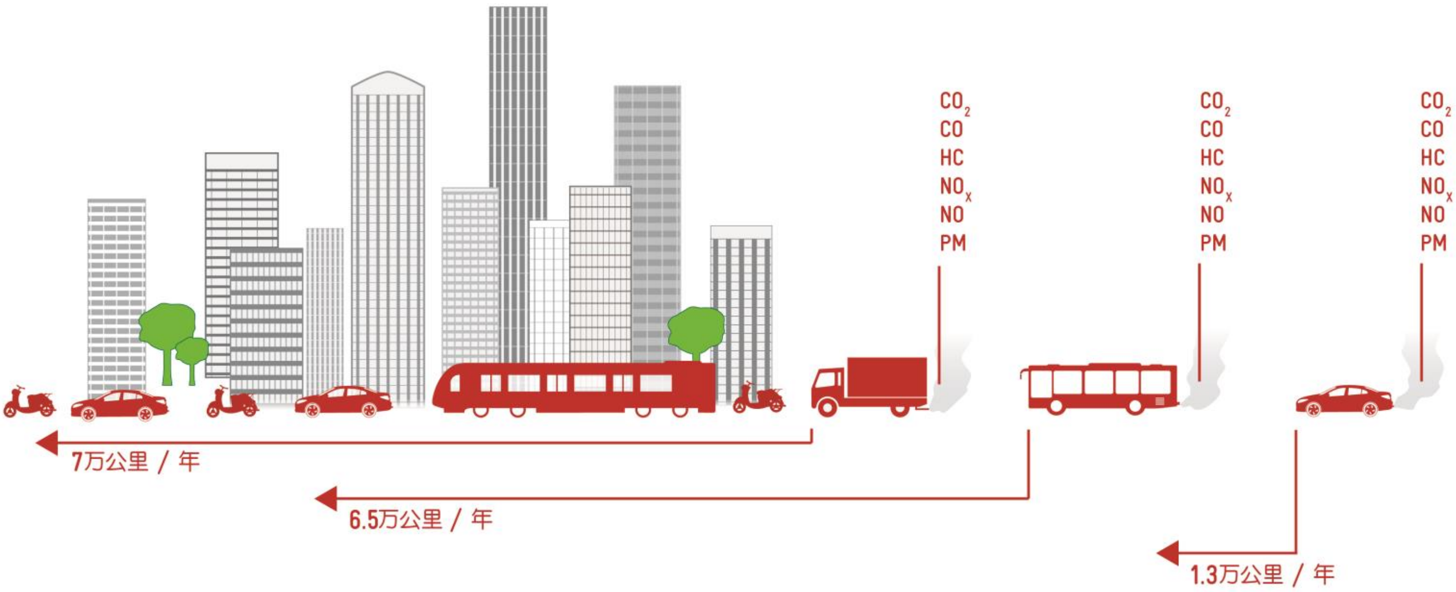

Modelling Energy Consumption and GHG Emissions of Road Transport in China

Technical Paper on GIZ CRTEM/HBEFA-China Model

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

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Modelling Energy Consumption and GHG Emissions of Road Transport in China

Technical Paper on GIZ CRTEM/HBEFA-China Model

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Executive Summary

With rapid economic development, China is experiencing substantial growth in vehicle population and motorised mobility, which has also led to a strong increase in greenhouse gas (GHG) emissions and air pollution caused by transport. To reduce emissions, the Chinese government introduced several mitigation targets over the past few years. City governments and decision makers are increasingly interested in understanding the effectiveness of transportation measures to reduce emissions and consider them important instruments to meet the carbon emission reduction targets.

To control GHG emissions and pollutants in any form, quantifying the emissions being released is a fundamental requirement. This, in turn, demands data on fleet composition, travel activities, and emission factors. In contrast to Europe and the United States, publicly accessible emission factor databases, particularly for the quantification of traffic-related GHG emissions, are not available in China. There is also no publicly released official tool or inventory model for GHG emissions accounting for mobile sources at the national or regional level.

To facilitate the GHG emission quantification in the Chinese transportation sector, GIZ initiated – as one task within the Sino-German cooperation framework – the development of a China transport emission quantification tool by adapting an internationally recognized model to the situation in Chinese cities. After a broad international review of emission factor databases and emission models, the Handbook of Emission Factors for Road Transport (HBEFA) was identified as the most suitable tool for Chinese cities. One of the advantages of HBEFA is that it is particularly adaptable to city characteristics as it provides emission factors for different road types (such as expressways, trunk roads or branch roads) and different levels of traffic situations (such as free-flow or stop-and-go traffic) 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.

The HBEFA was originally developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria. Other countries (Sweden, Norway, and France) as well as the JRC (Joint Research Centre of the European Commission) are supporting HBEFA. The current version of HBEFA is based on European emission measurement data of vehicles collected within the ERMES group. HBEFA is also the emission factor database for European models such as COPERT and TREMOVE, as well as for national models (e.g. TREMOD in Germany or HBEFA Expert Version in Switzerland and Sweden). Apart from only a few exceptions, HBEFA is the database for all emission quantifications of road transport in Europe.

The emission factors, i.e. the specific emissions in g/km included in HBEFA, cover all current vehicle categories (passenger cars, light-duty vehicles, heavy-duty vehicles, buses and motor cycles) and vehicle sizes (e.g. small, medium and large cars) - each divided into different road types and a wide variety of traffic situations. Each traffic situation is characterised by a typical driving pattern which is a series of data points representing the speed of a vehicle versus time (i.e. speed-time functions). HBEFA therefore provides emission factors in grams per vehicle-kilometre segmented by vehicle type and by traffic situation. The concept of traffic situations was developed in the context of HBEFA and describes typical driving cycles for Europe. The emission factors for different traffic situations are calculated using the Passenger Car and Heavy-Duty Vehicle Emission Model (PHEM, developed by the Technical University of Graz [TUG], Austria) which is calibrated by using all measurement data available in Europe.

To adapt HBEFA to Chinese conditions, two fundamental components had to be localised:

1. Local driving cycles, representing specific traffic situations in Chinese cities were established.
2. The emission factors calculated by the PHEM model were calibrated and validated to reflect the emission and fuel efficiency characteristics of vehicles in Chinese cites.

The Sino-German cooperation project focused on the adaptation of the traffic situation scheme and the calculation of CO_2 emission factors for specific Chinese traffic situations. For the identification of typical traffic situations in China more than 2,000 hours of GPS data were collected from passenger cars in Beijing and Shenzhen between 2012 and 2013. GPS transmitters were applied to record real road vehicle movements once every second (1 Hz) and were temporarily stored in the memory of the device. The GPS devices were installed in 20 taxis and private passenger cars and collected information about geodetic coordinates, speed and acceleration for each second for one week in both Beijing and Shenzhen. The driving data collection was 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. Typical driving cycles for each road type and Level of Service (LOS), e.g. free flow on expressway or stop-and-go traffic on minor arterials, were identified. These driving cycles for each traffic situation formed the input for the PHEM model in order to produce the set of base CO_2 emission factors for Chinese cities.

Based on the approach described, GIZ in collaboration with several partners in China and INFRAS in Switzerland have developed an advanced bottom-up emission model for urban transport in China – the China Road Transport Emission Model (CRTEM) which includes a Chinese emission factor database (HBEFA-China). CRTEM/HBEFA-China is a software package that simplifies and facilitates the emission calculation. It integrates all components of an emission model with a user-friendly interface. This tool was developed in Microsoft Access and is based on the HBEFA Expert Version of INFRAS. It is used for quantifying emissions of many cities in Europe. The prime objective of the model is to estimate road traffic emissions with high temporal and spatial resolution to be used as a tool to assess the impact of urban transport policy on emission reductions. It allows Chinese cities to account for their transport emissions and calculate the emission-related impacts of scenarios in travel demand models.

To develop the CRTEM/HBEFA-China, the European Handbook for Emission Factors (HBEFA) was adapted to the local situation in Chinese cities to provide reliable carbon emission factors for China. This was done by adapting the existing European emission factors to local traffic situations and fleet composition in China. The model facilitates a reliable estimation of energy consumption and carbon dioxide emissions of urban road transport. Equipped with China-specific default values, the model is flexible enough to be used by cities with and without travel demand models. If projections of traffic activity are available, the CRTEM/HBEFA-China can also be easily used to calculate future emission scenarios.

The China specific emission factors are already included within the CRTEM/HBEFA-China model. This 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-level emission data is of more interest when assessing air pollution (e.g. as an input to dispersion models) this example illustrates the potential of CRTEM/HBEFA-China for future applications. In the first phase, the adoption of HBEFA to China focused on passenger cars and greenhouse gas emissions. But based on the analyses for passenger cars, traffic situations for other vehicle categories were also derived. Currently, the model is calibrated and ready to use for carbon dioxide because fuel economy of a certain vehicle type is basically the same in Europe and China (considering the same traffic situations making carbon emission factors generated by the PHEM model with local driving cycles reliable.

HBEFA-China already contains emission factors for all air pollutants (e.g. NOx, HC, and PM). In contrast to CO_2 emissions, air pollutants are strongly influenced by fuel quality, engine and exhaust-after treatment technology (such as NOx reduction techniques), by vehicle maintenance and by the operational reliability of the catalytic converter. Because of this, emission factors for pollutants can vary between Europe and China even in the same driving pattern. Until now measurement data from Portable Emission Measurement Systems (PEMS) from Chinese universities has been used for checking air pollutant emission factors. But in order to further improve the calibration of the tool, more detailed analysis and further calibration will be carried out in the coming month. The objective is to provide reliable emission factors for air pollutants of vehicles for Chinese cities in 2015.

