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The German Vehicle Mileage Survey 2014: Striking the balance between methodological innovation and continuity

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Abstract

Vehicle kilometers travelled (VKT) directly reflect the extent of spatial interaction within society and economy. VKT is also a key figure to quantify the use of road infrastructure. Consequently, VKT is one of the most important statistical indicators in traffic and transport. For a country with substantial cross-border transport relations such as Germany, VKT must be differentiated in national and domestic VKT: national VKT is the mileage of vehicles registered in Germany while domestic VKT is the mileage on German territory by German and foreign vehicles. This paper presents the most current German VKT survey, Fahrleistungserhebung (FLE) 2014, which comprised two elements: a motor vehicle owner survey to measure national VKT and traffic counts to measure domestic VKT. Vehicle mileage figures with deep stratification of both national and domestic VKT can only be generated through such special empirical studies. The focus of this paper is on the vehicle owner survey and national VKT.

Keywords: German Vehicle Mileage Survey, vehicle owner survey, traffic count, vehicle kilometers travelled, mixed-mode design, stratified sample, separate ratio estimation

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1. Introduction

There is general agreement that comprehensive data on motor vehicle kilometers travelled (VKT) with deep stratification should preferably be generated through special empirical studies with surveys of motor vehicle owners (national VKT) and traffic counts (domestic VKT) as core elements. Owner-based national VKT surveys have a long history in Germany. In view of the associated costs, however, such studies are only conducted at long intervals and thus have the character of occasional individual studies ("vehicle mileage surveys"). The last three VKT surveys in Germany which are comparable in format and geographic scope (after the German reunification in 1990) were conducted in 1993, 2002, and 2014 (Hautzinger et al. 1996a, 1996b, 2005a, 2005b; Bäumer et al. 2016a, 2016b). All these surveys were planned, evaluated, conducted, and analyzed under the auspices of German Federal Highway Research Institute (BASt), with the organizational/ technical execution of the written/postal surveys being handled by the Federal Motor Transport Authority (KBA). This involved surveying a random sample of vehicles across the entire year (sample frame: central vehicle register (ZFZR) of the KBA) to determine the VKT through two odometer readings over a reporting period defined by the survey design.

As with many transport indicators, not only absolute levels of VKT are relevant but also the development over time. Hence, comparability of VKT survey results with results from earlier surveys is paramount. At the same time, there are various external changes that affect survey design. This ranges from survey design innovations (e.g. smartphone use) over generally declining response rates to changes in vehicle types and vehicle usage. Against this background, it is important to strike the right balance between methodological innovation and continuity when surveying VKT. In light of this objective, the paper describes the FLE 2014.

The paper is structured as follows. First, the methodological background of the FLE vehicle owner survey is presented (study design, questioning technique, data expansion and analysis). In the next section the main survey results are summarized and contextualized. For this purpose, the FLE national VKT figures are compared to the domestic VKT figures obtained from the FLE traffic counts which were conducted in parallel to the FLE vehicle owner survey. Furthermore, the FLE national VKT results are compared to VKT figures obtained from other surveys, in particular the German National Travel Surveys (MiD, MOP). Finally, some methodological and practical conclusions are drawn and an outlook is provided.

2. Methodology

2.1. Study Design

The objective of the FLE 2014 vehicle owner survey was to provide up-to-date indicators on the national VKT that are comparable in terms of content and methodology with previous studies while simultaneously taking into account changes in vehicle types and vehicle usage that have occurred in the intervening period. The study was intended not only to estimate the national VKT as a whole with the greatest possible precision, but also the VKT of particular sub-groups of German-registered vehicles as well. As classification characteristics for the delineation of these sub-groups, the study looks not only at register information (technical vehicle features and socio-economic characteristics of the vehicle owner) but also at survey characteristics that describe the predominant use or type of use of the vehicle.

The 2014 vehicle owner survey to determine national VKT was largely identical to the preceding study in 2002. The survey again included all motor vehicle types, from mopeds to semi-trailers (only a few special motor vehicle sub-groups such as agricultural tractors and vehicles of the federal police and military are not recorded).

