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Workshop on statistics on the volume of road traffic (vehicle-kilometres)

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Swiss calculation methods

Transmitted by the Government of Switzerland

1. Introduction

The increasing demand for road transport, especially the increasing use of passenger cars (accounting for 87% of the total volume of road traffic), prompted the Swiss Federal Statistical Office (SFSO) and the Federal Office for Spatial Development (ARE) to devise methods to estimate the total volume of road traffic. Here, are presented two such methods, focusing our attention primarily on estimation of the total volume of passenger car traffic. The first method is used by the Swiss Federal Statistical Office. It is based mainly on findings from the Microcensus on Travel Behaviour, which is conducted every five years. For the sake of simplicity, this method is referred to as the “Microcensus method”. The second method is based on reports from regular inspections of vehicles and the Swiss Motor vehicle Register (MOFIS). This method is referred to as the “PEFA method” (PEFA stands for “Periodische Erhebung Fahrleistungen” in German or “Periodic Survey of Annual Distance Travelled” in English).

2. Microcensus method

The Microcensus method relies on data from the Microcensus on Travel Behaviour, Swiss Annual Population Statistics (ESPOP) and Swiss Annual Motor Vehicle Statistics (AMVS).

2.1 Microcensus on Travel Behaviour

The Microcensus on Travel Behaviour is a joint survey conducted by the SFSO and ARE every five years. This survey is primarily intended to measure distances travelled by the permanent resident population aged 6 and over.

Roughly 28,000 households (about 30,000 individuals) were contacted by phone throughout the year 2000. Phone interviews began with respondents being asked to provide sociodemographic data as well as information about their passenger cars and motorcycles (age of vehicle, total distance travelled since vehicle was acquired, total distance travelled in 2000 in Switzerland and abroad). One or two members of the household (persons aged 6 and over) were then chosen for the rest of the phone interview. These respondents were asked to describe very precisely where they went on a specific day ("travel day"). Chosen at random for each household, the travel day was generally the day before the phone interview. Respondents were asked to indicate each trip segment (e.g. person going to work rides a bike to the train station for the first trip segment, takes the train for the second trip segment and then walks the remaining distance for the third trip segment), departure and arrival points, departure and arrival times, means of transport used (e.g. walked, rode bicycle, drove passenger car, rode in passenger car, etc.) and the distance travelled for each trip segment.

Based on random choices of households, respondents and travel days and with the help of the Swiss Annual Population Statistics, it is possible to estimate the volume of passenger car traffic for the entire Swiss population for the year 2000.

2.2 Calculating the total volume of passenger car traffic

The total volume of passenger car traffic for survey years (1994 and 2000) is calculated by adding up the distance of each trip segment in which a permanent resident drove using the equation below:

$$Dist = N_p N_j \sum_{p \in S_p} w'_p dist_{p,j_p}, \quad \text{où } w'_p = \frac{w_p}{\sum_{q \in S_p} w_q}$$

- Where
- Dist: Total volume of passenger car traffic for the year ([vhc·km])
 - $dist_{p,j}$: Total distance travelled by driver p for the given day of reference j (sum of all trip segments)
 - w_p, w_q : Weight of person p , weight of person q
 - S_p : Sample of persons
 - N_p : Permanent resident population aged 18+
 - N_j : Number of days in the year

Moreover, determining where each trip segment is located enables to calculate how many kilometres were travelled in Switzerland or abroad.

For non survey years, a model was devised to take into account variations in the population (based on Swiss Annual Population Statistics) and the total number of registered passenger cars (based on Swiss Annual Motor Vehicle Statistics). To this end, 6 population categories (based on sex and age of person) and 9 passenger car categories (based on age of vehicle and cylinder capacity) were created. The Microcensus on Travel Behaviour data was used to calculate average distance

travelled per driver and vehicle for each of the 54 possible combinations of population and passenger car categories. To obtain the volume of passenger car traffic for each category combination, the average distance travelled was multiplied by the number of people in the given population category and the number of vehicles in the given passenger car category. This gave 54 different volumes which, when added together, produced the total volume of passenger car traffic. These yearly estimations are then smoothed out.