1. Introduction

1.1. Background

With rapid economic development, China is experiencing substantial growth in vehicle population and motorised mobility which has also led to a strong increase in greenhouse gas (GHG) emissions and air pollution. Between 1990 and 2012 China's CO_2 emissions grew by 293 % (from 2.51 billion tons to 9.86 billion tons per year) (Oliver et al., 2013). Particularly during winter, smog periods with high air pollution affect large parts of the Chinese territory (CAA, 2013). GHG emissions and local air pollutants, as well as external costs of traffic congestion, are attracting increasing attention in the public domain, especially in metropolitan areas.

To reduce emissions, the Chinese government introduced several mitigation targets over recent years. For example, the transition to a low-carbon economy is one of the core objectives of the 12th Five Year Plan (2011 – 2015). By 2020 the carbon emissions per GDP are to be reduced by 40 to 45% compared to the year 2005 (Leggett, 2011). In the transport sector, overall energy consumption intensity of per unit turnover of commercial operation vehicles should decrease by 10% compared to the situation in 2005, 6% for commercial operation passenger vehicles, and 12% for commercial operation trucks, respectively. For carbon intensity the values are 11%, 7% and 13%, respectively. 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 large cities by 2017 compared to the 2012 level. For three key regions – Beijing-Tianjin-Hebei, the Yangtze River Delta and the Pearl River Delta – the annual average concentration of PM2.5 is to be reduced by 15 - 25% within this five year period (MEP, 2013; CAA, 2013). Energy and environmental indicators are becoming more and more important in the assessment of current local transport policy and in the development of future programmes. Against this background, city governments and decision makers are increasingly interested in understanding the effectiveness of transport measures to reduce emissions and consider them important instruments to meet the carbon emission reduction targets. One fundamental requirement in the effort to control GHG emissions and pollutants in any form is to quantify the emissions being released. This in turn requires data on fleet composition, travel activities and emission factors.

In contrast to Europe and the United States, publicly accessible emission factor databases, particularly for the quantification of traffic-related GHG emissions, 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 (EPBs) and the Chinese Ministry of Environmental Protection (MEP, 2011). The Vehicle Emission Control Centre of the MEP maintains the China Vehicle Emission Model (CVEM), a national emission factor database, but this database is primarily focused on pollutants emission factors such as NOx, PM, CO_2, etc. since management of energy consumption and GHG emissions do not fall within the responsibilities of MEP. 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 publicly released an official tool or inventory model for GHG emission accounting of mobile sources at the national level.

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), HBEFA was identified as the most suitable tool for Chinese cities. One of the advantages of HBEFA is that it is especially adaptable to city level characteristics as it provides emission factors for road types (such as expressways, trunk roads and arteries/branches) 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.

This technical paper describes a practical approach to quantify energy consumption and GHG emissions in the road transport sector as it was developed in the context of a Sino-German project on 'Transport Demand Management in Beijing – Emission Reduction in Urban Transport' funded through the International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). A key element of the project was to localise the Handbook for Emission Factors (HBEFA), which is widely applied in Europe to calculate transport emissions, by adapting the underlying emission factors to local traffic situations and fleet composition, thereby reducing uncertainty in the calculations. In addition, a bottom-up model was established to help cities quantify emissions from road traffic by accounting for the impact of road network performance on fuel consumption and emissions. The details of this approach are described in this technical paper.

The paper is organised as follows: Chapter 2 provides a basic introduction to HBEFA and the PHEM model which is the micro-level emission simulation model underlying HBEFA. Base emission factors of HBEFA were initially generated through the PHEM model. Chapter 3 describes the in-depth approach to adapt HBEFA to the context of Chinese situations and Chapter 4 presents the detailed process of localisation conducted in this study with regard to data collection, data processing and identification of typical driving cycles for Chinese cities. Chapter 5 then presents the localised emission factors and its database structure. Localised driving cycles for passenger cars for each traffic situation were input into the PHEM model to produce the set of emission factors for Chinese cities. Chapter 6 presents the software package for the China Road Transport Emission Model (CRTEM/HBEFA-China) and its applications.

1.2. Approaches to Quantify GHG Emissions in the Transport Sector

Emission calculation plays a key role to track transport emissions. Firstly, emissions from mobile sources cannot be comprehensively measured with tail pipe equipment and, secondly, the carbon in fossil fuels is completely transformed into carbon dioxide during combustion so that fuel consumption gives an accurate value for CO_2 emissions without the need for measurements. GHG emissions are best calculated on the basis of the amount and type of fuel combusted and its carbon content.

In general, two different methods to quantify emissions in the transport sector can be distinguished, top-down and bottom-up approaches. While top-down approaches use the total energy consumption of the study area and multiply it with the specific CO_2 content for each energy type, the bottom-up approaches use transport activity data and specific emission factors for the computation of CO_2 emissions. The purpose of top-down accounting is to provide a snapshot of GHG emissions during a specified time period with statistical data aggregated at a certain geographical level - for example, the total energy consumption or total fossil fuels sold in a year. Bottom-up calculations are applied to estimate emissions and reduction potentials in more detail. While the top-down accounting approach for the transport sector produces only the total GHG emissions from the transport sector, the bottom-up approach (as shown in Figure 1) provides more detailed data on GHG emissions by mode, vehicle type, trip purpose, fuel type, etc., thus providing useful information for understanding where emissions originate and for designing intervention measures.

Presently, for Chinese cities, GHG emissions are often calculated based on fuel sales figures only (top-down). As mentioned, one of the disadvantages of this approach is that emissions cannot be linked to the transport activities and therefore to the origin of the emissions. Furthermore, this approach is inappropriate for calculating air pollutants since it does not account for vehicle characteristics such as filter systems, catalysts or NOx reduction technologies.

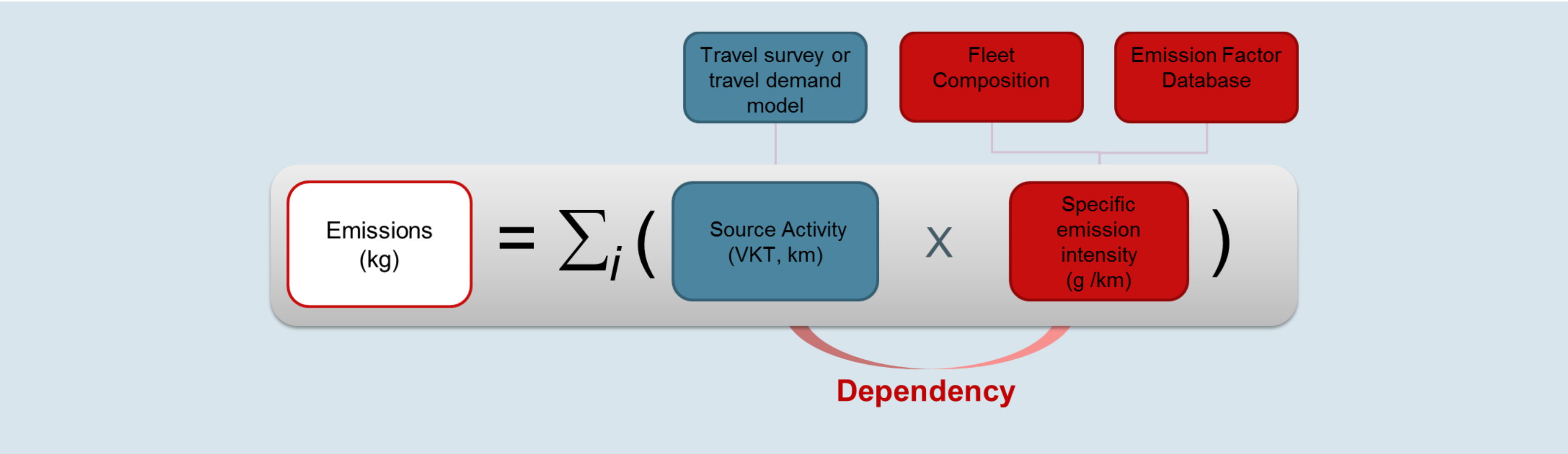

Figure 1: Emission modelling framework and formula

The key element of the bottom-up approach is a database for energy intensity of vehicles (fuel consumption per kilometre) that is combined with the carbon content of fuels such as gasoline and diesel to establish CO_2 emission factors. HBEFA is one of the most advanced emission factor databases and used for official national reporting as well as for emission quantification at regional or city levels in Europe. Carbon dioxide emissions of passenger cars (but also emissions of air pollutants and further GHGs such as nitro-dioxide and methane, as well as black carbon) are highly dependent on the size, weight and power of the vehicle as well as on speed and acceleration (represented by a characteristic driving pattern). Using disaggregated emission factors for various vehicle types, road types and traffic situations (speed and acceleration) allows local agencies to account for the impact of travel behaviour and road network performance on fuel consumption and emissions. However, the challenge of this approach is the need for disaggregated transport activity data at the city level as well as reliable emission factors.

System Boundaries

In principle, different methods are applied in order to attribute transport activities to a city. These are based on the judgement of the cities as to which transport activities fall within their areas of responsibility and thus within the field of action for emission reduction measures, but also on local availability of basic data. An illustration of the most common boundary definitions is given in Figure 2.

