Localising the Handbook of Emission Factors for Road Transport to Chinese Cities

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Abstract

Greenhouse gas (GHG) emissions caused by transportation have become a key challenge for sustainable development in China, particularly in the metropolitan areas. On the one hand most of the large Chinese cities are faced with the challenge of developing ambitious GHG mitigation strategies for the transportation sector in the next few years. On the other hand information about traffic-related GHG emission sources is missing. CO_2 emission factor databases for road traffic used in Europe or United States (U.S.) have not been established up to now in China. Hence, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) is currently working on a tool for the quantification of transport-related GHG emissions for Chinese cities. Therefore INFRAS was commissioned by GIZ to adopt the European Handbook of Emission Factors for Road Transport (HBEFA) to the situation in China. Besides vehicle categories and sizes, fuel types, vehicle ages, load factors and road gradients, HBEFA provides emission factors for different traffic situations. The latter describe typical driving cycles and can be characterised by areas (urban/rural), road types, speed limits and levels of service (e.g. free flow, saturated traffic, stop and go traffic). For the localisation of HBEFA, China-specific traffic situations had to be identified. This paper presents the approach for collection and analysis data needed to identify the typical traffic situations for China exclusively for passenger cars. The data collection, the data analyses and the identification of typical traffic situations were worked out together with the cities of Beijing and Shenzhen. Last but not least, the paper presents the China-specific CO_2 emission factors for passenger cars based on the new traffic situations identified.

Introduction

China's economic growth over the past decades has had some undeniably positive effects on the country's development but it has also led to a strong increase of greenhouse gas (GHG) emissions and air pollution. Between 1990 and 2012 China's CO2 emissions grow by 293 % (from 2.51 to 9.86 billion tons per year) (Oliver et al., 2013). Particularly in winter season, smog periods with high air pollution affect large parts of the Chinese territory (CAA, 2013). To reduce emissions the Chinese government introduced several mitigation targets over the last years. For example, the transition to a low-carbon economy is one of the core objectives of the 12th Five Year Plan (2011–2015) of the Chinese government. Until 2020 the CO2 emissions per GDP shall be reduced by 40-45% compared to the situation of the year 2005 (Leggett, 2011). The Action Plan for Air Pollution Prevention and Control, published in September 2013, has the objective of reducing the average concentration of particulates smaller than 10 µm (PM10) in diameter by at least 10% for big cities by 2017 compared to the 2012 level. For three key regions – Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta – the annual average concentration of PM2.5 shall be reduced by 15-25% within this five year period (MEP, 2013; CAA, 2013).

Caused by the rapid growth of the number of vehicles, transport by motorised vehicles has become one of the most significant sources of GHG emissions and air pollutants, especially in large cities. In Beijing, more than 2.2 million new vehicles have been registered between 2005 and 2010. This represents a 13% growth rate per year (Mingying et al., 2012). Today over five million cars cause not only GHG and air pollutant emissions but also traffic congestion, parking problems and accident costs. Introducing GHG emission and air pollutant mitigation strategies for urban transport is challenging for many Chinese cities since approved emission quantification methodologies are not available. Very often GHG emissions are calculated based on fuel sales figures for Chinese cities. The disadvantages of this so-called top-down approach are that emissions cannot be linked to the transport activities and therefore to the origin of the emissions. Furthermore, this approach is inappropriate to calculate air pollutants since it does not account for vehicle characteristics such as filter systems or catalysts. Bottom-up approaches which combine transport activity data (e.g. vehicle kilometre travelled by vehicle type and size) with specific emission factors allow for accurate emission quantifications, the identification of the cause of the emissions and the development of more comprehensive mitigation strategies. However, the challenge of this approach is the need for disaggregated transport activity data at city level as well as reliable emission factors.

In contrast to Europe and the United States publicly accessible emission databases are not available in China. Instead, emission factors are derived for different vehicle types based on measurement programmes for vehicles, which are carried out by local Environmental Protection Bureaus (EPB) and the Chinese Ministry of Environmental Protection (MEP, 2011). Since emission factor databases are not published many studies have been carried out to estimate vehicular emissions in China (Yao et al., 2011; Huo et al., 2011). While different sources for emission factors of air pollutants are available today, China has not released an official tool or inventory model for GHG emission accounting of mobile sources at the national level. In the context of the Sino-German project on low carbon transport in China, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) is currently developing an emission factor database for the quantification of transport-related GHG emissions at city level in China to close this gap. The project is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

After a broad international review of emission factor databases and emission models (e.g. (MOVES - Motor Vehicle Emission Simulator, COPERT - Computer Programme to calculate Emissions from Road Transport and HBEFA - Handbook of Emission Factors for Road Transport) as well as approaches used in Germany (Dünnebeil et al., 2012), the GIZ has identified HBEFA as the most suitable tool for Chinese cities. One of the advantages of HBEFA is that it is especially adaptable at city level as it provides emission factors for road types (e.g. express way, trunk road, branch) and different levels of services (such as free-flow or stop-and-go) as well as for different vehicle categories and sizes. Such categories and parameters are usually used by transport planners at city level and can be provided by transport statistics and travel demand models used in cities. Last but not least the HBEFA approach is also especially valuable for China due to similar fleet composition and vehicle types in China and Europe.

