On commuting-related energy consumption and its spatial patterns

Tomáš Peltan
Department of Spatial Planning
Faculty of Architecture, CTU in Prague
tomas.peltan@gis.cvut.cz

Transport energy risks and problems

- risks in areas of mining – geopolitical, natural
- natural limits of maximum exploitation of the resources – „peak oil“
- risks for transportation, processing and distribution (e. g. piracy, political unstability in transit countries, extreme weather events, large strikes…)
- changing patterns of consumption
- decreasing reserve mining capacity
- externalities of energy use (CO_2, environmental damage in mining areas)

Effort to increase energy efficiency

- areas of substantial improvements:
  - household appliances
  - light sources
  - car engines
  - houses
- legal tools and subsidies
- passive house in urban-sprawl area?
- energy efficiency of spatial structure of settlement?

Energy availability as the driver of spatial development

- development of American metropolis (Muller, 2004):
  - – walking and horse-drawn era
  - – streetcar and commuter railway era
  - – „recreational“ driving era (diffused car-based)
  - – motorway era
- similar development in Czech republic:
  - – interwar suburbanization in railway corridors
  - – car-driven urban sprawl of both both forms

Spatial structure and enegy consumption

- city level research
  - Newman, Kenworthy (1989, 1999): low density and high per capita and per GDP consumption
    - high consumption in USA, Australia
    - moderate to low consumption in Europe and rich SE Asia (Hong Kong, Singapore)
  - da Silva et al. (2007): cities in Brazil, consumption is best explained by density and shape (proportion of maximum EW and SN dimensions)
  - Naess (2006) – Copenhagen region
    - energy consumption 11 520 – 20 160 MJ per capita and year
    - main factors: distance to first and second order centre, distance to train station, workplace and residential density in area surrounding the dwelling

Criticism

- other non-spatial factors
  - income levels
  - demographic characteristics
  - personal preferences and history
  - impacts of weather
- self-sorting effects (Pinjari et al. 2007)
- reaction
  - advanced statistical analysis (Naess 2006)
  - per USD GDP rather than per capita normalization (Newman, Kenworthy 1999)
  - minimum commute analysis (Boussauw et al. 2011)

Energy security approach

- time scale of different activities
- vulnerability in the case of rather short-term events
  - supply disruption
  - price disturbances
- Krumdieck et al. (2010)
  - essentiality of trips (essential, necessary, optional)
  - different scenarios of spatial development („Concentration“, „Disperse“…) – different impacts
- Rendall et. al. (2010)
  - the idea of minimum energy necessary for access to important activity
  - incorporates the „active modes“ as means of adaptation
  - application of this method in Czech Republic for school commuting (Tuček, Peltan 2011)

Aims of the research

- to explore the transport energy consumption related to the spatial structure of the settlement in the Czech Republic
- working hypotheses
  - There is substantial difference in energy consumption for commuting between different municipalities.
  - The per capita energy intensity of commuting is of the same or higher order as the energy needed for heating and operation of the state-of-the-art family house.
  - The municipalities in suburban zones are among the most energy intensive.

The analysis

- based on Czech Statistical Office data on commuting – 2001 census
- ZABAGED data on roads and railroads used for estimating the distances
  - car, bus: along the road network between definitional points of the cities
  - train: for municipality pairs with distance from railway up to 5 km the distance along railway network, distance along road network otherwise

Estimating energy use

The energy was calculated with this formula:

$$E_i = 2.\left(n_p - n_d\right)\sum_j \sum_m n_{ijm.}.\, d_{ijm} e_m$$

Where:

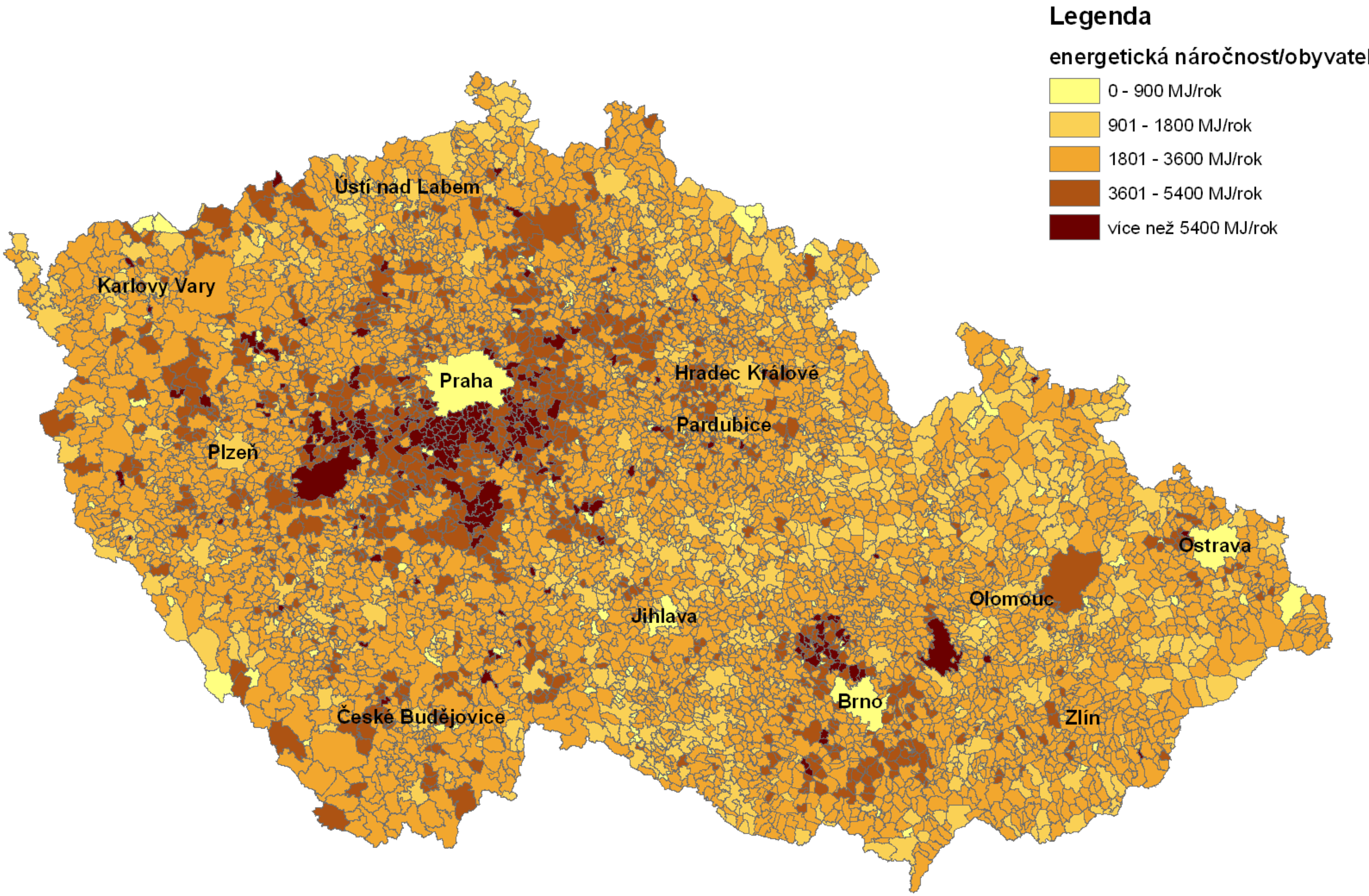
- E_i is the total amount of energy for commuting from municipality i to other municipalities
- n_p is the number of work days per year
- n_d is the number of vacation days per year
- n_{ijm} is the adjusted number of commuters from municipality i to municipality j using mode m
- d_{ijm} is the distance between municipalities i and j for mode m
- e_m is the energy intensity of mode m per unit of distance

Energy intensity of tranport modes

- based on (Schafer and Victor, 1999):

Transport mode	Energy intensity e_m
private owned vehicles (individual car transport)	2.2 MJ/person.km
bus	1.1 MJ/person.km
train (average for diesel and electric train)	0.9 MJ/person.km

- similar values used in other research (Naess, 2006, Marique and Reiter, 2012)


Legenda
energetická náročnost/obyvatel
0 - 900 MJ/rok
901 - 1800 MJ/rok
1801 - 3600 MJ/rok
3601 - 5400 MJ/rok
více než 5400 MJ/rok
Ústí nad Labem
Karlovy Vary
Praha
Hradec Králové
Pardubice
Plzeň
Ostrava
Olomouc
Jihlava
Brno
České Budějovice
Zlín

Conclusions

- location-related energy becomes dominant energy consumption of state-of-the-art houses
- the fast growth in most inefficient areas can be interpreted as deficit in territorial and spatial planning and governance
- limitations of analysis presented
- need for further research to develop tools for assessment in planning and explore other dimensions of energy use, e. g. energy security issues

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(1), s.42–60.
- Krumdieck, S., Page, S. & Dantas, A., 2010. Urban form and long-term fuel supply decline: A method to investigate the peak oil risks to essential activities. *Transportation Research Part A*, 44, s.306–322.
- Marique, A.-F. & Reiter, S., 2012. A method for evaluating transport energy consumption in suburban areas. *Environmental Impact Assessment Review*, 33(1), s.1–6.
- Muller, P.O., 2004. Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis. V S. Hanson & Giuliano, ed. *Geography of Urban Transportation*. New York: The Guilford Press.
- Naess, P., 2006. *Urban Structure Matters. Residential location, car dependence and travel behaviour.*, London and New York: Routledge.
- Newman, P. & Kenworthy, J.R., 1989. *Cities and Automobile Dependence: A Sourcebook*, Aldershot: Gower.
- Newman, P. & Kenworthy, J.R., 1999. *Sustainability and cities□: overcoming automobile dependence*, Washington: Island Press.
- Pinjari, A.R. et al., 2007. Modeling residential sorting effects to understand the impact of the built environment on commute mode choice. *Transportation*, 34(5), s.557–573.
- Rendall, S. et al., 2010. The Minimum Energy Transport Activity Access Model. V *4th International Conference on Sustainability Engineering and Science*. Auckland, New Zealand.
- Schafer, A. & Victor, D.G., 1999. Global passenger travel: implications for carbon dioxide emmisions. *Energy*, 24, s.657 – 679.
- 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(3), s.44–50.
- Tuček, I. & Peltan, T., 2011. Aplikace metodiky minimum energy transport activity access model na dojížďku do základních a středních škol. V *Udržitelná sídla, sborník příspěvků z mezinárodního workshopu.* Udržitelná sídla. Hostětín: Český svaz ochránců přírody Veronica.