Road transport GHG emission factors for Kenya
Pilot study for 2015

Short report
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Editorial Information

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1. Introduction

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) supports the assessment and reduction of greenhouse gas (GHG) emissions in the transport sector in developing countries and emerging economies through the project “TrACS” (‘Advancing Transport Climate Strategies in Rapidly Motorizing Countries’). One of the countries supported is Kenya.

In this context, GIZ has commissioned INFRAS to develop robust road transport CO₂-emission factors. The necessary local input data for the derivation of emission factors are supplied by the University of Nairobi.

The study presented in this report is best described as a pilot study, in the sense that a first version of emission factors is developed with relatively little effort. Consequently, some potentials for improvement are identified (see Chapter 4) but not yet addressed within this study. They may be addressed in follow-up studies.

2. Methodology

2.1. General methodology

The development of road transport emission factors in this study is based on the European Handbook of Emission Factors for Road Transport (HBEFA), Version 3.3 (Keller et al. 2017). The basic assumption is that the energy/fuel consumption and GHG emission factors at the most detailed level of the HBEFA, i.e. by vehicle subsegment and traffic situation, are transferrable from European countries to Kenya.

A vehicle “subsegment” is defined by the vehicle category (e.g. passenger car), the technology (e.g. Otto engine), the size class (e.g. 1.4-2.0 l capacity), and the emission standard (e.g. Euro-3). In the context of fuel consumption and CO₂ emissions, actually the emission standard is less relevant – what matters more are the gradual fuel efficiency improvements, and thus age.

A “traffic situation” is defined by the type of area (rural vs. urban), the road type (e.g. trunk road), the speed limit (e.g. 80 km/h) and the level of service (traffic density class, e.g. “freeflow”).

Given the basic assumption that the consumption and emission factors at the most detailed level are transferrable, the development of emission factors for Kenya mainly consists in the

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1 see also www.hbefa.net
correct derivation of the local fleet composition and distribution of traffic situations. The HBEFA Expert Version contains the tools to do so and was therefore used for this purpose.

2.2. Fleet model

2.2.1. Vehicle stock and traffic activity

The required inputs on vehicle stock and traffic activity were supplied by the team of Prof. Madara Ogot from the University of Nairobi. The methodology to obtain these inputs is also described in Ogot et al. (2018). In brief, a survey at petrol stations in large and small towns across the country was conducted. Customers at these petrol stations were asked about their vehicle odometer reading, their estimated monthly fuel expenditure and where their vehicle was mainly used, whether in town, rural area or highway. In addition, the license plate number was recorded. These data were then linked with the Kenyan motor vehicle registration database of the National Transport and Safety Authority (NTSA) using the license plate number. This way, the following input data for the HBEFA fleet model could be derived for the years 2015 and 2016:

▪ In-service vehicle stock by vehicle category
▪ Shares of segments (defined by technology and size class) within the vehicle category
▪ Age distributions by segment
▪ Annual mileage (vehicle kilometres per vehicle and year) by vehicle category and segment

Regarding vehicle categories:

▪ Within the light commercial vehicles (LCV), matatus and other LCVs were differentiated, since the two fleets differ in terms of technology, size class distribution, and annual mileage;
▪ All buses were classified as HBEFA “coaches”. HBEFA differentiates coaches and urban buses, but the NTSA registration database does not contain this differentiation. It was found that the Kenyan buses are overall more similar to European coaches than urban buses – this is why the HBEFA category “coach” was chosen to represent all buses.

The following adaptations were made by INFRAS to the inputs from the University of Nairobi:

▪ HGV: The input contained no large trucks of the size class 34-40 t. According to a study of Jomo Kenyatta University of Agriculture and Technology (Abiero et al. 2015), however, large trucks dominate goods traffic at least on the Mombasa – Nairobi corridor. Freely available images of Kenyan road traffic on the Internet also suggest that large trucks loaded with 40-ft containers are fairly common on Kenyan roads. The discrepancy may be due to fact that large trucks do not normally fuel at retail petrol stations (and may therefore have been...
missed in the petrol station survey), or that the categorization by UoN may have been based on empty, not full weight. We therefore reassigned the segment shares in the HGV fleet based on the latter assumption (not because it is more plausible than the first assumption – both may be valid – but because the first assumption does not yield an estimate of the segment share of large trucks).

- **Buses:** We reassigned all buses to the HBEFA segment “Coach Std <=18t” (standard Coach) since it is known that most buses in Kenya are in this size class (not the smaller “Coach Midi <=15t” as which all coaches were classified in the original input).