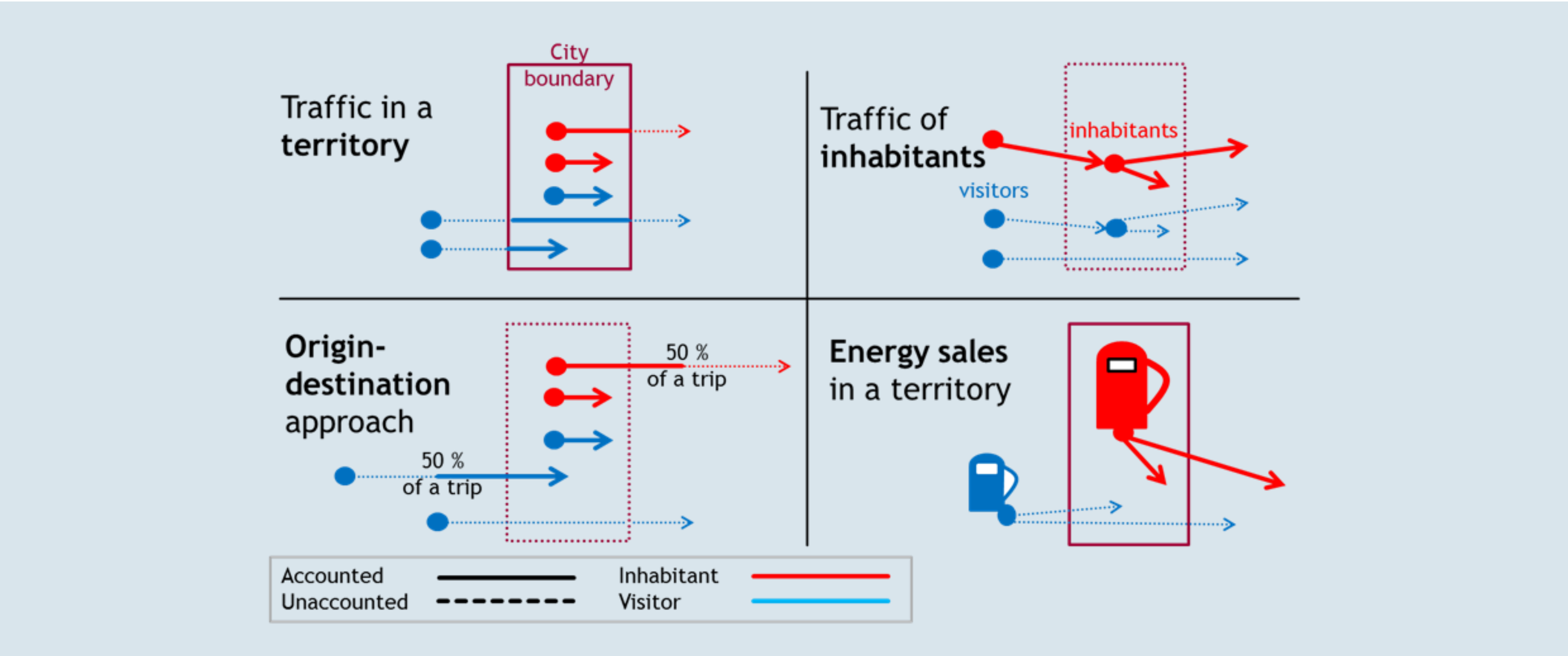

Figure 2: Typical system boundaries of GHG balances for urban transport (Source: IFEU Heidelberg, 2012)

- The territorial principle covers all transport activities in the communal district. With this geographic definition, it corresponds broadly with the political sphere of influence of a city. In order that a territorial balance can provide suitable information about the causes of transport-related emissions and help to identify effective emission reduction opportunities, further differentiations of transport activities within the territory are necessary.
- The inhabitants principle covers only transport activities by the inhabitants of the city. This includes not only trips on the city's territory but also to regional destinations and long-distance travel. This approach is often applied if only information on the inhabitants' mobility e.g. from household surveys, is available. In many cases, the balance is not even based on city-specific mobility information but on national average values.
- The city-induced principle focuses on transport-related GHG emissions caused by the city's role for living, working, supply of goods and services, etc. It covers trips of inhabitants as well as of non-inhabitants e.g. in-commuters, visitors. Emissions of origin-destination traffic are only partly assigned to the city considering the shared responsibility with that municipality the traffic comes from or goes to. No transit traffic is considered in the GHG balance.
- One special principle is the calculation of GHG emissions based on the sales of energy in the territory for the transport sector. This approach only works for cities with their own energy statistics at city level. Allocation of specific travel activities to the fuel sales is not possible.

Elements of different methods can also be mixed in the emission calculations.

2. Handbook of Emission Factors for Road Transport (HBEFA) and PHEM Model

2.1. International Overview of Emission Models

In principle, transport emission models can be classified according to their primary fields of application along the spatial resolution that they are designed for. Thereby, three levels can be distinguished: national level inventory models, regional or city level emission models and micro level emission models. Figure 3 presents the hierarchical structure of some typical emission models worldwide.

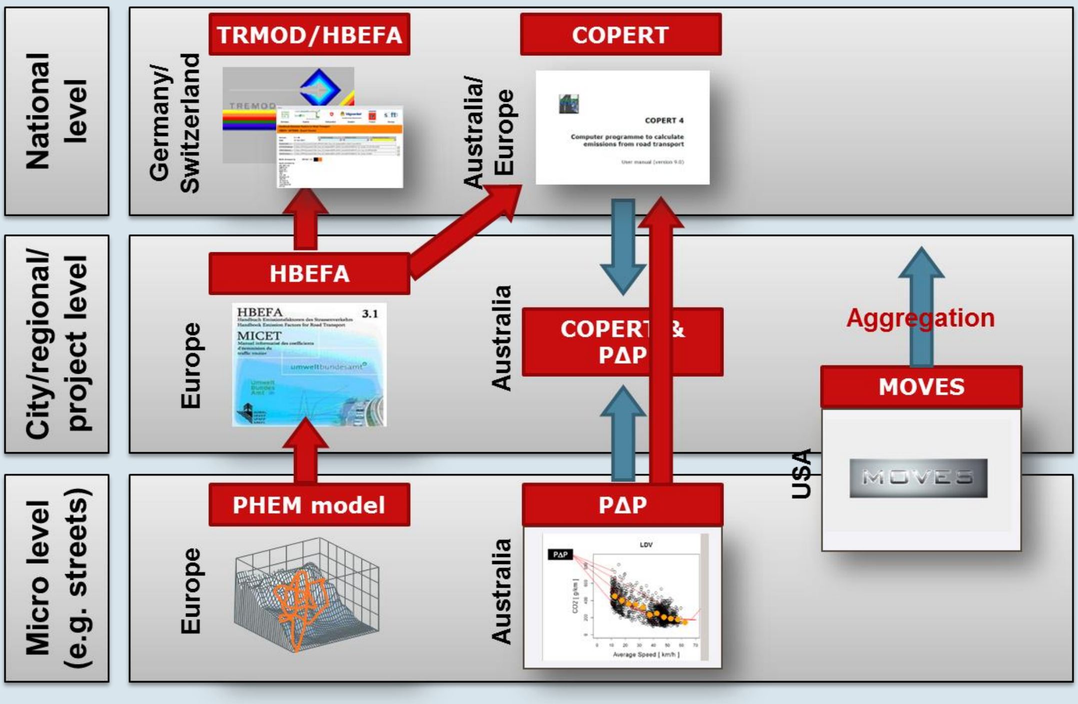

Figure 3: Classifications of different emission models (Source: Source: INFRAS/GIZ, 2013)

Different national and international emission inventory models are being used in Europe and the USA including:

- Handbook of Emission Factors for Road Transport (HBEFA) for a number of EU countries
- COPERT for the EU and EU countries
- TREMOVE for the EU
- TREMOD for Germany
- MOVES for the USA
- EMFAC for California
- IVE for developing countries

HBEFA is focused on emission factors, but also comprises tools for emission calculations at the city/regional and national level. COPERT, TREMOD and TREMOVE are mainly used for emission inventories and policy scenarios for specific regions. MOVES is a road transport emission calculation tool which is widely used in the USA for local authorities to prepare state implementation plans (SIP) and can also be used for greenhouse gas emission inventories from national to local scales. EMFAC is a trip-based macro emission inventory model specifically used in California. IVE is also an emission inventory model which was developed by the University of California Riverside and has mainly been used to simulate vehicle emissions of air pollutants in developing countries. All models cover a timeframe for simulating past and future emissions based on an emission calculation approach considering different vehicles, road types, fuels, emission categories and components. Road transport and tank-to-wheel emissions are covered in all models, but additional transport modes (train, ship and aircraft) and well-to-tank emissions are only considered in TREMOD and TREMOVE.

The emission factors in Europe are based on data from test laboratories and a number of research programmes coordinated by the European Research group on Mobile Emission Sources (ERMES). HBEFA and COPERT are directly linked to these research programmes. Moreover, emission factors and driving patterns are approached differently in the different models. To be specific, a 'traffic situation approach' is used in HBEFA vs. an 'average speed approach' used by COPERT. The traffic situation approach is typically appropriate for micro scale emission modelling, while the average speed approach can be considered suitable for macro scale emission modelling. Emission factors for MOVES are based on test data from various U.S. sources e.g. I/M (inspection and maintenance) programmes, engine certification tests and individual research and test programmes. Compared to other models in Europe, hot emission factors in MOVES are expressed in mass per time instead of in mass per distance. Emission factors in EMFAC are also based on the average speed approach and EMFAC2000 adopted new test cycles (California Unified Cycle) to collect emission factor data.

2.2. Handbook of Emission Factors for Road Transport (HBEFA)

The HBEFA was originally developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria. At this time other countries (Sweden, Norway and France) as well as the JRC (Joint Research Centre of the European Commission) support HBEFA. To develop the emission factors, the original data from various test laboratories are collected and processed with the Passenger Car and Heavy-Duty Emission Model (PHEM4) by the Technical University of Graz (Austria). The first version (HBEFA 1.1) was published in December 1995; an update (HBEFA 1.2) followed in January 1999. Version HBEFA 2.1 was available in February 2004. The newest version HBEFA 3.2 dates from January 2014. The current version of HBEFA is based on European emission measurement data collected within the ERMES group, which is also the emission data basis for other European models such as COPERT and TREMOVE.

