transport strategy (especially in its central zone) due to its spatial structure and its narrow, inadequate street network [32].

Commuting over bridges between new and old part of Belgrade is characterized by huge traffic congestions [32]. City authorities, unfortunately, chose not to prevent, but merely to treat the problem, attempting to quickly build a network of urban road infrastructure. The recent construction of an inner semi-ring road and additional bridges over the Sava River has been done without an accompanying strategy of land-use changes and without considering infrastructure-induced mobility (so-called hidden transport demand [33]). Hence, these huge investments are merely a temporary antidote, and not a long-lasting, valid solution.

It is usually completely overlooked that with its strong public transport (bus) orientation, insufficient street capacities (about 67% of the primary urban street network are single lane per direction [30]), as well as its frequent and heavy road congestions, Belgrade has for a very long time been ready not only for a much stricter private motor vehicle limitation strategy, but also for a rail (metro or LRT) system, with completely separated, exclusive right of way [23, 30].

As Vuchic [12] points out, a transit mode is defined by its three basic characteristics: (a) right-of-way category, (b) system technology, and (c) type of service. Transit modes vary with each one of these characteristics. Belgrade has struggled with the strategic decision of choosing between a metro, LRT or express-bus option. However, contrary to the common belief that technology mostly determines modal characteristics, the right-of-way category has a major influence on both performance and costs of modes [12].

During the past decades, different rail proposals have substituted each other, from metro (in 1958, 1968, 1976, 1982, and 2004), to LRT (in 2006) [34]. It is usually stressed that for the construction of a new urban rail system, more than five million people and above US$ 1,800 of GDP per capita are needed for a project to be economically viable [35]. But, as Vuchic [12] rightly points out, it is not such a simple, straightforward relationship, since high population densities and the high level of job concentration in the CBD are even more important.

In this respect especially encouraging was the recent introduction (2011) of BG train, a 25 kilometre line of urban rail system (with 7 km running through tunnels under the central part of the city, at 15-minute intervals during the rush hours) that serves the city of Belgrade. This first urban rail line runs through six Belgrade municipalities: Zemun, Novi Beograd, Savski Venac, Vračar, Zvezdara, and Palilula, with over 700,000 inhabitants in total (the residential areas of these municipalities through which the line runs have approximately 200,000 inhabitants).

In short, a variety of measures can counter rising energy consumption in the urban transport sector. The most obvious choice for Belgrade is the package of measures: (a) measures that limit the use of motor vehicles and promote improvement of their technical efficiency, (b) the promotion of public transport, walking and cycling, and (c) spatial-planning measures aimed at reducing the total demand for transport in the city.

Precisely defined phases of implementation of these urban transport policy measures are here of great importance. The phase in which restrictive instruments on private transport and measures for the promotion of urban public transport are introduced is crucial. While the degree of private car use is still relatively modest, it is very likely that the applied package of measures will obtain the desired results.

In this context, it can be concluded that Belgrade can prevent a dramatic increase in energy consumption and CO_2 emissions (and mitigate the negative local environmental effects off traffic congestion, traffic accidents, and air pollution) only if it:

– implements a more decisive strategy of limiting private vehicles use, while its level of car PKT is still relatively low (as was done in the wealthy Asian metropolises and Seoul, at a similar stage of development),
– does not try to solve its transport problems only by building a network of urban road infrastructure (bridges and ring roads),
– continues to provide priority movement for buses (a dominant form of public transport), while

– strongly orients itself towards the development of the urban rail systems (metro or LRT) with separate, exclusive tracks, which are completely immune to the traffic congestion on the urban streets.

In short, if Belgrade adopts a transport and spatial development strategy like the one wealthy Asian metropolises applied at a similar stage of development [24, 36], there is a good chance that its total urban transport energy consumption will stop at a reasonable level, around 7,000-10,000 MJ per capita.

Conclusions

It is evident that the strongly promoted thesis that significant savings in energy in the sphere of urban transport could be made by increasing the efficiency of motor vehicles has not provided the planned results. This is clearly proven in the huge energy consumption in the urban transport of US cities.

The most important role in this process is definitely played by the dramatically increasing level of personal mobility and the sharp rise of automobile use in urban transport.

These are the main reasons why US cities, which have the highest level of motorized mobility and use of automobiles in the world, also have the highest level of energy consumption in urban transport ever recorded.

If the metropolises of developing countries follow the example of the auto-dependent, low-density suburban development of US cities, as is imposed by globalization, there will be unforeseeable consequences in the succeeding decades. It will result in 18-times higher energy consumption in their urban transport in 2025 (compared to 2000).

Obviously, Belgrade is now at a major crossroad. Only if it adopts transport and spatial development strategy similar to that applied by wealthy Asian metropolises at a similar stage of development, is there a very high possibility that its total urban transport energy consumption will stop at a reasonable level, around 7,000-10,000 MJ per capita.

Acknowledgments

This paper contains the research results of the project No 37010 funded and supported by the Ministry of Science and Technological Development of the Republic of Serbia.