To adapt the emission factors of HBEFA to the local situation in China INFRAS was commissioned by GIZ to support this process. The localising steps were carried out in cooperation with the Beijing Transport Research Centre (BTRC) and the Shenzhen Urban Transport Planning Centre (SUTPC). This paper presents the results of the development of China specific CO_2 emission factors for passenger cars. Up to now passenger cars and CO_2 emissions were in the focus of the project. In the next steps of the project air pollutants and other vehicle types will be addressed.

Approach to adapt HBEFA to Chinese cities

Many Chinese cities are sceptical whether it is possible to use emission factor databases established in Europe or the United States even if these databases would be adapted to the local situation. Besides the question whether the vehicle characteristics and therefore the underlying emission factors would be comparable with the local situation the suspicion persists that the driving conditions in Chinese cities would be significantly different from European or U.S. American cities. Quite obviously, the share of congestion is considerably higher in Chinese cities. At the same time, driving situations during congestion period are different. The stop times are higher, the average speed is lower. This is often the reason why the cities, in cooperation with universities, derive own emission factors based on local measurements with portable emissions measurement systems (PEMS) (Huo et al., 2011; Huo et al., 2012). Although the measurements fulfil scientific requirements the representativeness of the emission factors derived from PEMS data is sometimes arguable. Furthermore, PEMS measurements are mainly used for the development of emission factors for air pollutants and less for CO_2 emissions.

In Europe but also in the U.S. a main objective of the development of emission factor databases like MOVES, COPERT or HBEFA was to provide systematically derived emission factors for different fleets taking into account different driving conditions. Additionally, the structure of the emission factors should be easily applicable for users at local, regional and national level. For example, HBEFA provides emission factors in grams per vehicle-kilometre structured by the following segments:

- Vehicle category,
- Vehicle or engine size,
- Fuel type,
- Emission standards (and implicitly by age),
- Load factor (only for heavy duty vehicles),
- Road gradient, and
- Traffic situations.

The concept of different traffic situations was developed in the context of HBEFA and describes typical driving cycles for Europe. Traffic situations are a concept to structure the emissions factors for easier application particularly at city level and are characterised by speed-time functions. In Europe the traffic situations are defined by areas (urban/rural), road types (e.g. motorway or trunk road/primary road in cities), speed limits (e.g. 80 km/h) and levels of service. HBEFA distinguishes four levels of service: Free flow, heavy-, saturated- and stop-and-go-traffic. In total HBEFA distinguishes 276 different traffic situations, thereof more than 120 traffic situations for urban areas. The typical European traffic situations were elaborated over a long time and are optimised continuously (Steven, 2011; Hausberger et al. 2009).

For each of HBEFA's European traffic situation specific emission factors are provided. The large number of traffic situations would make it very complex to measure all emission factors for each traffic situation. Therefore the development of the HBEFA emission factors is based on the following approach (see Figure 1): The emission factors for the different traffic situations are calculated with the Passenger car and Heavy duty vehicle Emission Model (PHEM), which was developed by the Technical University of Graz in several international and national projects, namely the German-Austrian-Swiss cooperation on the Handbook of Emission Factors (HBEFA), the EU 5th Research Framework Program ARTEMIS and the COST 346 initiative as well as in projects within the ERMES group (Hausberger et al., 2009, Hausberger et al., 2013).