- **Motorcycles:** The input from the University of Nairobi assigned most motorcycles (77% of stock) to the largest size class >750 cc; however, this input was judged as not reliable by the authors themselves. We therefore reclassified motorcycles according to the following size class distribution based on a study by Nyang’aya et al. (unpublished, information received via GIZ Kenya):
  - <150 cc: 64% of motorcycles
  - 151-250 cc: 35%
  - 251-750 cc: 2%

Since the annual mileage at segment level could not be reliable either if the assignment to size classes was implausible, all motorcycle segments were assigned the average annual mileage of approx. 17’000 km/a.

### 2.2.2. AC and DPF shares

Since the NTSA data do not contain information on the availability of air conditioning (AC) or diesel particle filters (DPF), the shares of passenger cars (PC) and light commercial vehicles (LCV) with these attributes were estimated based on the assumption that the shares are similar to those in Switzerland, but delayed by the mean difference in fleet age (about 8 years). This assumption can be challenged (see Chapter 4).

### 2.2.3. Fuel efficiency

Since over 90% of all PC in Kenya are imported from Japan, the same fuel efficiency development (by construction year) as in Japan is assumed, but with a delay based on the age of imported cars (i.e. 8 years in the case of the majority of PC).

The figures for Japan are based on ICCT (Tietge et al. 2017). Unfortunately, they are partially only published as graphics, and only for the average of the Japanese PC fleet (without...
differentiating fuel types or size classes). Therefore the following work steps/assumptions had to be made:

- Reconstructing numeric values of real-world CO2 emissions from graphic
- Assumption that development in Kenya conforms to that of entire Japanese fleet (ignoring that certain car types, size classes could be exported preferably to Kenya)
- Assumption that ratio in CO2 emissions between petrol and diesel cars, as well as PC size classes, is the same as in European HBEFA countries on average

For the other vehicle categories (besides PC), the HBEFA consumption factors without annual efficiency correction are applied.

2.3. Traffic situations

The distribution of traffic situations is based on a detailed spatial network of road links in Kenya containing traffic count results. These traffic count results were extrapolated to the road segments without traffic information by forming averages from the segment with counts by county, rural vs. urban area and road type, by the University of Nairobi. INFRAS then carried out the following work steps:

- The following street segments were classified as “motorway” (originally classified as “trunk road”), in order to consider motorway-specific driving patterns:
  - Thika road Nairobi – Kenol
  - Mombasa road Nairobi – Kitengela
  - Highway Nairobi-Limuru
- The assumptions on the Level of Service (LOS) by time of day, road type and area type shown in Table 2 were applied; a standard hourly traffic flow curve was used to translate times of day into percentages of daily traffic.
Table 1: Rules for the assignment of levels of service (LOS)

<table>
<thead>
<tr>
<th>Area</th>
<th>RoadType</th>
<th>TS_8pm_6am</th>
<th>TS_6_10am</th>
<th>TS_10am_4p</th>
<th>TS_4_8pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Motorway</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
</tr>
<tr>
<td>Urban</td>
<td>Motorway</td>
<td>Freeflow</td>
<td>Stop+Go</td>
<td>Saturated</td>
<td>Stop+Go</td>
</tr>
<tr>
<td>Rural</td>
<td>TrunkRoad</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
</tr>
<tr>
<td>Urban</td>
<td>TrunkRoad</td>
<td>Freeflow</td>
<td>Stop+Go</td>
<td>Saturated</td>
<td>Stop+Go</td>
</tr>
<tr>
<td>Rural</td>
<td>Distributor</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
</tr>
<tr>
<td>Urban</td>
<td>Distributor</td>
<td>Freeflow</td>
<td>Stop+Go</td>
<td>Saturated</td>
<td>Stop+Go</td>
</tr>
<tr>
<td>Rural</td>
<td>Access</td>
<td>Freeflow</td>
<td>Saturated</td>
<td>Heavy</td>
<td>Saturated</td>
</tr>
<tr>
<td>Urban</td>
<td>Access</td>
<td>Freeflow</td>
<td>Saturated</td>
<td>Heavy</td>
<td>Saturated</td>
</tr>
<tr>
<td>Rural</td>
<td>Local</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
<td>Freeflow</td>
</tr>
<tr>
<td>Urban</td>
<td>Local</td>
<td>Freeflow</td>
<td>Heavy</td>
<td>Freeflow</td>
<td>Heavy</td>
</tr>
</tbody>
</table>

2.4. Fuel quality, fuel mix

For fuel properties such as CO₂ emission factors and heating values, the default values from IPCC (2006) are used. Regarding the fuel mix, no biofuel shares are assumed.

2.5. Ambient conditions (relevant mainly for cold start)

The climatic conditions for Swiss summer are assumed. These are certainly cooler than the lower regions of Kenya but may be not that far off from the average climatic conditions in the highlands, where population and economic activity are highest and therefore also the highest shares of traffic activity take place.

