The Swedish car movement data project

Final report

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Summary

The aim of this project has been to gather and analyze a larger amount of data on the characteristics and distribution of the movement patterns of individual, privately driven cars in Sweden by measurement with GPS equipment. Potential cars to be logged were recruited from a stratified random selection of cars from the Swedish motor-vehicle register. The GPS equipment was sent by mail to be installed by the owner/driver. Over 700 cars have installed the equipment for around two months each in 9 campaigns with up to around 100 logging units. The first measurement period started in June 2010 and the last ended in Sept 2012. The data (timestamp, position (horizontal and vertical) and velocity (speed and direction, and identity of used satellites) gathered with 2.5 Hz was transmitted via the mobile net to a intermediary server, for later transfer to a final storage together with road information in a source database, from which various basic data and statistics for the trips and cars have been extracted and stored, Fig S.1. The intended goal of the project has been to finally have high quality car movement data for at least one month for each of at least 500 representative cars.

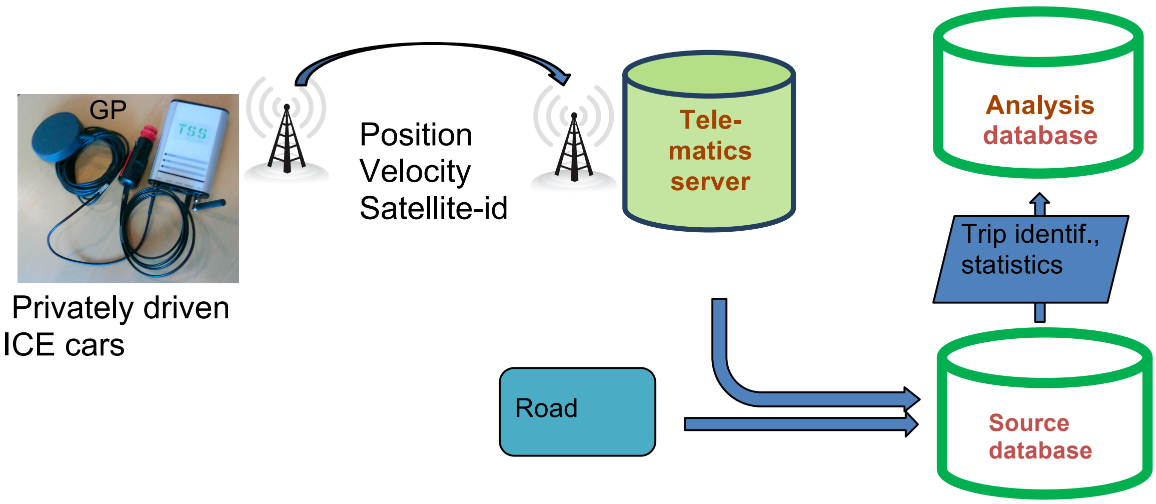

Fig S.1 Overview of the Swedish car movement data project.

The project has resulted in a unique dataset on the detailed movements of representative vehicles from the current fleet of privately driven cars in Sweden. The database contains 714 cars with data, of which 528 cars have loggings exceeding 30 days and over 450 cars more than 50 days. The measurement project was initiated for the purpose of achieving appropriate data for various types of analyses connected to the electrification of cars. It is currently used extensively for such purposes. However, the databases freely available for all kinds of research devoted to vehicle movements, energy efficiency, and environmental performance as well as traffic safety and societal planning. Due to the privacy character of some of the data, the availability is further classified according to type.

This revised final report presents the layout of the project, the performed measurements, experiences, and contrary to an earlier version results based on all the gathered data. This report is available at the project homepage (www.chalmers.se/brd).

Keywords — GPS measurement, car movement pattern, representative private driving, PHEV, Sweden

Sammanfattning

Syftet med detta projekt har varit att samla och analysera en större mängd data om egenskaper och fördelning av rörelsemönster för privatkörda personbilar i Sverige genom mätning med GPS-utrustning. Potentiella bilar att logga rekryterades brevledes från ett stratifierat slumpmässigt urval av bilar från bilregistret. GPS-utrustningen skickades med post att installeras av ägare/förare, Fig. S.1. Mer än 700 bilar har haft utrustning installerad i omkring två månader vardera i 9 kampanjer med upp till runt 100 utrustningar. Den första mätperioden startade i juni 2010 och den sista slutade i september 2012. Den med 2,5 Hz insamlade datan (tid, position (horisontellt och vertikalt), hastighet (fart och riktning), och identitet på använda satelliter) sändes via mobilnätet till en mellanhand server för överföring senare till en slutlig lagring tillsammans med väginformation i en källdatabas från vilken resor, och statistik för resor och bilar har extraherats och lagrats i en analysdatabas. Målet med projektet har varit att få högkvalitativa data för minst en månads bilrörelser för 500 representativa bilar.

Projektet har resulterat i ett unikt dataset med detaljerade rörelsedata för representativa fordon från den nuvarande flottan av privatdrivna bilar i Sverige. Databasen innehåller 714 bilar med data varav 528 bilar med loggningar överskridande 30 dagar och över 450 bilar med mer än 50 dagars mätningar. Mätningen initierades för att få underlag för olika typer av analyser kopplade till elektrifiering av bilar. Datan används redan i stor utsträckning för sådana ändamål. Men databaser är fritt tillgänglig för alla typer av forskning ägnade åt fordons rörelser, energieffektivitet eller miljöprestanda samt trafiksäkerhet och samhällsplanering. På grund av den personliga karaktären av vissa data, klassificeras tillgängligheten ytterligare efter typ.

I denna reviderade slutrapport presenteras utformningen av projektet, utförda mätningar, erfarenheter samt till skillnad från tidigare version resultat baserade på alla insamlade data. Denna rapport finns tillgänglig på projektets hemsida (www.chalmers.se/brd).

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THE SWEDISH CAR MOVEMENT DATA PROJECT

The aim of this project has been to gather and analyze a larger amount of data on the characteristics and distribution of the movement patterns of individual, privately driven cars in Sweden by measurement with GPS equipment.

The project has been a research project titled "Measurement and analysis of vehicle movements in the Swedish car fleet of relevance to future electrification" (*Sw.*: *Mätning och analys av bilrörelser i den svenska bilparken av relevans för framtida elektrifiering*) in the Program Energy and Environment within the co-operation Strategic Vehicle Research and Innovation (*Sw.: Fordonsstrategisk Forskning och Innovation (FFI)*) at the Swedish Energy Agency (*Sw.: Energimyndigheten*) and Sweden's Innovation Agency (*Sw.: Vinnova*). It has also from the beginning had financial support from Consat Sustainable Energy Systems AB, Göteborg Energy Research Foundation, Lindholmen Science Park AB, and Vattenfall AB. Telenor has contributed with provision of free of charge data traffic on its GPRS net. Also Chalmers University of Technology, through the Chalmers Energy Initiative, the Department of Energy and Environment and the Department of Signal and Systems, has financially supported the project. The build-up of the source database, the analysis database and the web page used for the project have been supported by the program Test Site Sweden at Lindholmen Science Park AB.

The project was lead by Lindholmen Science Park (LSP) and the program Test Site Sweden (TSS). The scientific responsibility has been at the Department of Energy and Environment (Division of Physical Resource Theory) at Chalmers University of Technology, which also has developed the analyses database. The daily administration of the measurements and data storage has been performed by Consat Sustainable Energy Systems AB, Gothenburg. Chalmers Teknologkonsulter AB has been involved in the development of the webpage.

A project steering group consisting of represents from the initial financial partners (which not included Telenor) have met a number of times during the project to discuss various issues of importance in the project. The project also had a reference group consisting of persons from other involved or interested parties: Telenor, The Swedish Road Administration/The Swedish Transport Administration, SUST, and SAFER and SHC at Chalmers University of Technology, that met a few times and was informed about and discussed the progress of the project.

1. WHY GATHER CAR MOVEMENT DATA?

For plug-in hybrid electric vehicles (PHEV), the optimal design, consumer viability, and its potential for transforming transportation to electric propulsion are dependent on the possibilities of the individual vehicles to substitute electricity for fuel. Major factors determining the possible driving on electricity are the battery capacity, the movement pattern of the individual car and the recharging possibilities in the form of available suitable infrastructure [1,2].

To facilitate a well-informed and efficient transition to electrified vehicles such as PHEVs we thus need knowledge of the distribution of individual vehicle's movements over longer periods. Today there is a lack of good data on the movement patterns for the cars. What is at needed is enhanced data on car trip lengths and trip characteristics such as speed, load and orography to be able to determine the possible energy use for individual trips, time and duration both for the trips and the stops in between the trips. The position of the car, especially for the stops, can also be of importance for evaluation of possible recharging options. It is necessary to have car movement data for a longer period of time. The individual vehicle's movement may not be fully captured without a time period of several months, or a year, considering the possible seasonality of driving, varying weather conditions and the low frequency of some purposes of the driving such as vacations. This is a type of data that has not been requested and gathered earlier, but which now with a possible approaching electrification of transport is urgently needed.

National or regional travel survey data is regularly gathered in many countries. However, in most cases, as in Sweden [3], there is not a tracking of cars' movements but of persons' only, and in many countries also for one day each only. In Western Europe only a few countries in their National Travel Surveys gather information specifically on the movements for several days of the cars, for instance, UK for one week (and four weeks for long distance travel), and France for five days [3].

Also the data quality can be hampered by the survey method when based on questionnaires or interviews. It is commonly recognized that this type of self-reporting will give an underestimate of the travelling, due to a certain share of non-reported trips [4,5]. This type of data does not give the exact position of the vehicles trips and their stops. The purposes of the trips, divided into different categories such at to work, leisure activities, shopping, visits etc, are commonly gathered in travel surveys, though.

Continuous measurement of time, speed and position with GPS (Global Positioning System) equipment is then a possibility to gather lacking information on car movement statistics. One drawback with this type of data is the lack of information of the purposes of the trips. On the other hand the position can give some clue to the some of the trips; regular workday parking in a non-residential area suggests trips for work. To actually excerpt this information with a high degree of quality will require some effort, though, and availability of information on positions of working sites, etc [6].

It can also be argued that measurement of today's car movement will not be representative for tomorrow's battery electric vehicles. These are in the near future probably very limited by range and therefore used in other ways than the current cars, maybe only in cities and as second car. However, for plug-in hybrid electric vehicles the range will not be as great a concern and it can be a reasonable assumption that these vehicles will be used in similar way as today's car. In countries like Sweden, with a fleet of for European condition relatively large cars, and which are also less subject to traffic jams, PHEVs will be the dominant electric vehicle type, according to many expert judgments. Therefore the movement patterns of current conventional vehicle fleet are of considerable interest.

Other direct measurements of car movements with for instance GPS equipment have been sparse, for specific purposes, or focusing vehicles in specific areas. For instance, an old tracking of cars for one day each were performed in St Louis [7]. Puget Sound Regional Council in the Seattle area, performed a logging with GPS of three months driving of 450 vehicles from 275+ volunteer households recruited among potential participants before and after hypothetical tolls were charged for use of major freeways and arterials in the Seattle metropolitan area [8, 9]. In USA travel surveys with GPS, not directly focusing cars, have been performed or are planned in, Baltimore, Washington, Chicago, and California [10-13]. In Australia cars have been tracked for the purpose of investigating driver behavior such as speeding [14,15]. In Italy a unique commercial dataset for car movements is from the GPS tracking of currently around 650 000 cars for insurance profiling performed by the company Octotelematics [16]. In Canada, Department of Geography at University of Winnipeg within the AUTO21 program, has been logging 76 cars in Winnipeg with GPS at one-second intervals for up to 12 months, to be able to, for instance, assess the prerequisites for electrification with PHEVs. A further logging of 50 rural vehicles often commuting into Winnipeg has also been performed. [17, 18, 19]

In Sweden specific datasets with GPS tracking are available for a small set of 29 cars logged for about two weeks for the purpose of driving behavior – emissions modeling verification [1]. In this case equipment was installed in 5 specifically prepared vehicles, which then were successively placed in 29 families, where they substituted a car of similar size. In another measurement for the evaluation of the impact and acceptability of Intelligent Speed Adaptation (ISA) equipment, about 200 cars were tracked for roughly 100 days [2]. Although valuable, both these datasets are covering limited geographic regions and are at this moment more than ten years old.