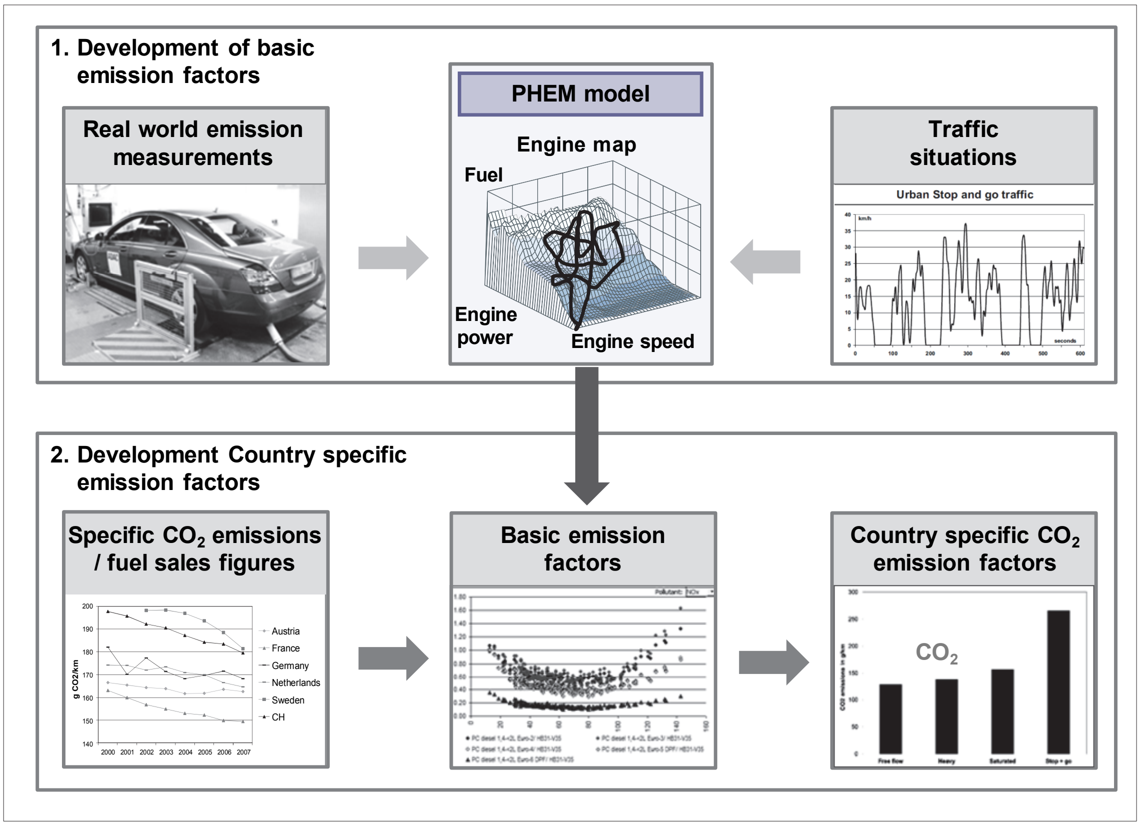

Figure 1: HBEFA approach for development of country specific CO_2 emissions in Europe

The model includes so-called engine maps for different vehicle classes, sizes and emission concepts which describe the quantity of emissions depending on engine power and engine speed. The model is calibrated by using emission measurement data of vehicles from roller test benches or engine test beds on a second-by-second basis. The PHEM model can translate all driving cycles (speed-time-curves) into emission factors by considering gear shift patterns, driving resistances, transmission losses and specifics of emission control technologies (e.g. the thermal performance of catalytic converters).

Regarding fuel consumption and CO_2 emissions the outputs of the model are emission factors for different size classes and concepts. In an additional step these values can be transformed into fuel consumption and CO_2 emissions for other construction years and engine sizes. For that purpose the country specific average CO_2 emissions of new registered passenger cars and light duty-vehicles as well as fuel sales figures are considered. This is necessary in order to adapt the emissions factors to country specific CO_2 levels since there can be big differences amongst the European countries within the same vehicle groups (e.g. passenger cars between 1.4 and 2.0 l engine size). These differences are accounted for with this second step of adaptation.

Analyses have shown that the passenger cars used in Chinese cities are very similar to those in Europe regarding engine characteristics. Nevertheless, the following steps to localise the HBEFA emission factors to China are necessary: First, typical traffic situations for Chinese cities have to be identified and compared with the driving cycles used in the European version of HBEFA. Originally, it was expected that the Chinese traffic situations would be very similar to Europe. However, there are significant differences:

- Instead of six road types only four road types are relevant for Chinese cities, these are: Expressways (including highway), major arterials, minor arterials and branches.
- Essentially, speed limits are linked to the road type and have not to be considered separately for Chinese cities.
- It was shown that the levels of service in Chinese cities are similar for free flow, heavy and saturated traffic. Based on the congestion levels used in Beijing and Shenzhen (see table 1) it was necessary to distinguish two types of stop-and-go-traffic: A first stop-and-go situation which is similar to Europe and a second one with higher shares of stop time and lower speed which is untypical for Europe but often occurs in large Asian cities. Therefore, along the lines of the five congestion levels, five levels of service are defined for Chinese cities to cover all driving situations (BMAQTS, 2011).

Since the Sino-German project on low carbon transport in China focuses on urban areas it is sufficient for the time to consider only 20 different traffic situations in total. For adapting the HBEFA approach to China firstly the typical driving patterns have to be identified and then compared to the existing European driving patterns. For new traffic situations the fuel consumption and CO_2 emission factors have to be calculated with the PHEM model. Finally, the CO_2 emission factors have to be calculated for each engine class and construction year based on the Chinese average CO_2 emissions of new registered cars based on PHEM output for standardised passenger cars similar to Europe.

The focus of the Sino-German project lies on the adaptation of the traffic situation scheme and the calculation of CO_2 emission factors for specific Chinese traffic situations. In a first project step this was performed for passenger cars only. Emission factors for air pollutants and emission factors for other vehicle types are planned in further project steps. For the identification of typical traffic situations China-specific speed-time curves for different driving cycles were recorded.

Collection and pre-processing of GPS data

For the identification of typical traffic situations in China more than 2,000 hours of GPS data were collected in Beijing and Shenzhen during the years 2012 and 2013. Before beginning data collection three different GPS devices have been tested in practice. After evaluation of the accuracy and reliability the GPS device Columbus V900 was selected. The measurements were made once every second (1 Hz) and were temporarily stored in the memory of the device. The GPS devices were installed in taxis and private passenger cars and collected information about geodetic coordinates, speed and acceleration for each second. The driving data collections in Beijing and Shenzhen were not designed on fixed routes, but tried to cover all typical road types and traffic situations on each day across peak and off-peak time periods. A broad range of different drivers and vehicles were selected considering gender, age, profession of driver and age of vehicles. The drivers were not given any instructions on how or where to drive. They were advised to drive their itineraries as they would normally do. For taxis, the operation status (with or without customer) was also collected via the fare meters. Only GPS data with customers on board were considered in the further investigations.

Before pre-processing unreliable data sets were removed. The pre-processing steps included the following steps: 1) Elimination of double records (with time difference = 0); 2) Interpolation where successive time difference is greater than 1 second and less than 5 seconds; 3) Splitting the GPS data into two separate cycles if the time difference was too long (5 seconds and longer). In the last case the time period without GPS data signal was not considered in further analyses steps. In Europe the original GPS data applied for the identification of typical traffic situations were not directly used because the speed-time curves often showed leaps in speed which couldn't be explained by the real driving behaviour of the car drivers. Because of this, the data was smoothed by using the T4253H smoothing algorithms of the SPSS software. To ensure the same pre-processing in China the Chinese GPS data were also smoothed by using the same algorithm.

