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Transport in Megacities -development of sustainable transportation systems

GUENTER EMBERGER, AO.UNIV.PROF.DR, UNIVERSITY OF TECHNOLOGY VIENNA, INSTITUTE OF TRANSPORTATION - CENTER FOR TRANSPORT PLANNING AND TRAFFIC ENGINEERING, GUENTER.EMBERGER@TUWIEN.AC

WULF-HOLGER ARNDT, DR.-ING., TECHNICAL UNIVERSITY OF BERLIN, WULF-HOLGER.ARNDT@TU-BERLIN.DE

TANJA SCHÄFER, PTV GROUP, HAID-UND-NEU-STR. 15, 76131 KARLSRUHE, GERMANY,TANJA.SCHAEFER@PTVGROUP.COM

OLIVER LAH, WUPPERTAL INSTITUTE FOR CLIMATE, OLIVER.LAH@WUPPERINST.ORG, JAN TOMASCHEK, ENERGIEWIRTSCHAFT UND SYSTEMTECHNISCHE ANALYSEN (ESA), UNIVERSITY STUTTGART, JAN.TOMASCHEK@IER.UNI-STUTTGART.DE

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Guenter Emberger, Ao.Univ.Prof.Dr, University of Technology Vienna, Institute of Transportation - Center for Transport Planning and Traffic Engineering, Gusshausstrasse 30/2, A-1040 Vienna, Guenter.Emberger@tuwien.ac

Wulf-Holger Arndt, Dr.-Ing., Technical University of Berlin, Center für Technology and Society, Research area "Mobility and Space", HBS 1, Hardenbergstr. 16-18, D-10623 Berlin, wulf-holger.arndt@tu-berlin.de

Tanja Schäfer, PTV GROUP, Haid-und-Neu-Str. 15, 76131 Karlsruhe, Germany, tanja.schaefer@ptvgroup.com

Oliver Lah, Wuppertal Institute for Climate, Environment and Energy, ProjektZentrum Berlin der Stiftung Mercator, Neue Promenade 6, 10178 Berlin,Germany, oliver.lah@wupperinst.org

Jan Tomaschek, Energiewirtschaft und Systemtechnische Analysen (ESA), University Stuttgart, Heßbrühlstr. 49a, 70565 Stuttgart, Germany, jan.tomaschek@ier.uni-stuttgart.de

ABSTRACT

Climate change and energy security are some of the key questions for the 21st century. Cities in developing and emerging countries are massively growing sources of energy demand. Although cities cover only 2% of the earth's surface, 50% of the world's population live in cities, but they are responsible for three-quarters of the global energy consumption as well as approximately 80% of the global greenhouse gas emissions. While the trend towards urbanisation and the growth of megacities creates huge challenges it also offers the unique opportunity to shape energy use especially in the transport and urban form towards a low-carbon pathway.
This is one of the core objectives of the Programme „Sustainable Development of the Megacities of Tomorrow"[1] supports knowledge exchange and mutual learning about good practice examples for sustainable urban development.

As part of the programme nine cities (Lima – Peru, Cassablanca - Marokko, Addis Abeba – Ethiopia ,Gauteng- South Africa, Tehran-Karaj - Iran, Ho Chi Minh City - Vietnam, Hyderabad - India, Urumqi - China, Hefei – China) were subject to a study on how climate change mitigation policies can be transferred to the specific circumstances in these cities. The research topics addressed in the projects range between water supply and urban agriculture as well as urban planning and transport issues. Urban transport is a vital focus for five of the mega cities projects. Interdisciplinary research teams develop city specific solutions in close collaboration with stakeholders from the partner-cities.
This paper provides a brief overview of the different transport related challenges these five cities face and the suggested mitigation and adaptation strategies. The challenges range from issues of data collection, modelling and planning in a fast growing environment to resistance of citizens against big infrastructure projects. The conclusions will compare and

[1] This programme was led by the German Federal Ministry of Education and Research (BMBF) and funded nine research projects in the years 2008—2013. More information on: http://future-megacities.org/index.php?id=119

contrast the findings and provide an outlook for future developments in Megacities of Tomorrow.

Transport in Megacities, Transport in developing countries, Transport strategies, Transport decision support tools, Climate change and transportation

1 THE RELEVANCE OF TRANSPORT FOR MEGACITIES

Author: Wulf-Holger Arndt, Günter Emberger

Since 2000 over 50% of the world's population is living in cities. The trend to urbanisation and further expansion of megacities is unbroken. The urban population is increasing in all countries even those with stagnating and decreasing numbers of inhabitants. Especially in emerging and developing countries cities are growing rapidly. Striving for a more ecological development of existing cities and new urban development must be an urgent priority in the global transformation towards sustainability[2]. Efficient energy production and consumption are central questions of the 21st century, especially for urban agglomerations and megacities in developing and newly industrialising countries. Although cities cover only 2% of the earth's surface, 50% of the world's population live in cities but they are responsible for three-quarters of global energy consumption as well as approximately 80% of the global greenhouse gas emissions. Future megacities therefore offer strategic approaches for efficient energy use and climate protection in all sectors of production and especially in the field of transport. 20 % to 35% of GHG emissions result of transport processes. In residential areas transport is the major GHG emission source with a share of 50%.

Several societal trends lead to a growth of traffic. Besides the growth of population and urbanisation, car-oriented settlement structures, income growth and new production methods as well as distance intensive trading relations are key drivers for transport demand. As the picture below shows population growth and car use have a progressive correlation.

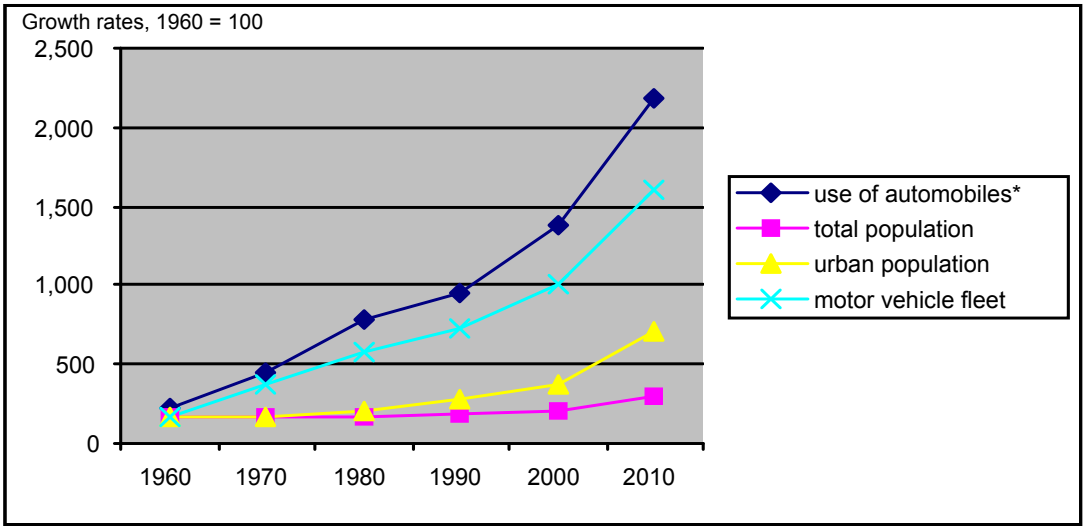


Figure 1: Development of population and car use in selected developing countries LDCS,
Source: Lakshmanan 2006

[2] Welt im Wandel - Gesellschaftsvertrag für eine Große Transformation, Hauptgutachten 2011, Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen WBGU, Berlin 2011

The main cause for transport demand growth is the interrelation between transport system and long-term adaption of settlement structure as shown in Figure 2. E.g.: The growth of average speed in the transportation system increases the accessibility of destinations in a wider distance. In the long run the spatial structure will adapt this and fixed activities with longer distances. This activity patterns