HBEFA provides emission factors, i.e. the specific emission in g/km for all current vehicle categories (passenger cars, light-duty vehicles, heavy-duty vehicles, urban buses, coaches and motorcycles), each divided into different size classes and for a wide variety of traffic situations. Each traffic situation is characterised by a typical driving pattern which is a series of data points representing the speed of a vehicle versus time. Figure 4 presents the typical traffic situations for motorways with a speed limit of 130km/h and 120km/h in free-flowing and saturated traffic respectively, as well as for an urban collector (arterial) with a speed limit of 50km/h and stop-and-go traffic.

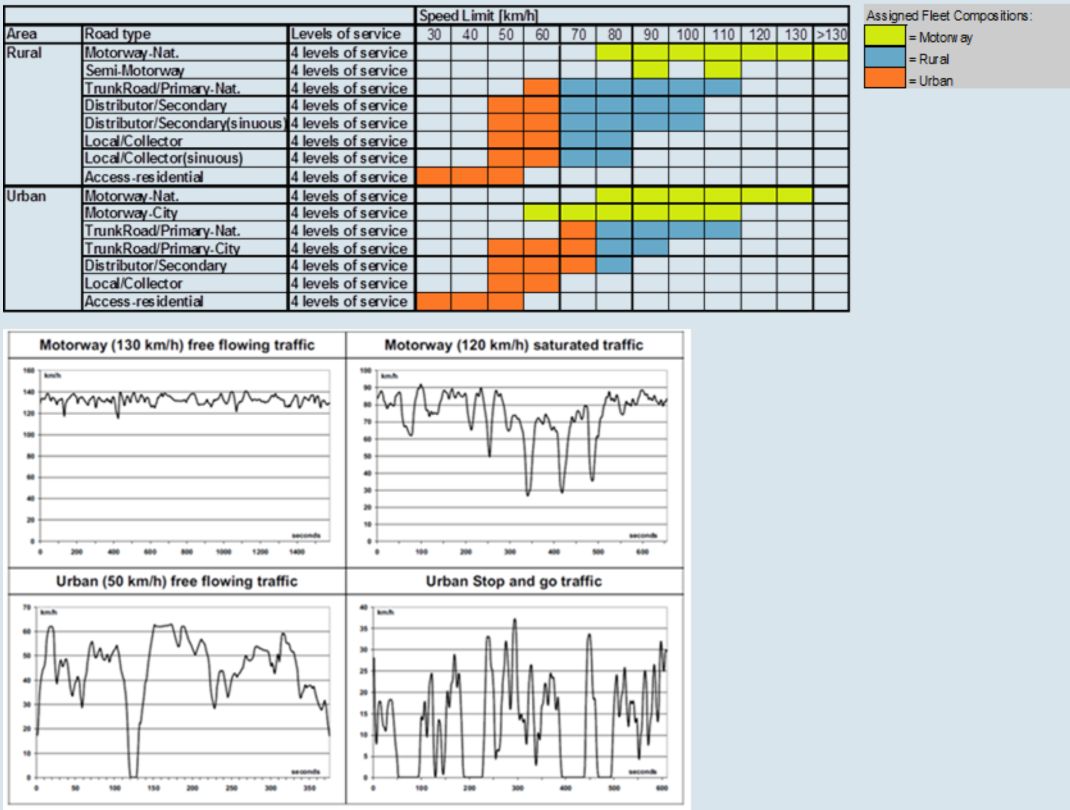

Figure 4: Example of traffic situations in HBEFA (Source: Source: INFRAS, 2013)

2.3. PHEM Model

The PHEM (Passenger Car and Heavy-Duty Emission Model) was developed by the Technical University of Graz (Austria). It was primarily developed to simulate the emission factors of heavy-duty vehicles (HDV) in the HBEFA 2.1 and the ARTEMIS inventory model (developed under the EU 5th Research Framework Programme). The PHEM was extended to be applicable for passenger cars as well as for light-duty commercial vehicles.

The PHEM calculates the engine power in 1 Hz based on the given courses of vehicle speed and road gradient, driving resistances and losses in the transmission system – this is referred to as ‘engine maps’ which are characteristic for a particular vehicle type.

The model includes engine maps for different vehicle categories, 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 1 Hz course of engine speed is simulated based on the transmission ratios and a gear-shift model. By considering gear shift patterns, driving resistances, transmission losses and specifics of emission control technologies (e.g. the thermal performance of catalytic converters) the PHEM can translate all driving cycles (speed-time-curves) into emission factors. Also the course of engine load and/or engine speed can be directly provided to the emission model. Transient influences on the emission levels can be taken into consideration by adjusting the results from the emission maps by way of transient correction functions. The model results are the 1 Hz courses of engine power, engine speed, fuel consumption and emissions of CO, CO_2, HC, NOx, NO, particle mass (PM) and particle number (PN).The model also includes a cold start tool and emission maps for additional cold start emissions.

PHEM has been used in several international and national projects, namely the German-Austrian-Swiss cooperation on the Handbook of Emission Factors (HBEFA), the EU 5th Research Framework Programme ARTEMIS and the COST 346 initiative, as well as in projects within the ERMES group (Hausberger et al., 2009, Hausberger et al., 2013).

3. Approach to Adapt HBEFA to Chinese Cities

HBEFA provides emission factors in grams per vehicle-kilometre segmented by vehicle type (i.e. vehicle category, size class, age and/or emission concept) and by traffic situations for different road gradients. The concept of 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 area (urban/rural), road types (e.g. motorway or trunk road/primary roads in cities), speed limits (e.g. 80 km/h) and levels of service (LOS). For Europe HBEFA distinguishes four levels of service: free flow, heavy, saturated and stop-and-go traffic. In total, HBEFA distinguishes 276 different traffic situations of which more than 120 traffic situations are for urban areas. The typical European traffic situations were elaborated over a long time and are continuously optimised (Steven, 2011; Hausberger et al. 2009).

For each of HBEFA's European traffic situations specific emission factors are provided for each vehicle type. The large number of traffic situations would make it very complex and expensive 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 5): The emission factors for the different traffic situations are calculated using the Passenger Car and Heavy-Duty Vehicle Emission Model (PHEM) described above.

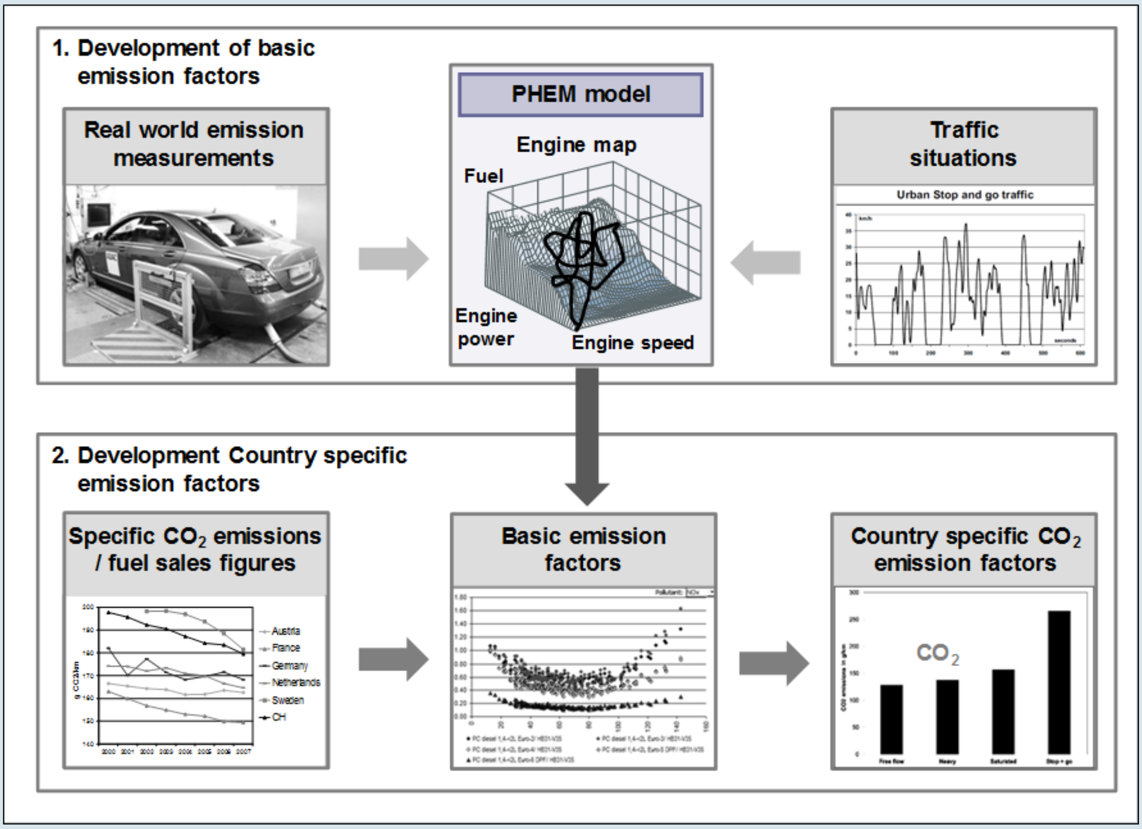

Figure 5: HBEFA approach for development of country specific CO2 emissions in Europe (Source: INFRAS, 2013)