The survey sample (about 30,000 interviews) provides a reliable estimate (margin of error of $\pm 3\%$) of the total volume of passenger car traffic for the year.

Table 1: Total volume of passenger car traffic, vehicles registered in Switzerland

Year	Population 18+		Total number of registered passenger cars		Total volume of passenger car traffic			
	Persons [pers]	Variation in %	Passenger cars [vhc]	Variation in %	Within Switzerland		Within Switzerland and abroad	
					Vehicle-km [vhc-km] In millions	Variation in %	Vehicle-km [vhc-km] In millions	Variation in %
	1994	5 510 500	0.0	3 165 043	0.0	37 739	0.0	42 275
1995	5 546 100	0.6	3 229 169	2.0	38 907	3.1	43 588	3.1
1996	5 575 500	1.2	3 268 073	3.3	39 689	5.2	44 470	5.2
1997	5 587 500	1.4	3 323 421	5.0	40 318	6.8	45 180	6.9
1998	5 601 700	1.7	3 383 273	6.9	41 032	8.7	45 987	8.8
1999	5 629 400	2.2	3 467 275	9.5	42 115	11.6	47 207	11.7
2000	5 667 200	2.8	3 545 247	12.0	43 274	14.7	48 512	14.8
2001	5 707 400	3.6	3 629 713	14.7	44 366	17.6	49 736	17.6
2002	5 780 300	4.9	3 700 951	16.9	45 577	20.8	51 093	20.9
2003	5 839 400	6.0	3 753 890	18.6	46 427	23.0	52 046	23.1
2004	5 892 800	6.9	3 811 351	20.4	47 379	25.5	53 114	25.6

3. PEFA method

The Periodic Survey of Annual Distances Travelled (PEFA) provides estimates of the total volume of road traffic per year for all types of motor vehicles. Conducted for the last time in the year 2000 (and before then in 1991 and 1995), the PEFA survey covers all civilian motor vehicles registered in Switzerland.

3.1 PEFA Survey

Data from the PEFA 2000 Survey came from vehicle inspections conducted by inspection offices in the various cantons (17 out of 26 cantons provided the requested information) in 2000 as well as from the Swiss Motor Vehicle Register (MOFIS), which contains a list of all vehicles registered in Switzerland along with their technical characteristics. All in all, vehicle inspection data were compiled for roughly 595,000 vehicles (total number of vehicles: approx. 5,000,000), 476,000 of which were passenger cars (total number of passenger cars: 3,545,247). The main variables were:

Vehicle inspection (PEFA Survey data obtained from vehicle inspection offices)	- License plate number - Odometer reading - Date of vehicle inspection
Swiss Motor Vehicle Register	- Type of vehicle

(MOFIS) (data gathered when vehicle was registered for the first time)	<ul style="list-style-type: none"> - Fuel type - Cylinder capacity - Gross vehicle weight (GVW) and load capacity - First vehicle registration date
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3.2 Calculating the average distance travelled per year

Calculating average distance travelled per year is fairly straightforward: One takes into account the age of the vehicle (difference between the vehicle inspection date and the first registration date) and the odometer reading recorded during vehicle inspection. By dividing the odometer reading by the age of the vehicle (in days) and multiplying by 365, we obtain the average distance travelled by that vehicle each year.

$$\text{Average distance travelled each year} = \frac{\text{Odometer reading}}{\text{Age of the vehicle (in days)}} \times 365$$

It should be pointed out, however, that various adjustments had to be made to compensate for biases in the PEFA survey. These biases are explained below.