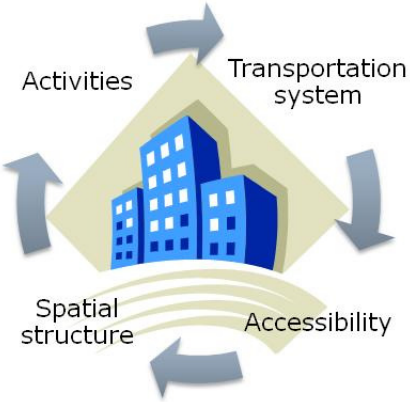
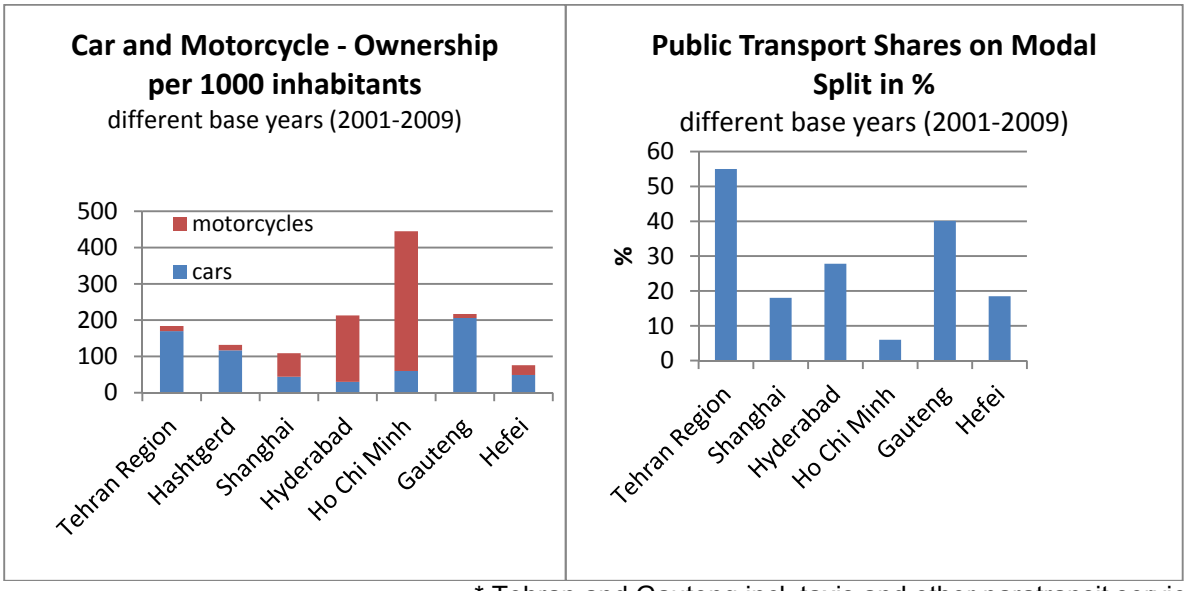


Figure 2: Interrelation between transport and spatial structure development (Arndt 2012, S. 120)

Capacities and velocity of transportation systems were expanded to solve short-term traffic problems. The high average traffic speed enables longer travel distances. This type of planning supports a development of mono-structural land-use (functions like living, working and shopping are separated) with a low population density. In addition, faster transportation goes along with the consumption of more resources such as materials, energy or land use. As a result an expansion of the transportation system, in particular of road networks improves the traffic performance in a short term as well as it increases the resource consumption and traffic impacts such as GHG emissions in the long run.
Figure 3 shows that until now car ownership remains at a low level and the Public Transport (PT) has a relative high share on urban Modal Split in the investigated cities.



* Tehran and Gauteng incl. taxis and other paratransit services

Figure 3: Car and motorcycle ownership and Public Transport shares

2 TRANSPORT CHALLENGES IN FIVE MEGACITIES

In this regard, mobility and transportation has been surveyed in urban agglomeration areas in the last decades as one of the main energy consumption sector. Hence transportation and mobility is a major topic in the BMBF research programme "Future Megacities". Within these Future Megacities program six megacities (**Gauteng - South Africa**, **Tehran-Karaj - Iran**, **Ho Chi Minh City - Vietnam**, **Hyderabad - India**, **Hefei – China, Shenyang - China until 2011**) are investigated how an adaption to future climate changes can be achieved from the perspective of transportation. In these megacities it is recognised that urban transport will play a major role in the future.

Within the Future Megacities programme the cross-link network *Megacities Mobility (MC Mob[3])* was established for the exchange of knowledge in transportation research in Megacities and to compare the different approaches for sustainable urban transport development.

In the following chapters the results of the transportation analyses from five of these six cities will describe.

2.1 TEHRAN – KARAJ, HASHTGERD (YOUNGCITIES PROJECT)

Author: Wulf-Holger Arndt

2.1.1 City Characteristics

One of the strategies for solving the challenges of population growth in Iran is to build New Towns. The construction of New Towns is meant to reduce the pressure on the large agglomerations. As secondary goal is the restructuring and deconcentration of the population of the metropolitan areas.
The main objective of the Young Cities project is to find out, whether the development of New Towns is a reasonable strategy to level off the population growth in urban agglomerations.
The biggest of the 30 planned Iranian New Towns is Hashtgerd, situated 65km northwest of the Megacity Tehran and 30km west of the Megacity Karaj. This city is planned for 660,000 inhabitants in 2027. In 2010 almost 50,000 people live there.
The research project[4] outlines the development of the planned New Town Hashtgerd in the agglomeration Tehran/ Karaj and implements research results in form of pilot projects within the New Town.

[3] http://future-megacities.org/index.php?id=119
[4] The project was carried out by the Technische Universität Berlin (Departments of City and Regional Planning, Architecture, Civil Engineering and Transportation Planning), More information on www.youngcities.org

Transport challenges

During the last decades Iran as a Oil Producing Countries has spent a big share of its income on reshaping and erecting the putative cities of tomorrow, whose transport systems are planned to rely to a great extent on private motorization. Most of the agglomerations in Iran have not been capable to supply their population with a basic safe, affordable and reliable transportation infrastructure. Moreover, the municipalities, overwhelmed by massive population growth, were not able to realign transport planning policies to accommodate the fast changing urban development framework.
As a result, growing travel distances in the uncontrolled spatially extending agglomerations of the MENA are mostly tackled by the fast growing stock of private vehicles and by the privately-operated, only partly regulated, and insufficient public transport, which to a great extent consists of mini-vans and shared taxis. This - from an environmental and social point of view - unsustainable development of the urban transport system, has fostered excessive reliance on private automobiles (World Bank, 2010)
In many developing countries, where the rates of motorization are increasing rapidly, the main coping strategy for the upcoming problems is to enlarge the street infrastructure. Today Iranian cities are facing nearly the similar: Already in 1997 20 % of all GHG emissions had their source in Tehran's urban transport sector (PLS Ramboll management 2003). Furthermore, between 1996 and 2002 the number of vehicle km travelled under traffic congestion has increased from about 21% to 27% (World Bank 2005)
The former Master Plan of Hashtgerd also prioritised car traffic. The results of a car-oriented policy are shown in the petrol consumption balance (s. Figure 4).

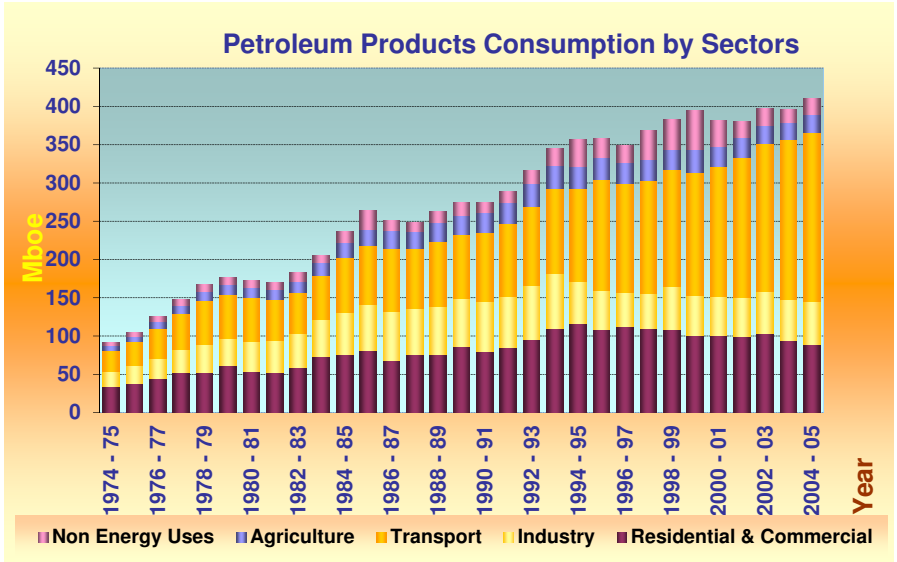


Figure 4: Petroleum Products Consumption by Sectors, Iran 1974-2005, Source: Ministry of Energy Iran, Energy Planning Department, 2008

2.1.2 Methods and Strategies

The Iranian government follows a long-term strategy to transform the country in a post-fossil society. One of the main instruments is the price policy. Energy prices rose dramatically in

the last years. As a result the energy consumption decreased in most of the societal sectors but not in transportation (s. Figure 4)where this price policy started very late only in 2008.
Following the strategy to reduce traffic related CO_2 emissions, a mixed-, land-use approach as the main element of an integrated urban transportation concept was developed for Hashgerd City. Thus, in the case of a 35 ha pilot area (Shahre Javan) the project tries to elaborate an integrated transport concept. The guiding principle for the elaboration of this concept is to consider the interrelations between spatial structure and traffic demand using innovative transport simulation software like VISEVA/VISUM[5].
"Reducing traffic and increasing mobility" is as the envisaged target. The main approach focuses on a shift of mobility routines and the support of environment-friendly means of transport, through the provision of a modern efficient public transport network, an information network on alternative ways of movement, and different measures to reduce the attractiveness of conventional motorised individual traffic. The special situation as a New Town is a chance to influence the availability of different transport means and the mobility behaviour of the new inhabitants towards sustainability.