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 production 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 significant 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 in 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, two fundamental components had to be localised: 1) driving cycles to represent China specific traffic situations and 2) calibration of the PHEM to reflect the emission characteristics of local vehicles. The following steps were taken to localise the HBEFA emission factors to China (Figure 6):

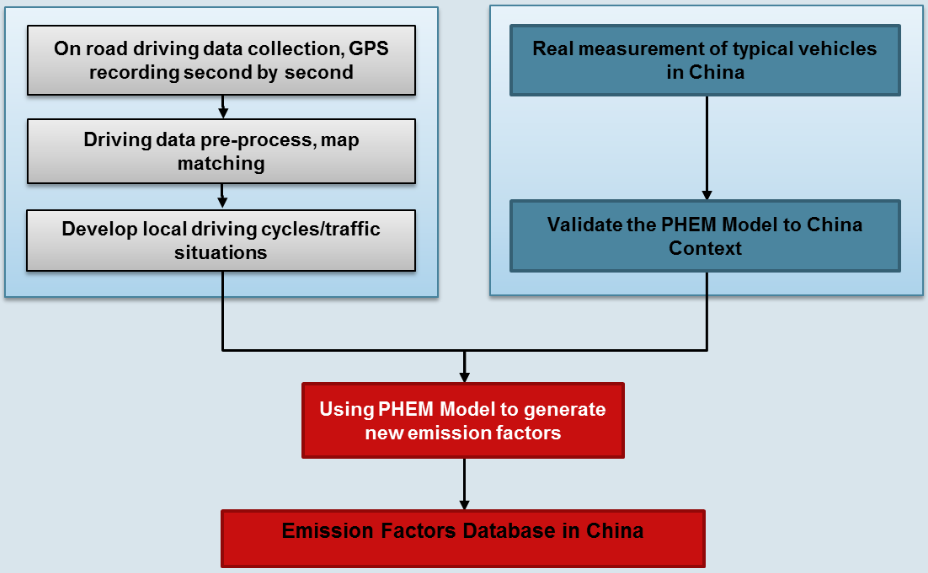

Figure 6: Framework to localise HBEFA

First, typical traffic situations for Chinese cities were identified and compared with the driving cycles used in the European version of HBEFA. Unlike the original expectation that Chinese traffic situations would be very similar to Europe, the measurements have shown that there are some significant differences:

- Instead of six, only four road types are relevant for Chinese cities. These are: expressways (including highways), major arterials, minor arterials and branches.
- Essentially, in China, speed limits are linked to the road type and do not have 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. However, 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 speeds 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, including heavy stop-and-go traffic.

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

Since the GHG emission quantification in this study is primarily focused on urban areas, for the time being it is sufficient to consider these 20 different traffic situations in total. Traffic situations on highway and in rural areas might be different. For adapting the HBEFA approach to China, firstly, the typical driving patterns had to be identified and then compared to the existing European driving patterns. Then, the emission factors were calculated for each engine class and production year based on the Chinese average CO2 emissions of new registered cars based on PHEM output for standardised passenger cars similar to Europe.

The focus of the Sino-German collaboration project lay on the adaptation of the traffic situation scheme and the calculation of CO2 emission factors for specific Chinese traffic situations. In a first project step this was performed for passenger cars only. Emission factors for other vehicle types such as coaches, urban buses, light-duty commercial vehicles and heavy-duty commercial vehicles, were also generated by the PHEM under the assumption that the traffic situations for these vehicle categories are the same as for passenger cars. However, traffic situations for heavy-duty trucks are obviously different from passenger cars. Consequently, emission factors for vehicle types other than passenger cars – for now – only provide a basic reference.

Presently, regarding air pollutants, the emission factors also only provide a first indication. Fuel consumption of a certain vehicle type is basically the same under the same traffic situation. Therefore, the carbon emission factors generated by the PHEM model with local driving cycles are reliable. In contrast to CO2 emissions, air pollutants are strongly influenced by fuel quality, engine and exhaust-after treatment technology (such as NOx reduction techniques), by vehicle maintenance and also by operational reliability of the catalytic converter. But due to a high uncertainty with respect to the proper conditions of catalytic converters, emission factors for pollutants can vary between Europe and China even in the same driving pattern. To use PHEM for the calculation of emission factors for air pollutants, the model has to be calibrated with measurements collected in China. At present, official data from the Chinese Vehicle Emission Control Centre (VECC) are not available; only measurement data from Portable Emission Measurement Systems (PEMS) carried out by universities exist, and these need to be collected, reviewed and compared to European values.

There are plans to localise and validate emission factors for air pollutants and other vehicle types in future project steps, since it will take a significant amount of time and resources to validate and calibrate the first results of the PHEM, which are not available for the current project.

4. Development of Local Driving Cycles

4.1. Data Collection

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.

GPS transmitters were applied to record real road vehicle movements once every second (1 Hz) and were temporarily stored in the memory of the device. Before beginning data collection, three different GPS devices were tested in practice. After evaluation of the accuracy and reliability the GPS device, Columbus V900, was selected.

The GPS devices were installed in 20 taxis and private passenger cars. They were used to collect information about geodetic coordinates, speed and acceleration for each second for one week in both Beijing and Shenzhen. The driving data collection was 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 their fare meters. Only GPS data with customers on board were considered in the further investigations since the taxi driving behaviour without passengers in the car is not a normal driving situation since it is likely that there will be more acceleration and decelerations when the driver is searching for customers.

Figure 7 on the left shows an example of GPS tracking of trips and each marker represents one measurement per second and on the right presents the example of road space coverage of data collected by one taxis in Beijing.

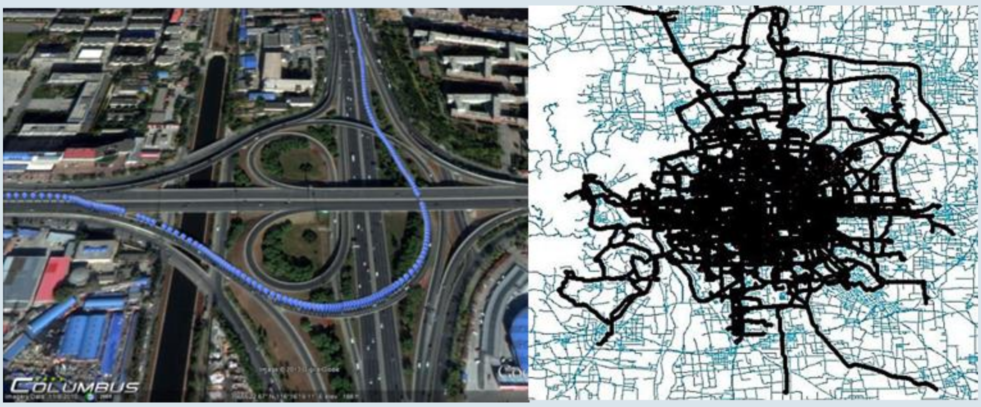

Figure 7: Example of GPS tracking of trip in Beijing

Table 2 Summarises the distances covered and hours of GPS data collected for each road type.

Table 2 Distance and total time of GPS data collected on different road types

Road Type	Distance(km)	Total time(hh:mm)
Highway	2683.08	75:35
National Highway	55.26	2:14
Provincial Highway	73.60	2:32
Expressway	5916.15	170:47
Expressway Sideroad	2083.92	92:11
Major Arterial	3919.51	202:35
Minor Arterial	2787.30	169:14
Sideroad	201.20	14:01
Branch	1804.30	138:31
Total	19524.32	867:41

4.2. Data Process

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 was 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 analysis 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 are the result of incorrect GPS signals rather than the real driving behaviour of the car drivers. Because of this, the data were smoothed out 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 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 were 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 the Beijing Transport Research Centre (BTRC) and the Shenzhen Urban Transport Planning Centre (SUTPC) within the Sino-German project.

In the last step of pre-processing, the continuous GPS measurements data were 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.

After pre-processing was completed, the average speed, relative positive acceleration (RPA) and 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 and can be calculated as in the equation below.

$$RPA = \frac{\int_0^T (v_i * a_i^+)\, dt}{x}$$

Where:

RPT	=	relative positive acceleration
v_(i)	=	vehicle speed at time i (at m/s)
a_i^+	=	vehicle acceleration at time i (at m/s^2)
T	=	total travel time for a trip (in s)
t	=	time interval (at s)
x	=	distance driven at time interval t (at m)

RPA can be interpreted as acceleration in m/s^2 as well as acceleration energy needed per kilogramme vehicle mass and per unit distance in kWs/(kg km). Stop-and-go traffic typically has RPA values between 0.25 and 0.5 m/s^2; steady driving has an RPA of 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 characterise driving cycles or traffic situations respectively (de Haan and Keller, 2004).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 3 Descriptive statistical parameters of cycles identified for passenger cars driven in Beijing

Road Type	LOS	Cell count	Dist (km)	Total Time (h)	Average weighted by distance		
					Speed (km/h)	RPA (m/S^2)	Stop Per
Highway	1	242	1650.3	24.6	68.8	0.11	1.99%
	2	54	284.4	6.3	45.1	0.15	9.06%
	3	73	276.8	8.3	33.7	0.16	17.81%
	4	88	291.0	11.7	25.2	0.16	22.83%
	5	102	180.6	24.7	12.9	0.17	43.33%
Expressway	1	491	2603.4	42.5	62.6	0.12	0.38%
	2	255	1058.6	23.5	45.3	0.14	1.81%
	3	233	802.7	23.0	35.1	0.16	5.94%
	4	294	797.2	32.5	24.9	0.17	8.71%
	5	358	654.2	49.4	14.9	0.17	21.71%
Major Arterial	1	82	272.0	5.4	53.1	0.14	7.54%
	2	233	642.2	19.0	34.1	0.18	19.05%
	3	697	1700.3	70.0	24.6	0.20	31.36%
	4	376	669.1	37.9	17.8	0.21	41.70%
	5	609	611.4	70.3	10.6	0.21	55.31%
Minor Arterial	1	57	196.6	4.8	41.9	0.17	9.59%
	2	313	700.0	24.4	28.9	0.18	16.27%
	3	791	1275.4	65.0	20.0	0.19	28.80%
	4	322	373.4	29.8	12.7	0.19	44.50%
	5	353	242.0	45.3	7.0	0.18	62.95%
Branch	1	47	174.4	3.8	48.5	0.16	4.16%
	2	154	308.1	10.6	29.3	0.18	11.15%
	3	528	802.6	41.2	19.9	0.18	21.89%
	4	308	296.4	23.7	12.6	0.17	37.15%
	5	399	222.8	59.2	6.5	0.16	61.09%

Statistical distribution of RPA and LOS for each road type were displayed as a box plot as shown in Figure 8.