To determine the 2014 national VKT, over 6 survey waves of 151 motor vehicle strata each, a total of 162.653 vehicles were randomly selected through systematic sampling from the central vehicle register (ZFZR) of the Federal Motor Transport Authority (KBA).

At the top level of a hierarchical system of stratification criteria the following 10 vehicle groups were distinguished:

- Motorcycles
- Passenger vehicles of private owners
- Passenger vehicles of business owners
- Buses

- Trucks of private owners
- Trucks of business owners
- Semi-trailers
- Other trucks
- Other vehicles
- Vehicle with insurance tag

The deeper stratification of the vehicle groups was made with regard to the following characteristics:

- the type of vehicle (subgroups within the vehicle groups)
- the age of the vehicle or the vehicle owner
- the engine power or mass of the vehicle
- the propulsion of the vehicle
- the economic sector of the vehicle owner (for business owners only)
- the number of seats (for buses only)

Within the 10 vehicle groups the breakdown by these characteristics was partly different due to group-specific constraints. Overall, the stratification of the sampling frame should be carried out with characteristics related to the vehicle kilometers travelled.

By surveying the respective vehicle owners with regard to the vehicle odometer readings on two key dates ten weeks apart, the study gathered data regarding the average daily mileage of the vehicles included in the study. In addition to the odometer reading on two occasions (called initial and final interview), the vehicle owner survey also collected information about some additional characteristics such as the predominant type of use of the vehicle and mileage driven outside Germany. These additional characteristics can not only be used to break down the total VKT, but can also be regarded as analysis variables in their own right.

2.2. Questioning Technique

With respect to the actual questionnaire, it has proven useful to retain the basic concept of the previous FLE vehicle owner surveys, i.e. focusing on the most important survey characteristics and use of a short, clearly structured and easily understandable two-page questionnaire. As in previous German vehicle owner surveys, owners of sampled vehicles received a paper questionnaire from the Federal Motor Transport Authority as a first contact. However, in contrast to previous studies of this type there were additional survey mode options that participants could choose from to answer the questionnaire: respondents could not only participate by mail, but also electronically using a laptop, smartphone or like device (mixed-mode survey design, see Figure 1). Related to all respondents, the proportion of participants using the Online&Smartphone-option amounts to 21 %.

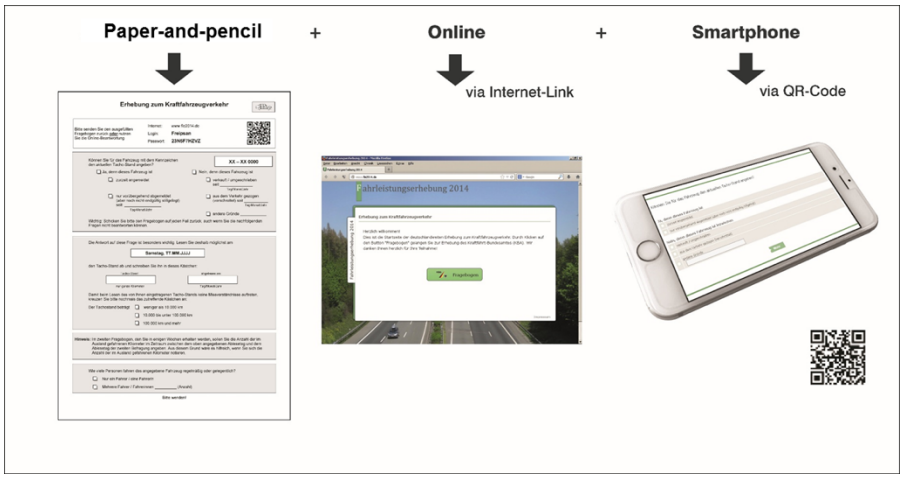

Fig. 1. Response options in the FLE vehicle owner survey (mixed mode-design).

Taken together, the simple and intuitive survey design and the multiple options to participate in the survey led to an overall response rate of 47 % (the response rate of the vehicle owners in the initial and final stage of the survey was 56 % and 85 %, respectively). Following the general trend, this rate was lower than in the preceding projects in 1990, 1993 and 2002, but actually somewhat above the target values defined prior to the survey. In an environment of generally declining response rates this can be seen as a good result. In total, the owners of 76.979 vehicles participated in the initial as well as the final interview, about 87% of the corresponding data sets could be used for estimating VKT.