Key elements of the transport concept are:

- Support of the mixed land use approach through adequate mobility systems,
- Accessibility (social and area related),
- Integration of all traffic means in transport and urban planning,
- Support of environment-friendly means of transport (slow modes, public transport),
- Filtered permeability (e.g. restriction for car traffic) of spaces and coequality for traffic modes regarding their environmental impacts (traffic management),
- A flexible and adaptable Transport and Mobility Planning approach,
- Avoidance of extraneous traffic through residential areas,
- Increasing traffic safety,
- Participation of all stakeholders in the planning process,
- Attention to disaster management.

In pursuit of these goals and sub-goals, the transport strategy of the Shahre Javan Community pilot project focuses on reducing travel distances and shifting both transportation routines and vehicle choices. In order to achieve these objectives, 'push' and 'pull' strategies are combined with hard and soft policy measures. Figure 5 shows a choice of possible measures.

[5] The enhancement of the model developed by partners at TU Dresden will be used for the first time for the optimisation of a traffic-reduced spatial structure.

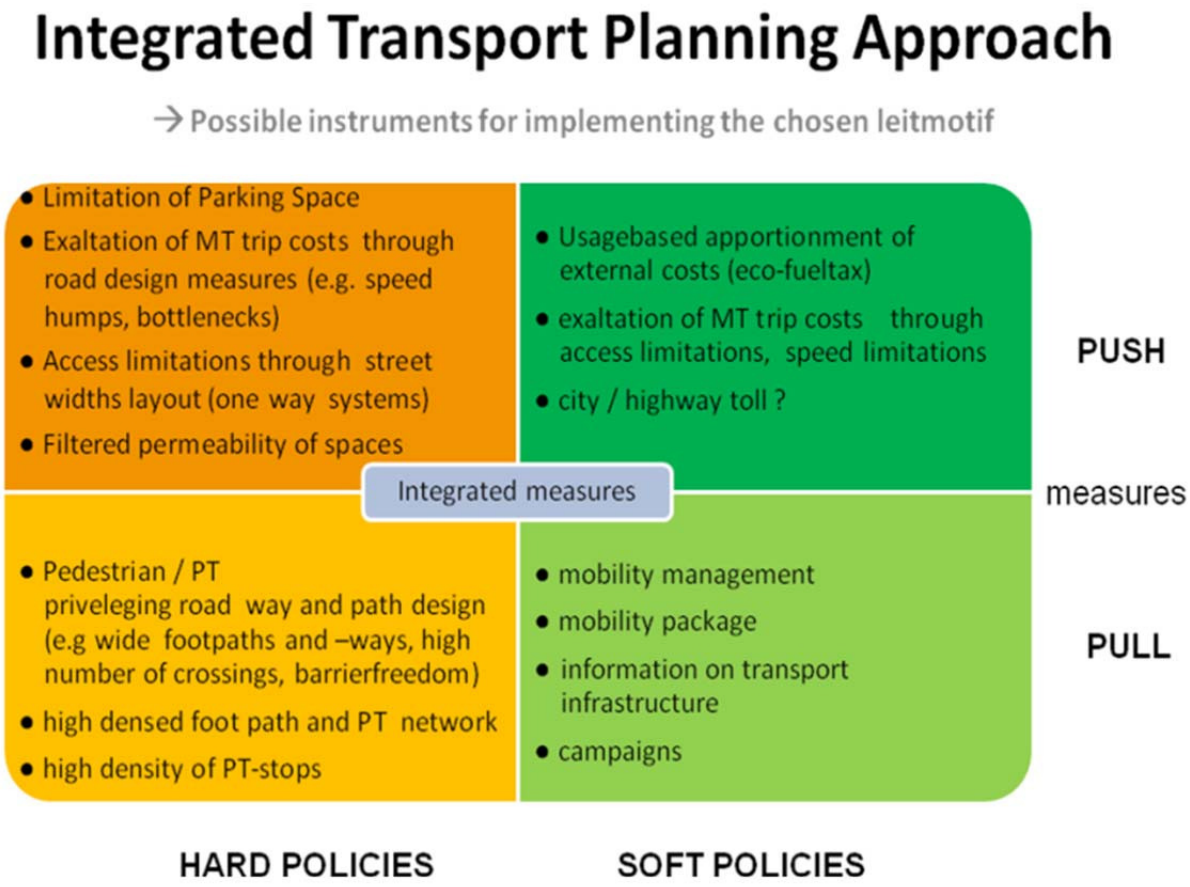


Figure 5 Transport Approach

On the level of the whole area of Hashtgerd, an Integrated Public Transport System as a major framework is envisaged. Its main task is to organize the hierarchically structured public transport system, consisting of a lightrail or bus rapid transit, citybus, neighbourhood-bus (as midibus or minibus). The often underestimated soft policies (e.g. information packages, campaigns) should provide the consumer with adequate information about the public transport system. This system also serves the city of Old Hashtgerd.

Since an individual develops its future mobility routines during a short reorientation phase after the move to a new location, instruments intended to influence this process towards eco-mobility are included in the transport concept. The mobility management primarily concentrates on the change of mobility routines, since new residents will largely originate from Greater Tehran or other urban agglomerations that rely heavily on individual motorized transport. One part of the strategy to support this shift of mobility routines towards more eco-mobility consists of soft policy measures. The key instrument in this strategy is a 'mobility package' for inhabitants, which would include information, services, and incentives (like a test ticket for the public transport system) that are needed for a modal shift away from individual motorized transport. In contrast, hard policies form the physical basis of eco-mobility encouragement, such as the development of attractive public transport, footpath and bicycle systems. In this part of the strategy, pedestrians, cyclists, and shared transport are prioritized, while motorized traffic is of secondary importance. Basic functions and accessibility are maintained for service, delivery, and rescue reasons as well as for limited

individual motorized traffic. The reduction of the car traffic will be achieved by a limitation of parking lots. In the pilot area a parking lots factor of 0,2 is intended.

Results and Conclusions

Three scenarios were made to evaluate the different measures of the integrated transport concept:

A: "Zero" Public Transport service as in old Masterplan for 2027 (Public Transport on main road only)

B: Dense Public Transport service and higher share of bicycle use

C: As scenario B, additionally soft policies and traffic optimised settlement structure by change of land-use

Based on these scenarios CO_2 emissions were calculated with a carbon emission model (TECT). As one of the results Figure 6 shows that the number of parking lots has a significant influence on vehicle use and CO_2 emissions.

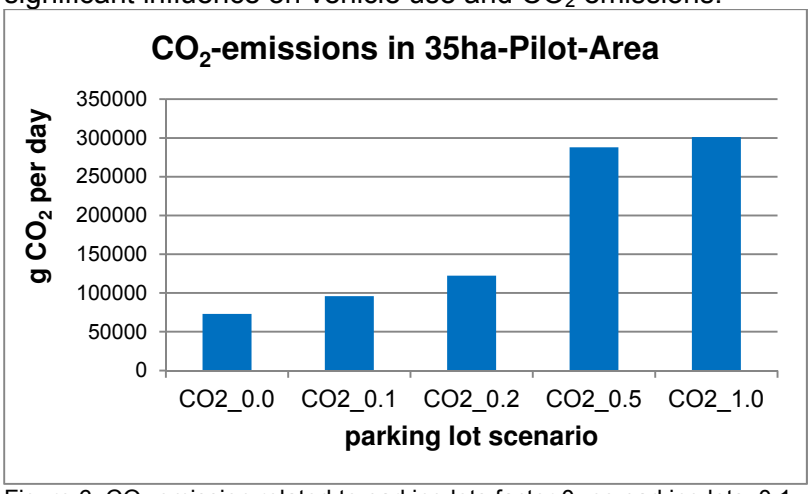


Figure 6: CO_2 emission related to parking lots factor,0=no parking lots, 0.1= number parking lots 10% of the dwelling number, etc.

As a result a detail plan was made and approved. An investor was found but the realisation of the pilot area is still pending because of political reasons.

Some other cities in Iran evince interest to the integrated transportation approach. Talks for implementation are going on.

2.2 HO CHI MIN CITY, VIETNAM

Author: Guenter Emberger

2.2.1 City Characteristics

Similar to other emerging mega-cities in South-East Asia, Ho Chi Minh City (HCMC) is undergoing a rapid process of urbanization accompanied by dramatically land use changes in the surrounding rural areas. It is characterised by urban structures of both planned and informal expansions of the urban morphology, which are both degrading valuable natural areas in the hinterland, and are increasing the vulnerability of these areas to climate-related environmental changes or hazards. As densely built-up urban area in a flat low lying region,

HCMC is historically a region sensitive to climatic effects. Due to its geographic location this flood-prone metropolitan area will always face natural hazards.

Ho Chi Minh has officially some 6.6 million inhabitants (year 2008), unofficial estimations are between 10 to 13 Million people. The city area comprises about 2095 km^2. The annual growth in population is about 3,5% per year. The GDP per head was around 2600 US Dollar per capita in the year 2007.

The results shown here were derived within the so called Megacity Research Project TP. Ho Chi Minh - Integrative Urban and Environmental Planning Framework Adaptation to Climate Change[6].