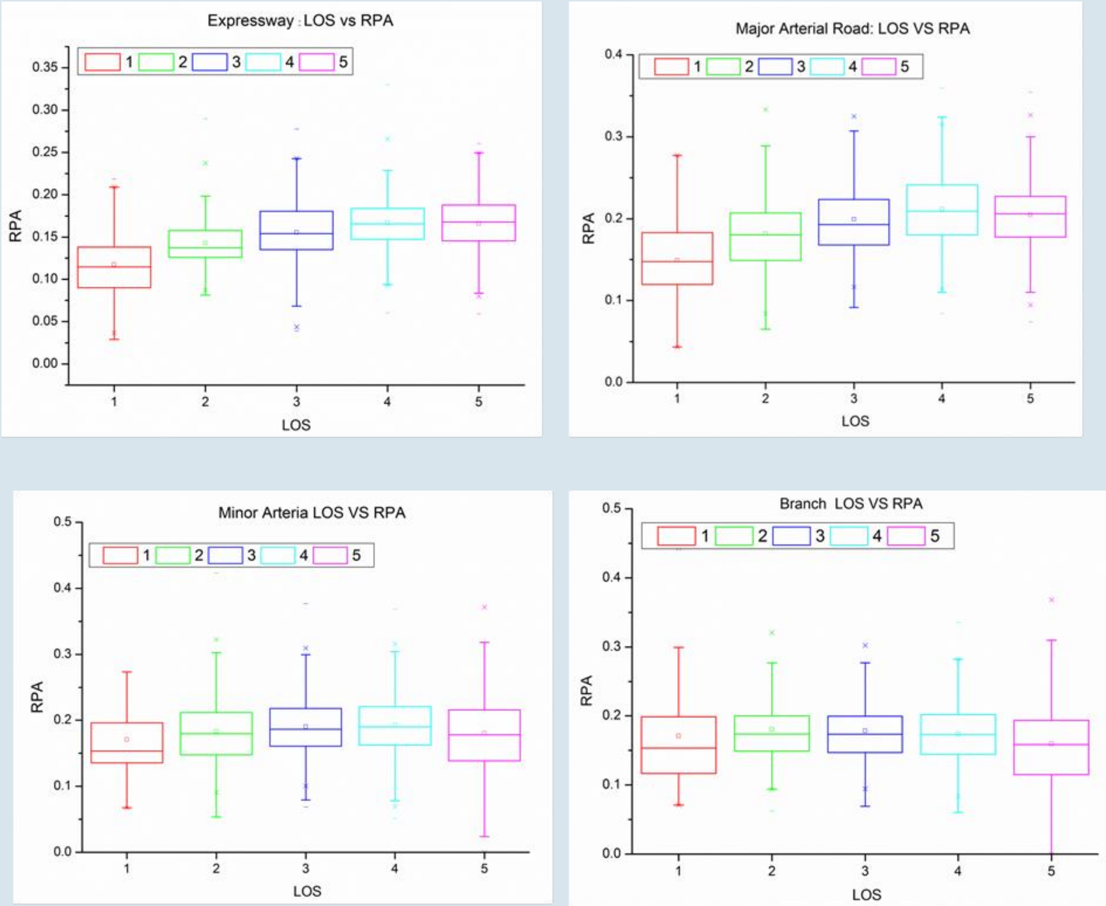

Figure 8: Statistical distribution of RPA and LOS for each road type in HBEFA China

4.3. Identification of Typical Driving Cycle for Each Traffic Situation

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

1. Identification of the 20 best-fitting driving cycles by analysing all available cycles per road type and LOS considering average speed, RPA and percentage of stop time;
2. Selection of one of the most typical cycles based on detailed analyses of time-speed curves and specific CO_2 emissions in g/km;
3. Comparison of the selected traffic situations with 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 9 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 data sets. Detailed analysis showed that the selected 10 cycles for Beijing and Shenzhen are very similar regarding the key parameters of 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 the same, 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 limitation.

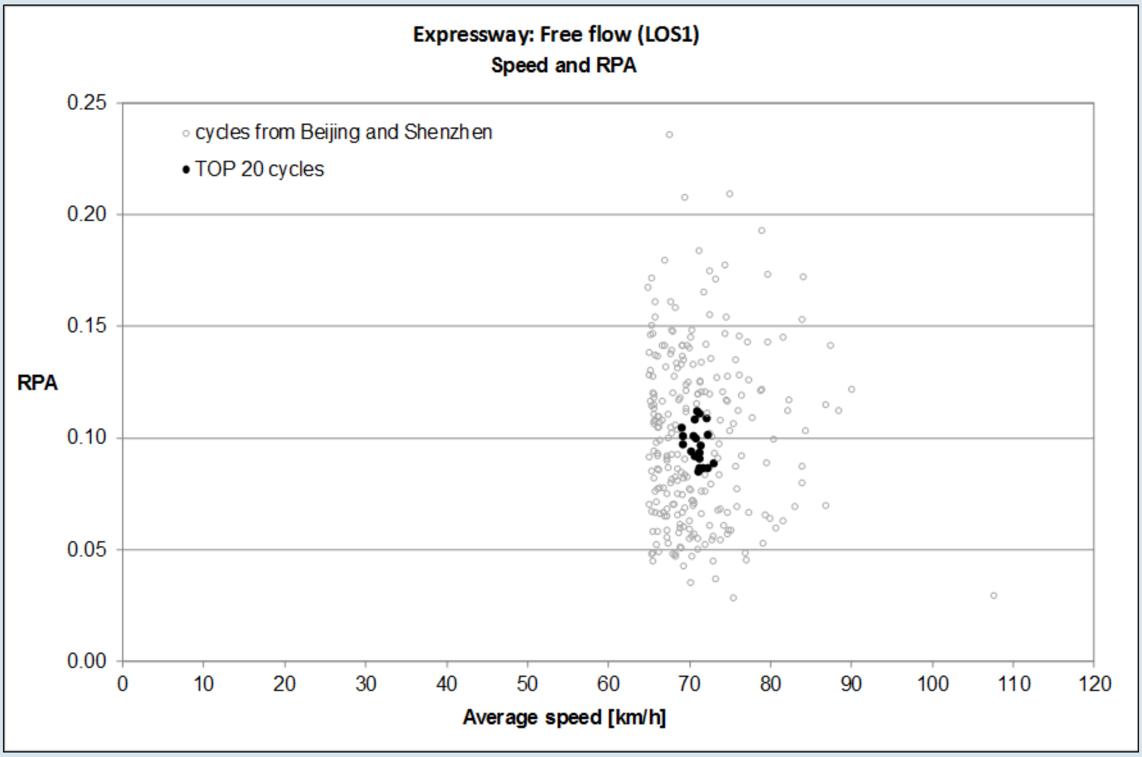

Figure 9: Selected top 20 cycles for passenger cars based on average speed, RPA and stop time (not included in the figure) using the example of the traffic situation "Expressway": free flow.

For each combination of road type and LOS the remaining 20 cycles were assessed in more detail during further steps of the analysis. For this purpose the fuel consumption and CO_2 emissions of all selected cycles were calculated using 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 as follows: The selection was basically carried out by analysing the time-speed curves. Due to the semi-automatic procedure for splitting larger cycles into smaller cycles by using the floating average speed, sometimes cycles were not optimally separated. Therefore cycles that were obviously a combination of two different levels of service were excluded from the further investigation. Also cycles which were 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 10).

In the next step, the remaining cycles related to the structures of the speed-time curves, average speeds, RPA, percentages of stop time and CO_2 emissions were compared. Based on these parameters the most typical and representative cycle was selected by expert judgment. The objective of this selection step was the identification of a driving cycle which is in the middle of all the remaining cycles with respect to the parameters considered. Figure 10 shows, as an example of 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 10: Second best-fitting driving cycle). Speed-time curves as well as CO_2 emissions of both cycles were almost the same. 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 proven that the traffic situations approach developed in Europe can be applicable in other countries such as China without reservation. Besides the selection of typical driving cycles for both cities a comparable European HBEFA cycle was identified (see also Figure 10).