2. Selection of vehicles

2.1 Excerpt of cars from the motor-vehicle register

First, for each campaign an excerpt of cars from the Swedish motor-vehicle register (*Sw.: bilregistret*) is performed, see Table 2.1.

Table 2.1 Excerpt of cars from the Swedish motor-vehicle register.

Parameter	**Selection**
Type of vehicle	Passengers cars, type I
Use of vehicle	Non-commercial vehicle (*Sw.: ej yrkestrafik*)
Model year	Car model 2002 and younger
Region in Sweden	Registered in Västra Götaland county or Kungsbacka municipality

2.1.1 Vehicles

The excerpt is restricted to passenger cars of type I in the motor-vehicle register, Table 2.1. A passenger car is a car mainly aimed for person transport and restricted to a maximum of 8 passengers apart from the driver, i.e., a maximum total of 9 persons, and with a weight of maximum 3.5 tons. Passenger car of type I excludes type II cars which comprise cars with a bodywork permanently equipped with an accommodation unit, e.g., campers (SIKA Fordon 2009, SFS 2001:559 2§).

Vehicles, which, according to the vehicle register, are used in commercial traffic, such as taxicabs, are not included in the excerpt due to the focus on privately driven cars. The excerpt is also restricted to cars of model year 2002 and younger.

2.1.2 Region

The extracted cars are registered in the county of Västra Götaland or in Kungsbacka municipality. The region is in South-West of Sweden and has around 1.6 million inhabitants and 0.75 million cars (roughly 1/6 of Swedish totals, respectively), Table 2.2 and Figure 2.1. It is reasonably representative of Sweden concerning average driving distance and car ownership and with its mixture of larger and smaller towns and rural areas. It contains Gothenburg, the second-largest town of Sweden. It is lacking very sparsely populated areas as in north of Sweden, though, which is reflected in the population density of around 65 inhabitants/km^2; three times the average for Sweden, but reasonable representative for the southern parts of Sweden where most of the inhabitants live.

Table 2.2 Data for the selected region at the end of 2010[a].

Parameter	Västra Götaland (VG) county and Kungsbacka municipality	Sweden	Quota for Region/Sweden
Inhabitants[a]	1 655 322	9 415 570	0.176
Land area[b] (km^2)	25 424	449 964	0.0565
Inhabitant/area (km^{-2})	65	21	3.1
Registered cars in use[c]	749 814	4 335 182	0.173
Cars/1000 inhabitants	453	460	0.984
Average driving distance in 2008[d] (km)	13 610 (VG only)	13390	1.016

[a] [SCB, Folkmängd i riket, län och kommuner 31 december 2010 och befolkningsförändringar 2010]

[b] Wikipedia.se Accessed 2011-05-13

[c] [Trafikanalys, Fordon i län och kommuner 2010]

[d] [Trafikanalys, Körsträckor 2008]

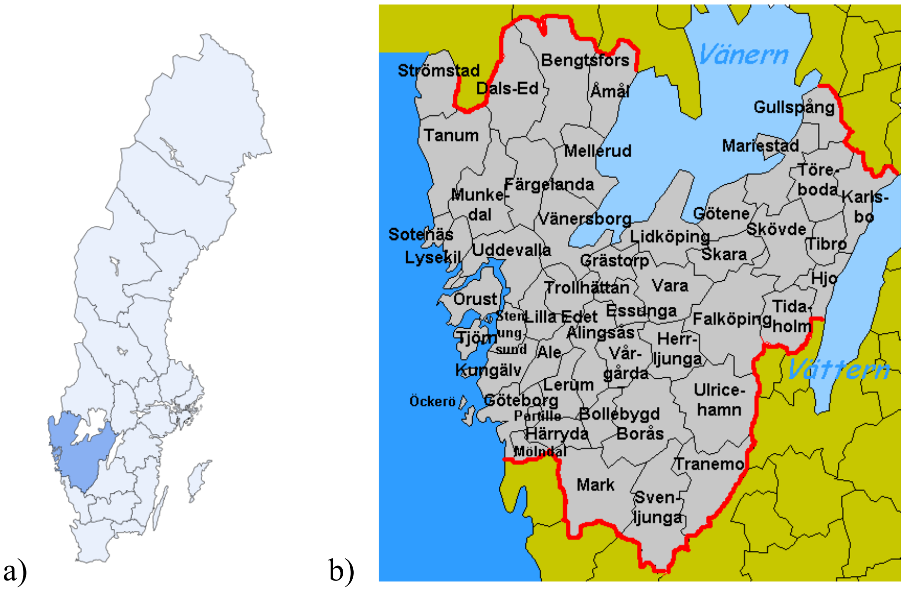

Figure 2.1 The selected region for the Swedish car movement data project, a) the Västra Götaland county is marked in darker blue on this map of Sweden; b) A larger map of Västra Götaland county with its 49 municipalities. The Kungsbacka municipality in the county of Halland, also included in the selected region, is the uppermost coastal municipality on the west coast south of Västra Götaland.

2.2 Further refinement of the extracted of cars

A further refinement of the extracted cars is performed to achieve the final selection.

2.2.1 Type of cars

Electric vehicles, of which only a few exist though, are excluded, due to their range limitation and therefore possible specific movement pattern. (In the project specifically also 20 electric cars are logged, but from another selection, see Chapter 2.4.)

2.2.2 Owner's addresses

Several cars have their owners not living within the region or companies situated in another area according to the registered postal address. This can concern cars with owner in a completely different part of the country such as Stockholm. It can also be owners with addresses belonging to a postal office close to, but outside the border. The selection is further restricted to owners of the cars with their addresses belonging to postal offices within the region. This restriction is accomplished by only including cars with owners having addresses with postal code number between 40000 – 54999 and 66000 – 66999. This realization of the selection may introduce ambiguity in some areas where the postal and county/municipality borders do not overlap. However, this should not be any concern for the purpose of this project.

The effects of the further refinements mentioned above is that about 0.5‰ of the cars belonging to natural persons (≈ 340 000) was excluded, and 1.5% of the cars registered for juridical persons (≈ 43 000) was not included in the final selection.

2.2.3 Private driving

Cars owned by companies or public institutions may be used in specific ways dependent on the situation specific for each vehicle, for instance, to transport personnel between patients in the eldercare. Use patterns of these cars are less representative and can sometimes be reasonably gathered by other means and have therefore not been included in this study focusing privately driven cars.

In the Swedish motor-vehicle register the owner/leaser is either a juridical person or a natural person. For the fleet from which the recruitment of cars occurs, the share of juridical persons is almost 12%. Many of these cars are company cars, i.e., cars leased or owned by companies or institutions, but to a large extent used by a person for his private driving. Roughly every second new car in Sweden is a company car. They are normally kept for 3 years, before entering the private car market as used cars. The Swedish motor-vehicle register does not keep track of company cars; it is not an administrative but a fiscal issue. A company car is supposed to be a fringe benefit in the Swedish income tax return if used for private driving more than 10 times a year or more than 1000 km/yr. If so, the taxed fringe benefit is relatively high and independent of the amount of private driving. It is therefore not favorable to have a company car if you do not drive much. The amount of private driving can therefore be supposed to be a strong selection for privately driven cars with juridical person ownership. In this study we extract the company cars by, for cars with a juridical person ownership, addressing the inquiry letter to the driver of the specified car and ask if it is a company car. If so, it is of interest to the project. Also cars registered as owned by a natural person can be a car owned by a private firm and not used for private driving. Also for these cars we thus need to in the inquiry initially ask if it is a privately driven car. By a communication mistake this question were not included in the request, though. A few of the cars in the final dataset have therefore not been privately driven.

Company cars (*Sw.: förmånsbilar*) consist of two categories of vehicles, private cars and light trucks. The private cars are largely a fringe benefit for employees in usually a bit larger companies or organizations. The owner in the motor-vehicle register is then a juridical person, who may be the employer, which either owns or leases the vehicle from a leasing company. The vehicle can also be registered for a company that leases the car to the company where the beneficiary is employed. Whoever owns depends on how the lease/loan agreement is designed, but the case in which the employer is the owner is the most common. But in both cases the vehicle may be registered in a place other than that where the beneficiary lives. First, of course, work place and residence address may differ. But the company that is the registered owner can have the car registered anywhere else than on the beneficiary's workplace address. In larger companies with workplaces and offices at various places in the country, this is rather likely. In the case that a leasing company owns the car, this is very likely. Large such firms may operate nationally with a head office and the cars registered in for instance the Stockholm area.

Light trucks are driven as company cars by employees in any company or by individual entrepreneurs. For employees most often holds, determined by the employer, that the truck may not be used for private purposes other than perhaps for commuting between work place and home if the truck is stationed there. This private driving to and from work is then not due to benefit taxation. For individual businesses the situation is different, especially if they do not have access to another car for personal driving. If they have no access to another car privately it can be difficult to demonstrate to the tax authorities that the truck is not used privately, and these light trucks must most probably be handled as a fringe benefit.

The number of company cars, as well as how many of these are light trucks, are not available in official statistics. By using the tax register it is possible to obtain the number of company cars to private individuals resident (tax purposes) in different regions. A difficulty arises when one wants to discern how many of these are passenger cars, though. Also a linking to the vehicle register is not possible. Thus one has to estimate or guess how many company cars. In this project it has been assumed that 97% and 70% of natural and juridical persons' cars, respectively, are privately driven. These figures have been used in a weighting to achieve a representative selection.

2.2.4 Car age

In the register excerpt the car model year is limited to 2002 and younger in order to focus on that part of the car lifetime, which mostly influences the economic viability considerations and the purchase decision for new cars. As the study and selection is stretched out over one and a half year, the registration date is successively shifted toward later dates thus keeping constant the age of the oldest cars in the selected fleet. Initially for the first period the registration date is set to March 1, 2002 and younger. It is then for the later campaigns shifted according to Table 2.3. The small difference in age is mainly due to differences between the expected campaign periods at the time for selections of cars and the actual campaign periods. This selection of younger cars constitutes roughly 45% of the car fleet and 60% of the total driving distance [15]. For the oldest cars the market value has sunk even more. Thus the selection represents a major share of the total economic value of the car fleet.

Table 2.3 Selections of cars according to age.

Measurement campaign	Cars model year	Cars registered at or later than	Campaign started	Time since first registration (months)
1	2002+	March 1, 2002	Beg. of July 2010	≈ 100
2	2002+	May 1, 2002	Mid of Sept 2010	≈ 100.5
3[a]	2002+	July 1, 2002	End of Jan 2011	≈ 103
4	2002+	Dec 1, 2002	Mid of May 2011	≈ 101.5
4:1[b]	2002+	Feb 15, 2003	Beg. of July 2011	≈ 100.5
4:2	2002+	May 1, 2003	Mid of Sept 2011	≈ 100.5
5	2002+	July 1, 2003	Mid of Nov 2011	≈ 100.5
6	2003+[c]	Oct 1, 2003	Mid of March 2012	≈ 101.5
7	2003+	Feb 1, 2004	Mid of June 2012	≈ 100.5

[a] In campaign 3 the excerpt from the motor-vehicle register was the same as in campaign 2, which means that possible new cars registered between campaign 2 excerpt and the campaign 3 intended excerpt are missing in campaign 3.

[b] No separate selection from the car register, but taken from unused positive responses from campaign 4. Same remark as in note 1 can be done.

[c] The increase in model year from 2002 to 2003 excludes about 2200 cars with register date later than Oct 1, 2003.