3.3 Sampling bias

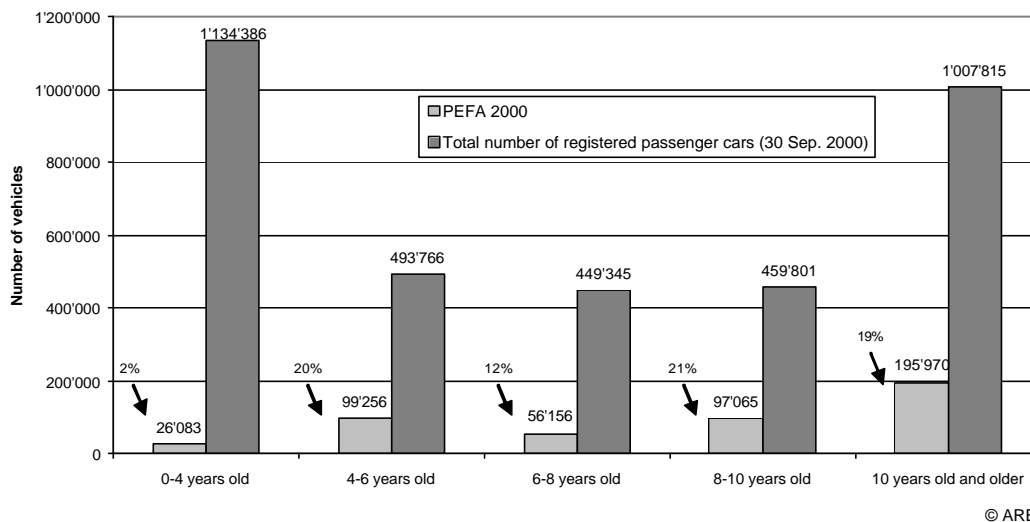
The PEFA sample was not chosen at random. The sample only includes vehicles inspected by a cantonal vehicle inspection office. Vehicle inspections are not conducted at random but rather at regular intervals established by law. Generally speaking, vehicle inspections take place at the following intervals:

- Vehicles must be inspected four years after the first vehicle registration date. Vehicles must be inspected again three years after the first vehicle inspection. From that moment onwards, vehicles must be inspected every two years.
- Passenger service vehicles (e.g. motor coaches, taxis, etc.) must undergo vehicle inspection every year.

Apart from these intervals, vehicle inspections may also take place if ownership of the vehicle changes hands, if the vehicle was involved in an accident or if a serious material defect is discovered.

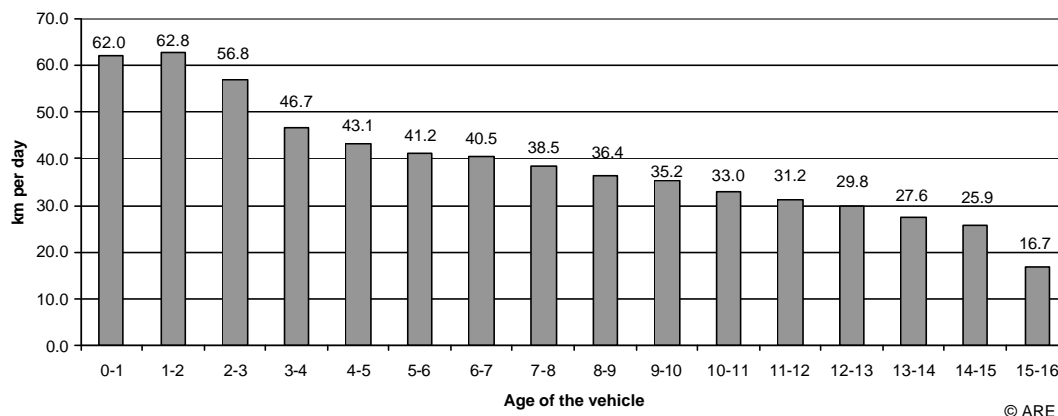
Because of these legal requirements, the vast majority of vehicles are inspected four years after the first vehicle registration date. This means that vehicles that have not reached the four-year mark are underrepresented in the sample, unlike old vehicles. In fact, the sample only includes 2% of the passenger cars that are less than four years old. In contrast, the sample includes 21% of passenger cars between 8 and 10 years old (see Chart 1).

Chart 1: Passenger cars per age category, based on the PEFA 2000 sample and the number of registered passenger cars as of 30 September 2000.



If the average distance travelled per year by passenger cars in the PEFA sample is observed, passenger cars under the age of four are not only underrepresented, but the average distance travelled by these passenger cars is also very high, certainly not representative of vehicles in this age category (see Chart 2).

Chart 2: Passenger cars: Average distance travelled per day according to vehicle age category.