2.2.2 Transport challenges

Transport is a major issue in HCMC – congested roads, noise and air pollution and extreme growth in motorization (cars and motor scooters) are the main challenges. At present modal split for trips is 3-5 % pedestrians, 1-3 % cycling, around 6% public transport, 9-11% private car and the rest of more than 80% is based on motor scooters. The car motorisation rate was 60 cars per 1000 inhabitants (base year 2008) with a growth rate of 16% per annum. The motorcycle ownership is about 390 motor scooters per 1000 inhabitants with a growth rate of 8% per year. These very high growth rates in motorisation in combination with low infrastructure provision will lead to increasing congestion levels and a deterioration of quality of life in HCMC. The public transport system, which presently counts for only one tenth of all trips is bus based and strongly underfinanced. Besides that the bus fleet lacks modern vehicles, there are no dedicated traffic measures implemented to speed up bus journey times such as priority lines, prioritisation at traffic lights etc. on an area wide basis. The individual transport is based on motor scooters since scooters are flexible, fast and affordable. Parking is allowed nearly everywhere in the city and is also relatively cheap. Since the overall speed of the motor scooter fleet is between 15 to 20 km/h an hour HCMC shows a special kind of traffic flow. Foreigners get the feeling that the whole transport is in steady motion without nearly any rules. Nowadays the increasing rate of private cars seem to disturb the motor scooter flow; traffic rules and their enforcement become more and more necessary to ensure movement in the combined motor scooter and car fleet in HCMC.

2.2.3 Methods and Strategies

To mitigate present and arising transport problems the City authority of HCMC started a series of initiatives and produced several political documents on how to tackle the future

[6] The project is coordinated by the University of Technology Cottbus. In total nine universities /research institutions from Germany and Austria are involved. More information on http://www.megacity-hcmc.org/

development of HCMC. One transport relevant document is the Transport Master Plan (TPM)(JICA, MOT et al. 2004) developed in the year 2004.
The HCMC TPM comprises 7 objectives, 35 strategies and 105 actions to overcome HCMC's transport problems. To give the reader an idea regarding the content of the HCMC TPM a short summary regarding the vision, the objectives and the 35 strategies are given, taken from the original HCMC TPM (Japan International Cooperation Agency (JICA), Ministry of Transport et al. 2004).
The overarching Vision of the TPM is the following:
"Ensure mobility and accessibility to needed urban services for its People and Society, through public transport-based urban transport system with safety, amenity and equity"

To reach this vision the following seven goals were specified:

1. *Promotion of social understanding on present and future urban transport*
2. *Management of sustainable urban growth and development*
3. *Promotion and development of attractive public transport.*
4. *Effective management of traffic and demand*
5. *Comprehensive development of transport spaces and environment*
6. *Enhancement of traffic safety*
7. *Strengthening of transport sector administration and management capacity*

As mentioned above, the 105 actions to overcome the HCMC's transport challenges comprise a series of "soft instruments" such as awareness rising campaigns, use of ICT, demand management instruments and others. Still, the main core of the HCMC TPM is a major extension of the existing road and highway network within and around HCMC. For these road infrastructure investments concrete realization horizons are provided and the necessary funding is reserved. The TPM also includes a public transport improvement program and presents concepts for a subway system. However, the final decisions regarding financing and realisation horizons are far more uncertain compared to the road infrastructure extension programs.

In the document "Preparing the HCMC City metro Rail System" (MVA Asia Limited, SYSTRA et al. 2010) it was stated that HCMC plans to have a modal split share for public transport of 22-26% in the year 2010 to 2015 and 47-50% by 2020.
One of the intentions within the HCMC Megacity project was to evaluate if the set objectives regarding the modal split can be reached with the suggested policy instruments listed in the HCMC TPM. Therefore a dynamic land use and transport model called MARS (Metropolitan Activity Relocation Simulator) developed by TU Vienna was adapted to HCMC circumstances. In collaboration with local authorities and colleagues from the HCMC University of Transport the TPM transport strategies (=combination of individual transport policies) were transferred to the MARS model and their impacts were simulated for the coming 30 years. These simulation results were then assessed against the do-nothing scenario in terms of CO_2- emissions, modal split, km travelled, etc. Additionally MARS delivered dynamic GIS maps where the development of population, household location, workplaces distribution etc was shown for a 30 year simulation period.

2.2.4 Results and Conclusions

With the HCMC Megacity project the following 6 scenarios were simulated to test whether the transport objectives regarding modal split and CO_2 can be reached with the in the TPM suggested measures or not. The scenarios were

1. Business as Usual – base run
2. Policy rail 2015
3. Policy rail_2015+parking fees
4. Policy rail_2015+ppl[7] (parking place)reduction -20%
5. Policy rail_2015+ppl reduction -40%
6. Policy rail_2015+BRT inner districts

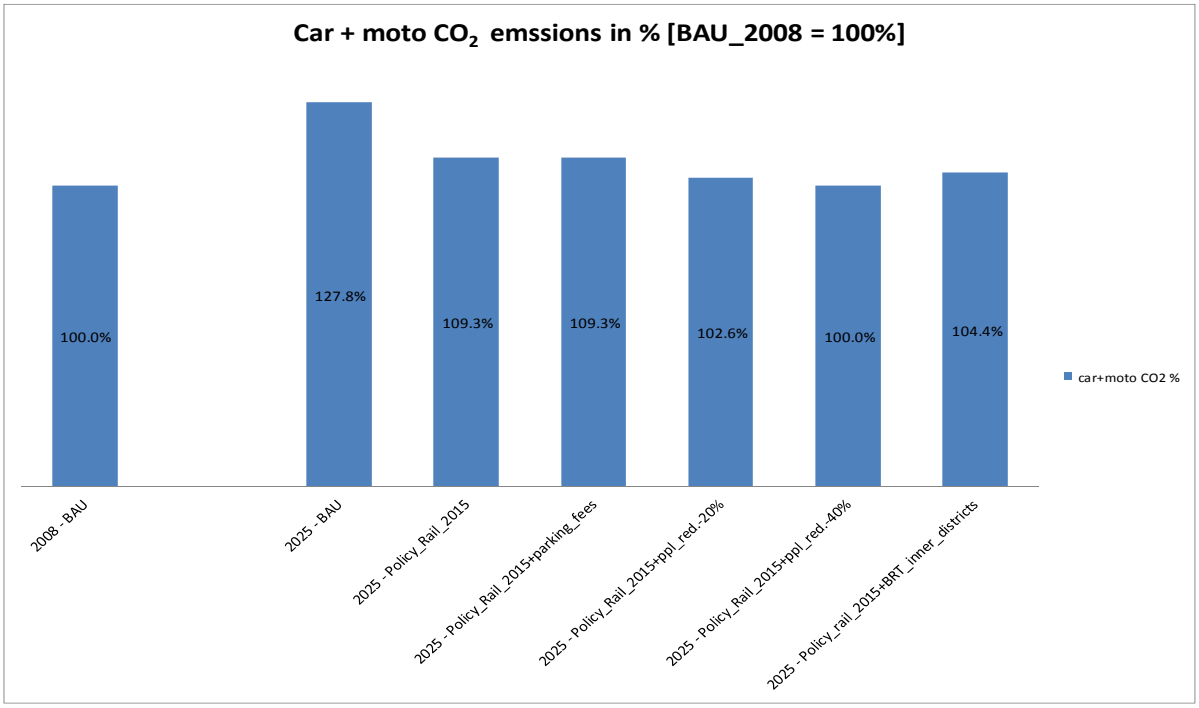


Figure 7: Car + moto CO2 emissions in % [BAU_2008 =100%]

Figure 7 shows the system wide CO_2 emission development of the tested scenarios. As it can be seen in the BAU scenario the CO_2 emissions in HCMC will go up by about 30% compared to today's level. From the viewpoint of CO_2 emissions savings the very car restrictive scenario "policy_Rail_2015_+ppl_red.-40%" delivers the best result. In this scenario the total CO_2 emissions can be frozen to today's level. But also the other tested scenarios are very effective in keeping the CO_2 emissions at an acceptable level compared to the BAU scenario.

A detailed description of these simulations results can be found in the working paper titled "AF 1 WP 5 Urban Transport, MARS modelling exercise HCMC – Report on simulated policy scenarios for HCMCM" (Emberger 2012).

[7] ppl = parking place

Summarized very briefly, the simulations showed that HCMC is not at all in the position to reach their self-defined objectives laid down in their policy documents by implementing the policy measures as defined in the scenarios. The growth rates in population, the increase in household income, the related increase in car an motor scooter motorisation, the car friendly environment (tax reductions of car purchase), and the resulting urban sprawl will increase the transport problems of HCMC in the future significantly. [8]

The "traditional" approach to increase transport infrastructure capacity through the construction of highways and ring roads as a first step and the improvement of public transport facilities as a second step, has - as can be seen in all cities around the world - never led to an environmental friendly and efficient and sustainable transport system.
The HCMC case will be no exception.

