ROAD CAPACITY IN CITIES – HOW THE VEHICLE FLEET MIX INFLUENCE THE LEVEL OF SERVICE

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ABSTRACT

Road congestion is a growing problem all over the world. In nearly all developed and undeveloped countries road transport is growing rapidly and causes congestion. Traditional solutions to overcome congestion are the increase of road capacity and the use of ICT. Road capacity increase faces a natural limit in cities and metropolitan areas and so the application of ICT seems to be a cheap and effective solution.

In this paper the results of empirical road traffic counts are shown. The investigations were carried out in three different countries (cities) with three different developing stages. The countries are Austria (Vienna), Thailand (Bangkok) and Vietnam (Ho Chi Minh City).

It will be shown that the vehicle fleet mix (cars and 2wheelers) and following from that the grade of order of road users has a significant influence on the overall throughput of roads. The gained results raise the question whether the "export" of 1st world congestion solutions (as mentioned above road capacity increase) and "travel behavior" (such as car traffic rule obeying) can contribute to road congestion mitigation or maybe not.

In this paper also other aspects such as impacts on average travel speeds, road safety, pedestrian friendliness, space, consumption, environmental impacts and long term sustainability will be addressed, too.

The paper is an updated version of the paper already published in "Beiträge zu einer ökologisch and sozial verträglichen Verkehrsplanung", ISBN978-3-9503375-0-1, proceedings of the WCTRS SIG 10 workshop, held in Vienna March 2012.

Road capacity, Vehicle fleet mix, Congestion

Inroduction

As mentioned in the abstract growing road congestion seems to become more and more a major problem cities face around the world. To solve this congestion problem transport planners, mostly educated as civil engineers, suggest as a general solution the increase of road capacity either through new road construction or more recently, through the application of ICT, for example optimization of traffic signaling, real time routing, etc. On the other hand none of these solutions applied in the past solved the congestion problem as far as we have experienced, in the contrary in all cities around the world it can be seen the congestion levels are still increasing. The reasons are manifold and when looking into detail they hardly identifiable; but when looking from a more systemic point of view it can be seen that when the GDP of a nation (the income of household) is increasing the motorization rate increases and following from that the likelihood that a person uses a car to fulfill his/her mobility needs is increasing, too. On the other hand more cars "need" more road infrastructure and therefore more capacity is provided (new road construction or ICT = traditional solution). Following this line of argument it can be concluded that there is a vicious circle (see Figure 1) and as long we as transport planers do providing additional (road) capacity, we only postpone the congestion problem into the future.

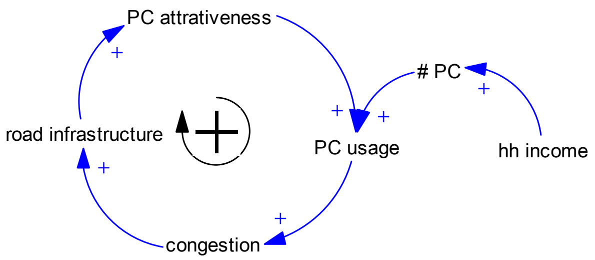


Figure 1: Vicious circle

As educated transport planners we were taught to avoid "chaos" or chaotic transport (traffic) behavior and to establish "order" in the transport systems we are responsible for. To achieve this we were trained that there exists a set of common rules (Republik Österreich, 1960; United Nations, 1968), etc.) transport system users have to obey. In line with these rules also a set of corresponding planning principles was developed. These rules define for example the minimum knowledge/skills a car driver must have, regulates the direction where the traffic is going (right lane traffic/left lane traffic), set the maximum allowed speed limits, define how to cross a road as pedestrian, regulate the right of way, define the maximum dimensions of vehicles and many other things. Based on these rules standards for street layout and general planning principles (FSV, 1995; HCM, 2000) have been established and taught at civil engineering universities all over the world. Interestingly is, that the definition of these principles are mainly driven by rich, car friendly societies.

As mentioned above these rules define very clear how the different transport system users should behave and move on streets and roads, and if not, how they should be punished.

If we define "order" as movements based on a defined and obeyed external rule set then "chaos" are movements not following an external rule set or, in other words, movements based on self-organizing principles.

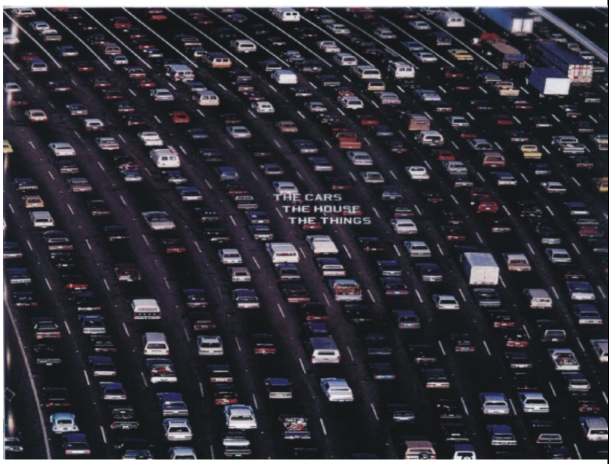
Order or chaotic?	
	