As it happens, most of the vehicles under the age of four included in the PEFA sample underwent vehicle inspection outside the intervals provided for by law. These vehicles were either passenger service vehicles (e.g. taxis), vehicles that were remodelled or vehicles that changed hands. In all three cases, it is very likely that these vehicles are driven more than “normal” passenger cars. We should point out that the same phenomenon is observed for all vehicle categories, with the exception of motor coaches, which are subject to mandatory vehicle inspection each year.

In order to create homogeneous groups, passenger cars were broken down into age categories: 0-4 years old, 4-6 years old, 6-8 years old, 8-10 years old, 10-12 years old, 12-16 years old, 16 years old and older. The average distance travelled per year was calculated separately for

each of the seven age categories. It was assumed that vehicles in the 0-4 age category travel the same average distance per year as vehicles in the 4-6 age category. The average distance travelled per year for each age category was then multiplied by the total number of registered passenger cars in that category as of 30 September 2005. The volumes for each of the seven age categories were then added together to obtain the total volume of passenger car traffic for the year. For non survey years, the total volume of passenger car traffic per year is based on a simple model that takes into account variations in the number of registered vehicles for each age category.

Table 2: Comparison of PEFA and Microcensus methods used to calculate total volume of passenger car traffic per year, vehicles registered in Switzerland.

Year	Total number of registered passenger cars		Total volume of passenger cars (within Switzerland and abroad)				Comparison PEFA / M
	Passenger cars [vhc]	Variation in %	PEFA Method		Microcensus Method		
			Vehicle-km [vhc-km]	Variation	Vehicle-km [vhc-km]	Variation	
			In millions	in %	In millions	in %	
1994	3 165 043	0.0	41 904	0.0	42 275	0.0	99.1%
1995	3 229 169	2.0	42 877	2.3	43 588	3.1	98.4%
1996	3 268 073	3.3	43 518	3.9	44 470	5.2	97.9%
1997	3 323 421	5.0	44 382	5.9	45 180	6.9	98.2%
1998	3 383 273	6.9	45 311	8.1	45 987	8.8	98.5%
1999	3 467 275	9.5	46 568	11.1	47 207	11.7	98.6%
2000	3 545 247	12.0	47 751	14.0	48 512	14.8	98.4%
2001	3 629 713	14.7	49 027	17.0	49 736	17.6	98.6%
2002	3 700 951	16.9	50 131	19.6	51 093	20.9	98.1%
2003	3 753 890	18.6	50 992	21.7	52 046	23.1	98.0%
2004	3 811 351	20.4	51 918	23.9	53 114	25.6	97.7%

To estimate the bias resulting from vehicles in the 0-4 age category, the calculation described above can be perfected by applying a smooth linear extrapolation of the average volumes of passenger car traffic for the vehicles in the 4-6 year, 6-8 year and 8-10 year category to the average volume of passenger car traffic for vehicles in the 0-4 age category. Compared to the equation that was used, this equation tends to increase the total volume of passenger car traffic by about 3% (from 1% to 4% for other categories of vehicles). This gives an idea of the bias that vehicles in the 0-4 age category bring to the calculation of total distance travelled. It should also be mentioned that the margin of error for passenger cars is negligible: far below 1%.

3.4 Method bias

Although it is relatively easy to test for and correct sampling bias, the method bias is extremely difficult to quantify in a reliable manner, due to the lack of external means of verification. Below, a non exhaustive list of potential sources of method bias is presented:

- The PEFA method assumes that the distance travelled per year remains constant for the entire life of the vehicle. However, this hypothesis may not be correct. Survey data seems to indicate that the average distance travelled per year steadily decreases as the vehicle gets older (see Chart 2), regardless of the type of vehicle. Therefore, the PEFA method overestimates the average distance travelled.
- Vehicles that undergo vehicle inspection before the standard legal interval may actually have travelled more kilometres than others (at least, this is the conclusion that is drawn from the average distance travelled per year for vehicles in the 0-4 age category). However, since these vehicles are overrepresented in the sample, once again there have an overestimation of the average distance travelled.