2.3 HYDERABAD, INDIA

Author: Tanja Schäfer

2.3.1 City Characteristics

Hyderabad is the capital of the Indian State of Andrah Pradesh with a population of approximately 6.8 Million (census 2011) in an area of 650 Km^2. It is thus the fourth most populous city in India. As the city is simultaneously the economic centre of Andrah Pradesh, it is very attractive for migrants and therefore also rapidly and almost uncontrollably expanding to the surrounding municipalities, foremost rural areas. It is predicted that Hyderabad will reach a population of 10.5 Million in 2015.
Economic growth, driven in part by having the highest number of Special Economic Zones[9] of all Indian cities, is enabling higher living standards and modern lifestyles for the rapidly emerging middle class. This is resulting in escalating energy and resource consumption and degradation of resources, which is due to changes in the transport sector. Hyderabad used to have a high percentage of pedestrians and PT users, the latter due to a bus system with good coverage. In 2003 the modal split for Pedestrians was ~30%, Bicycle ~3%, PT ~28%, Motorcycles ~31%, car ~2% and 5% others like ox-carts or three-wheelers. But these shares are changing quickly due to a rapid growth of private transport. In 2007 the proportion of two

[8] A detailed description of these simulations can be found in the working paper titled "AF 1 WP 5 Urban Transport, MARS modelling exercise HCMC – Report on simulated policy scenarios for HCMCM".

[9] The project is coordinated by the Humboldt University zu Berlin, Division of Resource Economics. Besides PTV Group and nexus, four more German universities/research institutions are involved. More information on the overall project approach and partners can be found on the project homepage: www.sustainable-hyderabad.de. Downloads of mentioned case studies are provided under: hyderabad.nexusinstitut.de and conceptsandsolutions.ptvgroup.com/de/referenzen.

[9] Special Economic Zones in India were announced in April 2000 and are intended as engine for economic growth supported by quality infrastructure complemented by an attractive fiscal package, both at the Centre and the State level, with the minimum possible regulations. For more information see: http://www.sezindia.nic.in

wheelers was 76% and cars & jeeps 14%. The highest percentage of growth has been observed in the four-wheeler segment (75%) followed by two wheelers (54%) (HMDA 2011).
In terms of climate Hyderabad is already characterised by weather extremes: flooding in monsoon times and severe draughts. For the future it is predicted that climate change will lead to even more extreme events, like disastrous floods, extreme droughts and significantly - due to its location in an semi-arid area with little natural water resources but high consumption - increasing water scarcity.
The first research results for the city of Hyderabad presented in this chapter were gained within the scope of the research project "Sustainable Hyderabad", Work Package "Sustainable Transport Planning for Hyderabad" lead by PTV Group[10].

2.3.2 Transport challenges

In acknowledgement of the importance of urban centres for India's economic growth, a growing awareness of the negative effects of increasing motorised traffic on urban development by relevant ministries and planning bodies is being recognised: referring not only to Hyderabad but to the majority of Indian cities. The main focus is on traffic and environmental quality of cities but increasingly also on climate change effects to and from the transport sector, as documented in the National Action Plan for Climate Change (Government of India, without date). The transport sector is not only contributing with approx. 20 per cent of the greenhouse gas (GHG) emissions to climate change, but its functionality is also badly affected by the consequences of climate change (International Transport Forum 2010). For example when floods caused by extreme rains lead to traffic interruptions or deviations because these themselves cause additional GHG emissions.
To rectify this situation, the Ministry of Urban Development (MoUD) 2006 has launched a policy framework: The National Urban Transport Policy (NUTP), which focuses on moving people not vehicles (MoUD 2006). The implementation of this policy is supported by Guidelines and Toolkits, an important one of them being the Comprehensive Mobility Plans (CMP). CMPs are looked at as key documents to provide the rationale for transport proposals in line with the NUTP. They are also considered as a prerequisite when applying for central government funding under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM[11]). Furthermore, the MoUD strongly recommends all cities to prepare CMPs (MoUD 2008).
The objective of CMPs is – in line with the NUTP – to provide, long-term urban transport strategies, which comprise measures for a sustainable, equitable and cost-effective improvement of people's mobility rather than vehicle movement, emphasising integrated land use and transport planning, public transport and promotion of non-motorised transport. Herewith environmental issues as well as issues of energy-efficiency and mitigation of greenhouse gases are addressed implicitly by NUTP and CMP.

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[11] The Jawaharlal Nehru National Renewal Mission was launched in December 2005 by the Government of India to provide financial assistance for selected Indian Cities to overcome deficiencies of urban infrastructure, like water and transport, and service delivery. JNNURM aims at integrated developments and urban reforms. For more information see http://jnnurm.nic.in/

However, so far no standardised methodologies exist in India to explicitly quantify environmental impacts (energy efficiency, air pollution, GHG emissions) ex-ante for different strategies in order to take these effects into account when designing and choosing the most appropriate strategy for a "future-proof" and resilient transport system.
Therefore the Comprehensive Transport Study, which is currently under way in Hyderabad and leading towards a CMP for Hyderabad, whose implementation will seek funds under JNNURM, will not be able to address these issues appropriately, either.
In this given context, the objective of the project is to provide planning bodies with a tool that supports them in answering the following questions, within their development-process of the CMP for Greater Hyderabad.

- How can the transport infrastructure be adopted most efficiently to extreme climatic events, which Hyderabad will face more often in future (adaptation planning)?
- What potentials for reduction of energy consumption, GHG emissions and air pollution can be expected by certain measures in the transport sector (mitigation planning)?

2.3.3 Methods and strategies

The tool – including the methodologies - which was developed and applied in the project, is called the Strategic Transport Planning Tool (STPT) and consists of

- a prototypical, multi-modal transport model, set-up with PTV software VISUM[12] and based on secondary data from Hyderabad[13] and
- a method (partly implemented in an excel-based assessment tool) to analyse local and mid-term adaptation requirements as well as city-wide mitigation potentials and adaptation requirements of long-term transport strategies.

Within the project the existing state-of-the-art-tools (VISUM transport model) and assessment methodologies were enhanced and modified to Indian conditions and project requirements based on input from our Indian partners, literature review and our own empirical work.
In order to facilitate the design and implementation of an appropriate adaptation strategy an approach was developed by the German research partner PIK[14] to downscale the regional climate change effects to concrete locations with the tool CATHY[15], which indicates which locations will be flooded in extreme rain events. The flood-prone locations identified in such a way were subsequently integrated into the transport model, by a technical interface.

[12] VISUM is a state-of-the art software for macroscopic transport modelling
[13] Set-up of a transport model requires a lot of actual/current input data as well as of plausible future developments. As data and models on current or future transport demand is not available for Hyderabad at the moment, the prototypic model was set-up with available outdated secondary data. Current data will be available after the Comprehensive Transport Study is completed (earliest end of 2013). With this data the prototypic model can be updated easily.
[14] Potsdam Institute for Climate Research
[15] CATHY: Climate Assessment Tool for Hyderabad is an open-source GIS-database which shows the effect of different climate change scenarios for Hyderabad up to 2100 on different parts of the city fabric (e.g. slums, water and transport infrastructure).

To identify the most vulnerable and critical locations for the functioning of the transport and city system, where adaptation should have highest priority, an additional method was developed to model and assess these locations.
Own observations and literature review showed that in most cases the roads are not completely blocked for a full day but maximum a few hours and most hours of the day the road capacity is merely reduced. In order to assess the adaptation need, this effect has to be modelled correctly according to the severity of rain events in the future and the specific conditions of the location.

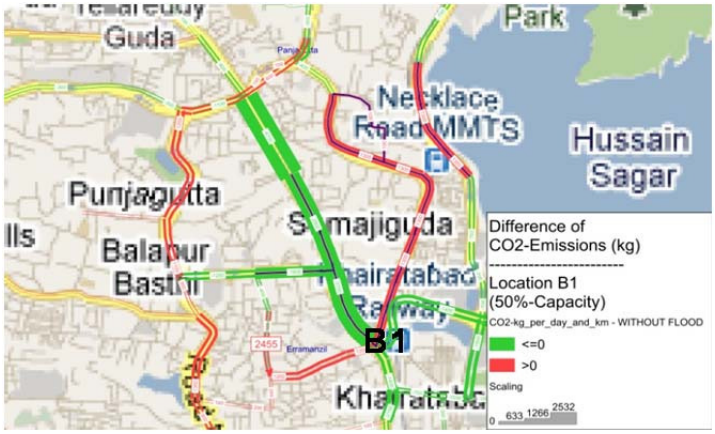

Figure 8: Difference in $C0_2$-Emissions between the cases no flood and flood of location B1. green=less emissions than no flood case, red more emissions (Source: own graphic, based on transport model VISUM & google maps).