Ho Chi Minh City, 2010	Somewhere in the USA

Figure 2: Road transport impressions

In the eyes of a 1st world educated transport planner it is clear that the left hand picture represents a chaotic transport system whereas the right hand picture shows a well organised, ordered transport system. The question arises here is where does the necessity for order come from? – The intuitive evident answer is the higher speed levels of motorised transport systems.

Human speed levels

Human beings are adapted through their evolution to a certain speed level based on walking and running. This speed level is in the range of 3 to 15 km/h. Within this speed range human sensory organs (eyes, ears, etc.) and reflexes are able to react in time to avoid collisions with other fixed or at the same speed level moving objects. Therefore movements within this speed range are easily to handle for human beings and no formal rules needed to pass by other moving people. But as soon a transport system operates on a higher speed level rules have to be applied and obeyed to avoid incidents.
The downside now is that speed increases have a series of further implications, especially in an urban context, where surface space is a scare good. Faster transport users need more space (see Figure 3) to navigate without collisions.

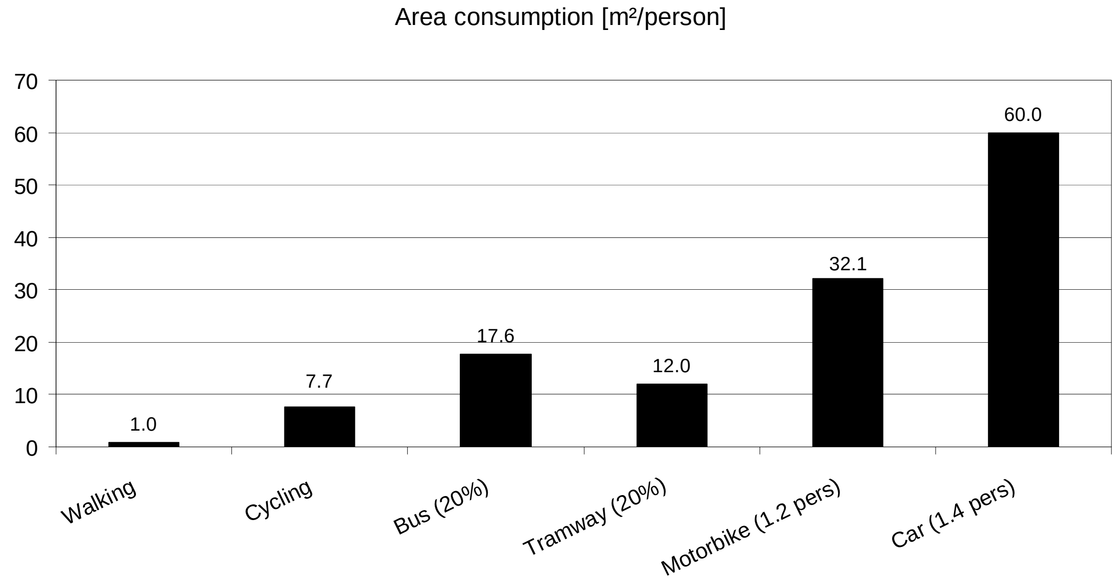


Figure 3: Area consumption for different means of transport, Source (Pfaffenbichler, 2001), own additional calculations

Faster transport system users need more external, fossil energy (see Figure 4) to travel at their high speed level. This again has negative impacts on cities and settlements on a local and global level.

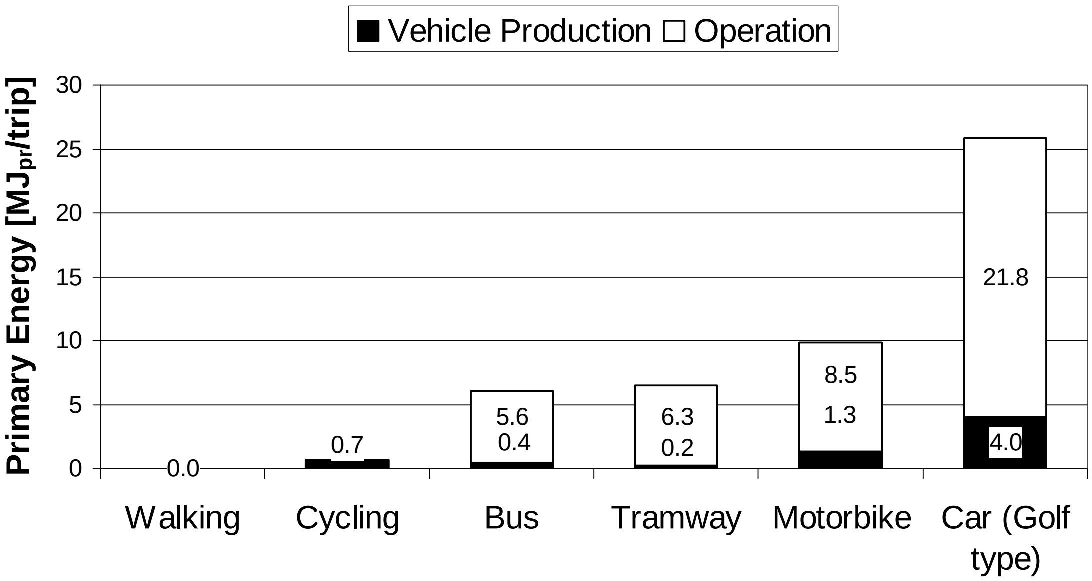


Figure 4: Energy consumption per means of transport per average trip [MJ/trip], source (Pfaffenbichler, 2001)