In the next step of pre-processing the GPS data were assigned to the road network by using the latitude and longitude information for each second. The data was assigned to the four road types Expressway, major arterial, minor arterial and branch. Map matching algorithms are well developed in China and applied in floating car systems used in Beijing and Shenzhen. Both cities have their own software packages to conduct this task. The map matching steps were carried out by BTRC and SUTPC within the Sino-German project.

In the last step of pre-processing the continuous GPS measurements data was divided into separate cycles by road type. After this step the cycles were assigned to the five levels of services by using the average speed per cycle. Depending on the speed ranges of the five congestion levels used in Beijing and Shenzhen (BMAQTS, 2011) the cycles were allocated to one of the five Chinese levels of service (see table 1). If the cycle was longer than 600 seconds then the cycles were subdivided into smaller cycles based on driving speed profiles. For this step the floating average speed over 60 seconds was calculated. If the floating average speed changed to the next congestion level and therefore to the next level of service the cycle was separated into multiple parts. This step was done semi-automatically by using a tool which was developed by GIZ in cooperation with BTRC and SUTCP.

Table 1: Definition of level of services based on congestion levels, road types and ranges of average speed in km/h in China

Level of service (LOS)	**LOS 1: Free flow**	**LOS 2: Heavy traffic**	**LOS 3: Saturated traffic**	**LOS 4: Stop and go**	**LOS 5: Heavy stop and go**
Congestion level	**Unimpeded**	**Basically unimpeded**	**Mild congested**	**Moderate congested**	**Severe congested**
Expressway	>55 km/h	>40-55 km/h	>30-40 km/h	>20-30 km/h	≤20 km/h
Major arterial	>40 km/h	>30-40 km/h	>20-30 km/h	>15-20 km/h	≤15 km/h
Minor arterial	>35 km/h	>25-35 km/h	>15-25 km/h	>10-15 km/h	≤10 km/h
Branch	>35 km/h	>25-35 km/h	>15-25 km/h	>10-15 km/h	≤10 km/h

After pre-processing was completed the average speed, the relative positive acceleration (RPA) and the percentage of stop time were calculated for each cycle. RPA is the integral of vehicle speed multiplied by the positive acceleration and the time interval, divided by the distance of the cycle. RPA can be interpreted as acceleration in m/s^2 as well as acceleration energy needed per kilogram vehicle mass and per unit distance in kWs/(kg km). Stop and go traffic has typically RPA values between 0.25 and 0.5 m/s^2, steady driving has a RPA between 0.01 and 0.02 m/s^2. Analyses in the context of HBEFA have shown that these three parameters are the key parameters to characterize driving cycles or traffic situations, respectively (de Haan and Keller, 2004). Table 2 shows exemplarily the number of cycles and the average speed, RPA and stop time for all 20 traffic situations identified for Beijing. In total 680 hours of GPS data with a total distance of more than 14,000 km has been used for further analyses. In total (together with Shenzhen) more than 14,000 cycles covering 1,500 hours and 32,500 km were available to identify the 20 typical traffic situations for Chinese cities.

Table 2: Descriptive statistical parameters of cycles identified for passenger cars driven in Beijing

Road type	Level of service (LOS)	Number of cycles	Total time [hours]	Average weighted by distance		
				Speed [km/h]	Relative positive acceleration [m/s^2]	Percentage stop time [%]
Express-way	1	491	42.5	62.6	0.12	0.4%
	2	255	23.5	45.3	0.14	1.8%
	3	233	23.0	35.1	0.16	5.9%
	4	294	32.5	24.9	0.17	8.7%
	5	358	49.4	14.9	0.17	21.7%
Major arterial	1	82	5.4	53.1	0.14	7.5%
	2	233	19.0	34.1	0.18	19.1%
	3	697	70.0	24.6	0.20	31.4%
	4	376	37.9	17.8	0.21	41.7%
	5	609	70.3	10.6	0.21	55.3%
Minor Arterial	1	57	4.8	41.9	0.17	9.6%
	2	313	24.4	28.9	0.18	16.3%
	3	791	65.0	20.0	0.19	28.8%
	4	322	29.8	12.7	0.19	44.5%
	5	353	45.3	7.0	0.18	63.0%
Branch	1	47	3.8	48.5	0.16	4.2%
	2	154	10.6	29.3	0.18	11.2%
	3	528	41.2	19.9	0.18	21.9%
	4	308	23.7	12.6	0.17	37.2%
	5	399	59.2	6.5	0.16	61.1%

Legend: LOS: 1 = Free flow; 2 = Heavy traffic; 3 = Saturated traffic; 4 = Stop and go;
5 = Heavy stop and go

Identification of typical traffic situations

The selection of the typical cycles per traffic situation, i.e. the combinations of road type and level of service, were carried out in three steps:

- Identification of the best 20 fitting driving cycles by analysing all available cycles per road type and LOS considering average speed, RPA and percentage of stop time;
- Selection of one of the most typical cycles based on detailed analyses of time-speed curves and specific CO_2 emissions in g/km;
- Comparison of the selected traffic situations with the European traffic situations.