2.3. Data Expansion and Analysis

Based on the vehicle owner survey data, VKT estimates both for the complete vehicle population and for subgroups of motorized vehicles were calculated. Due to the large size of the FLE 2014 sample, it was possible to derive deeply stratified indicators both regarding the current state as well as – through comparison with the FLE 2002 survey – the development over time of VKT generated by vehicles registered in Germany. For the first time, it was also possible to collect useful VKT data for vehicles with alternative drive technologies and energy sources (e.g. electric, hybrid). The same applies to vehicles used in the context of new transportation options (e.g. long-distance buses).
The empirical results obtained are based on the statistical method of separate ratio estimation for stratified samples (auxiliary variable: number of vehicle-days registered). The starting point here is the aforementioned decomposition of the study year into 6 time periods ("waves") and the vehicle population into 151 strata. For each combination of vehicle stratum h and time period w, the VKT per vehicle and day of registration, i.e. the population ratio $R_{hw} = \frac{Y_{hw}}{X_{hw}} = \frac{\overline{Y}_{hw}}{\overline{X}_{hw}}$ is usually estimated by a ratio of two sample means

$$r_{hw} = \frac{\overline{y}_{hw}}{\overline{x}_{hw}} \tag{1}$$

where $\overline{x}_{hw}$ and $\overline{y}_{hw}$ denote the per-vehicle mean of vehicle-days of registration and vehicle-kilometers travelled, respectively. The external total of the auxiliary variable "number of vehicle-days registered" for vehicle stratum h and time period w is approximated by $X_{hw} = (365/6)N_{hw}$, where N_{hw} denotes the corresponding population number of vehicles registered (calculation of this quantity is based on the ZFZR vehicle register). Thus, $\hat{Y}_{hw} = X_{hw} r_{hw}$ is the ratio-type estimator of the VKT total for the stratum-period combination under consideration; in large samples the bias of $\hat{Y}_{hw}$ becomes negligible. Finally, the separate ratio estimator of the overall annual VKT total is given by

$$\hat{Y} = \sum_h \sum_w \hat{Y}_{hw} = \sum_h \sum_w X_{hw} r_{hw} = \frac{365}{6} \cdot \sum_h \sum_w N_{hw} r_{hw} \tag{2}$$

If, for given vehicle stratum h the estimators $\hat{Y}_{hw}$ are summed over all time periods w, the estimated stratum-specific annual VKT total is obtained. The estimated annual stratum-specific VKT totals can be aggregated either across a subset of strata (e.g. all passenger vehicle strata) or - like in equation (2) - across all strata of vehicles (motor vehicles as a whole).

As the estimated overall VKT total (2) had to be broken down by a variety of vehicle and vehicle-owner characteristics which had *not* been used for stratification, it proved useful to replace the ratio of means (1) by the

following mean of ratios

$$\bar{r}_{hw} = \frac{1}{n_{hw}} \sum_{i=1}^{n_{hw}} \frac{y_i}{x_i}$$

(3)

Using (3) instead of (1) to estimate VKT per vehicle and day of registration, has the advantage that irrespective of the characteristics used for the definition of subgroups of vehicles ("domains of study"), the sum of estimated subgroup totals always equals the estimated overall VKT total. The use of the biased estimator (3) instead of the approximately unbiased estimator (1) is justified, as the estimated bias of $\bar{r}_{hw}$ proved to be small (the bias can be estimated as X_{hw} is known from external sources). For methodological details see Barnett 2009, pp.69-76.

Due to the design of the FLE 2014 vehicle owner survey, the absolute and relative standard error of VKT estimators can be estimated using classical variance estimation approaches and standard statistical software (no resampling and replication methods required). In addition, sampling error estimation is simplified by the fact that neither the non-coverage nor the non-response study for the FLE vehicle owner survey indicated a need to correct for nonsampling biases.