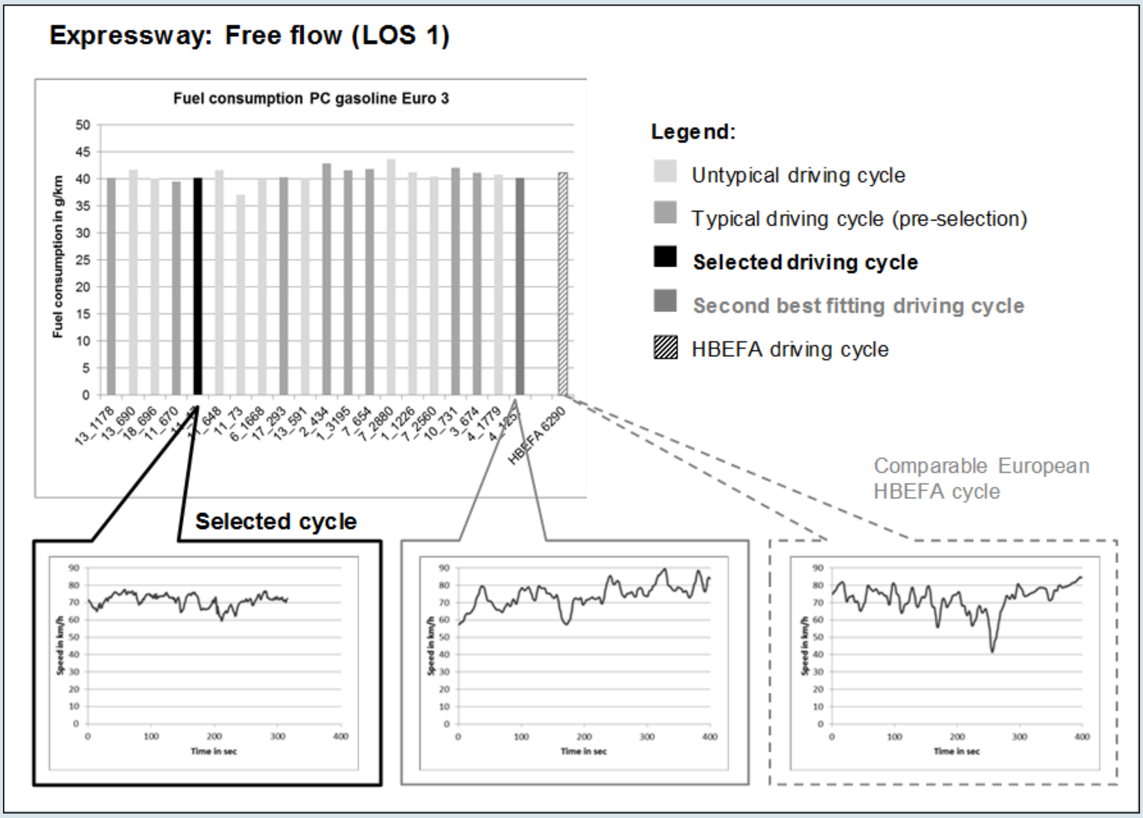

Figure 10: Selection of the typical traffic situation for passenger cars for the traffic situation "Expressway": Free flow based on the top 20 cycles selected for Beijing and Shenzhen

The average speed, RPA and percentage of stop time are included in Table 4 for each of the typical traffic situations 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 despite 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 examples included in Figure 11 are calculated for a standardised passenger car (production 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 section. 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 section.

Table 4 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/s²]	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%

5. CO_2 Emission Factors for Passenger Cars for Chinese Cities

Localised driving cycles for passenger cars for each traffic situation was input into the PHEM to produce a set of emission factors for Chinese cities. For each specific year, emission factors were structured by:

- 4 road types (expressway, major arterial, minor arterial and branch),
- 5 levels of services (1 = Free flow; 2 = Heavy traffic; 3 = Saturated traffic; 4 = Stop-and- go; 5 = Heavy stop-and-go),
- 8 fuel types (diesel, petrol, CNG, hybrid-diesel, hybrid-petrol, PHEV-diesel, PHEV-petrol, FFV),
- Fuel consumption and seven exhaust gas components (CO_2, NOx, NO_2, HC, CO, PM, PN)
- Emission concepts (pre China 1, China 1, China 2, China 3, China 4, China 5, China 6, China 6c)

Figure 11 shows the basic CO2 emissions of a standardised passenger car (production year 2002; engine capacity 1.4 - 2.0 l) for the Chinese traffic situations identified. The emission factor 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 CO2/km is caused by the traffic situation 'Branches: Heavy stop-and-go traffic'; but normal stop-and-go traffic generates high specific CO2 emissions also. The values between 196 and 327 g CO2/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) generated more than 15 million tons of CO2 emissions in 2010 in Beijing. One third of these emissions were caused by stop-and-go traffic situations while less than 20% of the vehicle kilometres travelled (VKT) performed at these levels of service. Nearly 20% of the CO2 emissions resulted from heavy stop-and-go traffic. These first results show the relevance of transport demand measures to reduce stop-and-go traffic as one key GHG emission strategy.

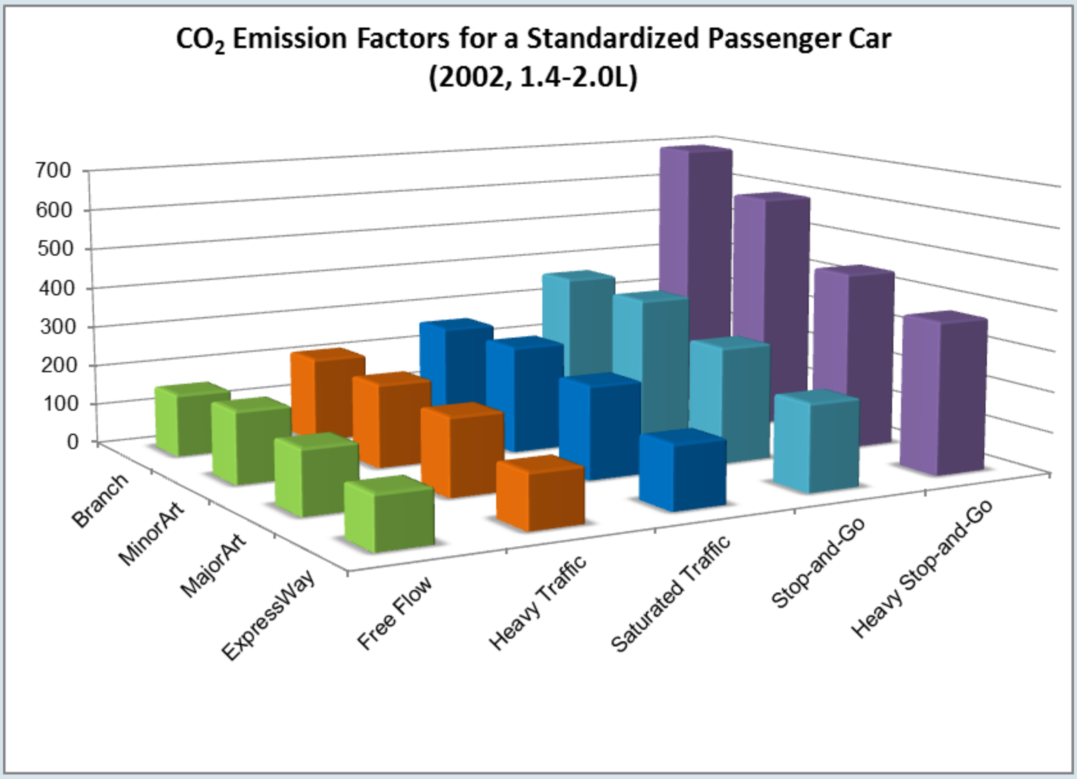

Figure 11: CO2 emission of a standardised passenger car (construction year 2002, engine capacity 1.4 - 2.0 l) for Chinese traffic situations

Based on these results, the emission factors of the standardised passenger car were extended to other production 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 2002 to 180 g/km in 2010, based on the new European driving cycle (ICCT, 2012). Considering these reduction rates and the fleet composition in Beijing, city-specific CO_2 emission factors can be calculated based on the standardised passenger car.

Table 5 provides the average CO_2 emission 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 5 are calculated for the average passenger vehicle fleet in Beijing in 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 age are almost negligible. For GHG quantification, it is at least as important to identify the correct traffic situation pattern as it is to appropriately map the car fleet composition. This is the reason why Beijing and Shenzhen have combined their travel demand models with the HBEFA-China Expert Version (INFRAS, 2014b).

Table 5 CO2 emission factors for passenger cars in 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

6. Emission Quantification Tool – Software Package

For one specific year, there are more than 40,000 emission factors defined by several dimensions. It is a complex task to calculate total emissions by employing such a comprehensive emission factor database with spreadsheets. To facilitate the emission calculation, a software package was developed by integrating all components of an emission model with a user friendly interface into the China Road Transport Emission Model CRTEM/ HBEFA-China. This tool was developed within the Microsoft-Access/Visual Basic for Applications environment based on the HBEFA expert version of INFRAS. The prime objective of the model is to estimate road traffic emissions with high temporal and spatial resolution to be used as a tool to assess the impact of urban transport policy on emission reductions. The tool has the following features:

- A bottom-up approach to estimate emissions on a disaggregated level. Alternatively, fuel sales figures can also directly be entered as an input for CO_2 calculations.
- Three key inputs into the model - source activity, emission factors and fleet compositions.
- Default values that can be used if no local data is available.
- Inclusion of data for passenger cars, freight and public transport.
- Disaggregation of the source activity data (VKT) to vehicle categories, road types and level of service (LOS) in order to allow street-wise emission data.
- A user-friendly interface with step-by-step navigation providing easy access to the sub-modules of the tool and allowing efficient use of the tool.

The interface of the package is shown in Figure 12.