2.1.5 Stratification

The random selection is stratified into 14 groups along five parameters, which are known or thought to statistically influence the car movement patterns, Table 2.4. The cars are divided into privately owned cars and cars owned by juridical persons, the two categories available in the motor-vehicle register. The juridical cars focused here, the company cars, are supposed to possibly have another movement pattern then private cars, although this can not be directly confirmed in official statistics. In the statistics the driving by the juridical cars is larger than for private cars, see Table 2.5, which shows the average driving distance for cars of different owners. But the category juridical cars also contains other cars than company cars, for instance fleet cars and taxis. However, the privately seen capital costs for juridical cars are the direct and indirect effects of any salary adjustment and the tax on fringe benefit for the car (*Sw. förmånsvärdet*), which is independent of the yearly driving. Also the running costs can be lower. It is therefore reasonable to assume that these cars are chosen and driven by persons who expect to drive and will drive more than the average driver. Table 2.5 also shows the “leased cars” category, which probably to a large extent consists of company cars. Apparently this data does not contradict the assumption.

Table 2.4 The applied stratification of the vehicle selection into 14 groups.

Fleet	Stratification parameter					Strata designation
	Ownership	***Geographic area***[a]	***Fuel***	***Car age***[b]	***Kerb weight***[c]	
Selected fleet	Natural person[d]	Gothenburg, Mölndal, Partille	All other fuels[e] (AOF)	Young	Heavy	GB7T
					Light	GB7L
				Old	Heavy	GB6T
					Light	GB6L
			Diesel	Young		GD7
				Old		GD6
		Remaining region	AOF	Young	Heavy	ÖB6T
					Light	ÖB6L
				Old	Heavy	ÖB7T
					Light	ÖB7L
			Diesel	Young		ÖD7
				Old		ÖD6
	Juridical person[d]		AOF			JB
			Diesel			JD

[a] Place of registration: Gothenburg, Mölndal and Partille are the three more densely populated municipalities in and around Gothenburg These are determined by the LKF-code (*Sw.: LKF-kod*) 1480xx, 1481xx, and 1402xx, respectively.
[b] Car model year: Young = model year 2007 and younger. The registration date is successively adjusted for the selections to later campaigns, see Table 4.
[c] Kerb weight (*Sw.: tjänstevikt*) (vehicle mass + 75 kg for driver): Heavy ≥ 1500 kg.
[d] 30% of the vehicles owned by a juridical person are initially assumed not to be privately driven to a large extent. Corresponding figure for vehicles owned by a natural person are assumed to be 3%.
[e] Except electricity. In the end of April 2012, there were in the geographic area in question 81 electric vehicles registered of model year 2003 and newer, of which 79 were registered for juridical persons.

Table 2.5 Average yearly driving for cars of different owners in year 2008 [Source: Trafikanalys, Körsträckor 2008]

Owner	**Average annual driving distance (km)**
Natural persons	12 420
- Men	11 890
- Women	12 680
Juridical persons	16 800
- of which personal enterprises	15 140
Total	13 390
- of which leased cars	20 140
- of which taxi	72 240

The diesel car is more expensive than the corresponding gasoline model, while the operating costs are lower due to the more energy efficient engine and also cheaper fuel (in recent years not always per liter (SKR/liter) but so far per energy unit due to the higher energy density (MJ/liter) of diesel). This leads to an expected considerably larger yearly driving for diesel cars, which is also reflected in the statistics, see Table 2.6. The diesel cars have almost twice the driving distance compared to gasoline cars. Due to the relatively recent interest in the diesel cars, these are also newer which should explain part o the difference.

Table 2.6 Average yearly driving for cars with different fuels in Sweden 2008. [Source: Trafikanalys, Körsträckor 2008]

Fuel	Number of cars	Average annual driving distance (km)
Gasoline	4 202 558	12 180
Diesel	469 922	22 740
Natural gas/Biogas	12 570	23 620
E85	143 168	16 950
Electricity	157	5 310
Others	14 068	17 610
Total	4 842 443	13 390

Table 2.7 Average yearly driving for cars of different model year/manufacturing year in 2008. [Source: Trafikanalys, Körsträckor 2008]

Model year/ manufacturing year[a]	Average annual driving distance (km)
2000	13 960
2001	14 620
2002	15 250
2003	15 880
2004	17 370
2005	18 220
2006	19 310
2007	19 730

[a] Denotation according to the data source, which do not differ between model and manufacturing year.

We have stratified the cars geographically in two groups: those situated in or around Gothenburg and the rest of the selected area. The Gothenburg area includes the municipalities of Partille and Mölndal, which are indivisible parts of the town area. It is assumed that the movement pattern in this larger town area can possibly differ considerably from the rest in various aspects. Younger cars are often used more intensively than older ones, see Table 2.7. The cars are stratified along age in two groups according to Table 2.8.

Table 2.9 and Figure 2.2 give the resulting number of vehicle in the different strata for the 9 different measurement campaigns. We can observe that during the measurement campaigns covered by the project, the number of diesel cars have increased considerable on the expense of cars propelled by other fuels, although the total number of cars has increased with around 2% in this period.

The distribution of cars in different strata over four groups of differently sized municipalities is exemplified in Fig 2.3. We can conclude that diesel cars, especially older ones, are more common in the smaller municipalities, while new and smaller gasoline cars are more common in larger cities, (a-c). Cars owned by juridical persons are more common in larger cities, and especially in the Gothenburg area, (d). Also, there is a tendency that the cars in larger municipalities are smaller and less old, (e-f).

Table 2.8 Determination of the strata "young cars" in the age stratification in the different logging campaigns.

Campaign	Young car if		Measurement campaign started roughly	Time since first registration of oldest car in the young car strata [months]
	Model year	***Registered at or later than***		
1	2007+	March 1, 2007	Beg. of July 2010	≈ 40
2	2007+	May 1, 2007	Mid of Sept 2010	≈ 40.5
3	2007+	Sept 16, 2007	End of Jan 2011	≈ 40.5
4	2007+	Dec 1, 2007	Mid of May 2011	≈ 41.5
4:1	2007+	Feb 15, 2008	Beg. of July 2011	≈ 40.5
4:2	2007+	May 1, 2008	Mid of Sept 2011	≈ 40.5
5	2007+	July 1, 2008	Mid of Nov 2011	≈ 40.5
6	2008+	Oct 1, 2008	Mid of March 2012	≈ 41.5
7	2008+	Feb 1, 2008	Mid of June 2012	≈ 40.5

Table 2.9 Number of vehicles in the different strata at the time for excerpt of the data from the motor-vehicle register.

Strata desig-nation	Measurement campaign[a] / date for excerpt of natural person (P) and juridical person (J) cars									
	1 2010-04-28 (P) 2010-04-27 (J)	*2 2010-07-28(P) 2010-07-28(J)*	*4 2011-02-14(P) 2011-02-14(J)*	*5 2011-10-09(P) 2011-10-09(J)*	*6 2012-01-12(P) 2012-01-12(J)*	*7 2012-04-26(P) 2012-04-24(J)*	*Mid date value[b]*	*Share (%)*	*Mid date value, privately driven[c],*	*Share (%)*
GB7T	5 202	5 089	4 464	4 759	4108	4095	4584	1.26	4446	1.31
GB7L	17 123	17 324	15 678	15 354	14681	14700	15831	4.36	15357	4.51
GB6T	21 844	22 037	21 082	19 853	19244	18763	20579	5.66	19962	5.86
GB6L	37 413	37 573	37 725	37 599	37060	36470	37344	10.28	36223	10.63
GD7	8 321	8 804	10 168	12 545	12745	14046	10966	3.02	10637	3.12
GD6	4 099	4 504	6 028	8 012	8932	9950	6866	1.89	6660	1.95
ÖB7T	12644	12 584	11 007	4 759	10361	10520	11401	3.14	11059	3.25
ÖB7L	28 934	29 945	27 596	15 354	26699	26896	27976	7.70	27136	7.97
ÖB6T	55 832	56 114	53 334	19 853	49377	48542	52592	14.47	51014	14.97
ÖB6L	78 438	78 043	77 004	37 599	74063	72503	76033	20.93	73752	21.65
ÖD7	24 114	24 473	27 063	12 545	33196	36938	29526	8.13	28641	8.41
ÖD6	17 225	18 325	23 811	8 012	32237	35480	26049	7.17	25267	7.42
JD	18 645	19 419	21 579	25 194	26398	27613	22987	6.33	16091	4.72
JB	24 112	21 987	20 663	19 478	18757	18183	20618	5.67	14433	4.24
TOTAL	353 946	356 221	357 202	372 277	367858	374699	363352	100	340678	100

[a] In campaign 3 the excerpt from the motor-vehicle register was the same as in campaign 2, adjusted for age of cars and in the division between age strata. This means that new cars registered between the excerpt for campaign 2 and any possible date for excerpt for campaign 3 is missing.

[b] Linear regression to day 365 after first excerpt 2010-04-28 (or ≈ 2011-04-28. i.e., ≈ 12 months)

[c] For natural and juridical person 97% and 70%, respectively, are assumed to be privately driven.

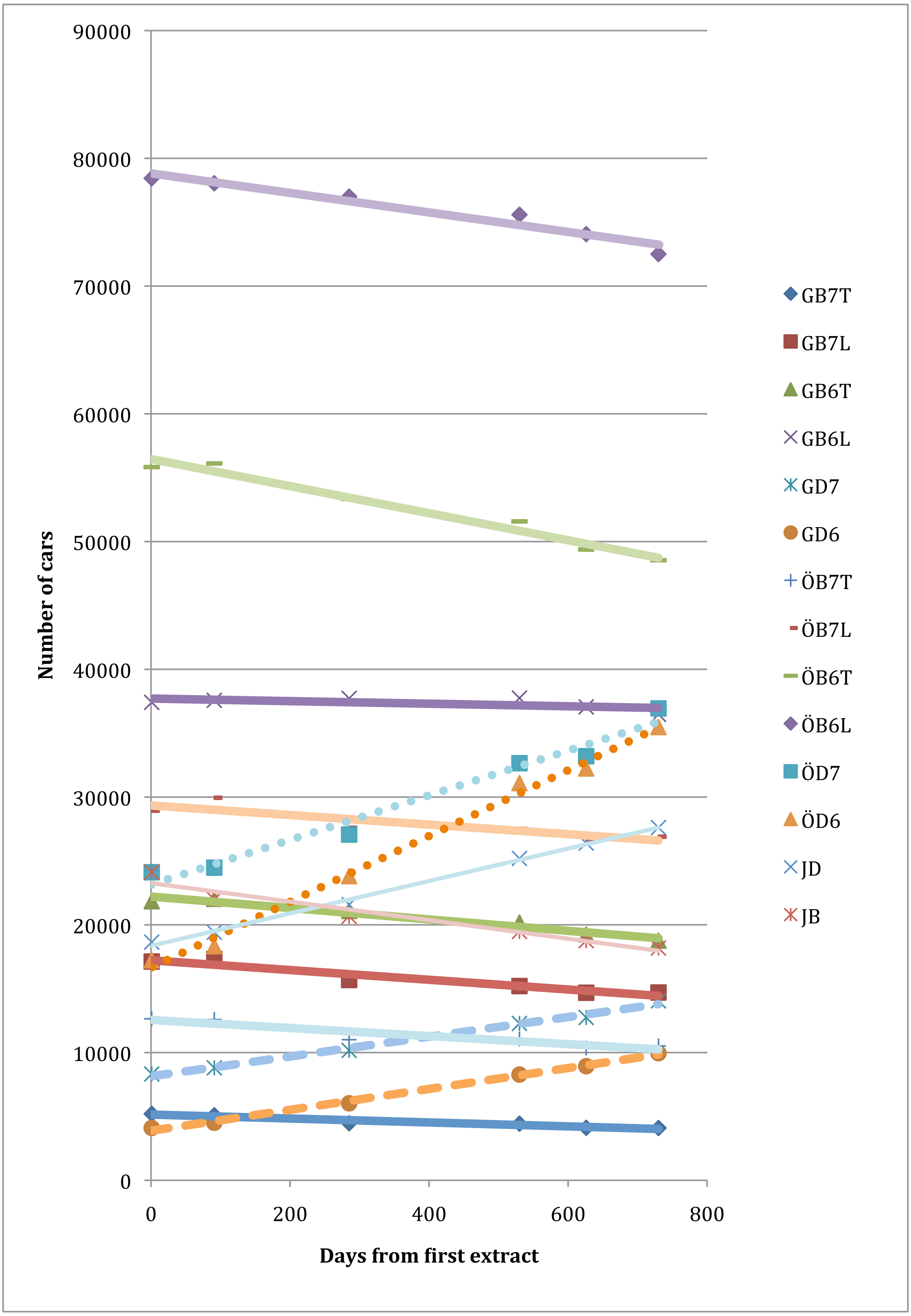

Figure 2.2 Number of vehicles in the different strata at the time for excerpt of the data from the motor-vehicle register.