After modelling the effect, emission-calculation (GHG and others) was done in VISUM directly, with the newly embedded Module "HBEFA" which is based on the latest version of the European Handbook of emission factors for road transport (Keller 2010). Figure (above), shows an extract from both transport models. It displays directly the difference in CO_2-emissions between base case and analysis case (called difference plot). The red colour indicates roads where an increase of CO_2-emissions can be expected compared to the base case due to traffic deviations.
However some parameters of the module needed to be adapted for Indian conditions. The advantage of this approach is that effects of the flooding, like deteriorating traffic flow (see Figure above) or changes in level of services, can be considered accurately and with greater ease than in post-modelling external calculations.
With the chosen set of indicators the tool is simultaneously suited for ex-ante analysis of energy-efficiency of long-term transport strategies and therefore able to contribute valuable information to the planning process on how to design a climate friendly transport system[16].

Furthermore two different case studies (in geographically limited planning areas) were carried out, with strong support of our Indian research partner, NIT Warangal and relevant authorities to get a better understanding of the mitigation potential of different measures.

[16] For a detailed description of the approach and indicators please see Schäfer (2013).

Case study 1 dealt with options to improve a highly loaded road corridor in Hyderabad for bus service and pedestrians and was based on the microscopic simulation PTV-software VISSIM.
Case study 2 tried to identify potentials to optimize the existing network and to design a bus network with regard to future developments, e.g. up-coming Mass Rail Transit System (MRTS-System and was based on the existing strategic VISUM transport model, which had to be refined for the planning area.

Figure 9: Simulation of one measure of case study 2: median bus lane and bus stop (Source: own graphic, based on simulation model VISSIM & google maps).

The essence of the mitigation potentials identified by these geographically limited case studies will be up-scaled on to the city - and strategic level in the last work-steps of the research project and ultimately fed into the strategic planning process.

2.3.4 Research and conclusions

The implementation of the case studies (amongst all other activities) showed that the methods and tools developed within the project are suitable to design network-options that improve the energy-efficiency and overall sustainability of the transport system even without building of major new infrastructure by road widening etc.
Nevertheless the activities also indicated that there is still a long way to go until the National Urban Transport Policy of the MoUD will be properly implemented on the local level.
This is on the one side due to a lack of appropriate data needed for the planning process but on the other side also due to the fact that know-how on options to design a sustainable urban land use and transport system is not widely spread amongst the transport professionals. So far transport planning is very much focused on improving the situation for the individual motorized transport and not the more energy-efficient modes. Therefore capacity building measures on sustainable transport planning is a major issue to be tackled to improve the situation.

2.4 HEFEI, CHINA

Author: Oliver Lah

2.4.1 City Characteristics

Rapid motorization in Hefei and other Chinese cities is driving energy demand and greenhouse gas emissions and has severe impacts on the quality of life in the city through pollution, noise and safety issues. The METRSYS project[17] focuses on the city of Hefei, the capital of Anhui Province, China. Hefei is a so-called second-tier city of which there are many in China. Many first-tier cities, such as Shanghai, Beijing, Tianjin and Guangzhou, experienced rapid growth since the early 1990s and are now approaching their population limits. Now a growing number of second-tier cities, many of which are provincial capitals, are now experiencing rapid urbanisation with currently between 2 to 7 million inhabitants and projected 10 million in the near future. Hence, Hefei represents a cluster of similar cities and findings may be transferable to similar Chinese second-tier cities.
There are a number of drivers affecting transport in Hefei over the coming decades. The Hefei City Region Master Plan expects the population of the city to be almost 9 million by 2030 and 10 million including the surrounding areas. The percentage of population over the age of 60 is expected to almost double by 2050 from 11% today to 22%. China will soon be experiencing an unprecedented ageing rate of its population, comparable to many advanced economies. This will result in a major shift in its population structure.

2.4.2 Transport challenges

Over the last decades China's urban population has grown exceptionally fast. Forecasts indicate that Hefei, along with other cities in China is likely to experience increased demand for transport infrastructure over the next twenty years, through population growth and demand for freight transport. The need to manage this growth effectively and maximise transport efficiencies will require an integrated concept that addresses energy demand, carbon and harmful emissions, congestion, pressures on infrastructure, urban amenity and quality of life, and access and mobility. The rapid increase of travel demand and the growing vehicle fleet in Hefei are accompanied by substantially growing GHG emissions and local pollutants. The modelling of the METRASYS project also shows that under a business as usual scenario that the modal split of non-motorised and public transport is substantially decreasing from currently 72% to less than 50%, with the percentage of private cars doubling by 2030 (Figure 10).

[17] Project leader is Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) Institut für Verkehrssystemtechnik (TS), More information: http://www.metrasys.de

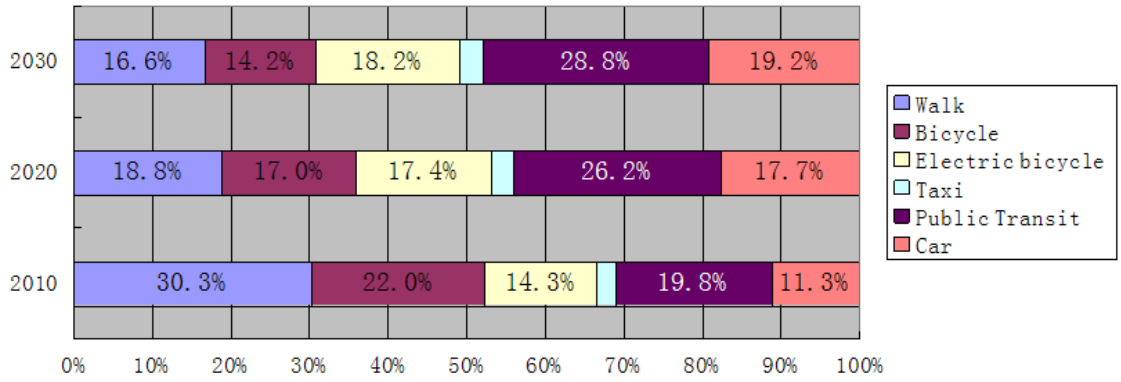

Figure 10: Modal share projections for Hefei (2010-2030), Source: Metrasys 2012

The size and shape of the vehicle fleet is a vital factor for energy consumption and the emission of harmful substances and GHG. Under a business as usual scenario the vehicle fleet the city of Hefei can be expected to grow almost rapidly, from currently about 200,000 cars to over 1.8 million by 2030. This figure is based on annual growth rates of 18.1% over the first five years declining to 5.5% by 2030.

Electric cars will remain a niche product in Hefei with only 4,000 in the fleet by 2030. E-bikes will increase slightly to over 14,000 by 2030 up from 10,000 today and conventionally powered motorcycles will disappear in Hefei by 2030 due to ban on new registrations. The number of diesel powered heavy-duty vehicles is expected to grow tenfold from 17,600 to over 170,000 by 2030.

The number of taxis in Hefei is projected to increase only marginally from 8,855 now to 12,750 by 2030, due to the high cost of taxi permits in the city. The number of buses is expected to almost double from currently 2,896 to 5,232 by 2030, which is however, a considerably lower growth rate than the one projected for private cars.

2.4.3 Results and strategies

The core objective of the METRASYS project is to improve the efficiency of the existing transport network (better traffic flow and increased transport energy efficiency) through traffic management. Traffic management has the potential to reduce congestion and contribute to seamless transport in urban environments. It can also make a contribution to the improvement of air quality in the city centre by diverting traffic. However the design of traffic management schemes and their embedment in a wider concept are crucial if these schemes are supposed to contribute to a sustainable transport system. Applied in isolation, traffic management is likely to be less effective in delivering its primary objective to reduce congestion and is likely to generate trade-offs with other objectives such as energy efficiency of the transport system, greenhouse gas emissions and economic efficiency.

As part of the METRASYS project it is planned to make real-time traffic information available to allow individuals, but also taxi drivers and transport companies to plan and route trips more effectively. Technology based traffic information and management systems can contribute to better traffic flows and can reduce congestion (ECMT 2007). While this improves the utilisation of the existing road network it may not necessarily improve energy

efficiency of the transport sector in urban areas. Improved reliability of individual motorised transport will improve the attractiveness of this mode of transport and may even induce transport demand (Goodwin 1996; Lam, T.C., Small 2001).

The effectiveness of traffic management measures in terms of energy efficiency depends on how travellers respond to improved traffic flows in the road network. Several studies suggest that behavioural changes may erode a considerable share of the efficiency gains. In a policy environment such as China, where travel demand is surging and fuel prices are subsidised rebound effects are likely to be substantial. Reduced travel time and fuel costs are often leading to increased travel demand, which undermines the efficiency gains and may even outweigh them (Ruzzenenti and Basosi 2008). While road network capacity is largely predetermined, it varies significantly with the irregularity of travel demand, which can be influenced by traffic management. The level of induced travel through improved efficiencies in the system depends to a certain extent on the level of income (Portney, P.R., Parry, I.W.H., Gruenspecht, H.K., Harrington 2003). The levelling off of rebound effects from efficiency improvements observed in OECD countries (Small, K.A., Van Dender 2007), is unlikely to occur in emerging economies like China at this stage as the link between discretional income and travel demand is still very high, even though it tends to decline with increasing household incomes (Wang et al. 2012).