References

[1] ***, Key World Energy Statistics, OECD/IEA, 2011
[2] Metz, B., *et al*., (Eds.) Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 2007
[3] ***, World Energy Outlook 2008, IEA, 2008
[4] Creutzig, F., *et al.*, Climate Policies for Road Transport Revisited (I): Evaluation of the Current Framework, *Energy policy, 39* (2011), 5, pp. 2396-2406
[5] Stern, N., The Economics of Climate Change: Stern Review, Cambridge University Press, Cambridge, UK, 2007
[6] Raux, C., The Potential for CO_2 Emissions Trading in Transport: the Case of Personal Vehicles and Freight, *Energy Efficiency, 3* (2010), 2, pp. 133-148
[7] Kenworthy, J., Decoupling Urban Car Use and Metropolitan GDP Growth, *World Transport Policy and Practice, 19* (2013), 4, pp. 7-21
[8] Newman, P., Kenworthy, J., 'Peak Car Use': Understanding the Demise of Automobile Dependence, *World Transport Policy and Practice, 17* (2011), 2, pp. 31-42
[9] ***, Limiting the Magnitude of Climate Change, National Academy of Sciences, Washington DC, USA, 2010

[10] Joumard, R., The Stakes of air Pollution in the Transport Sector, from the French Case, *Atmospheric Environment, 39* (2005), 13, pp. 2491-2497
[11] ***, Urban Patterns for a Green Economy: Leveraging Density, UN-HABITAT, 2012
[12] Vuchic, V., *Urban Transit Systems and Technology*, John Wiley and Sons, New York, USA, 2007
[13] Kenworthy, J., Energy use and CO_2 Production in the Urban Passenger Transport Systems of 84 International Cities: Findings and Policy Implications, in: *Urban Energy Transition: from Fossil Fuels to Renewable Power* (Ed. P. Droege), Elsevier, Amsterdam, The Netherland, 2008
[14] ***, Census Data for 2002 and 2011 (Level of Statistical Circles), Statistical Office of the Republic of Serbia
[15] ***, Land-Use Categories of Belgrade's Master Plan Area (for 2002 and 2010), Urban Planning Institute of Belgrade, Belgrade, 2011
[16] Kenworthy, J., *et al*., An International Sourcebook of Automobile Dependency in Cities, University Press of Colorado, Boulder, Col., USA, 1999
[17] Kenworthy, J. R., Laube, F., The Millennium Cities Database, UITP, Brussels, Belgium, 2001
[18] ***, Statistical Yearbook of Belgrade 2011, Institute for Informatics and Statistics, Belgrade, 2012
[19] ***, Belgrade Transport Model, Faculty of Transport and Traffic Engineering (In Serbian), Belgrade, 2007
[20] ***, Study of the Characteristics of Transport Demands, Transport Supply, Efficiency and Quality of the System of Mass Public Transport of Passengers in Belgrade (in Serbian), Faculty of Traffic and Transport Engineering – Institute SF, Belgrade, 2002
[21] Jovanović, M., Ratkaj, I., Functional Metamorphosis of New Belgrade, *disP – The Planning Review, 50* (2014), 4, pp. 54-65
[22] Newman, P., Kenworthy, J., Urban Design to Reduce Automobile Dependence, *Opolis, 2* (2006), 1, pp. 35-52
[23] Jovanović, M., Interdependence of Urban Transport Strategy and Spatial Development of a Metropolis (in Serbian), Faculty of Geography, University of Belgrade, Belgrade, 2005
[24] Barter, P., An International Comparative Perspective on Urban Transport and Urban Form in Pacific Asia, Murdoch University, Perth, Australia, 2000
[25] Kenworthy, J., Transport Energy use and Greenhouse Gases in Urban Passenger Transport Systems: A Study of 84 Global Cities, Third Conference of the Regional Government Network for Sustainable Development, Notre Dame University, Fremantle, Australia, 2003
[26] Dunn, J., Driving Forces; The Automobile, its Enemies and the Politics of Mobility, The Brookings Institution, Washington DC, 1998
[27] ***, World Urbanization Prospects: the 2009 revision, United Nations, New York, USA, 2010
[28] Chatelus, G., *et al*., Central and Eastern European Countries, in: *Transport*: *New Problems, New Solutions*, ECMT, Paris, 1996
[29] Newman, P., Kenworthy, J., *Sustainability and Cities: Overcoming Automobile Dependence*, Island Press, Washington DC, 1999
[30] Jovanović, M., Sustainable Urban Transport and Spatial Development of Belgrade, in: *Sustainable Urban & Transport Planning – SUTP 2013* (Ed. N. Martins), UNIDO, Belgrade, 2013, pp. 75-84
[31] ***, Cities on the Move, World Bank, Washington DC, 2002
[32] Jović, J., Djorić, V., Traffic and Environmental Street Network Modelling: Belgrade Case Study, *Transport, 25* (2010), 2, pp. 155-162
[33] Cervero, R., Hansen, M., Induced Travel Demand and Induced Road Investment: A Simultaneous Equation Analysis, *Journal of Transport Economics and Policy, 36* (2002), 3, pp. 469-490
[34] Korica, R., Furundzic. D., Metro or Light Rail: Belgrade Transport Proposals, *Proceedings*, Real Corp 2011- Change for Stability: Lifecycles of Cities and Regions, Essen, Germany, 2009, pp. 613-621
[35] Loo, B., Li, D., Developing Metro Systems in the People's Republic of China: Policy and Gaps, *Transportation, 33* (2006), 2, pp. 115-132
[36] Jovanović, M., Urban Transport and Environment (in Serbian), Faculty of Geography, University of Belgrade, Belgrade, 2014

Paper submitted: November 6, 2014
Paper revised: March 8, 2015
Paper accepted: March 22, 2015