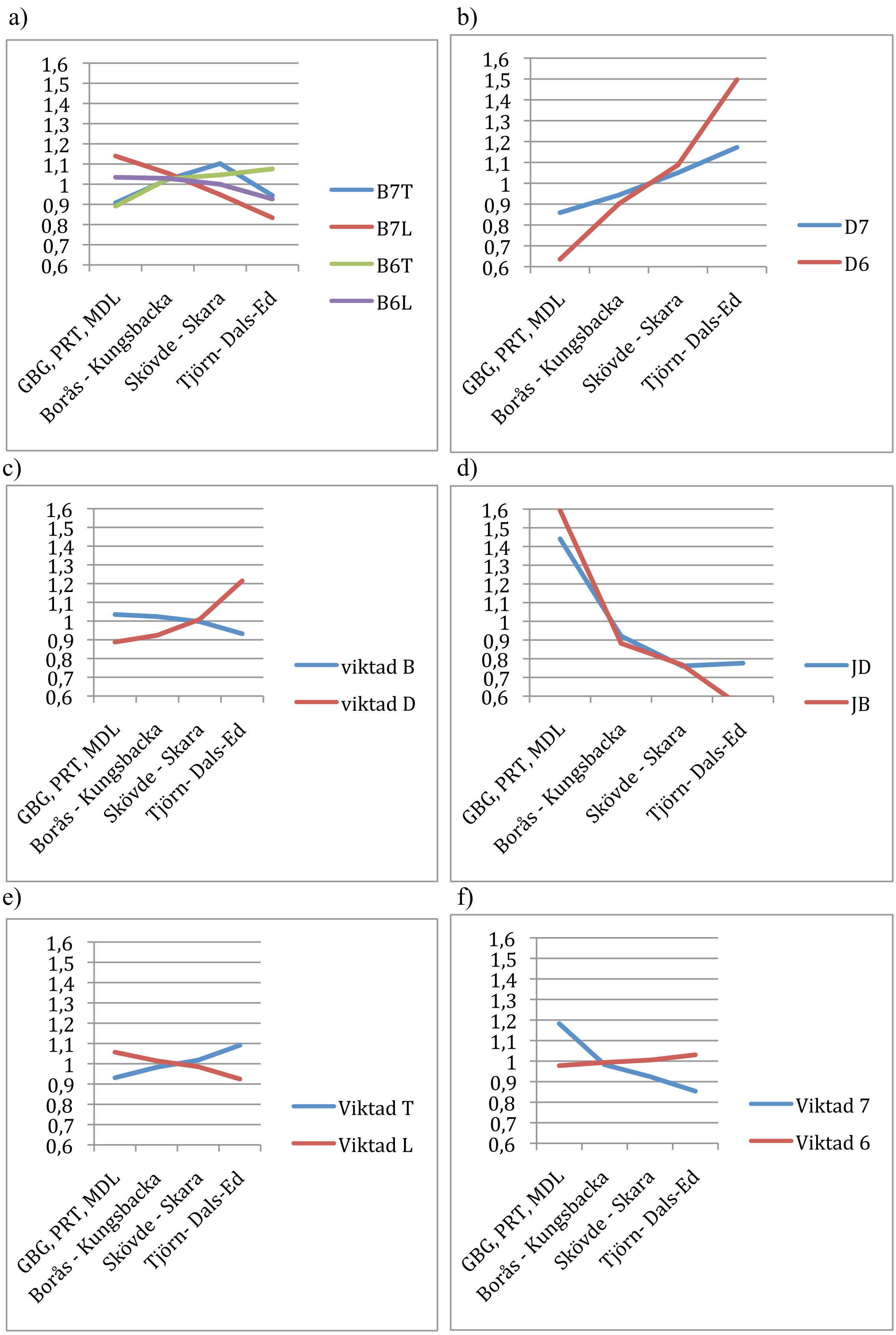

Figure 2.3 Distribution of weighted privately driven cars in various strata in four groups of municipalities from large to small ones according to the size of the car fleet in the municipality. GBG, PRT, MDL = Göteborg, Partille, Mölndal. Data from the Swedish motor-vehicle register excerpt 2011-02-14 to campaign 4.

2.3 Recruitment

2.3.1 The request

The recruitment of vehicles was accomplished with a request to a random selection of car owners contained in the refined excerpt from the motor-vehicle register. A request letter was sent to the owner with an inquiry to participate in the measurement campaign. The second campaign was checked for overlap with the first one. Due to the time consuming process this was not performed in the later campaigns. It can be estimated that about 150 cars have been contacted more than ones. Also owners may have been contacted for different vehicles. In the final measurement one car has been logged twice: in campaign 1 as well as in campaign 5, though. Table 2.10 gives the number of persons contacted in each campaign.

Table 2.10 Number of person inquired for participation in the project.

Campaign	Number of cars/persons inquired	Positive answer[b]
1	1603 (in two batches)	≈ 98
2	2000	≈ 228
3[a]	340	n.a.
4	1939	≈ 135
4:1[a]	-	-
4:2	475	≈ 30
5	2000	≈ 130
6	2000	≈ 150
7	2000	≈ 161
All	12357	≈ 932

[a] In campaigns 3 and 4:1, leftover inquiries from the proceeding campaigns was used.
[b] Somewhat ambigious, when extra positive answers can have been registered after the specific moment at which the numbers were counted (around three 3-4 weeks after inquiry).

For private cars the request was addressed to the owner of the vehicle. For car owned/leased by juridical persons the addressing was to the driver of the selected vehicle specified by its registration number but with postal address of the juridical person.

Small changes to the originally formulated recruitment letter have occurred with time due to achieved experience and successive changes in the implementation of the project. For instance, it was only from campaign 3 and forward explicitly stated that we were only interested in privately driven cars.

The recruitment letter as sent out in the latest campaigns is reproduced in Appendix B.

2.3.2 Questionnaire response

Table 2.10 gives an estimate of number of positive responses from the inquired persons. Altogether more than 900 persons have agreed to participate in the different campaigns. The figures are given as rough numbers. Because we need the response within a certain time to be useful, the exact number depends on at which time you count them. In campaign

2 a larger number of persons gave a positive answer. It was used to decrease the amount of requests in campaign 3.

The in-time positive response frequency of the inquiry for participation in the campaigns has been around 7.5%. The number of requests is a balance between fulfilling the requirements set up and the costs for the mailings and handling of the answers. It can't be guaranteed that enough positive answers can be obtained with a specific number of requests, especially if it is also required that each of the strata should be filled with enough vehicles. The actual number (around 2000 requests per campaign) is therefore a compromise between costs and fulfillment of the requirements. In practice each of the strata has not always been filled up.

The number of necessary requests was a learning process. From campaign 2 and on it has been about 20 times the number of actually needed cars in the campaigns, with some adjustment in the different strata due to size and response frequency, although it has been difficult to see a stable response frequency between different strata. In the first campaign two batches of requests were sent out before we had enough participants. Also, in the first campaign a reminder was sent out a week after the second batch. The effect of the reminder on the response frequency was low though, why this reminder for cost reasons has been skipped in the requests for later campaigns. Instead a large enough number of requests was decided to be sent out.

2.3.3 Agreement

A positive response to the request is announced by sending back a signed agreement, which was sent together with the request. The agreement is reproduced in Appendix C. With the signing, the participant confirms that he/she will participate in the logging, install and take care of the equipment and send it back when the measurement is finished, and allows the gathered data to be stored and be used for research concerning movement patterns, energy efficiency and environmental properties of vehicles, and concerning traffic and social planning. The participant is free to leave the project at any time without motivation.

2.4 Twenty electric vehicles

Within the project also 20 electric vehicles should be logged in the same manner as the 500 ordinary cars. In the current situation not enough electric vehicles have been available, i.e., vehicles that are of newer model year in the region in question, see Table 2.11. The electric cars owned by juridical person are (almost) exclusively not driven for private reasons.

Table 2.11 Number of electric vehicles of model year in question (see Table 2.3) in this study in Västra Götaland + Kungsbacka.

Date	Owner	
	Juridical person	Private person
April 2010	8	2
May 2012	79	2

It was decided in the steering committee, though, that for fulfillment of the project goal it was enough to refer to the data that has been gathered from loggings of electric cars driven in Malmö in the EU project Green eMotion. The logged data is stored in the same way in the same databases as for this project. The results of the Green eMotion project are not further discussed here.

3. THE LOGGING EQUIPMENT AND DATA HANDLING SYSTEM

3.1 Logging equipment

3.1.1 The GPS equipment

During the start-up phase of the project needed to select suitable logger equipment. A requirement for the choice of equipment has been to avoid any possible inference with the car's electronic system, for instance, by a connection to the CAN bus. Also, after consideration of the possible handling costs for different ways of distributing/installing the equipment, it was decided that the equipment should be able to be sent to the car owner/driver by ordinary mail services for installation by her/himself. Several alternatives were examined, including a smart phone with GPS, but problems with the accuracy made it unsuitable. At the end a commercially available logger from Host Mobility was selected, the MX3, Fig 3.1. It is a dedicated GPS logger with GSM modem and the possibility to store data locally on a memory card. The equipment includes a roof-mounted (magnetic holder) antenna, supplied from the 12V outlet in the car.

The logged data is successively transmitted in batches (after intermediate storage on a micro SD-card situated in the equipment box) on the mobile net (gprs) for intermediary storage on a server. The micro-card storage allows for storing data for a longer period without contact with the mobile net. This means, for instance, that also movement patterns for driving abroad can be gathered.

Table 3.1 Specifications of the Fastrax IT500 GPS module [Source: Fastrax datasheet]

General		SPS 22 + 66 channels
Update rate		1 fix/s (user configurable)
Accuracy	Position	1.8 m (CEP) Circular Error of Probability (horizontal position)
	Velocity	0.1 m/s
	Time	+/- 50ns RMS
TTFF	Cold Start	34 s typical
	Warm Start	3 s typical
	Hot start	1 s typical
Sensitivity	Acquisition (cold)	-148 dBm
	Navigation	-165 dBm
	Re-acquisition	-160 dBm
Other	Operating temperature	-40°C to +85°C
	Chip set	MediaTek MT3329
	Firmware	AXN 1.3
Memory		4 Mbit Flash

The gprs communication is bidirectional making updating of the software and control of the equipment possible.

Figure 3.1 The GPS equipment. The logger is contained in a box with antenna for gprs communication (short stick mounted to the right). It is powered via a connector plug for 12 V outlet ((black/red in the middle) and supported with a GPS antenna with a magnetic holder for car roof mounting (blue "puck" to the left).

3.1.2 Modifications and repair

The unit was adapted for the project. The sampling frequency was increased from 1 to 2.5 Hz, to get a better basis for using the data for simulation. A larger memory card was installed to be able to store data for a longer period without mobile net coverage, for instance, when abroad. The equipment was also adjusted for handling the different applied power outlet strategies when the car is turned off. During the project the software has also been updated due to detected malfunctioning, further discussed later in Section 7.2.

3.1.3 Logged signals

The signals logged by the equipment are

- Timestamp (current and last valid)
- Position (latitude, longitude and altitude)
- Velocity (speed and direction)
- Used satellites (identity)
- Dilution of precision (pdop, hdop, vdop)

- Over-the-air-provision OTAP

Further specification of the logged and stored signals is given in Ch 4.