More space for transport leads to less density and therefore increases the dependency on fast transport systems (= vicious circle). More users and higher speed levels increase the energy consumption and the demand for other resources (metals, synthetic materials, etc…), too and increase the regional and global emissions of pollutants.
Why is now speed such an attractive thing that societies, individuals, city planners and transport planers want to increase speed levels all the time? An exhaustive discussion of this issue is not possible within this paper I just would like to mention some key issues:

"Time is Money" Benjamin Franklins 1748 "Advice to Young Tradesmen" [economy]
„Survival of the fittest" Charles Darwin, The Origin of Species , 1859 [biology – evolution]

Historical application

Anyhow, let us conclude that speed level increase, for whatever reason, is a decision leading principle in our societies, then the following compilation provides some measurements/principles applied in the past and present to support this speed level increase. Table 1 shows in which part of the world certain principles and measures were invented, first applied and how they spread all over the world over time.

Measures/principles/impacts	
Time past since transport rules are in operation	USA – Europe – JPN/AUS - South America - Asia – Africa
Rule obeying and enforcement	USA – Europe – JPN/AUS - South America - Asia – Africa
Market penetration of cars and car orientated infrastructure developments	USA – Europe – JPN/AUS - South America - Asia – Africa
Duration of experience with cars	USA – Europe – JPN/AUS - South America - Asia – Africa
Car motorization rate	USA – Europe – JPN/AUS - South America - Asia – Africa
Sustainability	
Energy consumption for mobility	USA – Europe – JPN/AUS - South America - Asia – Africa
Resource consumption for mobility	USA – Europe – JPN/AUS - South America - Asia – Africa
Household income/Quality of Live	USA – Europe – JPN/AUS - South America - Asia – Africa

Table 1: Spreading of measures/principle/impacts

The list begins with the issue "time past since transport related rules in operation". These rules were developed in Europe and USA (United Nations, 1968) and were already implemented before the invention and penetration of cars. Close related to these rules was the implementation of enforcement to obey the rules. The invention of the mass production of cars (Wikipedia, 2012) made the market penetration with private cars possible. The starting advantage of car mass production in the USA and the fact that the USA never experienced a war on their own territory is responsible for the highest car motorization rate worldwide. The USA also provided the most car friendly settlement structures compared to all other regions worldwide. Related to this long term development the USA leads in front of Europe, Japan/ Australia and the rest of the world in the energy and other resource consumption for mobility.
When looking on this list one is tempted to say that there exists/is applied a value system where car driving (or individual motorized transport) is dominating.

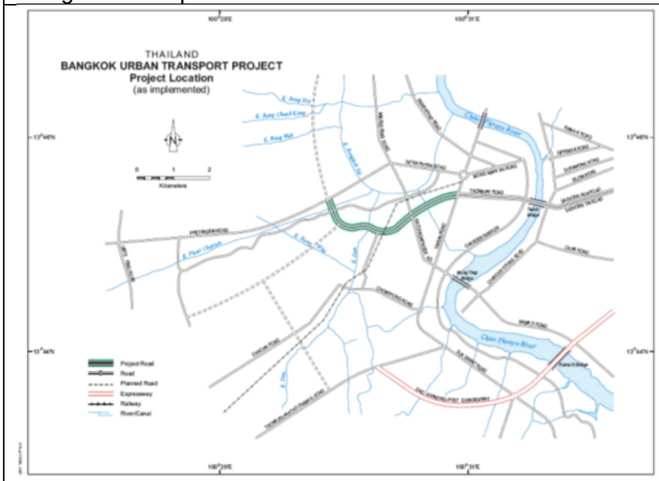
Transferability ??

When I started to work in the field of transport planning I was also convinced that that stuff taught by my forerunners is correct and I should apply this knowledge wherever I can. Now after working some years in national and international research I am not that sure anymore: For me arose the question whether developments in the 1st world could or better say should be applied in other parts of the world.

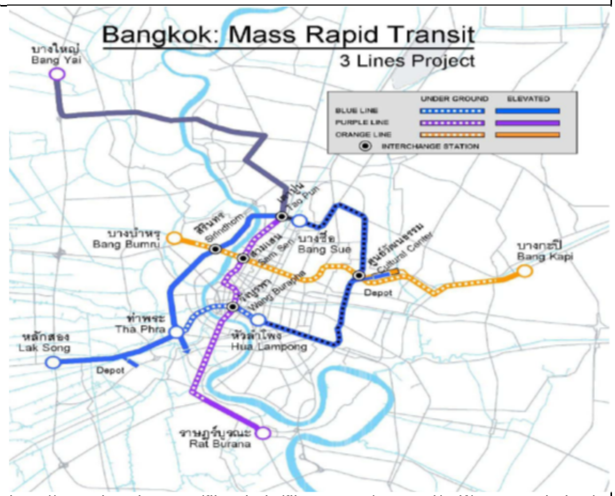
Vienna Transport Master Plan

Source: (Winkler and Oblak, 2003)