2.4.4 Results and Conclusions

The current approach to congestion management in the city of Hefei focuses primarily on the expansion and completion of the road infrastructure network. The increased road network capacity, however, induces additional traffic, which undermines the intended objectives of congestion relief, hence not only eroding efficiency gains, but also calling into question the investments made into additional road capacity (Hymel, K.M., Small, K.A., Dender 2010). The direct rebound effect of efficiency measures in urban passenger transport was estimated at 96% for China (Wang et al. 2012).

One very effective option to improve traffic flow *and* reduce overall travel demand is congestion charging. Congestion charging systems have been operating in Singapore for several decades and were implemented more recently in London and Stockholm. Liu et al. (2009) undertook such a study for China, focusing on the example of a congestion change for the old central city of Beijing. The study suggests that congestion charging can reduce the number of cars entering the 2nd Ring Road by about 10% during peak time hours (Liu et al. 2009). It was stressed, however, that congestion charging should be implemented according to the regional circumstances and emphasised that complementary measures such as improved public transport are required to provide affordable and reliable alternatives to the private car (Liu et al. 2009).

Traffic management is a vital element of the METRASYS project. The project develops a policy package of traffic management and complementary measures that contribute to climate change mitigation and energy efficiency improvements in transport sector in the city of Hefei, China. It will also explore options for international climate finance and will provide some practical steps towards this option.

2.5 GAUTENG, SOUTH AFRICA

Author: Jan Tomaschek

2.5.1 City Characteristics

Gauteng province is the smallest of all nine South African provinces and occupies less than 2% of the total land area of the country. However, the province is home to about one fifth of the national population, which currently stands at about 11 million people (Stats SA, 2011) and generates about a third of national GDP. Moreover, Gauteng's population is expected to grow at a rapid rate − even faster than other parts of the country due to high immigration rates. A population of about 20 million people by 2040 is, therefore not an unreasonable prediction (Wehnert et al., 2010).

The economic dominance of Gauteng is a major driver of transport activity and transport-related energy consumption and greenhouse gas (GHG) emissions (Figure 10). Consequently, Gauteng was responsible for about 29% (about 770 PJ) of the total final energy consumption (FEC) of the country in 2008 (Tomaschek et al., 2012a), (IEA, 2008). Taking into account the energy provision, GHG emissions corresponding to the energy consumed in Gauteng were about 122 Mt CO_2eq in 2007, (Tomaschek et al., 2012a). In comparison, GHG emissions produced within the province are calculated at only 45 Mt CO2eq (Tomaschek et al., 2012a) as only minimal capacities for energy provision are located in Gauteng. The transport sector accounts for approximately 33% of the total final energy demand in Gauteng (Tomaschek et al., 2012a). The GHG emissions caused by Gauteng's transport sector were around 16.1 Mt CO_2eq, which is about 13% of the total GHG emissions that Gauteng is responsible for (Tomaschek et al., 2012a). However, further emissions are caused by energy provision for the transport sector. These emissions are caused by crude oil refining, but most significantly, also, by the production of synthetic fuel using Fischer-Tropsch coal-to-liquid synthesis (CTL) (Telsnig et al., 2013).

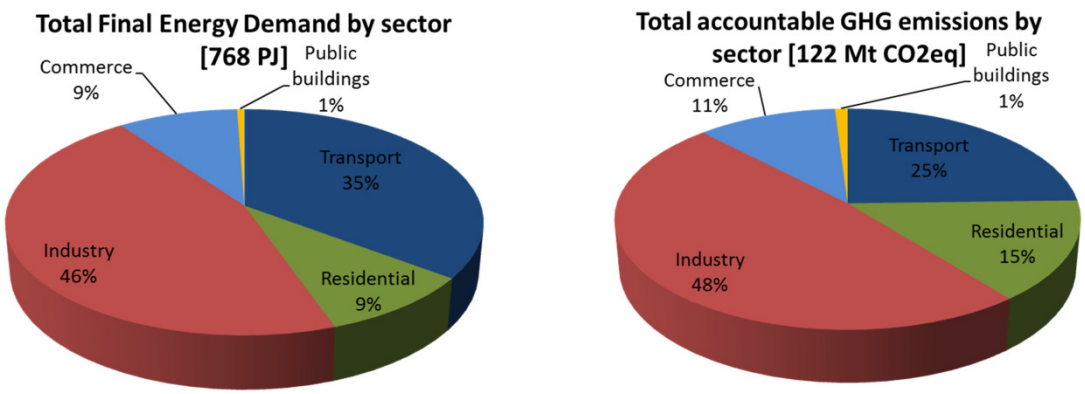

Figure 11: Final energy consumption and greenhouse gas (GHG) emissions caused by Gauteng in 2007. GHG emissions of energy supply and conversion have been allocated to end-use sectors (Tomaschek et al., 2013b)

2.5.2 Transport challenges

Within the three tiers of transport governance in South Africa, numerous strategies and master plans have been developed over the last years. Moreover, climate policies and air-quality strategies have been developed within the other departments e.g., in the DOE or the GDARD.

An important transport strategy to mention on a national level is the National Land Use Transport Masterplan 2005−2050 (NATMAP) of the DOT. The goal of NATMAP was to "Develop a dynamic, long-term, sustainable land use / multi-modal transportation systems framework for the development of networks infrastructure facilities, interchange termini facilities and service delivery." (DOT 2008). In order to implement this framework, available national, provincial, local data, and tools have been evaluated and consolidated. It proposed, for example, the extension of the national road infrastructure, the change of the model subdivision in favour of public transport and the institutional reorganisation of the rail freight sector (DOT, 2008).

National and Provincial Climate Protection was emphasised in the long-term mitigation scenario (LTMS) and in the Gauteng Integrated Energy Strategy (GIES). In the LTMS, scenarios were developed within the scope of the United National Framework Convention on Climate Change (UNFCCC). However, the LTMS did not provide in-depth analysis of the transport sector (Winkler, 2007). Within the GIES, pathways to improved sustainable energy-use in Gauteng were promoted and Gauteng was identified as the region which would play a leading role for climate-protection in South Africa. However, also the GIES did not either emphasise the transport sector or the transport energy supply (DLGH, 2010). Proposed measures for GHG mitigation include: a higher share of biofuel use in the transport sector, de-carbonisation of electricity provision through renewable energy, solar water heating in the residential sector, and a general increase in energy efficiency. However, the priorities for the implementation of different measures in all sectors are not always clear. Moreover, the actual mitigation potential of possible measures (e.g. in the transport sector: new modes of transport like BRT, new vehicle technologies like electric vehicles or alternative transport fuels) remains unclear. Moreover, even the actual performance of vehicles currently used in Gauteng it not always known.

2.5.3 Methods and Strategies

To quantify transport energy-use and transport-related energy emissions and moreover, to quantitatively evaluate promising measures for mitigation transport and transport-related GHG emissions, two transport tools (i.e., TEMT and TIMES-GEECO) were developed as part the EnerKey project. EnerKey is an abbreviation for Energy as a Key Element of an Integrated Climate Protection Concept for the City Region of Gauteng, (www.enerkey.info) and is part of the broader megacities funding-scheme of the German ministry of education and research (BMBF, 2013). The EnerKey project is a German−South African collaboration which aims to develop and implement innovative projects in urban energy supply and use, in order to improve the policy-making process to reduce energy consumption and GHG emissions in the province while keeping in mind the demands of society and budget

constraints. A detailed representation of the two models, their assumptions as well as initial results can be found in several publications, (e.g., Haasz et al. 2013; Tomaschek et al., 2012b; Tomaschek et al., submitted; Tomaschek, 2010; Dobbins, et al. 2009; Tomaschek et al., 2009). The following section gives a short overview of the two tools:
The TEMT emission model was created by TÜV Rhineland to generate real-world emission factors for Gauteng and to visualise transport emissions spatially. TEMT operates using Visual Basic code. It is a combination of a transport emission tool based on European research data on vehicle emissions and a Geographic Information System (ArcGIS) for visualisation of vehicle travel of the different vehicle types and their specific emissions directly on a map. This software model incorporates emission factors for existing individual vehicles, as well as emission factors for alternative vehicle technologies and fuel use. Three main databases were used as an input data for TEMT.
This data is then used in the TIMES-GEECO energy-system model, which has been developed at the IER University of Stuttgart (Tomaschek, 2013a), (Tomaschek et al., 2012b) (Tomaschek, 2010). The data can be used to identify least-cost measures to achieve the climate and energy efficiency goals of the region by integrating proposed energy policies and technologies within a defined technical and socio-economic framework. Obviously, this integration includes the transport sector, but the other components of the energy system as well. The consideration of the entire energy system has the advantage that interdependencies and interlinkages in the energy system are taken into account which allows identifying least-cost mitigation targets in the whole system and ensure not to set mutually exclude targets for different part of the energy system. Moreover, in the TIMES-GECCO model the emissions of fuel production, as well as the associated costs for energy provision are included which can result in a significant further climate impact (Tomaschek et al., 2012c). Using TIMES-GEECO, a scenario analysis was conducted in order to identify robust measures and reach provincial targets at minimum cost.