3.1.4 Installation

The equipment was sent to the driver/owner by ordinary mail in a protected envelope. The users are supposed to install the equipment in the chosen car as soon as possible when they receive it.

The installation of the equipment and the measurement campaigns are supported by information appended to the equipment, see Appendix D. This information has also been available at the project's homepage [21]. The installation is very easy, the unit should be placed somewhere where it is not in the way and then place the magnetic antenna on the roof and the power cord in the cigarette lighter outlet. A branch connector to be put in the 12 V power outlet make it possible to also connect other equipments to the same outlet as the logging equipment. A branch connector has been available on request from the beginning of the project, but not many persons have requested one. We have seen in the data and in the comments done in the questionnaire that persons have disconnected the GPS to, for instance, charge their mobile phone or occasionally connect entertainment facilities. In campaign 6 a branch connector has been included in the measurement equipment and sent out together with all the GPS units. Because a considerable share of these were not returned with the equipment after the campaign, it was decided in campaign 7 to once again only send out these connectors on request.

3.1.5 Logging procedure

When installed the unit will work autonomously. Each time the car is started the MX3 will power up and start recording GPS positions etc to its working memory. When a certain number of measurements have been made, the MX3 will normally connect via GSM to the TSS Telematics server and transmit the data. If it is not possible to connect the data will be saved on the memory card and it will be transmitted later when the MX3 has GSM coverage again. This can occur for example, when the car is in a tunnel or abroad. The GSM subscription was only for Sweden. When the logging period comes to its end, a signal is sent to the unit by the administrator. The unit will then beep the first time it is active. The user is then supposed to disconnect the unit, put it in the supplied, padded and addressed envelope and put it in a mailbox.

From campaign 4-2 and on, the car odometer readings at the mounting and uninstall of the equipment were asked for. The readings are then possible to use for, for instance, comparison to the actually logged total distances. (The readings are not stored in the database, though.)

3.2 Data handling

A system for communication and handling of the data has been built for this as well as other projects at Lindholmen Science Park The complete data handling system is still (2012) at a constant developing state due to the requirements of new project and new types of measurements. The basic parts of the system are shown in Fig 3.2.

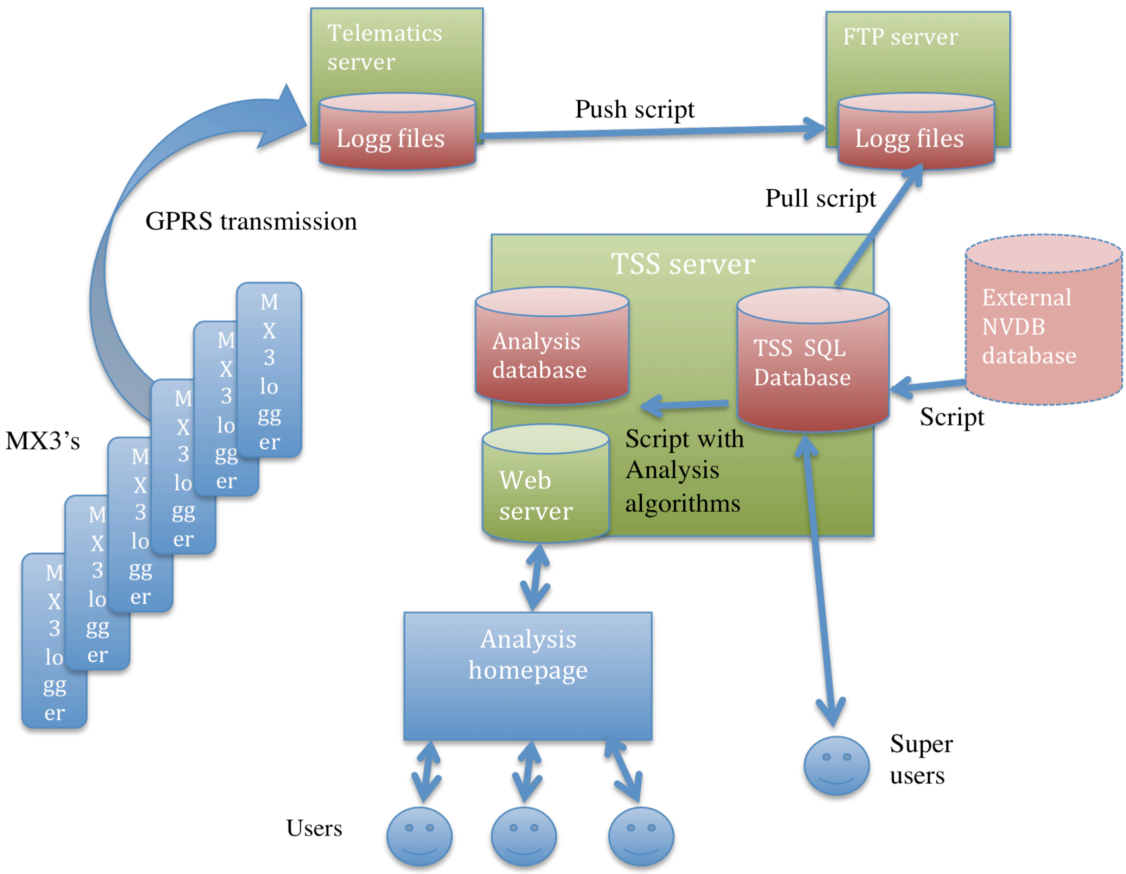

Figure 3.2 Data collection, storage and analysis system for car movement data.

The MX3's collect data in packages corresponding to 1 – 3 minutes of data and transmit them as byte streams via tcp/ip to the TSS Telematics server. The Telematics server translates the data and packs and stores measurements into files. The Telematics server then, normally once a day, automatically puts together files from each MX3 unit in a new file, marks and pushes it to an FTP server. The TSS server pulls (so far by a manual initiation of the administrator) the files from the FTP server and places each measurement in the SQL database (Schema "tss-ev"). The script also assigns a road point to each data point with the help a shape file derived from the The Swedish National Road Database (NVDB), and adds an identifier for road type and speed limit into the TSS SQL database. The SQL database is organized in an expandable way, so that additional data sources can be introduced continuously without affecting already collected data.

Now super users can pull data from the source database and do advanced analyses on the data. But this requires good SQL knowledge, which may not be the case for most users. Therefore also basic analyses of the data are made (also so far manually initiated) and the results are placed in a separate analysis database (Schema “tss_calc”). From the analysis database, a web server will present the analyzed data on a web page. On this web page normal users can analyze and download their own data in an easy but yet powerful way. (The scheme for the data handling presented here is not restricted to the car movement data project, but is used for other measurements as well.)

4. PROCESSED AND STORED DATA

4.1 Data transferred into the source database and the analysis database

4.1.1 Source database structure

The current (autumn 2012) basic data structure of the source database (Schema “tss_ev”) is shown in Fig 5.2.

4.1.2 Stored signals

As mentioned the signals logged are

- Timestamps (current and last valid)
- Position (latitude, longitude and altitude)
- Velocity (speed and direction)
- Used satellites (identity)
- Dilution of precision (pdop, hdop, vdop)
- OTAP

The logging frequency for all data is 2.5 Hz, i.e., the position and speed etc are logged every 0.4 second. Table 4.1 gives the signals stored in the source database (Schema “tss_ev”, Tables “SAMPLE_BRD_SET1-9”) and in the analysis database (Schema “tss_calc”, Tables “device_data”) and their format.

The horizontal position is given in longitude and latitude according to the standard used in the GPS system, WGS84. The values are given with six decimals and copied into the databases. One degree in latitude corresponds to roughly 10^5 meters why the last digit corresponds to roughly decimeters. The last digit in the longitude must be multiplied by the cosine for the latitude, which at our latitude (around 58 degrees in Västra Götaland) gives that the last digit corresponds to only around half a decimeter.

The vertical position, the altitude, is given in decimeters above the modeled mean sea level (msl) in WGS84. The used msl local value is probably interpolated from a lock-up table if state of the art for cheap GPS receiver technology is used, which it is no reason to question. This WGS84 mean sea level can differ considerably from the real sea level locally, why the absolute value in the altitude can be less accurate.

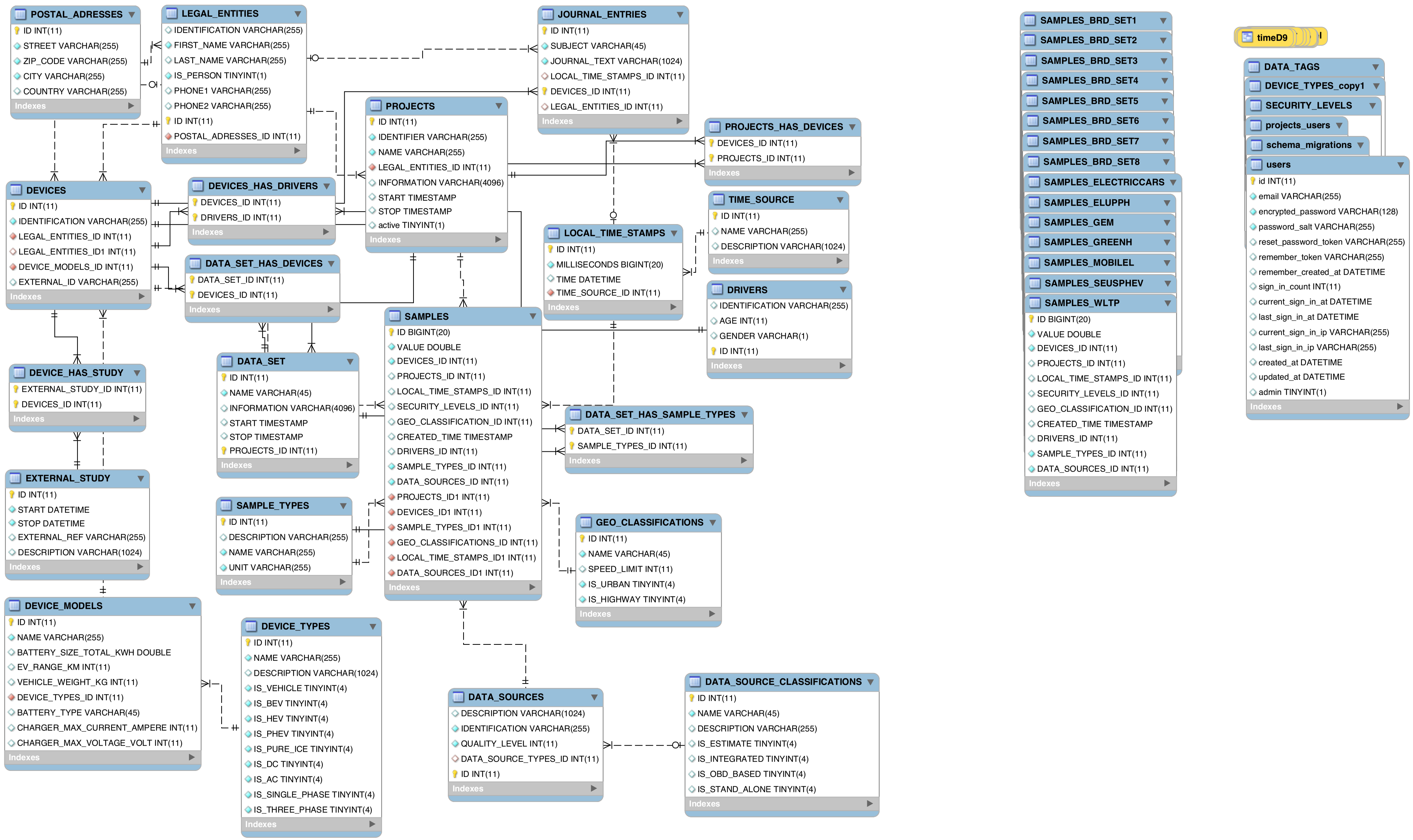

Figure 4.1 Database structure of the TSS SQL source database (Schema "tss_ev") as of Oct 2012.

Table 4.1 Signals as stored from the tracking equipment and as stored in the source database and analysis database, respectively.