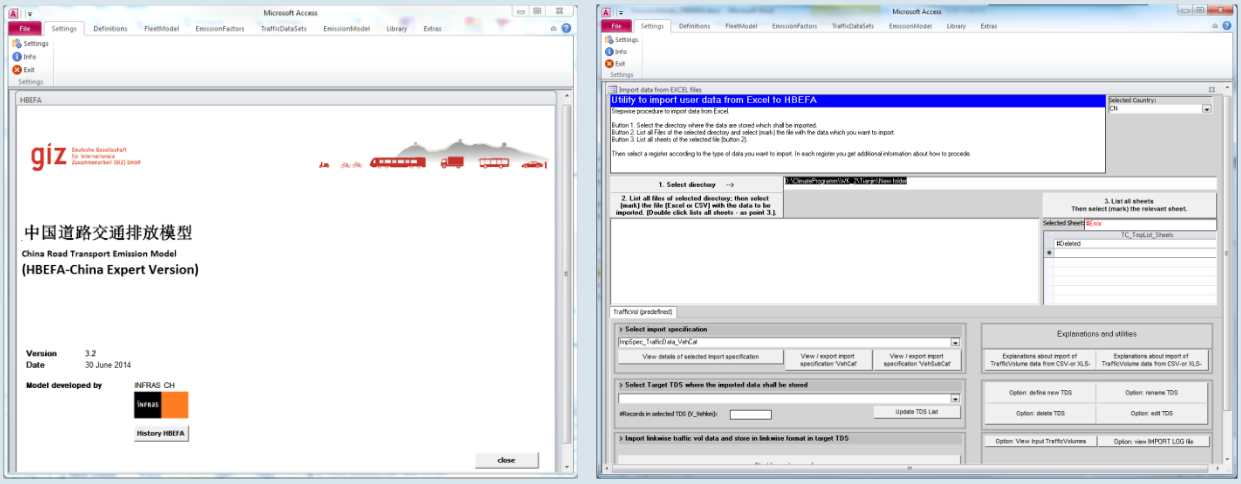

Figure 12: Interface of the CRTEM/HBEFA-China Expert Version (Source: HBEFA-China Expert Version, 2014)

Considering the complex situations of data availability on various levels of Chinese cities, the tool is designed in a flexible manner that can be applied in cities with highly detailed data in an advanced approach or in cities with limited availability of required data - in this case default parameters which are included in the tool – that can be used to a certain extent. To estimate the emissions, the user needs to prepare three key data sets:

- Transport activities. This is basically described by the vehicle kilometres travelled (VKT) i.e. the distance covered by vehicles in a certain period of time in a region. A further specification of this VKT data could be classified by road type, e.g. expressway, major arterial, minor arterial, etc. The data can be derived from a transport survey, a travel demand model or be a rough estimation based on fleet population.

- Road traffic situations. Fuel consumption and emissions are linked closely to traffic situations. CRTEM/HBEFA-China supports assessing the impact of network performance on fuel consumption and emissions, which significantly improves the accuracy of estimation. To do so, the user needs to prepare the shares of VKT by the five Levels of Service (LOS) defined by the China national standard.
- Fleet composition. A statistical distribution of regional vehicle population classified by vehicle age, engine size, fuel type and emission standard which corresponds to the emission factor database is required in order to apply the advanced estimation approach. Otherwise, an average emission factor would be applied if the city is unable to access this detailed information.

7. Conclusion and Outlook

The China Road Transport Emission Model (CRTEM/HBEFA-China) is a software package that allows Chinese cities to track data on emissions and calculate the emission impacts of transport scenarios. The model facilitates a reliable estimation of energy consumption and carbon emissions of urban road transport. Equipped with China-specific default values, the model is flexible enough to be used by cities with and without travel demand models. If projections of traffic activity are available, the CRTEM/HBEFA-China can also easily be used to calculate future emission scenarios.

The specific emission factors for China are included within the software package for CRTEM/HBEFA-China. The model is currently being used in Beijing, Shenzhen, Tianjin and Harbin. Shenzhen has furthermore developed an internet tool to visualise the CO2 emissions at street level. Although it is clear that street-level emission data are of more interest when assessing air pollution (e.g. as an input to dispersion models) this example illustrates the potential of CRTEM/HBEFA-China for future applications.

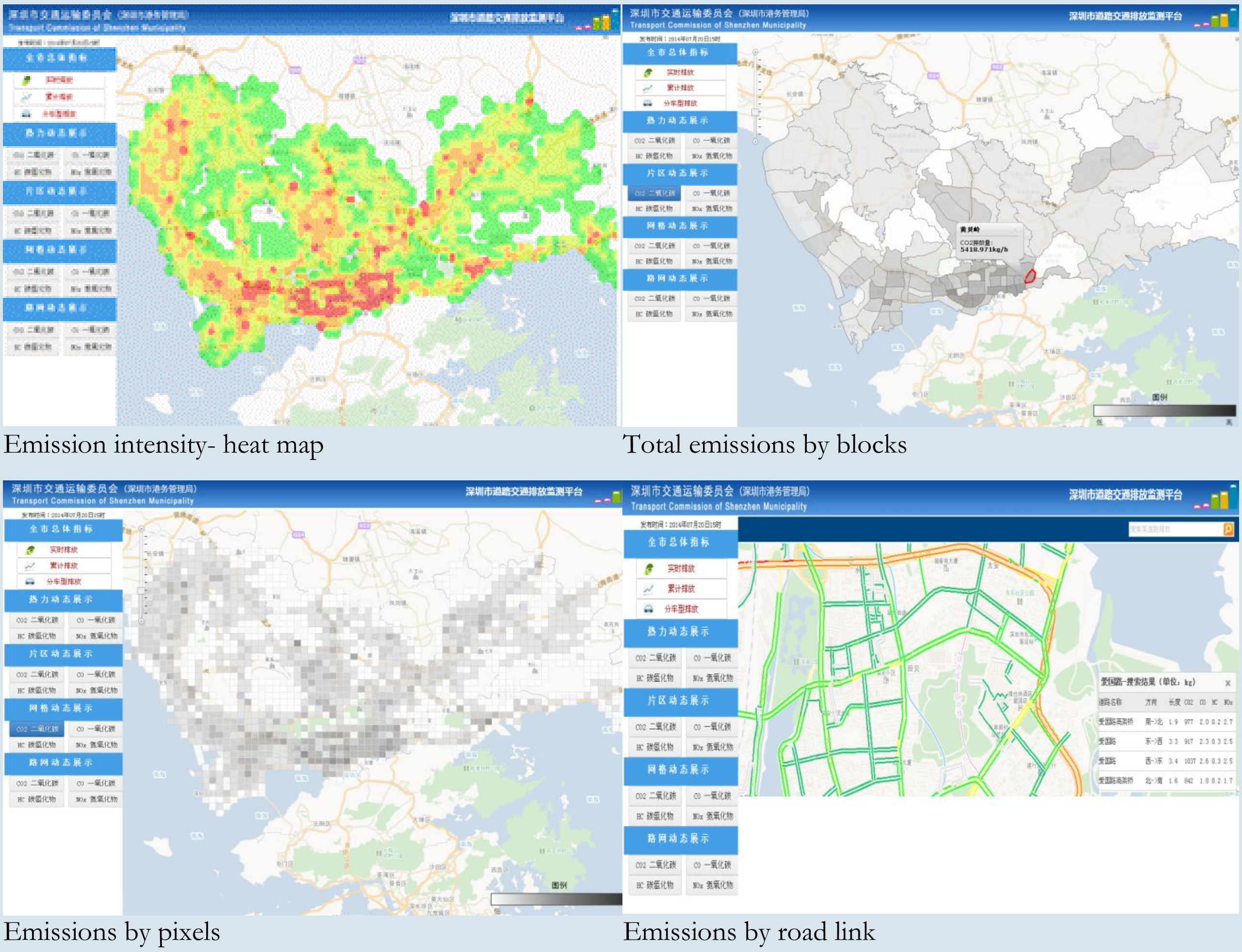

Figure 13: Screenshot of Emission Monitoring System in Shenzhen (Source: Shenzhen TRC, 2014)

GIZ is therefore planning to work towards expanding CRTEM/HBEFA-China by integrating evaluated emission factors for air pollutants. All cities cooperating in the Sino-German project on low carbon transport expressed the objective to integrate air pollutants, as well as emission factors for other vehicle categories into their models in the future. While the adaptation of emission factors for other vehicle categories to situations in Chinese cities is straightforward, incorporating China-specific emission factors for air pollutants in the CRTEM/HBEFA-China model is more complex.

Today HBEFA-China already contains emission factors for all air pollutants (e.g. NOx, HC, and PM). In contrast to CO_2 emissions, air pollutants are strongly influenced by fuel quality, engine and exhaust-after treatment technology (such as NOx reduction techniques), by vehicle maintenance and also by operational reliability of catalytic converters. Emission factors for pollutants can vary between Europe and China even in the same driving pattern.

In order to further improve the calibration of the tool, more detailed analysis and further calibration will be carried out in the coming month.

One of the first steps is to systematically compare the PEMS data collected by Chinese universities with measurements of European vehicles in order to provide reliable emission factors for air pollutants of vehicles for Chinese cities. After this the PHEM Model for the calculation of emission factors for air pollutants will be calibrated with measurements collected in China. The objective of this task is to provide reliable emission factors for air pollutants of vehicles for the Chinese cities as soon as possible.

In the meantime, we will develop the typical driving cycles in Chinese cities for other vehicle types other than light duty passenger cars, for example urban bus, coach and light duty trucks etc..

Some of the cities already use CRTEM/HBEFA China to develop sustainable transport strategies and monitor transport emissions in projects supported through international or national project funding. By applying an internationally recognised methodology for emission accounting with China-specific emission factors, cities using HBEFA China are at the forefront of emission quantification. This gives them a competitive advantage when applying for national or international climate or development funds. GIZ china offer trainings on emission quantification in the transport sector and model application, provide technical support to adapt the model to city specific needs, and extend policy consultancy on sustainable transport development and travel demand management.

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