2.5.4 Results and Conclusions

The results of the scenario analysis show that in the reference scenario, the energy demand and GHG emissions in Gauteng are likely to increase significantly until 2040, i.e., by almost 80% to almost 240 Mt CO_2eq. This is caused by two main factors: the expected increase in population and GDP, and the demographic shift and increase in personal wealth. The total final energy consumption (FEC) will increase significantly in all sectors under the implemented policies. For example, in the transport sector the calculated increase in FEC is 87%. Moreover, under the conditions of the implemented policies scenario, the energy supply will still be largely based on coal and fossil fuels. GHG emissions through fuel combustion in the transport sector increase from about 16.1 Mt CO_2eq to about 22.7 Mt CO_2eq under the conditions of the implemented policies scenario which is equivalent to an increase of more than 40% (Figure 11, left). The vehicle technology use in the transport sector in the IPO scenario by 2040 is still likely to be primarily based on internal combustion engines, although some alternative vehicles like hybrid-electric vehicles or vehicle using CNG-engines will be more widespread by then.

In order to counter this development, policy-makers will have to intervene. When one compares all the mitigation scenarios, the share of alternative powertrains in the transport sector increases most significantly in the LRS scenario (Figure 11, right). Hybrid vehicles are initially used for the modes with long annual mileages and high proportions of urban driving, like public buses, the BRT, and minibuses as well. Moreover, the share of CNG vehicles increases, but with the use of a different energy source than in IPO. While under implemented policies, methane gas is sourced from coal gasification; in the alternative scenario natural gas is used as an alternative. Additionally, some gas is provided via upgrading gas from landfill and sewage sites. E85 vehicles are applied to accommodate the higher supply of ethanol in the system which is in the LRS scenario based primarily on sugarcane. Additionally, changes in the fuel supply can be identified which do not require alternative vehicle powertrains like the substitution of fossil synthetic fuels with ones from biomass (i.e. BTL) and biodiesel from waste cooking oil.

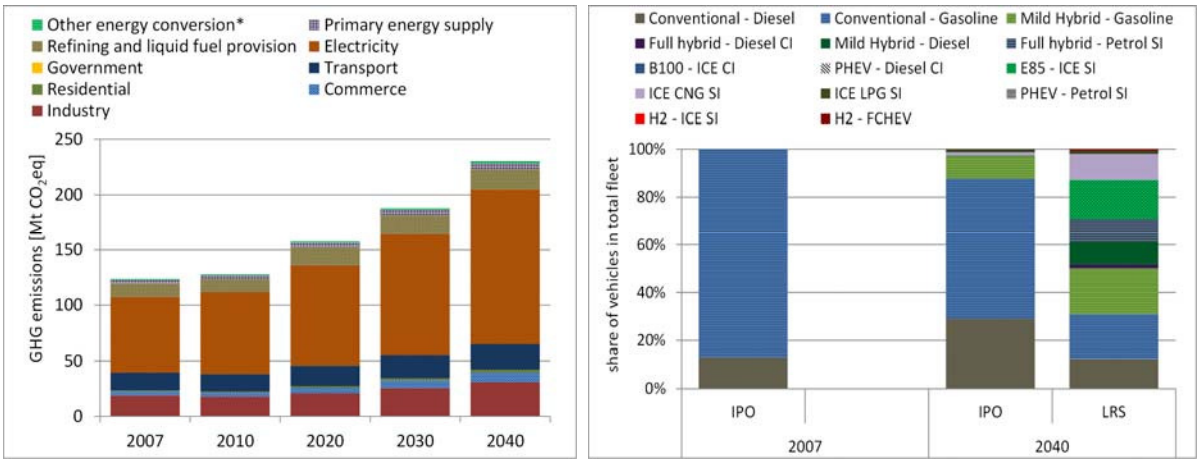

Figure 12: Greenhouse gas emissions by sector in under 'implemented polices' for 2007−2040 (left) Gauteng vehicle fleet by technology in the IPO and in the LRS scenario (right)

Consequently, GHG emissions in the transport sector are reduced by 4.4 Mt CO_2eq (-20%) by 2040 in comparison to the implemented polices scenario. Total GHG emissions that are attributable to Gauteng would thus be reduced by 156.6 Mt CO_2eq (-68%). This would mainly be based on changing the means of electricity provision, but also due to the changes in transport energy-supply. In the alternative scenarios, the change of the fleet into alternative technologies indicates not only a general reduction of the GHG emissions, as well as, and especially, in the highly frequented highways and urban roads (Figure 12).

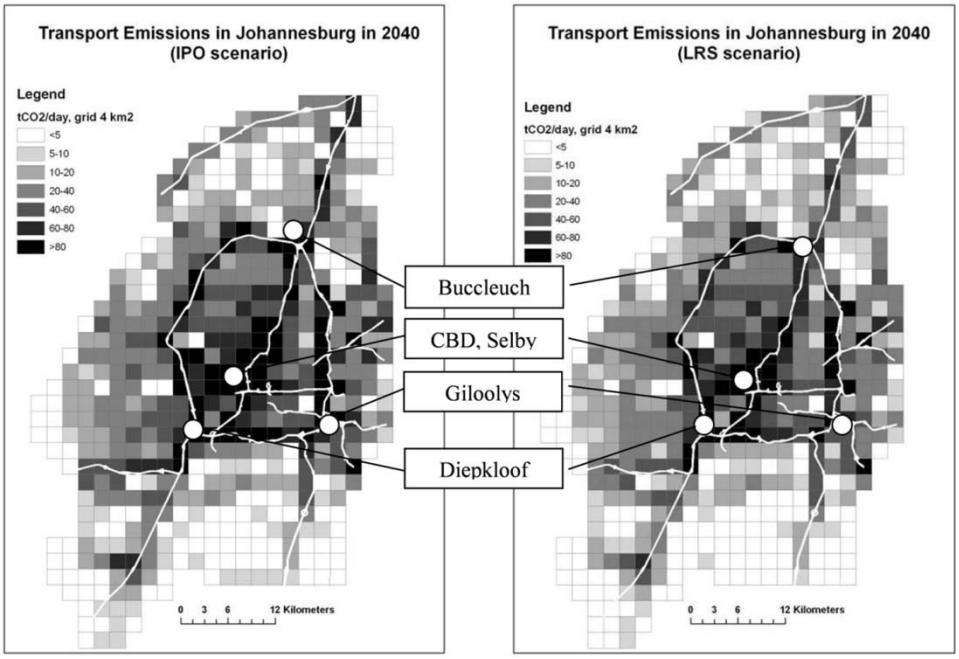

Figure 13: Illustration of the application of the TEMT model to the city of Johannesburg. On the left-hand side CO_2 emissions from road transport in the year 2040 are shown for the reference scenario. The results for the LRS scenario for the same year are shown in the right-hand figure (Tomaschek et al., submitted).

3 OVERALL CONCLUSIONS

All cities under investigation in this Megacity programme face the challenge of increasing demand for car traffic with annual growths rates above 10 percent. In all cities road congestion, air and noise pollution and safety problems are rocketing and have significant negative impacts on the quality of life for the inhabitants living in there. The transport concepts currently applied or in development in these cities can be characterised by an extensive expansion of the existing transport infrastructure, with a dominating focus on road infrastructure provision and to a less extent on public transport infrastructure improvement. However, policies which encourage walking and cycling as potential solutions towards a sustainable, low energy and environmental friendly transport system are de facto non-existent.
But the expansion of networks capacities, as it can be learned from examples also in first world countries, such as the USA or Europe, is not a solution for the present and future traffic and transport problems.

To achieve a sustainable transportation system, car use must be restricted and short ways have to be promoted. The street design has to integrate slow modes (bikes and pedestrians) and parking lots have to be reduced. Simultaneously public transport services have to be improved, too. The public transport systems have to be adequate for the cities, which means enough capacity, affordable (from the operator and from the user point of view) and has to be dense enough to generate a network with a mesh width below 500 meters between the transport stops. Such systems can only be realised through a combination of bus, bus rapid transport systems and tramway systems. Additionally considering the informal structures in many Megacities in emerging countries so called Paratransit services as informal taxis and

carpooling can play a supporting role of this flexible public transport system. Only in very limited circumstances are subway/skytrain systems affordable and necessary.
Soft policies (for example, information campaigns, promotion of eco-mobility, restriction for car traffic, etc.) have to be an integrated part of these future transport concepts.

As it can be derived from the city descriptions within this paper that in all cities tools and decision support systems, which were developed in Europe, were applied and transferred to the Megacity case studies. In all projects it was shown that the objectives of the existing transport strategies cannot be reached with the planned or presently implemented policy instruments. This uniform result, derived with the application of different tools applied on different cities should initiate a rethinking process for the design of future transport masterplans. It can be concluded that “traditional” solutions, based on (road-) infrastructure provision are by no means able to deliver a sustainable, viable and seminal transport system.

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