GPS signals stored in the FTP server						Source database		Analysis database	
Type	**Signal**	**Unit**	**Format/Possible value**	**Example**	**Last valid digit**	**Signal**	**Example**	**Signal**	**Example**
Position	Longitude	WGS84[a] decimal	0.000000 – 359.999999	13.024383	10^{-6} degree ~ ≈ 0.1 meter * cos(latitude) ≈ 0.05 m	Longitude (copy)	13.024383	Longitude (copy)	13.024383
	Latitude	WGS84[a] decimal	0.000000 – 89.999999	55.603614	10^{-6} degree ~ ≈ 10^{-1} meter	Latitude (copy)	55.603614	Latitude (copy)	55.603614
	Altitude	decimeter	0.0 – ?	86.0	0.1 meter	Altitude (in dm) (no decimal)	86	Altitude (in meter) (1 decimal)	8.6
Time	Timestamp for current time	UTC[b]	YYMMDD:hhmmssd	100622:1025394	0.1 second	Unix time - x[g] (in milliseconds)	1277187939400	Unix time (ms), YYYY-MM-DD hh:mm:ss.d[h]	1277195139400, 2010-06-22 08:25:39.4
	Timestamp for last valid time	UTC[b]	YYMMDD:hhmmss	100622:102539	1 second	Unix time - x[g] (in milliseconds)	1277187939000	Unix time (ms)	1277195139000,
Velocity	Speed	Knot[c]	0.00 – ?	11.31	≈ 0.02 km/h ≈ 0.005 m/s	Speed (copy)	11.31	Speed (km/h)[b] (5 decimals)	20.94612
	Direction	Degree[d]	0.0 – 359.0	46.0	1 degree	Direction (no decimal)	46	Direction (no decimal)	46
Satellites in use	Identity of currently used satellites	Decimal of a 32-digit binary	+/- ??	272667346	Satellite identity	Identity of used satellites (copy)	272667346	Identity of used satellites (copy)	272667346
Precision[e]	Dilution of precision, positional	Pdop in tenths	(0) 10 – 255	35	0.1 pdop	Pdop in tenths (copy)	35	Pdop[i] (truncated, no decimal)	3
	Dilution of precision, horizontal	Hdop in tenths	(0) 10 – 255	92	0.1 hdop	Hdop in tenths (copy)	92	Hdop[i] (truncated, no decimal)	9
	Dilution of precision, vertical	Vdop in tenths	(0) 10 – 255	86	0.1 vdop	Vdop in tenths (copy)	86	Vdop[i] (truncated, no decimal)	8
	OTAP[f]	binary	0 or 1	0	Software update	–		–	

[a] WGS84 decimal, World Geodetic System 1984 in decimal form. The global geodetic system used in the GPS system.
[b] UTC, Coordinated Universal Time. The timestamp is reasonably adjusted for leap seconds, although the internal GPS system time contains no leap seconds and starts from 1980-01-06 00.00.00, but the signal contains information on elapsed leap seconds (16 leap seconds as of Jan 2013)
[c] 1 knot = 1 nautical mile/h, where 1 nautical mile is defined as 1 852 meters. The km/h value is derived by multiplying the knot value with 1.852.
[d] Degrees from northward clockwise.
[e] The “Dilution of precision” is the factor with which the errors in the measurement propagate into errors of the estimated position due to the geometry of the positions of the utilized satellites. For an xdop value of 1 there is no dilution of the precision because the satellites are in an optimal positions for the measurement.
[f] OTAP = over-the-air-provisioning. Is set to 1 when software is updated, otherwise 0. The OTAP value is not stored in the two databases.
[g] Unix time = Time in milliseconds since 1970-01-01 at 00.00.00, but without the 25 added leap seconds since then (as of Jan 2013). x is the number of milliseconds for the, in the data storing, incorrectly assumed necessary conversion from Swedish to UTC time, that is, x = 72 000 000 and 36 000 000 in summer- and wintertime, respectively.
[h] YYYY-MM-DD hh:mm:ss.d is in the analysis database given in Swedish time, that is, UTC time + 2 and 1 hours in summer- and wintertime, respectively.
[I] The dop values are truncated to nearest lower integer value.

The two timestamps ("actual" and last valid) out from the GPS equipment are given in UTC = Coordinated Universal Time, in the format YYMMDD:hhmmssd and YYMMDD:hhmmss,, respectively, that is, the actual timestamp is given in tenth of a second. (The accuracy of this timestamp is higher though, see Table 3.1.) When stored in the source database the timestamps are converted to Unix time, that is, the number of seconds elapsed since the Unix Epoch at 1970-01-01 at 00:00:00. (The Unix time is always given without the leap seconds (25 leap seconds as of Jan 2013) though, which have been inserted since then in UTC to adjust for the length of the year. The actual number of seconds elapsed is thus 25 more than what the Unix time says.) However, by a mistake, in the storage script it has been assumed that the timestamp is given in Swedish time, not UTC. The time difference between Sweden and UTC was therefore first withdrawn before conversion. The stored Unix timestamps are therefore Unix times corresponding to UTC time – 3 600 000 milliseconds (= 1 hour) during wintertime, and UTC – 7 200 000 milliseconds (= 2 hours) when summertime prevailed. Thus currently it is not accurate values of the Unix time in the source database.

In the analysis database the mistake has been adjusted. In the analysis database the timestamps and last valid timestamp are given as Unix time. The timestamp is also given in Swedish time, that is UTC + 1 hour in wintertime and UTC + 2 hours in summertime. The format is a text string: YYYY-MM-DD hh:mm:ss.d.

The mistake and its correction may introduce an occasional ambiguity. In spring when going from winter- to summertime, data from the two hours surrounding the time point of change will have got the same Unix time value in the source database. Very few if any data points from these nightly hours in 2011 and 2012 are there in the source database, though.

The GPS unit gives the velocity in the form of speed and direction. The speed is given in knots with is stored with two decimals in the source database. For the analysis database this value is multiplied with a factor 1.852 to get the speed in km/h. The direction is given in degrees and stored as an integer value in the databases.

The GPS unit transfers the satellites used for the calculation of each position in the form of a binary number with 32 digits, one for each satellite. This number is in the Telematics server converted into the corresponding decimal number, which is stored in the source database and the analysis database.

The dilution of precision gives the factor by which the error variance in the position should be multiplied due to the relative geometry only of the satellites-GPS receiver involved in the calculation the position. The hdop is the factor for the horizontal position, vdop for the vertical position (altitude), and pdop is for the combination of both. The hdop values are typically in the range of one to two, but are larger when the used satellites happen to be more aligned. The uncertainty in the vertical is normally larger than in the horizontal because the satellites are all always on one side of the receiver (above). For high latitudes they are always south of the receiver as the maximum latitude for the satellite orbits are around 55 degrees. The values are stored as tenth of the real dop values in the source database. Thus for instance a figure 28 corresponds to a dop value of 2.8. For the analysis database this value is truncated to nearest lower integer (in the example the value will be 2)

4.2.3 Complementary data

To each measurement device is a vehicle connected in the form of the car register number. While the data is stored to the source database, a road classification identity is connected to each point in the dataset. The identity points to a table, which gives the speed limit and categorize the road into urban, highway or other, see Appendix E. An algorithm has been developed for connecting a data point (the horizontal position) to a specific spot on a road to be able to get the road classification identity.

4.2 Derived data in the analysis database

All the GPS or movement data is more or less directly copied into the analysis database (Table "device_data") as described in Section 4.1 above. The data is stored with one row per set of data and identified with and sorted along (besides project) device, trip, and point of time.

Some manipulations are performed before the storage of the sets and the generation of the statistics, though. Possible sets with datum before roughly 2005 and after 2014 are discarded. Possible duplicating datasets are identified and discarded. Spikes in speed values are limited to 500km/h. The division into trips needs a definition and identification of trips, as the raw movement data in the source database is data points identified only by (besides project) the device and the timestamp.

First, trips are identified by dividing the data into two trips whenever data is missing at a point of time. We should here note that a loss of GPS fixation will not lead to loss of data. Such a situation occurs whenever the car is somehow shielded and can not receive signals from at least four satellites, for instance, when the car enters a tunnel. The GPS receiver will continue to deliver data but now not measured but extrapolated data, and with a last valid timestamp, which differs from the actual timestamp.

Second, two derived trips are merged into one trip if the time step between the stop and start points is less than 10 seconds. For these shorter periods of no data, data points are interpolated and filled in. The data is filled in linearly in position and speed. The minimum time of the pause between trips has deliberately been kept low to avoid too much data filling and leave as much as possible to the data user. But at the same time it is important for any trip statistics to avoid a division of the driving into a lot of trips, which are not considered different trips in reality but are occasional loss of data.

A lot of data points are actually from a real pause in the driving. This occurs when the GPS equipment has not turned off when the car has stopped. These points consist of data with (almost) zero speed and no/little change in position. Data is therefore discarded if the speed is less then 0.1 km/h for more than 10 minutes. Only the data after the 10 minutes is discarded. And the data is possibly divided into two trips as a consequence.

Table 4.2 Movement statistics per vehicle and per trip available in the analysis database and available at the web interface (see Section 4.4).

Statistics[a] for each device/vehicle		**Statistics[a] for each trip**	
Parameter	**Web**	**Parameter**	**Web**
Number of trips	x	Start time	x
Start time for first trip	x	Stop time	x
Stop time for last trip	x	Trip duration	x
Total duration of the trips	x	Pause time before trip	x
Total travel distance	x	Pause time after trip	x
Average trip distance	x	Start horizontal position	
Maximum trip distance	x	Stop horizontal position	
Trip distance histogram	x	Travel distance	x
Maximum speed	x	Maximum speed	
Average speed	x	Average speed	x
Average of speed squared		Average of speed squared	
Average of speed cubed		Average of speed cubed	
Speed histogram	x	Final speed	x
Average of positive acceleration • speed			
Average of negative acceleration • speed			
Average number of trips per day[a]			
Maximum number of trips per day[a]			
Pause time histogram	x		
Travel timepoints-of-the-day histogram			
Travel distance per day histogram[a]			
Number of trips per day histogram[a]			
Acceleration vs Speed diagram			

[a] Applied definitions: *Day*: The break point of time between days is 03.00 in the morning. Trips starting before this point of time is accounted to the day before; *Time*: The start and stop times for a trip is the time for start and stop of the logging, whether the car moves or not. This definition is used also in the estimates of the averages.

Table 4.3 Data quality and analysis statistics per vehicle and per trip available in the analysis database.

Device/vehicle	**Trip**
Number of defect entries discarded	Final speed
Number of early entries discarded	Number of corrected speed values
Number of late entries discarded	Number of interpolated regions
Number of overlapping entries discarded	Number of interpolated points
Number of zero-speed entries discarded	
Number of corrected speed values	
Number of interpolated regions	
Number of interpolated points	

Statistics are then generated for vehicles movements (Table “device_stats”) as well as for trips (Table “trip_stats”). In a specific array (Array “arrays”) is stored the statistical distribution of acceleration vs. speed for the different vehicles. Table 4.2 lists the movement statistics currently available in the analysis database.

Furthermore, the analysis database contains some statistics for the quality of the dataset and the manipulation of the data, which have been done before the copying into the Table "device_data". This generated statistics are listed in Table 4.3.

The parameters given in this section on the identification of trips as well as many others used in the analysis are input parameters to the analysis program and possible to change. A new compilation and running of the program is then necessary, though. Appendix F gives a further description of the derived data in the analysis database and the parameters used.

4.4 Web interface

A web interface is connected to the analysis database. There excerpts of the data in the analysis database are presented, see Fig 4.2. This data can also be downloaded as Excel files. The web interface is under continuous development.

4.5 Availability

The use of the data is restricted to research concerning vehicle movements, energy efficiency and environment issues, as well as traffic safety and societal planning, in accordance with the agreement with the car owners. Due to the privacy character of some of the data, the availability will further be classified according to type. Access to the data is administered by Lindholmen Science Park.