In the representation of survey results, the annual VKT total is additionally related to the annual average number of registered vehicles. This ratio suggests itself since vehicles can fundamentally only generate VKT on days on which they are registered.

3. Results

3.1. FLE 2014 Vehicle Owner Survey

With an average motor vehicle registration stock of 53.5 million vehicles (the motor vehicle stock also includes vehicles with insurance tags; see footnote in Table 1), the national VKT in 2014 came to roughly 707 billion vehicle kilometers travelled. The overwhelming majority, at just under 599 billion km or 85 % of the total value of national VKT, was recorded by passenger vehicles (including motor homes). Goods transport vehicles (trucks and semi-trailers) accounted for roughly 84 billion VKT in 2014, which corresponds to approximately 12 % of the total VKT. Table 1 summarizes the main results.

Table 1: Total and mean VKT broken down by vehicle group (FLE 2014 vehicle owner survey)

Vehicle group	National vehicle kilometers travelled 2014		Average registered motor vehicle stock 2014		VKT per vehicle and year
	in billion km	in %	1,000 vehicles	in %	in km
Motorcycles	12.4	1.7	4.148	7.8	2,982
Passenger vehicles	598.7	84.7	44.126	82.5	13,568
Buses	4.0	0.6	77	0.1	51,309
Trucks	63.8	9.0	2.674	5.0	23,891
Semi-trailers	19.3	2.7	194	0.4	99,692
Other trucks	0.6	0.1	133	0.2	4,209
Other vehicles	3.6	0.5	304	0.6	11,921
Vehicles with insurance tag[1]	4.6	0.7	1.824	3.4	2,532
Total	707.0	100.0	53.480	100.0	13,220

[1] Mopeds, trikes, squads with maximum speed < 45 km/h and cubic capacity < 50 cm³ (no vehicle registration required)

Relating the entire national VKT to the average registered motor vehicle stock in 2014, the result is an average VKT of 13,220 km per vehicle and year (more precisely: 13,220 km per 365 days of vehicle registration). Eliminating vehicles with insurance tags, the average value rises to 13,598 km. For passenger vehicles in 2014, an average VKT of roughly 13,600 km per passenger vehicle was obtained, while the corresponding figure for trucks was 23,900 km per truck.

According to information provided by surveyed vehicle owners, roughly 3% of the VKT for German-registered motor vehicles were driven in foreign countries (21.25 billion km). Subtracting this foreign share from the total national VKT yields the national VKT on German roads, which amounted to approximately 685.8 billion km for all vehicle groups. The highest foreign shares were found for motorcycles and semi-trailers. Across all vehicle types, about 400 km per vehicle and year were driven abroad; here semi-trailers and buses came in well ahead of all others (approx. 6,450 and 2,200 kilometers abroad per vehicle and year, respectively).

3.2. Comparison with other Surveys

3.2.1 Comparison with FLE 2014 Traffic Count

The tasks of the entire FLE 2014 project also included determining the "domestic VKT" (annual total of all motor vehicle kilometers travelled on the German road network, no matter where the vehicles are registered). Thus, simultaneously with the vehicle owner survey, an automatic count of motor vehicle traffic at randomly chosen locations and days was also conducted. The 24-hour vehicle counts, yielding count data broken down by vehicle type and vehicle nationality, were distributed across the entire German road network and the entire year of 2014. Consequently, this survey (FLE 2014 traffic count) also provided the option for the first time to disaggregate indicators of the VKT on the German road network by road class and location (inside/outside built-up areas) as well as by type of day and time of day. The conceptual frame of the whole FLE 2014 project consisting of the vehicle owner survey and the vehicle counts is shown in Figure 2.

Territory of VKT / Registration of vehicle	Germany	Abroad	Total
Germany	vehicle owner survey traffic count	vehicle owner survey	vehicle owner survey
Abroad	traffic count	-	-
Total	traffic count	-	-

national VKT

domestic VKT

Fig. 2. Conceptual frame of the entire FLE 2014 project.