Bangkok Transport Master Plan



Source: (Asean Develpment Bank, 2005)



http://www.ita-aites.org/fileadmin/filemounts/general/pdf/ItaAssociation/Organisation/Members/MemberNations/Thailand/B-4MRTA.pdf

Ho Chi Minh City Transport Master Plan

Source:(Japan International Cooperation Agency (JICA) et al., 2004)

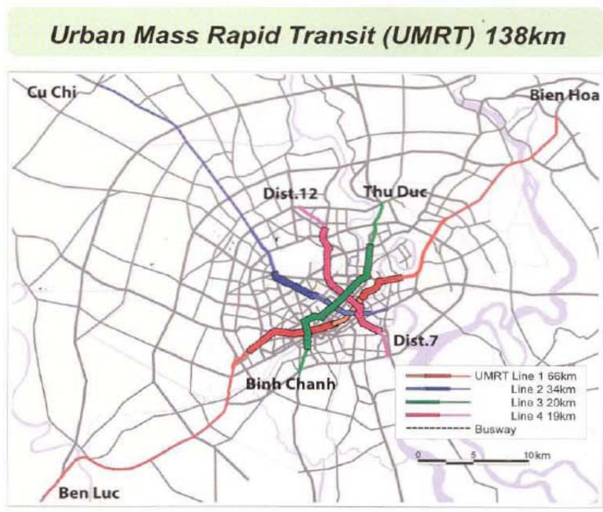


Figure 5: Examples of Transport Master Plans (Vienna, Bangkok, Ho Chi Minh City)

For example, master plans in all cities look like very similar. Most cities were founded before cars were the dominating means of transport and consisted of dense populated city centers and less dense populated suburbs. Walking speed (= human scale) influenced the settlement layout, e.g. every 200 to 300 meters there was an open space (place) to enable a rest for people walking and to create space for activities such as trading and communication (Knoflacher, 1993, 1997, 2001). Then the railway was invented and the settlement development took place alongside of these public transport axes. With the penetration of cars the development alongside corridors was abandoned and an uncontrolled settlement growth took place (Emberger and Pfaffenbichler, 2003). Transport planers tried to solve the occurring transport problems with systems of ring roads and arterial roads (=road capacity provision). Some years later, realising that road capacity provisions have a natural limit in urban regions transport planers introduced high quality public transport systems in the cities, such as subways and sky trains. With this suggestion they tried to kill two birds with one stone, firstly the provided a mean of transport to move a huge amount of passengers very fast within a metropolitan area and secondly the freed up road space from public transport (bus, tramways) for more car traffic. Nearly in all (Mega-) cities around the world this process took place.

Although this concept was applied in the same way in hundreds of cities around the globe and none of these cities solved their transport problems[1], this concept is still exported to 2nd and 3rd world cities without any reflection or adaptation. Just to give you an example – Ho Chi Minh City plans to improve its transport system by increasing the road capacity significantly through hundreds of kilometer of new road construction and of course through the implementation of a subway system (see Figure 5). When looking into more detail into the Transport Master Plan of HCMC (Georget, 2009; ICEM – International Centre for Environmental Management, 2009; JICA et al., 2004) it can be seen that the road construction plan is already finalized, the financing is guaranteed and the roads will be finished in the year 2020; whereas the subway network is still in the planning phase, no money is reserved for the realization and no implementation time frame is given. In other words – HCMC follows the road all other cities are gone – It will become a car/motor scooter depending, energy consuming mega city.

Following from that discussion the paradigm of free (car)travel for everyone has to be challenged. Also the paradigm of increasing accessibility through increasing individual travel speed is questionable since we have seen that daily travel time is more or less constant all over the world, independently from household income or motorization rate (Schäfer and Victor, 2000). Additionally the negative impact of energy and resource consumption on a global level will cause problems for future generations and has to be tackled sooner than later.

On the other hand we see that the biggest urban agglomerations and the highest population densities in the world are in regions where relatively less energy is consumed for mobility (Figure 6).

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[1] Please see Figure 1: vicious cycle: → more road infrastructure (either through ICT-application, road construction but also through subway construction, sky trains) leads to more car traffic in the long run