4.6 Possible further post-processing

Post-processing of the positional data is planned to achieve enhanced positional data quality and make possible more correct and easier assignment of data to the national road database. The accuracy for the used type of GPS equipment should be a few meters for non-disturbed conditions. Still this can be a problem for accurate assignment to correct road, especially in urban or other environments with parallel or crossing overhead roads [23]. Also, in urban canyons the accuracy can be much less due to signal scattering. The intended post-processing will possibly utilize SWEPOS, the Swedish national network of permanent reference stations for GPS. The expected horizontal accuracy will then be increased to around one meter [24]. Furthermore, discussions are ongoing on connecting also weather data to the data points.

5. THE QUESTIONNAIRE

As a complement to the GPS data, we have, by a questionnaire intended to be sent back with the equipment, surveyed the specific environment for each car, such as, commuting habits, working site addresses, number of persons and driving licenses in the household, yearly mileages, etc. We have also made an identification of the possibility to charge an electric vehicle at home and at the possible working place. We have also tried to reveal specific characters of the driving during the measurement period in relation to their driving in general. Finally there has been a check if there have been specific problems with the installation, etc. This data is not available in the source database, though. The questionnaire is reproduced in Appendix G.

The questionnaire has been answered to a very high degree, Table 5.1. The questionnaire was sent with the equipment and therefore it has been answered more or less independently of the amount and quality of gathered data, although participants, who for different reasons returned the equipment early were more reluctant to answer.

Besides to achieve the above-mentioned data, the answers have been used for control of which vehicle actually has been measured by a device as the car register number was collected also in the questionnaire. For instance, the equipment has occasionally been installed in another vehicle belonging to the household instead of into the one originally intended, the car has been sold and a new one bought instead, etc. For a number of vehicles the identity has in this way been possible to correct in the database.

Table 5.1 Answers to the questionnaire.

	Vehicle with data	Vehicle w/o data	Total answers
Answers	667	30	697
No answers	47		
Total with data	714		

6. RESULTS

We will here present the logging in terms of the involved cars, their household and spatial distribution, report the outcome of the measurement and its quality, and give some exemplary results concerning the car movements.

Altogether around 770 cars have had GPS equipment sent to them for measurement of their movements. Some of these have not installed the equipment or the equipment has not registered any data. 714 cars have delivered data. (These cars are directly available in for instance the analysis database.) Of these cars 528 cars have had their movements logged for 30 days or more, that is, the difference between first and last gathered data is at least 30 days. (Still there can be missing data within this logging period.) (These 528 cars can relatively easily be extracted from the analysis database.) We will in the continuation term the 714 cars *Data All Cars* and the 528 vehicles *Data Cars 30d+*. We have also derived a dataset, for which we have interpolated apparent missing data (non-continuity in position) and excluded time periods for which possibly missing data have not been possible to identify. See further discussion on this procedure in Section 6.3. This data set contains 445 vehicles with data for 30 days or more. Here we call this dataset *Data Cars Corr 30d+*. (This last vehicle excerpt is not directly available in the analysis database, but require some data manipulation.) The 697 answers to the questionnaire (see Chapter 5) we will term *Questionnaire.*

6.1 Participating cars and their households

The recruitment procedure has not lead to any significant misrepresentation concerning the properties of the cars. Table 6.1 shows that the 714 cars with data are fairly representative for the vehicles they are supposed to represent as determined in the excerpt from the vehicle register described in Section 2.2.3.

Table 6.1. Average values for selected parameters of vehicles in Data All Cars in comparison to the vehicles in the vehicle register.

Parameter	Average for cars with data (*Data All Cars*)	Average[a] from vehicle register
Model year	2006.37	2006.12
Maximum engine power (kW)	98.2	99.5
Cylinder volume (cm^3)	1819	1812
Kerb weight (kg)	1456	1457
Fuel use (liter/100km)	7.22	7.26
CO_2 emission (g CO_2/km)	176	177

[a] Weighted average between juridical and private cars in the same proportion as in the excerpt from the vehicle register further discussed in Section 2.2.3.

Over 70% of the cars are in households with 2 adults, see Fig 6.1. The figure also shows that most of the adults in the households have driving licenses. A majority of the cars belongs to households with more than one car, see Fig 6.2. We can also see that compared to the Swedish households in general there is a slight overrepresentation of households with more than one car. This is probably (partly) due to the fact that this study is directed towards newer cars, which predominantly may belong to wealthier household with several cars. The comparably low age of "our car" also explains why it also has somewhat longer yearly driven distance than the other car(s) in the households, see Fig 6.3. In average it is not perceived bigger than the other cars though, see Fig 6.4.

63% of the selected cars are used for commuting, although not necessarily during the measurement period, with an estimated average commuting (one-way) distance of 29 km, see Fig 6.5.

The outcome concerning the distribution of the cars over the different strata is shown in Table 6.2. It agrees reasonably with the desired distribution. There is a major over-representation for newer diesel cars in the Gothenburg area as well as a major underrepresentation of juridical cars, especially diesel cars. Most of the juridical cars are situated in the Gothenburg area, are relatively new cars and diesels. These misrepresentations may therefore concern close categories of customers, why they to some extent may compensate for each other.

Table 6.2 Distribution of the logged vehicle over the different strata (se Table 2.4). Source: Data All Cars.

Strata	Outcome (*Data All Cars*) (Number)	Outcome (*Data All Cars*) (%)	Desired distribution[a] (Number)	Desired distribution[a] (%)
GB7T	10	1.40	9.3	1.31
GB7L	33	4.62	32.2	4.51
GB6T	41	5.74	41.8	5.86
GB6L	71	9.94	75.9	10.63
GD7	29	4.06	22.3	3.12
GD6	15	2.10	14.0	1.95
ÖB7T	26	3.64	23.2	3.25
ÖB7L	59	8.26	56.9	7.97
ÖB6T	110	15.41	106.9	14.97
ÖB6L	147	20.59	154.6	21.65
ÖD7	62	8.68	60.0	8.41
ÖD6	52	7.28	53.0	7.42
JD	29	4.06	33.7	4.72
JB	27	3.78	30.2	4.24
Unknown	3	0.42	0	0
Sum	714	100	714	100

[a] Values at mid-project point of time for privately driven cars. (From last column in Table 2.9.)

The geographical distribution of the cars is shown in Table 6.3. The representation of the single municipality varies especially for small municipalities, in which the desired numbers of cars are very small. However when aggregated into 4 groups with municipalities of different sizes (the three municipalities in the Gothenburg area are aggregated in a separate group), the various sizes are well represented. We can see a small overrepresentation of smaller cities, while the other groups have fewer cars than desired.

Table 6.3 Distribution of cars over the different municipalities in the region. Source: Data All Cars and The Swedish motor-vehicle register.

Municipality	Distribution over municipalities (*Data All Cars*)	Desired[a] distr. over the municipalities	Distribution over four subregions[b] (*Data All Cars*)	Desired[a] distr. over the four subregions
GÖTEBORG	167	183.7	220	227
MÖLNDAL	31	27.8		
PARTILLE	22	15.5		
BORÅS	34	47.0	80	88
KUNGSBACKA	46	40.9		
SKÖVDE	31	25.1	290	261
UDDEVALLA	24	23.3		
TROLLHÄTTAN	21	22.4		
KUNGÄLV	23	20.4		
LERUM	14	19.0		
HÄRRYDA	24	16.8		
ALINGSÅS	25	17.1		
LIDKÖPING	25	17.1		
MARK	22	16.1		
VÄNERSBORG	12	15.3		
FALKÖPING	21	13.2		
ALE	8	12.8		
STENUNGSUND	16	12.6		
ULRICEHAMN	7	11.4		
MARIESTAD	11	10.5		
SKARA	6	8.1		
TJÖRN	10	8.0	124	138
ORUST	9	7.6		
VARA	3	7.3		
LYSEKIL	4	6.6		
TANUM	8	6.4		
GÖTENE	7	6.2		
STRÖMSTAD	3	6.0		
ÖCKERÖ	3	5.7		
TRANEMO	7	6.0		
LILLA EDET	3	5.6		
SVENLJUNGA	5	5.1		
TIDAHOLM	0	4.7		
ÅMÅL	7	4.8		
VÅRGÅRDA	3	4.8		
SOTENÄS	2	4.9		
BOLLEBYGD	5	4.6		
TIBRO	1	4.6		
MUNKEDAL	7	4.6		
BENGTSFORS	6	4.4		
MELLERUD	4	3.8		
HJO	1	3.8		
HERRLJUNGA	2	3.9		
TÖREBODA	8	3.8		
KARLSBORG	2	3.1		
FÄRGELANDA	2	2.7		
GRÄSTORP	2	2.5		
ESSUNGA	1	2.3		
GULLSPÅNG	4	2.3		
DALS-ED	2	2.0		
Unknown	3	0	3	0
ALL	714	714.0	714	714

[a] The desired distribution is in proportion to the distribution of cars over the different municipalities in the selection of cars used in campaign 4, roughly corresponding to the mid-project point of time. Data from the Swedish motor-vehicle register 2011-02-14.
[b] Same four subregions of differently sized municipalities as used in Figure 2.3.

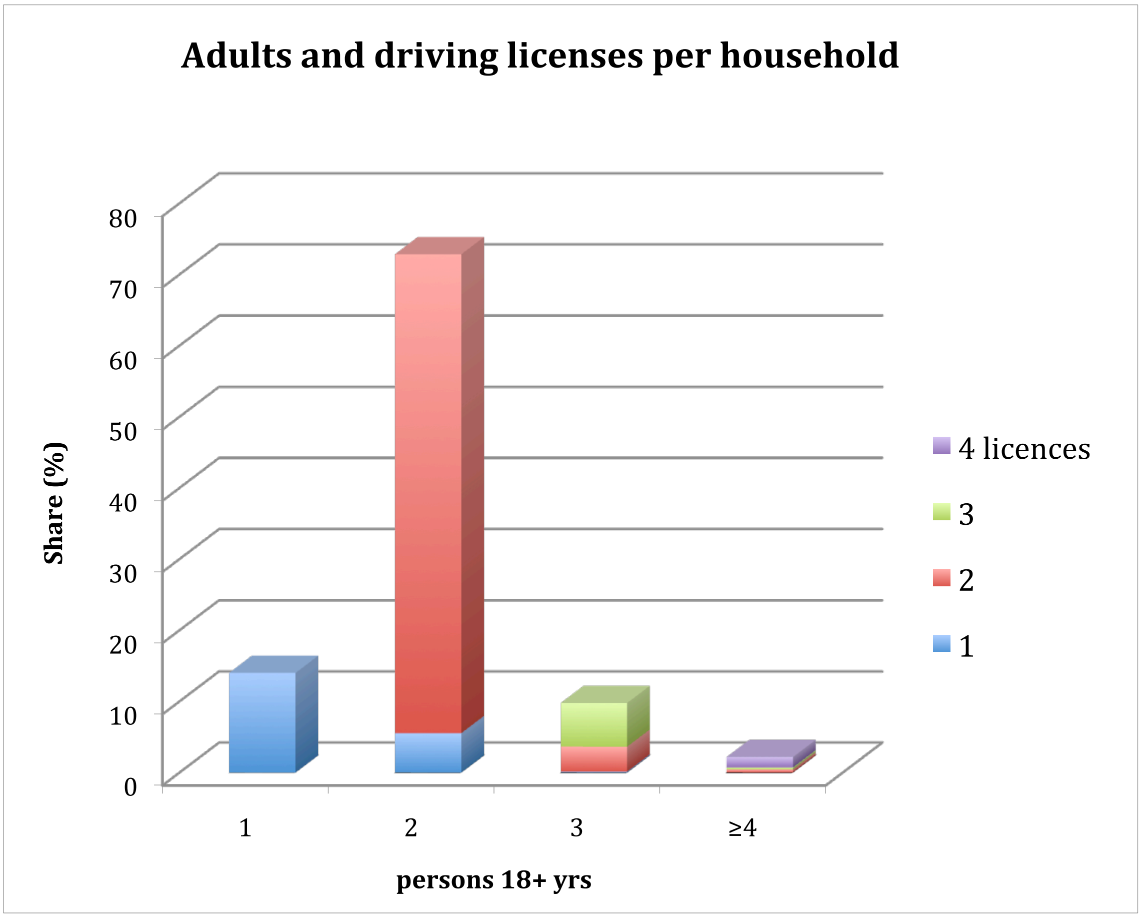

Figure 6.1 Number of adults and driving licenses in the households. Source: Questionnaire.