The first row comprises the data sources leading to the "national VKT", i.e. VKT of German-registered vehicles in Germany and abroad. The first column encompasses the data sources that allow estimating the "domestic VKT", i.e. VKT on German road network

As vehicle nationality has been recorded in the traffic count, the domestic VKT of German-registered vehicles can be estimated using the traffic count data. The same key figure can be estimated from the vehicle owner survey, as vehicle holders had also to report the number of kilometers travelled abroad (see figure 2). A comparison of the two alternative approaches is given in Table 2. In order to perform a proper comparison, the vehicle groups of the owner survey had to be rearranged in a way that they are comparable to the vehicle classification used in the traffic counts (motorcycles + vehicles with insurance tag = powered two-wheelers; trucks with permissible maximum weight ≤ 3.5t = delivery vehicles; trucks with permissible maximum weight > 3.5t = trucks>3.5t; semi-trailers + other trucks = tractors).

As Table 2 shows, the two surveys yield very similar results for most of the vehicle groups. In this context it has to be mentioned that the VKT estimate for powered two-wheelers from the traffic count has been adjusted by using the vehicle owner survey. The only vehicle group where a substantially larger difference emerges are trucks (permissible maximum weight > 3.5t), where the traffic count results in a higher VKT value. This can, at least partially, be explained by the fact that a few special motor vehicle sub-groups such as agricultural tractors and vehicles of the federal police together with military vehicles are not covered by the vehicle owner survey. In addition, there might be a certain amount of vehicle misclassification in the traffic count.

Table 2: Domestic VKT of German-registered vehicles broken down by vehicle group (FLE 2014 vehicle owner survey and FLE 2014 traffic count)

Vehicle group	Domestic VKT of German-registered vehicles (billion vehicle km) according to…		Difference (billion vehicle km)
	Vehicle owner survey	Traffic count	
Powered two-wheelers	15.9	15.9	0.0
Passenger cars	577.7	579.1	-1.4
Delivery vehicles	46.8	48.8	-2.0
Buses	3.8	4.3	-0.5
Trucks>3.5t	19.4	32.5	-13.1
Tractors	18.6	17.9	0.7
Other vehicles	3.6	3.5	0.1
Total	685.8	702.0	-16.2

3.2.2 Comparison with National Household Surveys using Trip Diaries

In Germany there are two interlinked National Travel Surveys (NTS), using trip diaries for data collection:

The German Mobility Panel (Mobilitätspanel, MOP) is an annual panel survey on travel with a relatively small sample size (about 2.000 persons). Panel participants stay in the panel for three consecutive years before they are rotated out of the sample and replaced by new participants. In each year of participation, respondents fill in a seven-day trip diary. The annual reporting season is in fall (September to November) for the entire MOP-sample. The MOP uses a paper-and-pencil questionnaire and trip diary. In addition to the trip diary, MOP participant households with cars take part in a survey on mileage and fuel consumption (in short: Survey on Fuel Consumption). This MOP component takes place between April and June every year. Hence, the survey on fuel consumption is a vehicle-based survey that samples the vehicles through sampling households. The Survey on Fuel Consumption covers annually about 1.500 cars (Vortisch et al., 2012; Weiß et. al., 2016).

The empirical study Mobility in Germany (Mobilität in Deutschland, MiD) is a cross-sectional survey with a large sample size (about 60.000 persons) which is carried out on an irregular basis. Surveys with this format were performed in 1976, 1982, 1989, 2002 and 2008 (Infas & DLR, 2010). Currently (as of August 2017) a new MiD-survey is underway. MiD participants fill in a one-day trip diary. The reporting days of the respondents are distributed equally over the entire year, i.e. they cover all seasons. There are multiple forms of communicating with the respondents and eliciting travel and other information (telephone interview, online-questionnaire, paper-and-pencil questionnaire).

Figure 3 shows the annual average mileages of passenger cars as measured by the different approaches excluding traffic counts.