2.6. Inputs relevant for air pollutants

Air pollutant emissions are not in the scope of the current study. However, to get HBEFA to run, some inputs must be provided. Therefore, all inputs relevant for air pollutants (emission standards and introduction schemes, emission factors) were taken from Europe (Germany in particular) as “dummy” values.
3. Results

The average CO\textsubscript{2} emission factors by vehicle category are displayed in Table 2. HBEFA exports of the emission factors at various aggregation levels, which represent the main outcome of the present project, are provided separately in Excel files.

Table 2: Road transport CO\textsubscript{2} emission factors for Kenya for the reference year 2015, by vehicle category

<table>
<thead>
<tr>
<th>VehCat</th>
<th>g CO\textsubscript{2}/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>pass. car</td>
<td>185.20</td>
</tr>
<tr>
<td>LCV</td>
<td>216.48</td>
</tr>
<tr>
<td>HGV</td>
<td>759.88</td>
</tr>
<tr>
<td>coach</td>
<td>846.26</td>
</tr>
<tr>
<td>motorcycle</td>
<td>68.46</td>
</tr>
</tbody>
</table>

Table INFRAS. Source: own calculation

4. Potentials for improvement

4.1. Fleet inputs (vehicle stock)

- MC:
  - Redo segment shares based on latest available information. According to Prof. Nyang’aya, new results are now available that put almost all MCs in the <250 cc capacity class.
  - Age distribution shows longer service life than for HGV. Is this realistic? One would expect MC to have a shorter service life.

- Buses: Check segment shares. According to Prof. Nyang’aya, NTSA data allow differentiation between “mini buses” (capacity up to 33 passengers) and “buses”

- PC and LCV: The assumption regarding AC and DPF shares described in Chapter 2.2.2 should be verified.

- Generally: How robust are the results regarding vehicle age distributions and survival probabilities, and thus in-service stock numbers? Since “too little” modelled fuel consumption results in comparison to statistical fuel sales, might in-service vehicles stock be underestimated? (See also Chapter 4.4).
4.2. Traffic activity inputs (mileage)

- Generally: Individual mileage (vehkm/veh*a) seems high (see also Table 1, comparison with Switzerland). This is, at least in parts, not surprising as petrol station surveys tend to overestimate average mileage, since the cars with high mileage have to fuel more often and are therefore more likely to fall into the sample.

Therefore the sample should be analysed again, assigning each vehicle a weight to account for the probability of being in the sample.

- Matatus have almost same mileage as PC and less than other LCV –their mileage could be expected to be significantly higher

- MC: Mileage by segment cannot be used since the NTSA data based on which the classification into segments was done are not reliable. Therefore, a more reliable source of mileage by segment would be welcome.

<table>
<thead>
<tr>
<th>Vehicle category</th>
<th>km/a in Kenya (UoN petrol station survey 2017)</th>
<th>km/a in Switzerland (HBEFA)</th>
<th>KE/CH [%]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>22'223</td>
<td>13'409</td>
<td>166%</td>
<td></td>
</tr>
<tr>
<td>LCV (non-matatu)</td>
<td>30'811</td>
<td>11'100</td>
<td>276%</td>
<td></td>
</tr>
<tr>
<td>LCV (matatu)</td>
<td>22'356</td>
<td></td>
<td></td>
<td>No matatus in Switzerland</td>
</tr>
<tr>
<td>Bus</td>
<td>43'815</td>
<td>49'510</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>HGV</td>
<td>63'205</td>
<td>38'718</td>
<td>163%</td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>17'807</td>
<td>3'110</td>
<td>573%</td>
<td>Higher figure in KE explainable by Bodabodas, which don’t exist in Switzerland</td>
</tr>
</tbody>
</table>

Table 3: Individual mileage by vehicle category - comparison Switzerland vs. Kenya

4.3. Further inputs

- Road pavement condition is not yet accounted for. Current EF assume road conditions like in Europe (IRI approx. 3, i.e. “good”)

- More in-depth information is needed on the origin of imported trucks and buses, and the modifications made to them in Kenya. This is e.g. relevant for the determination of fuel efficiency development (and also, for the determination of air pollutant emission factors)
4.4. Bottom-up vs. top-down comparison

- Find out more about additional fuel consumers that fall into the same statistical category as road transport (i.e. “Retail pump outlets and road transport”) in the Kenyan fuel sales statistics and whether they can account for the underestimation of fuel sales by modelled consumption.
- Review robustness of in-service vehicle stock (possibility of underestimation?) and mileage
Literature