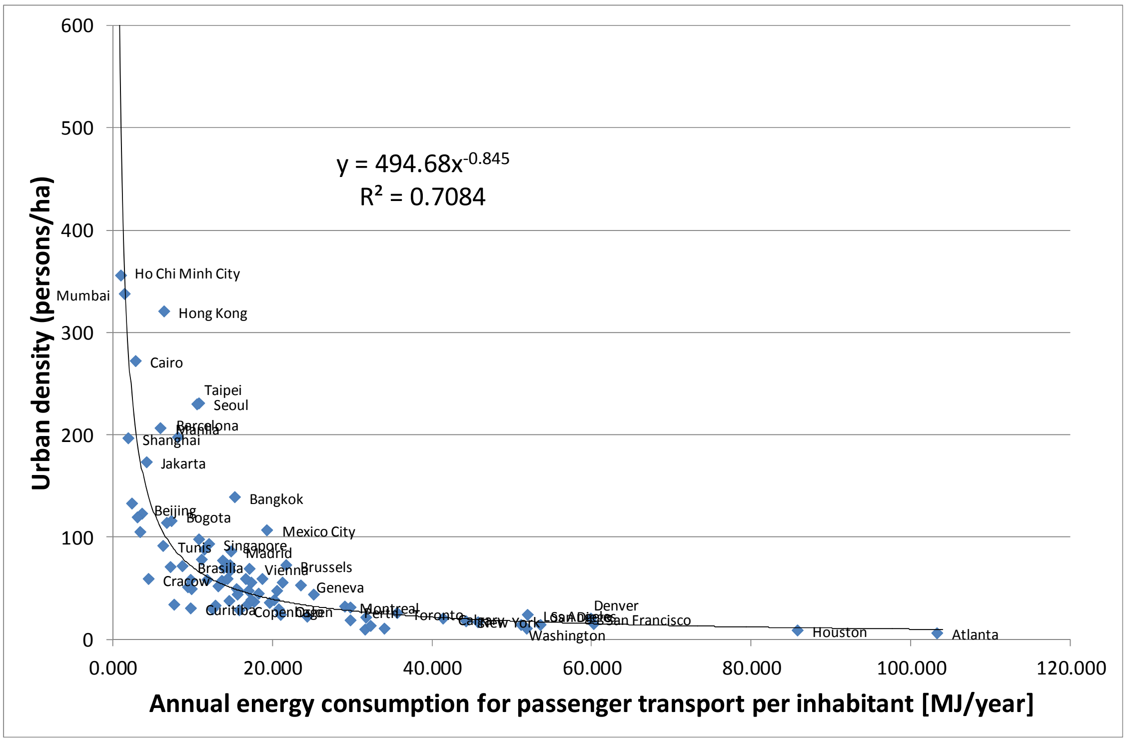

Figure 6: Urban density vs Energy consumption for mobility, Source (UITP, 2001)

Of course this starts instantly the discussion of quality of life and who lives better. But this discussion is based on a 1st world perception of quality of life and forgets the global perspective (keywords: ecological footprint, peak oil, climate change, emissions, noise, etc…). Therefore it is necessary to find a compromise between the individualistic, consume-oriented and man-kind concentrated point of view and a more general systemic, ecological and sustainable point of view.

One opportunity to find a compromise is to use the knowledge we see and can experience in 2nd and 3rd world countries and how they handle their transport systems and check what we can learn from them.

Space consumption / densities

As showed in Figure 3 higher speed levels need more space. This fact can also be found in the data of the Millenniums database (UITP, 2001, 2006).

Figure 7 shows that the urban density goes down when more roads are provided. As it can be seen there exist nearly a functional relationship between city density and road length. An increase of road length will therefore have major impacts on the overall city structure of Ho Chi Minh City.