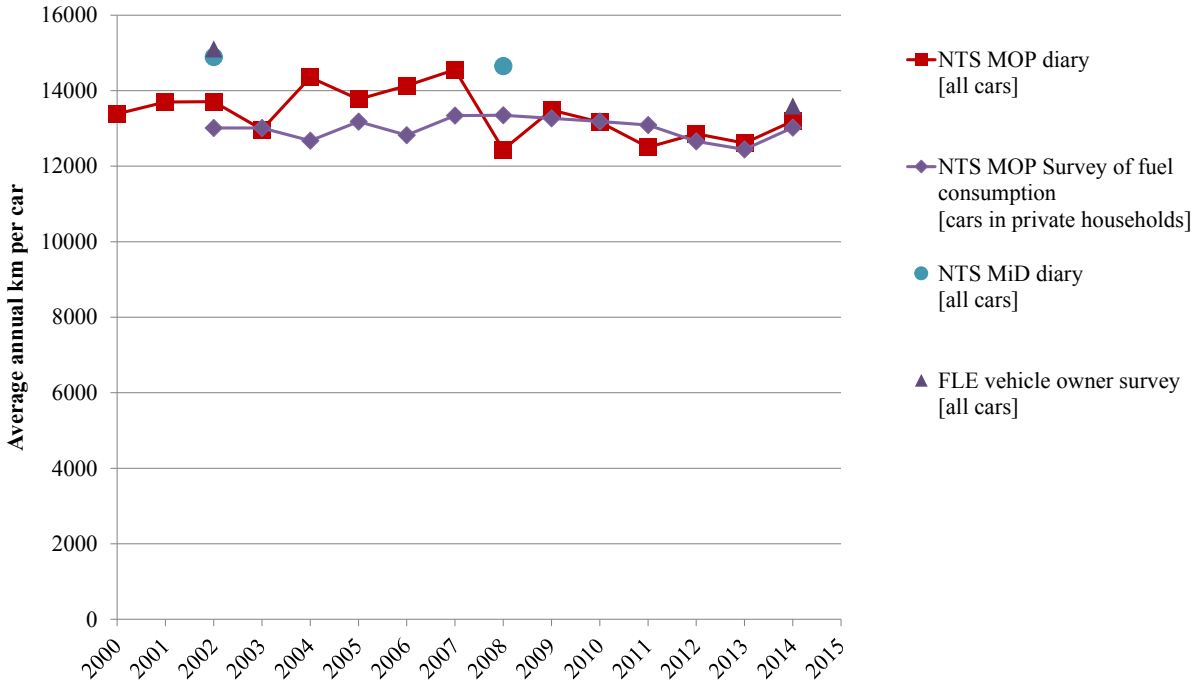

Fig. 3. Annual mileages per passenger car as measured by FLE, MOP and MiD in Germany since 2000.

In the travel diary car driver trips are recorded including the length (in km) of each trip. By definition these reports also include driver trips in vehicles that don't belong to the household, e.g. when driving a rented car, an ambulance or police car on the job etc. These car driver trip distances can be summed up for the entire person day. Thereafter, these daily total Km at the person-level can be extrapolated to annual car km for the entire population. Dividing this total mileage by the total number of cars results in the average number of Km per vehicle per year. However, this does not include information about distributions and differentiating by type of vehicle (e.g. by fuel) is also not possible.

Figure 3 shows that the average annual passenger car mileages derived with this method are relatively close to the result of approaches that are dedicated to establishing vehicle mileages. However, the small sample size of the MOP together with the large variance in travel diary travel information (caused by substantial intra-personal day-to-day variation) results in a strong year-to-year variability of the MOP results.

4. Conclusions and outlook

It has proven useful to retain the basic concept of the previous FLE vehicle owner surveys (sampling vehicles from the national vehicle register, focusing on a limited number of survey characteristics and use of a short, clearly structured and easily understandable questionnaire) and extend it to include the option of participating not only via post, but also electronically using a laptop, smartphone or like device (mixed-mode design). This modification made it possible to account for the changed response behavior in public and corporate surveys and counteract the downward trend in willingness to participate in such surveys, as the high response rate of 47 % demonstrates.