In the first step ten cycles per road type and LOS were selected for Beijing as well as for Shenzhen by using the method of least squares considering speed, RPA and percentage of stop time. For example "Expressway: free flow" figure 2 shows the average speed and RPA of the top 20 cycles selected in total for both cities in comparison with all cycles available for the analyses. The selected cycles are in the middle of the cloud of all datasets. Detailed analyses show that the selected 10 cycles for Beijing and Shenzhen are more or less identical regarding the key parameters average speed, PRA and stop time. That means that the traffic situations approach used in Europe can also be used for Chinese cities. If the parameters for segmentation (in this case road type and LOS) are identical the driving cycles are similar independent of the city analysed. Or in other words: The traffic situations which are identified based on the GPS data of Beijing and Shenzhen can also be used for other Chinese cities without limitations.

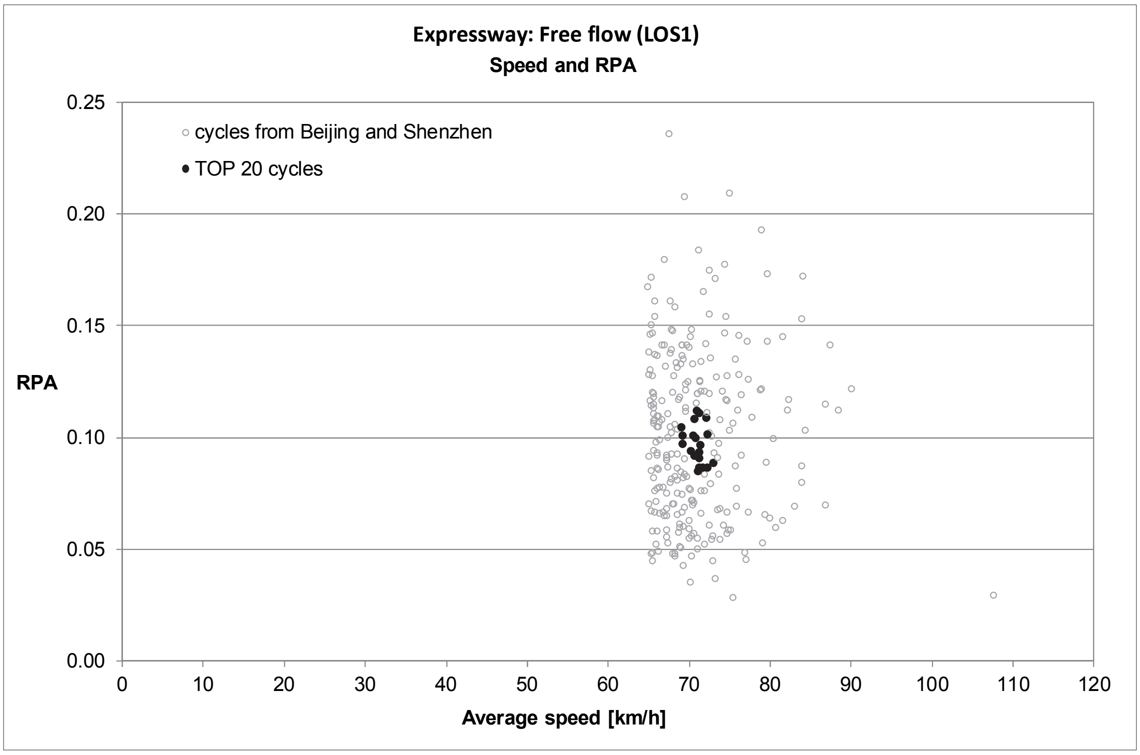

Figure 2: Selected top 20 cycles for passenger cars based on average speed, RPA and stop time (not included in the figure) using the example of the traffic situation “Expressway: free flow”

For each combination of road type and LOS the remaining 20 cycles were analysed in more detail in further analyses steps. For this purpose the fuel consumption and CO_2 emissions of all selected cycles were calculated with the PHEM model. Based on these results and the speed-time functions the most typical driving cycle was chosen. In a first step the “untypical” cycles were removed (see the upper part of figure 3) as follows: The selection was basically carried out by analysing the time-speed curves. Due to the semi-automatically procedure for splitting larger cycles into smaller cycles by using the floating average speed, sometimes cycles aren’t optimally separated. Therefore cycles which are obviously a combination of two different levels of service were excluded from the further investigation. Also cycles which are characterised by high differences regarding the speed at the beginning and at the end of the driving cycle as well as by continuously increasing or decreasing speeds during the whole cycle were not further considered. In the example of the traffic situation “Expressway: Free flow” ten driving cycles were labelled as “untypical” (see figure 3).

In the next step the remaining cycles were compared related to the structures of the speed-time curves, average speeds, RPA, percentages of stop time and CO_2 emissions. Based on these parameters the most typical and representative cycle was selected by expert judgment. Objective of this selection step was the identification of a driving cycle which is in the middle of all remaining cycles with respect to the parameters considered. Figure 3 shows as an example the selected driving cycle which is typical for the traffic situation “Expressway: Free flow”. In this case the selected cycle was recorded in Beijing. To assure the accurateness of the selection a second cycle based on GPS data collected in Shenzhen was additionally selected (see also Figure 3: so-called second best fitting driving cycle). Speed-time curves as well as CO_2 emissions of both cycles were nearly identical. This comparison shows that a typical traffic situation, which is identified for one Chinese city can be used without restrictions for other cities in China. Moreover, the comparison has proved that the traffic situations approach developed in Europe is applicable in other countries like China without reservation. Besides the selection of typical driving cycles for both cities a comparable European HBEFA cycle was identified in addition (see also figure 3). With exceptions for stop and go traffic the European traffic situations can be principally used also for China. But to increase the credibility it is recommended to identify generally country or region specific traffic situations and compare them afterwards with the European traffic situations.