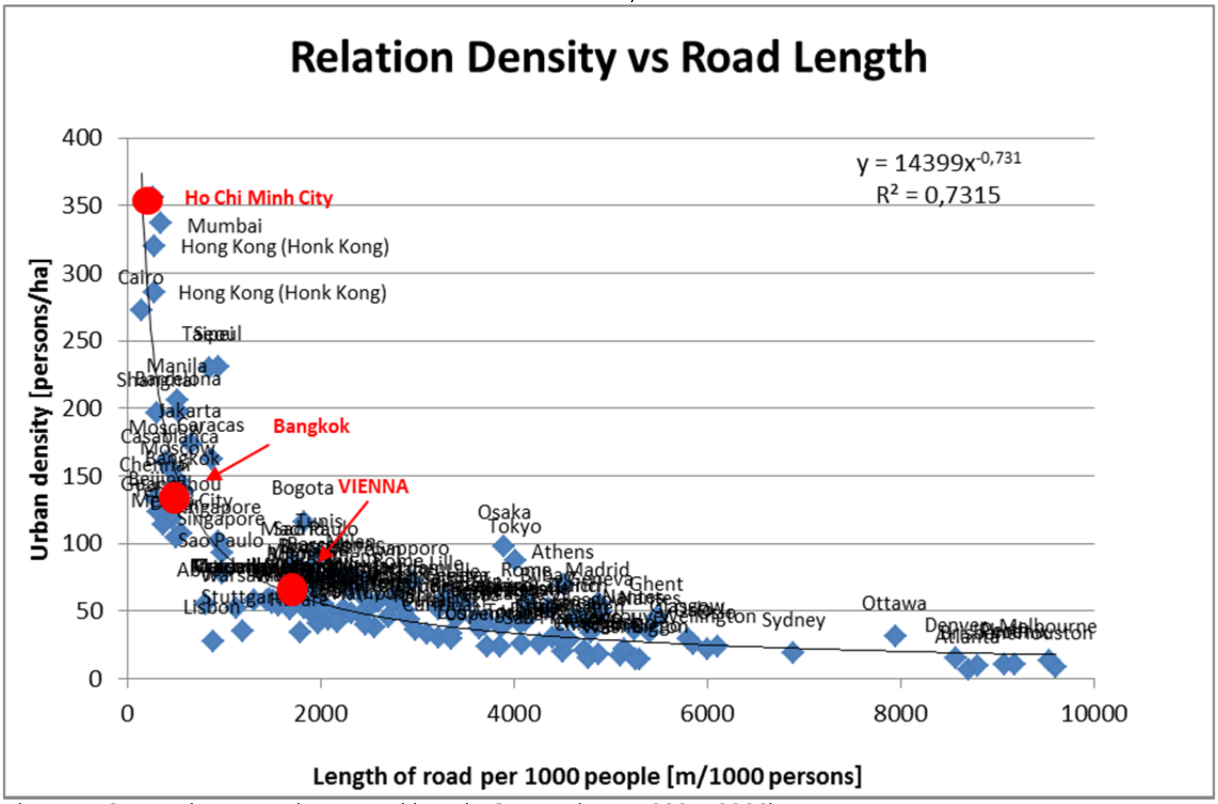

Figure 7: Comparison Density vs road length, Source:(UITP, 2001, 2006)

When analyzing the road length of these cities I wondered how they can handle their transport system. The relation between Ho Chi Minh City (HCMC) : Bangkok : Vienna is 1 : 2,2 :6,7. So how can the traffic flow in HCMC with only a seventh part of road length compared to Vienna? To answer this question I initiated the following empirical investigation.

Comparison of road capacity depending on traffic mix

Traffic counts were carried out at 11 different places in HCMC in the year 2010[2]. This was done in close collaboration with the Technical University of HCMC. Additionally traffic count data from a similar research exercise carried out in Bangkok from the year 2009 [3] were accessible. Finally traffic count data for Vienna[4] for the year 1995 were incorporated in this analysis, too.
Figure 7 shows the maximal empirical detected number of vehicles per hour per lane for the different cities (Vienna, Bangkok and HCMC)
On the y-axis of Figure 8 the modal split share of cars (vehicles with more than 2 wheels) is shown. In Austria the car share on roads is nearly 100%, in other words nearly no motor scooters are on the streets. In Bangkok the share between cars and motor scooters varies between 88% and 60%, depending on the specific road site. In HCMC the share of motor scooters lies between 85% to nearly 100% (car share between 15% to 3%).

[2] Own traffic count data, carried out in the Megacity project VN-HCMC, in collaboration with Technical University HCMC
[3] Traffic count data organised by Prof. Sittha Jaensirisak, Ubon Ratchathani University (UBU), Thailand.
[4] In Vienna the maximum road throughput on this specific location was already reached in the early 1980ies. Since then there was no increase in the maximum number of vehicles could be observed.