Looking to the future of VKT statistics, it appears that a further methodological innovation may improve data quality in this field. If odometer-reading data from periodical technical inspections (PTI) together with appropriate concomitant vehicle characteristics (including type of vehicle) are made available for statistical purposes, estimation of vehicle mileage totals can be based on a huge amount of empirical data on vehicle use. Caution is advised, however, when using this type of mileage data as one normally aims at estimating the annual sum of vehicle kilometers, i.e. the total vehicle mileage per calendar year. Thus, the population to which the required estimate refers is the universe of

vehicles registered in the current year. The sample yielding the new type of data, however, is the subpopulation of vehicles which had to undergo PTI during the current year. Obviously, in every year only part of the complete vehicle population has a positive chance of appearing in the sample. Moreover, the mileage at time of PTI corresponds to the overall number of kilometers travelled since first registration of the vehicle. Clearly, data on the number of vehicle kilometers travelled during the current year would be more useful. Therefore, a crucial prerequisite for this method is that it becomes possible to use odometer-reading data for motor vehicles in two successive vehicle inspections. In Germany this will soon be available to the Federal Motor Transport Authority. The estimation of VKT on the basis of process data already available offers the opportunity to make the system of mileage surveys even more efficient in the future. The availability of vehicle inspection data for mileage estimation purposes would reduce the necessary sample size of the still-indispensable vehicle owner survey (general vehicle use data together with specific odometer reading data can only be obtained by vehicle owner surveys) significantly.

References

Barnett, V., 2009. Sample Survey Principles and Methods 3rd Edition. John Wiley & Sons, Chichester.

Bäumer, M., Hautzinger, H., Pfeiffer, M., Stock, W., Lenz, B., Kuhnimhof, T. und Köhler, K., 2017a. Fahrleistungserhebung 2014 - Inländerfahrleistung. Berichte der Bundesanstalt für Straßenwesen, Reihe Verkehrstechnik, Heft V 290, Bergisch Gladbach.

Bäumer, M., Hautzinger, H., Pfeiffer, M., Stock, W., Lenz, B., Kuhnimhof, T. und Köhler, K., 2017b. Fahrleistungserhebung 2014 – Inlandsfahrleistung und Unfallrisiko. Berichte der Bundesanstalt für Straßenwesen, Reihe Verkehrstechnik, Heft V 291, Bergisch Gladbach.

Hautzinger, H. et al., 2005a. Fahrleistungserhebung 2002 – Inländerfahrleistung. Berichte der Bundesanstalt für Straßenwesen, Reihe Verkehrstechnik, Heft V 120. Bremerhaven: Wirtschaftsverlag NW.

Hautzinger, H. et al., 2005b. Fahrleistungserhebung 2002 - Inlandsfahrleistung und Unfallrisiko. Berichte der BASt, Reihe Verkehrstechnik, Heft V 121. Bergisch Gladbach: Wirtschaftsverlag NW.

Hautzinger, H. et al., 1996a. Inländerfahrleistung 1993. Berichte der Bundesanstalt für Straßenwesen, Reihe Mensch und Sicherheit, Heft M 61. Bremerhaven: Wirtschaftsverlag NW.

Hautzinger, H. et al., 1996b. Inlandsfahrleistung und Unfallrisiko 1993. Berichte der Bundesanstalt für Straßenwesen, Reihe Mensch und Sicherheit, Heft M 68. Bremerhaven: Wirtschaftsverlag NW.

Infas & DLR, 2010. Mobilität in Deutschland 2008/2009. Ergebnisbericht. Bonn; Berlin: BMVBS (Bundesministerium für Verkehr, Bau und Stadtentwicklung).

Vortisch, P., Chlond, B., Weiß, C., Streit, T., Wirtz, M., & Zumkeller, D., 2012. Deutsches Mobilitätspanel (MOP) wissenschaftliche Begleitung und erste Auswertungen. Bericht 2011/2012: Alltagsmobilität und Tankbuch. Institut für Verkehrswesen. Karlsruhe.

Weiß, C., Chlond, B., Behren, S. v., Hilgert, T., & Vortisch, P., 2016. Deutsches Mobilitätspanel (MOP) - wissenschaftliche Begleitung und Auswertungen. Bericht 2015/2016: Alltagsmobilität und Fahrleistung. Institut für Verkehrswesen. Karlsruhe.