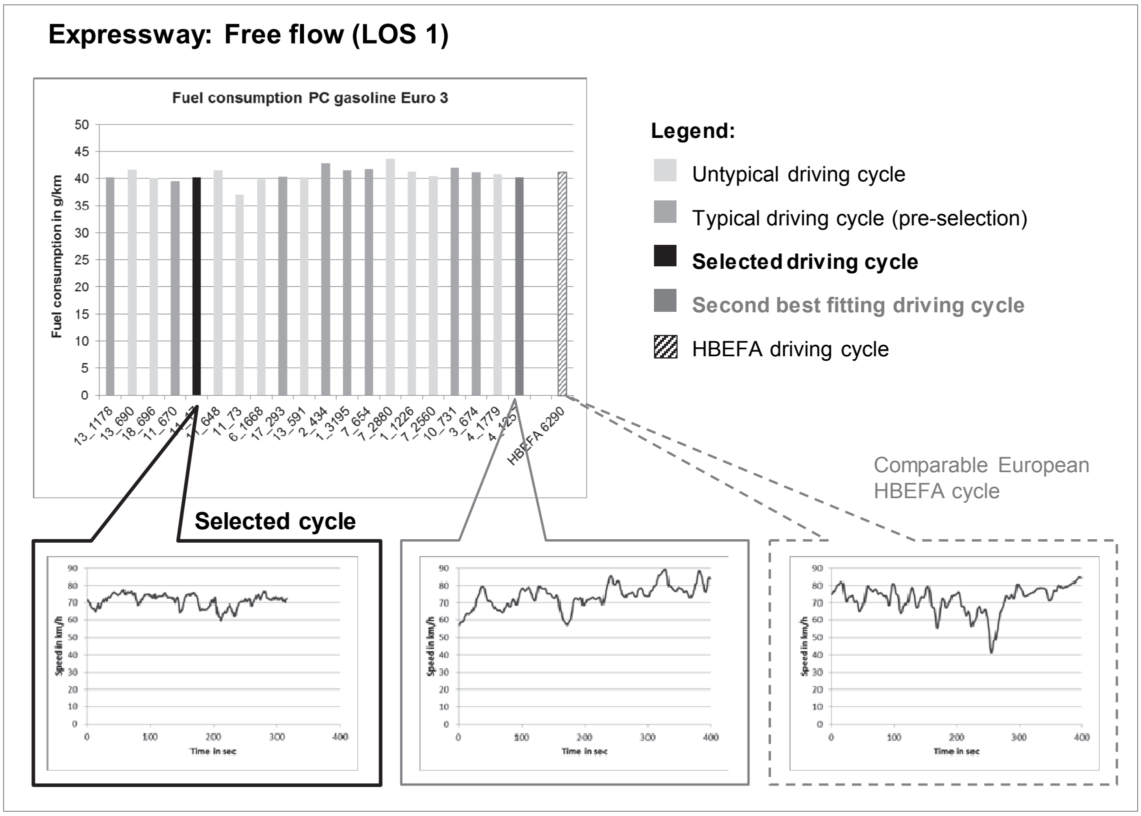

Figure 3: Selection of the typical traffic situation for passenger cars for the traffic situation "Expressway: Free flow" based on the top 20 cycles selected for Beijing and Shenzhen.

The average speed, RPA and percentage of stop time are included in table 3 for each of the typical traffic situation identified for Chinese cities. Independent of the road types the average speeds decline starting from free flow over heavy and saturated traffic to stop and go traffic. The average speeds for heavy stop and go traffic lie between 5 and 8 km/h for major arterials, minor arterials and branches. Only for expressways the average speed for heavy stop and go traffic is higher than 10 km/h. In the same order the percentages of stop times increase. For major and minor arterials as well as for branches the stop times of heavy stop and go traffic reach values between 60% and 65%.Only for expressways the percentage of stop time is considerably lower (e.g. 26% for heavy stop and go traffic).

At first glance the development of RPA is unexpected. For all road types the RPA increase from free flow over heavy and saturated traffic to stop and go traffic. Surprisingly the RPA decrease from stop and go traffic to heavy stop and go traffic although acceleration should be much more important. But the decrease of RPA is easily allegeable. Speed, which is considered in the calculation of RPA, is lower for heavy stop and go traffic compared to the normal stop and go traffic. During stops the speed is zero and these phases are more important for heavy stop and go traffic. Thus the development of RPA is explainable and logical.

The CO_2 emissions e.g. included in figure 3 are calculated for a standardised passenger car (construction year: 2002; engine capacity: 1.4-2.0 l). The basic CO_2 emission factors for all Chinese traffic situations identified are presented in the next sub-chapter. But adapting emissions factors includes not only the identification of typical traffic situations for Chinese cities but also the adjustment of emissions factors by average CO_2 emissions of the fleet. The result of this adjustment is also presented in the next sub-chapter.