*Road **c**apacity – traffic mix*

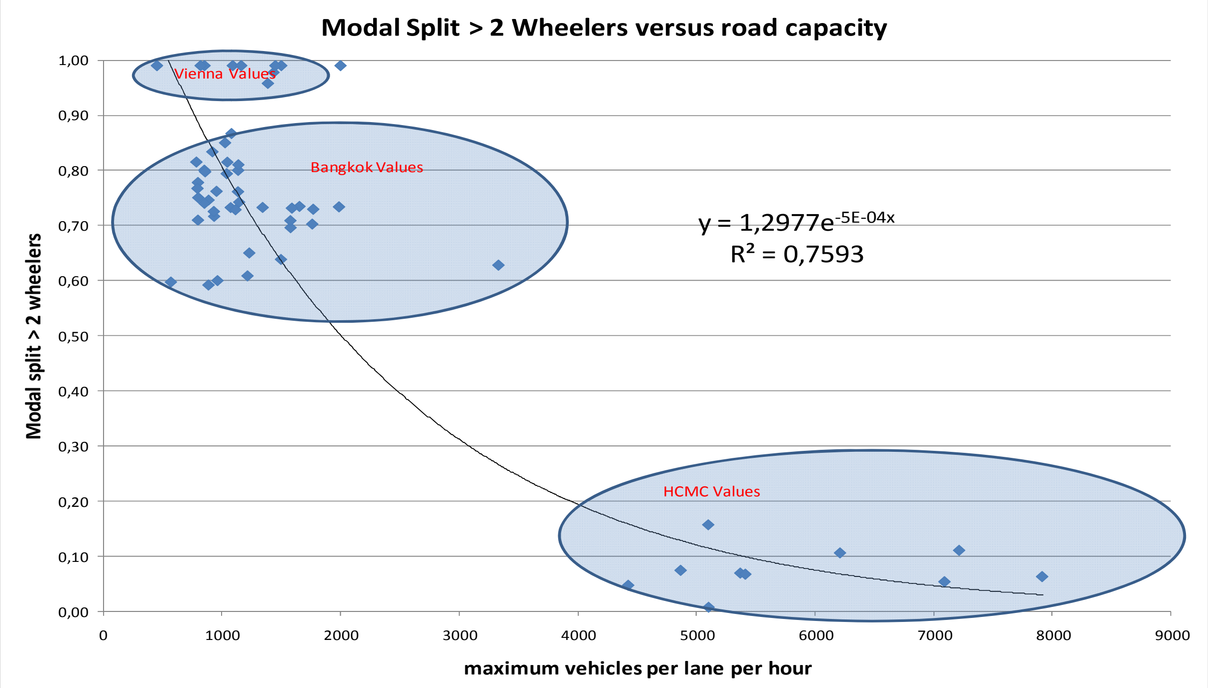

Figure 8: Comparison of road capacities depending on car mode share

Comparing the vehicle capacity by taking into account the different mixture of traffic (car/motor scooter) it becomes very obvious that the higher the share of cars the lower the vehicle capacity per lane (x-axis) becomes. Whereas in HCMC between 4500 and 8000 vehicles per lane can pass a certain road cross section this value goes down in Bangkok to less than 1500 vehicles per hour per lane. In a "developed" country such as Austria the road capacity is around 1000 to 1500 cars per hour per lane. The values depicted in Figure 8 are all counted on urban roads, where traffic signals, intersections and pedestrian crossings exist.

It has to be noted that in Figure 8 vehicles per lane and hour are showed on the x-axis. The relations between the countries/cities become even bigger when using passengers instead of vehicles. The car occupancy rate in Vienna is around 1,2 persons per car, whereas the occupancy rates for cars in Thailand and Vietnam are higher and even the average occupancy rate for motor scooters is above 1,2 persons per scooter.

From this investigation it can be derived, that a "chaotic" system like the system in HCMC in combination with high motor scooter modal share has a 2,7 to 8 times higher vehicle capacity and a 4 to 12 time higher passenger capacity as well organised systems in Europe and elsewhere in the world.

A very important and obvious implication directly derived from this investigation is that the congestion level in HCMC will increase very strongly through the future increase of car ownership (about 16% per year – see Table 2 in the annex) and the directly related car use in the future.

Road safety issues

The following investigation puts in relation the number of passenger fatalities with the annual energy consumption for passenger transport for different regions on earth:

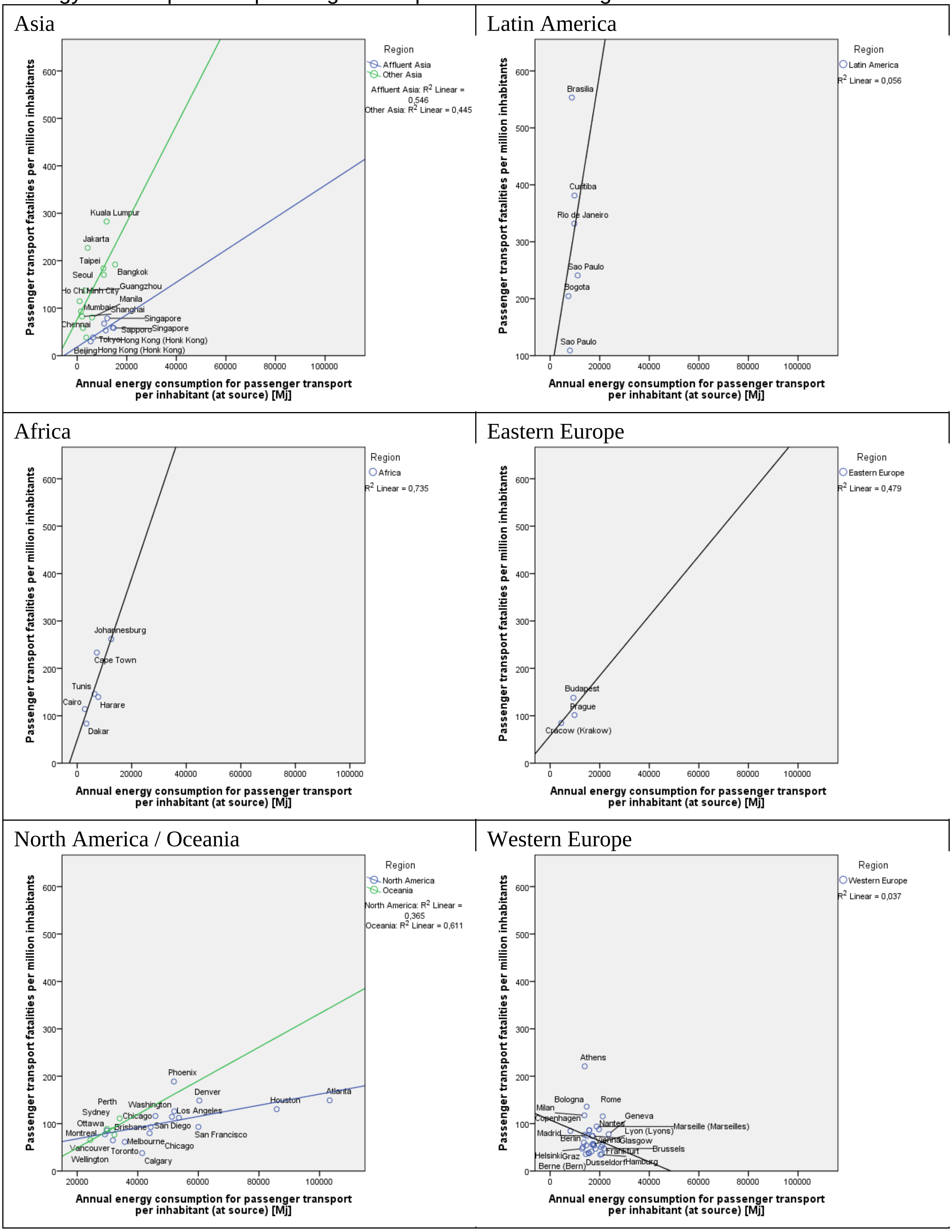

Figure 9 1-6: Comparison fatalities vs energy consumption per inhabitant, source (UITP, 2001, 2006)