- It is reasonable to assume that old vehicles are disposed of just prior to vehicle inspection. If the vehicles in this age category travel fewer kilometres than vehicles in the other age categories, then the average distance travelled are again overestimated.
- Odometer readings reset to zero after the maximum number of kilometres is reached, which leads to an underestimation of the average distance travelled.
- Finally, the economic cycle certainly has an influence, especially on the volume of road freight traffic. Depending on whether the economy is booming or in the doldrums, the volume of road traffic will be underestimated or overestimated. However, this influence is not accounted for in the PEFA method.

Most of these influences are difficult to verify. Moreover, they vary considerably from one type of vehicle to another.

However, the Distance-Related Heavy Vehicle Fee (HVF), which was introduced in Switzerland in 2001, provides an external database that can be used to precisely determine method bias for heavy goods vehicles (i.e. weighing 3,500 kg and over). Odometer readings are taken every day of the year for all vehicles subject to the HVF (i.e. over 90% of all heavy goods vehicles). Not only can this information be used to precisely determine the total distance travelled per year for all road goods vehicles subject to the HVF, but it can also be used to estimate the average volume of road freight traffic using the PEFA method. A comparison of these two estimates shows that the PEFA method overestimates the total volume of road traffic by nearly 15% for heavy goods vehicles. Of course, this is an extreme case. As can be seen later on, the bias for other means of transport is certainly less.

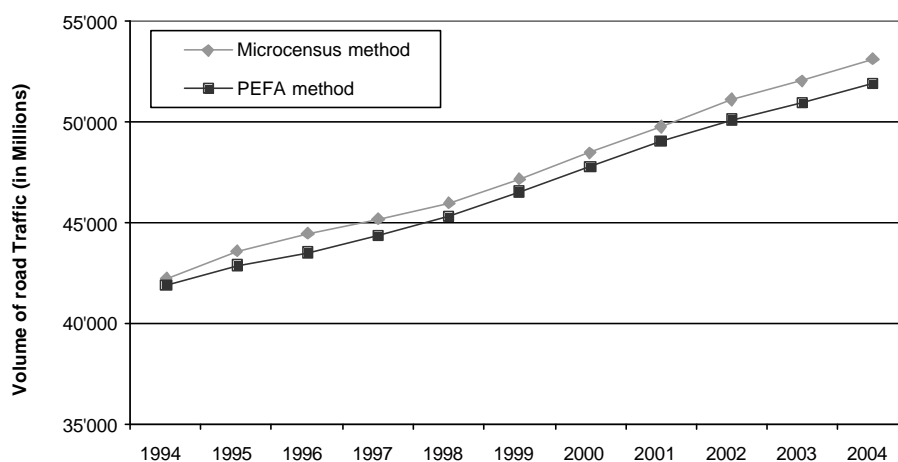
Maintaining the data from all vehicle inspections conducted at regular intervals should enable us to adjust the method slightly and, in so doing, considerably lower the bias. This variant will be implemented (i.e. new variables will be added to the Swiss Motor Vehicle Register) and tested in Switzerland in the coming years.

4. Comparison of methods

Although the financial aspect plays an increasingly important role, it is not included in the discussion of the two methods. Indeed, the financial aspect depends to a great extent on already existing data at the national level, such as data from the Microcensus on Travel Behaviour or information from the Swiss Motor Vehicle Register.

If the total volume of passenger car traffic obtained is compared using the Microcensus method with the total volume of passenger car traffic obtained using the PEFA method, it can be found that the figures are quite close even though the two methods are different (see Table 2 and Chart 3). The differences between the two figures do not exceed 2% for survey years and 3% for non survey years, which is lower than the margin of error resulting from sampling bias. It may therefore be concluded that the PEFA method bias for passenger cars is low in comparison to the PEFA sampling bias.

Chart 3: Comparison of the total volume of passenger car traffic using the two methods.



To conclude, the advantages and disadvantages of each method are presented.

4.1 Advantages and disadvantages of the Microcensus method

Advantages:

- **Notion of territoriality**

The distinction drawn between the volume of passenger car traffic within Switzerland and the volume of passenger car traffic abroad enables us to monitor traffic at the national level.