Table 3: Average speed, relative positive acceleration (RPA) and stop time for the selected traffic situations for passenger cars used in Chinese cities based on GPS data collected in Beijing and Shenzhen

Road type	Level of service (LOS)	Average Speed [km/h]	Relative positive acceleration [m/s^2]	Percentage stop time [%]
Express-way	Free flow	71.2	0.09	0%
	Heavy traffic	57.3	0.11	0%
	Saturated traffic	42.3	0.13	1%
	Stop and go	25.8	0.17	7%
	Heavy stop and go	12.0	0.17	26%
Major arterial	Free flow	49.8	0.17	5%
	Heavy traffic	34.8	0.20	18%
	Saturated traffic	24.2	0.20	28%
	Stop and go	17.6	0.23	40%
	Heavy stop and go	8.4	0.21	62%
Minor Arterial	Free flow	41.0	0.19	5%
	Heavy traffic	27.3	0.18	16%
	Saturated traffic	18.8	0.19	27%
	Stop and go	12.5	0.23	43%
	Heavy stop and go	5.3	0.20	65%
Branch	Free flow	45.7	0.12	3%
	Heavy traffic	28.5	0.20	14%
	Saturated traffic	19.6	0.19	21%
	Stop and go	11.9	0.19	27%
	Heavy stop and go	4.5	0.18	60%

Results: CO_2 emission factors for passenger cars for Chinese cities

Figure 4 shows the basic CO_2 emissions of a standardised passenger car (construction year: 2002; engine capacity: 1.4-2.0 l) for the Chinese traffic situations identified. The emission factors for heavy stop and go traffic is 2.6 to 3.2 times higher compared to free flow situations. The highest emissions with 621 g CO_2/km is caused by the traffic situation “Branches: Heavy stop and go traffic”. But also the ‘normal’ stop and go traffic generates high specific CO_2 emissions. The values between 196 and 327 g CO_2/km are 55% to 89% higher than emission values for free flowing traffic. First calculations for Beijing show the heavy impact of stop and go traffic. Passenger cars (including taxis) generate more than 15 million tons of CO_2 emissions in the year 2010 in Beijing. One third of these emissions are caused by stop and go traffic situations while less than 20% of the vehicles kilometres travelled (VKT) are performed at these levels of service. Nearly 20% of the CO_2 emissions result from heavy stop and go traffic. These first results show the relevance of transport demand measures to reduce stop and go traffic as GHG emission strategies.

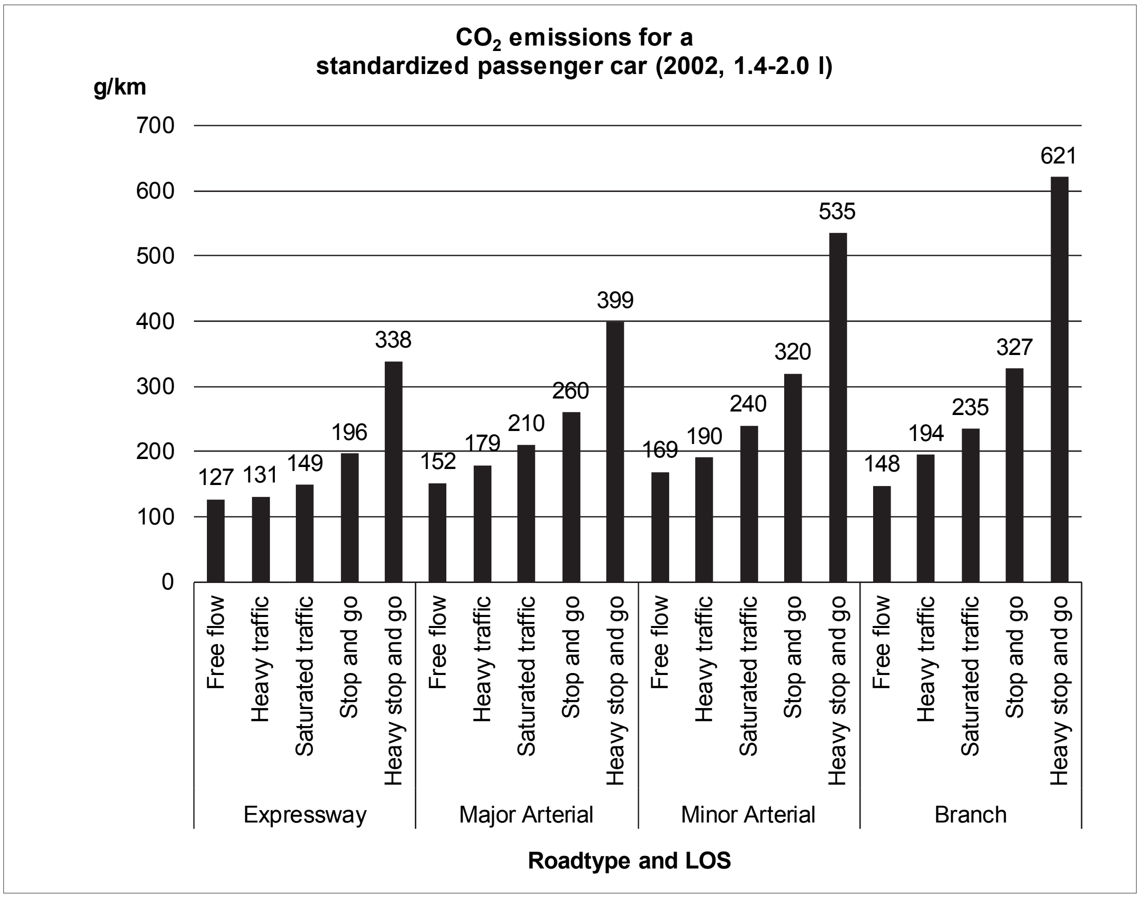

Figure 4: CO_2 emission of a standardized passenger car (construction year: 2002, engine capacity: 1.4-2.0 l) for Chinese traffic situations.