It can clearly be seen that the more energy is used/needed (= higher trsport system speed = higher car usage) to fulfill the transport needs the higher is the number of fatalities (except in Europe). Especially in 3rd world countries the development towards more motorized passenger transport will increase the fatalities numbers significantly (highest slopes in the regression models).

The scale of the x- and y-axes is the same for all graphs. It can be seen that total number of fatalities in Europe is between 80 to 90 fatalities per million inhabitants per year. The second lowest level for fatalities is in North America, but there the energy consumption for passenger transport is more than twice as high as in Europe and about 10 times higher than in 3rd world cities. Then the number of fatalities goes up a maximum of nearly 600 in Brasilia (South America). Interesting here is that Europe and North America seem to have stabilized the number of fatalities on a low level but on a very high transport energy level and low settlement densities. This could be interpreted in that way that these regions have the safest transport systems but using a not sustainable amount of resources (space, fossil energy) and high air and noise pollutions.

SUMMARY

1. 1st world countries “export” their value system into the 2nd and 3rd world countries. (faster = better, GDP growth forever, etc…)
2. Car oriented development supports this value system and is inherent the existing transport system and transport planning principles.
3. The higher the speed level the higher will be the dependency on car transport (the lower will be the city density), the higher will be the energy-, resource- and space consumption.
4. The higher the speed level the more difficult it will become to create a sustainable society

In some places in the 1st world some of these issues are already recongised and tackled in a way similar to what is at present in place in 2nd and 3rd world cities. Such transport policies are the redistribution of public space back from solely car use towards mixed uses (e.g. pedestrian zones, bike lanes, tramway renaissance) and the concept of shared space. These “new” policies are successful because they bring down the speed level of the transport system to the human speed level as introduced at the beginning of this paper. These policy instruments create public spaces where humans can move in a rule free and self organising transport environment which in cities like Bangkok and HCMC already/still are in place.

APPENDIX

Basic information regarding the three Cities Vienna, Bangkok, Ho Chi Minh City:

Indicator	Unit			
General				
City	Name	**Vienna**	**Bangkok**	**Ho Chi Minh City**
Population	Inhabitants	1.714.142	5.701.394	6.610.000
Area	km²	415	1.569	2.096
Density	Inhabitants/km²	3.708	13.869	35.565
Population Growth	% (Year)	1	0	4
Average Age	Years	41	n.a	n.a.
GDP	USD/Inhabitant (Year)	41.500	11.497	2.600
Modal Split				
Base Year		2010	2010	2007
Pedestrians	%	28	2	3-5
Bike	%	5	1	1-3
Public Transport	%	36	40	6
Motorcycles	%	0	20	>80
Car	%	31	37	9-11
Level of Motorisation				
Car Ownership	cars/1000 inhabitants	385	655	60
Growth Car Ownership	% (Year)	1	5	16
Motorcycle Ownership	motorcycles/1000 inhabitants	31	453	385
Growth Motorcycle Ownership	% (Year)	1	3	8
total passenger vehicle ownership	veh /1000 inhabitants	416	1.108	445

Table 2: Basic data describing Vienna, Bangkok and HCMC

Sources:
Citylabs_MVA_Ho Chi Minh City - Transport Modelling in a Rapid Growth Environment.ppt
http://203.155.220.118/info/NowBMA/frame.asp
http://office.bangkok.go.th/pipd/05_Stat/08Stat(En)/Stat(En)53/stat_eng2010.pdf
http://office.bangkok.go.th/pipd/07Stat(Th)/Stat(th)54%20(6%20Months)/02_traffic%2054%20(6%20Months).xls
http://service.nso.go.th/nso/nsopublish/download/syb_53/SYB53_T.pdf
http://www.bangkokbrt.com/main.php?m=3
http://www.bmvit.gv.at/verkehr/gesamtverkehr/statistik/downloads/viz07_kap5.pdf, tabelle 5.1.6
http://www.gso.gov.vn/
http://www.nachhaltigkeit.wienerstadtwerke.at/daseinsvorsorge/oepnv/modal-split.html
http://www.otp.go.th/th/pdf/Statistic/carregister/compare_carregis_car_54(jun)
http://www.otp.go.th/th/pdf/Statistic/social/person_bkk-53.pdf
http://www.otp.go.th/th/pdf/Statistic/speed/mainroad_54
http://www.statistik.at/web_de/statistiken/bevoelkerung/bevoelkerungsstruktur/bevoelkerung_nach_alter_geschlecht/023470.html
http://www.wien.gv.at/stadtentwicklung/studien/pdf/b008179.pdf
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