- **Efficiency of passenger car traffic** (number of road passengers and passenger-kilometres)

During the Microcensus on Travel Behaviour, the number of vehicle occupants (i.e. number of road passengers, which includes the driver) is recorded for each trip segment travelled by passenger car. By multiplying the distance by the number of vehicle occupants for each trip segment, the efficiency of passenger car traffic can be obtained (assessed in terms of the number of road passengers and passenger-kilometres).

Table 3: Total volume and efficiency of passenger car traffic per year, vehicles registered in Switzerland

Year	Population 18+		Total number of registered passenger cars		Total volume of passenger car traffic		Efficiency of passenger car traffic			
	Persons	Variation	Passenger cars	Variation	Vehicle-km	Variation	Passenger-km	Variation	Passengers	Variation
	[pers]	in %	[vhc]	in %	[vhc-km]		[pkm]	in %	[pers]	in %
					In millions	in %	In millions	in %	In millions	in %
1994	5 510 500	0.0	3 165 043	0.0	37 739	0.0	61 492	0.0	4 654	0.0
1995	5 546 100	0.6	3 229 169	2.0	38 907	3.1	63 171	2.7	4 856	4.4
1996	5 575 500	1.2	3 268 073	3.3	39 689	5.2	64 172	4.4	5 012	7.7
1997	5 587 500	1.4	3 323 421	5.0	40 318	6.8	64 911	5.6	5 153	10.7
1998	5 601 700	1.7	3 383 273	6.9	41 032	8.7	65 774	7.0	5 308	14.1
1999	5 629 400	2.2	3 467 275	9.5	42 115	11.6	67 185	9.3	5 513	18.5
2000	5 667 200	2.8	3 545 247	12.0	43 274	14.7	68 709	11.7	5 735	23.2
2001	5 707 400	3.6	3 629 713	14.7	44 366	17.6	70 464	14.6	5 881	26.4
2002	5 780 300	4.9	3 700 951	16.9	45 577	20.8	72 453	17.8	6 047	30.0
2003	5 839 400	6.0	3 753 890	18.6	46 427	23.0	73 874	20.1	6 166	32.5
2004	5 892 800	6.9	3 811 351	20.4	47 379	25.5	75 482	22.8	6 300	35.4

Disadvantages:

- **Volume of road traffic for other types of vehicles is not readily available**

First of all, the survey design does not enable to estimate the volume of road freight traffic. Secondly, obtaining a reliable estimate of the volume of road traffic for other means of passenger transport (e.g. motorcycles, motor coaches, etc.), which are less frequently used as a means of transport, would require a major increase in the size of the sample.

- **Respondents may not provide reliable estimates of distance travelled**

Respondents asked to estimate the distance travelled for each trip segment may make mistakes. Indeed, it is difficult to precisely estimate the distance travelled even if the interview takes place the following day. However, total distortion does not seem to be excessive. Short distances tend to be overestimated and long distances underestimated, which means that estimates partially balance each other out. Online geocoding of trip segment locations, which was recently introduced for the Microcensus on Travel Behaviour 2005, should enable us to determine more precisely any bias in the statements made by respondents.

4.2 Advantages and disadvantages of the PEFA method

Advantages

- **Volume of road traffic for all types of vehicles is readily available**

By gathering information from vehicle inspection of all types of vehicles, a reliable estimate can be easily obtained (low margin of error without taking into account possible method bias) of the volume of road traffic for all types of vehicles, even those less frequently used by the population (e.g. motorcycles, motor coaches).

- **Technical characteristics of vehicles**

The distance travelled can be calculated according to various technical characteristics of vehicles, such as load capacity or gross vehicle weight, cylinder capacity and fuel type. This additional information is very useful when it comes to calculating emissions of pollutants.

Disadvantages

- **Method bias**

As mentioned earlier, the method bias can be quite high, especially when it comes to estimating the total volume of road freight traffic. Experience has shown, however, that method bias is much lower in other vehicle categories.

- **Notion of territoriality unavailable**

Odometer readings alone do not enable to determine how much of the volume of road traffic was within Switzerland and how much was abroad.

- **Efficiency of road traffic unavailable**

Without any outside information regarding average vehicle occupancy rates, it is not possible to estimate the efficiency of road traffic (in passenger-kilometres).