In the meantime the emission factors of the standardised passenger car were extended to other construction years and engine sizes within the Sino-German project on low carbon transport in China. The International Council on Clean Transportation (ICCT) analysed a reduction of the average CO_2 emissions for passenger cars from 213 g/km in the year to 2002 to 180 g/km in the year 2010, based on the new European driving cycle (ICCT, 2012). Considering these reduction rates and the fleet composition of Beijing, city-specific CO_2 emission factors can be calculated based on the standardised passenger car. Table 4 provides the average CO_2 emissions factors for Beijing for the year 2010 considering traffic situations and emission standards of passenger cars. The emissions standards China 1 to China 4 are comparable to the European emission standards Euro 1 to Euro 4. The values in table 4 are calculated for the average passenger vehicle fleet in Beijing in the year 2010.

Compared to the basic emission factors for a standardised passenger car the specific CO_2 emission factors for Beijing are higher. The differences of the specific CO_2 emissions between China 1 introduced in 1999 and China 4 established in 2008 is moderate (around 10%). Compared to the impact of traffic situations on CO_2 emission factors the effects caused by efficiency gains over this time period and indirectly by vehicle ages are nearly negligible. For GHG quantification it is at least as important to identify the correct traffic situation pattern compared to the appropriate mapping of of the car fleet composition. This is the reason why Beijing and Shenzhen have combined their travel demand models with the HBEFA “Expert Version” (INFRAS, 2014b). The HBEFA “Expert Version” is the follow up of the ARTEMIS road emission model (Keller and Kljun, 2007). It is not only a database of emission factors like the ‘Public Version’ of HBEFA (INFRAS, 2014a). The HBEFA “Expert Version” allows additionally to calculate emissions at aggregate or disaggregate levels (e.g. for each street link of a network). Furthermore, the HBEFA “Expert Version” includes a fleet model which provides a detailed fleet breakdown of present and/or future fleets (FOEN, 2010). Hence it allows to assess the impacts of measures which focus on the vehicle fleets (e.g. scrapping schemes).

For China an interface was developed, so that the outputs from travel demand models can be easily imported into the HBEFA “Expert Version”. The advantage of the interface is that the impacts of measures like parking management, congestion charging or constraints for new vehicle registrations can be directly calculated in the travel demand models and can afterwards be imported to HBEFA for assessing the CO_2 emissions. The Chinese Version of the HBEFA ‘Expert Version’ has got the working title “China Handbook for Emission Factor Model (CHEF Model)”.

Table 4: CO_2 emission factors for passenger cars in Beijing in the year 2010 according to traffic situations (road type and LOS) and emission standards

Road type	Level of service (LOS)	CO_2 emission factor in g/vkm			
		China 1	China 3	China 2	China 3
Express-way	Free flow	146	143	137	133
	Heavy traffic	151	148	141	138
	Saturated traffic	171	168	160	157
	Stop and go	226	222	212	207
	Heavy stop and go	389	381	364	356
Major arterial	Free flow	175	171	164	160
	Heavy traffic	207	202	193	189
	Saturated traffic	242	237	226	221
	Stop and go	299	293	280	274
	Heavy stop and go	459	450	430	420
Minor Arterial	Free flow	194	191	182	178
	Heavy traffic	219	215	205	200
	Saturated traffic	276	271	259	253
	Stop and go	368	361	345	337
	Heavy stop and go	616	603	577	563
Branch	Free flow	170	167	159	156
	Heavy traffic	224	219	210	205
	Saturated traffic	270	265	253	247
	Stop and go	376	368	352	344
	Heavy stop and go	715	700	669	653

Outlook: Next steps

The China specific emission factors are already included within the so-called CHEF model. The model is currently being used in Beijing, Shenzhen, Tianjin and Harbin. Shenzhen has developed an internet tool to visualise the CO_2 emissions at street level, although it is clear that street-based emission data are only interesting for air pollution. All cities which are cooperation partners in the Sino-German project on low carbon transport have the objective to integrate air pollutants in their model as well as emissions factors for other vehicle categories. While the adaptation of emission factors for other vehicle categories to situations in Chinese cities is easily possible, incorporating China-specific emission factors for air pollutants in the CHEF model is more complicated.

In contrast to CO_2 emissions air pollutants are strongly influenced by fuel quality, by maintenance of the vehicles and especially by operational reliability of the catalytic converter. To use PHEM for the calculation of emission factors for air pollutants the model first has to be calibrated with measurements collected in China. At present official data from the Chinese Vehicle Emission Control Centre (VECC) are not available. Measurement data are available from PEMS carried out by universities. In next project steps it is planned to compare systematically the PEMS data with measurements of European vehicles. The objective of this task is to provide as soon as possible reliable emission factors for air pollutants of vehicles for the four partner cities.

Figure 5: Internet-based visualization tool for CO_2 emissions of passenger cars in Shenzhen based on HBEFA (Song, 2014)

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