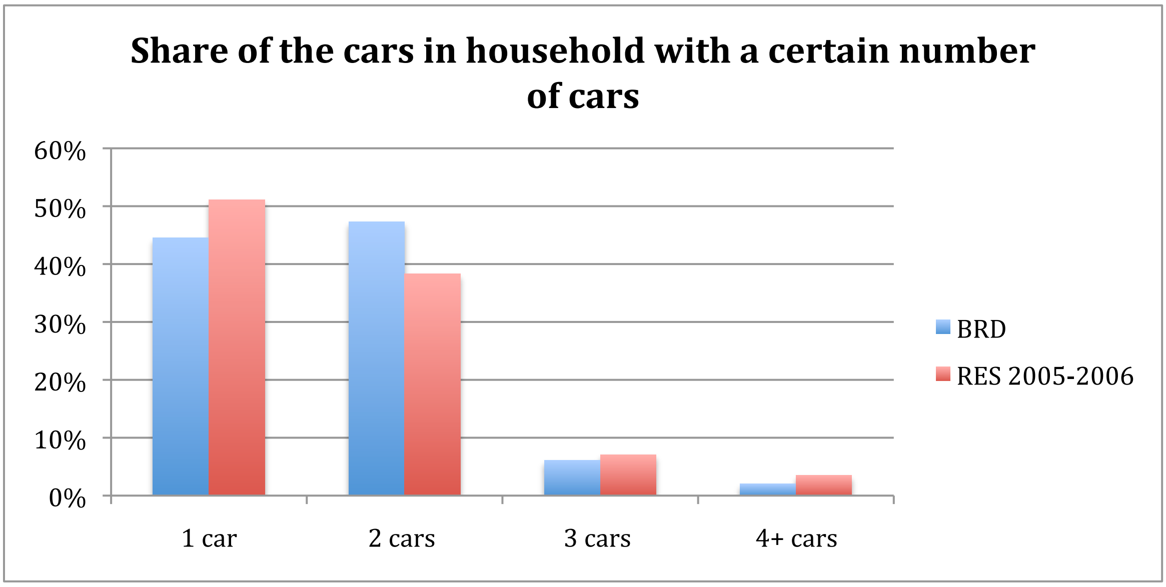

Figure 6.2 Share of the cars belonging to household with different number of cars in this study (BRD). For comparison the corresponding figures for whole of Sweden given in The Swedish Travel Survey (RES 2005-2006). Source: Questionnaire and SIKA 2007.

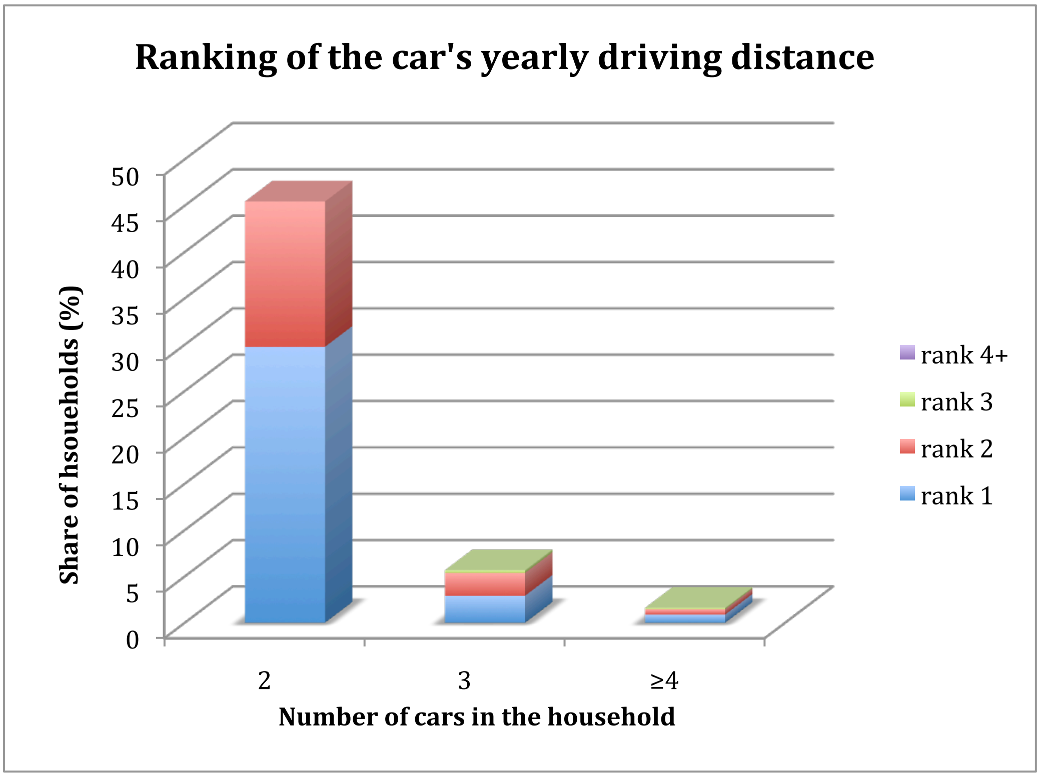

Figure 6.3 Owner's ranking of the car's yearly driving distance in comparison to the other cars in the household, where rank 1 = longest yearly driving distance. Source: Questionnaire.

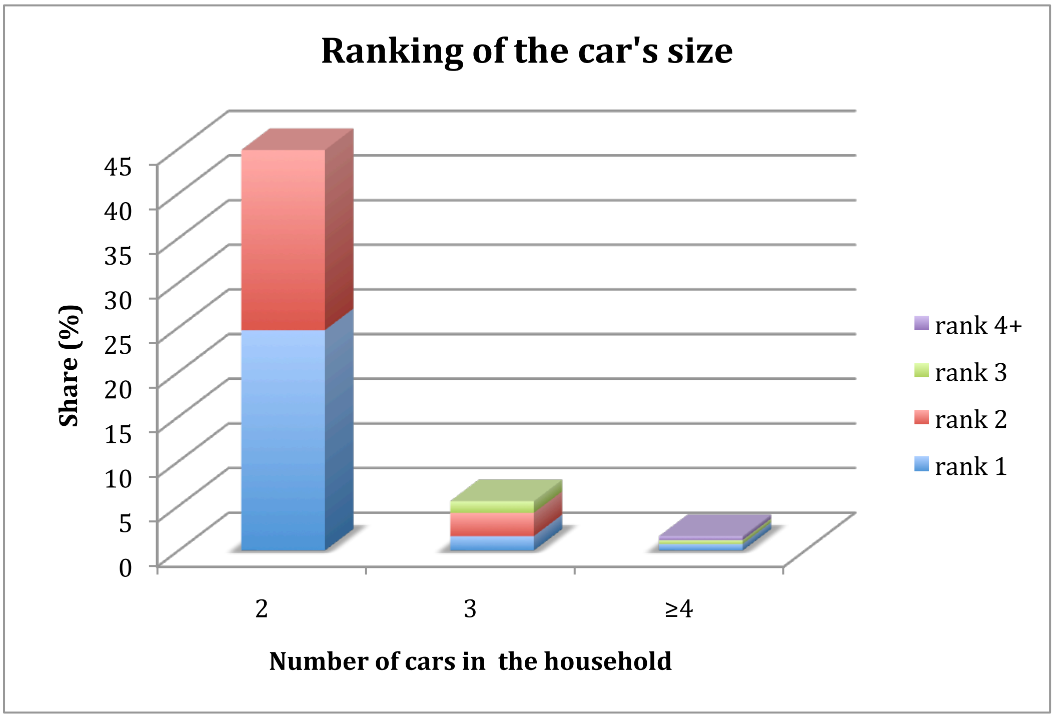

Figure 6.4 Owner's ranking of the size of the car in comparison to the other cars in the household, where rank 1 = largest. Source: Questionnaire.

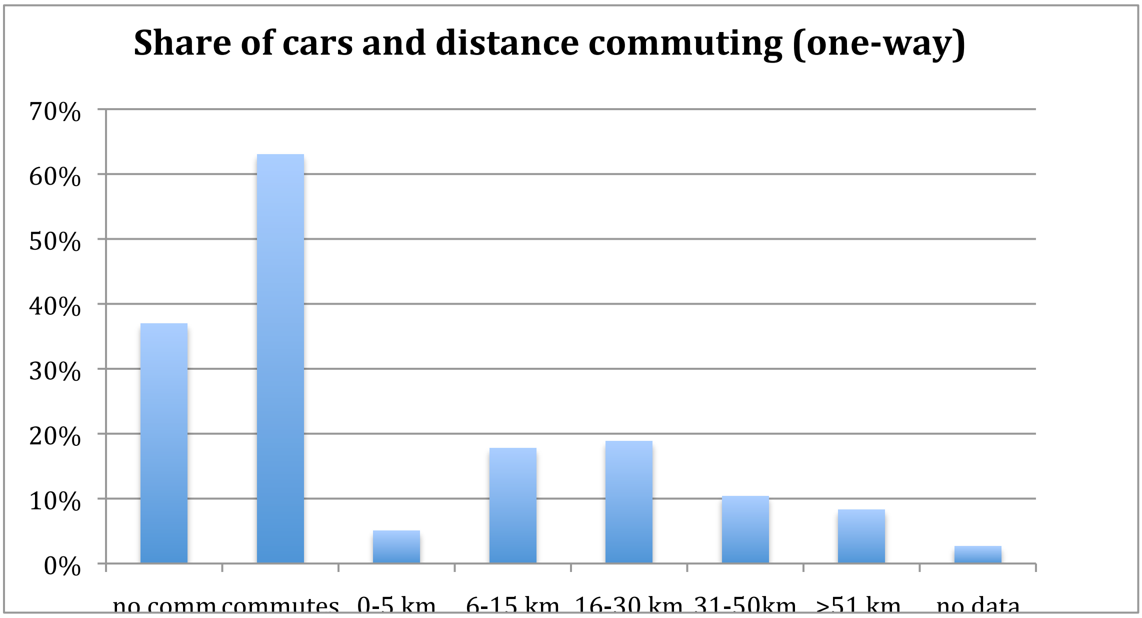

Figure 6.5 Stated commuting for the vehicles (not necessarily during the logging period) Source: Questionnaire.

6.2 Logged driving

Table 6.4 gives some basic statistics for the logging

Table 6.4 Basic statistics for the logged car movements.

	Data All Cars	*Data Cars 30d+*	*Data Cars Corr 30d+*
Number of cars with data	714	528	445
Total distance (km)	1 314 002	1 207 141	1 174 298
Total travel time (hour)	24 801	22 776	n. a.
Average distance (km)	1 840	2 286	2 639
Average speed (km/h)	53	53	n. a.
Number of trips[a]	134 425	124 458	113 293
Average number of trips[a]	188	236	255
Average trip length[a] (km)	9.8	9.6	10.4
Average number of trips per day[a]	3.8	3.7	4.4

[a] Trip statistics are sensitive to the division of the car movements into trips. Here we use the procedure discussed in Section 4.2 to divide the data into trips.

The intention has been to distribute the logging over the year, although simultaneously a continuity of the campaigns and the availability of equipment must be taken into account. Figure 6.6 gives the distribution of the performed logging over the year. We can see that there is a somewhat larger concentration of loggings in the summertime during the Swedish vacation period in July. Several campaigns started just before the vacation period, because otherwise it had to be delayed to after be summer.

The length of the actual measurement period, shown in Fig 6.7, is for many vehicle much shorter than intended due to malfunction of the equipment as further discussed in Section 7.2. 528 vehicles have loggings for more than 30 days (= *Data Cars 30d+*) and over 450 for more than 50 days.

Many vehicle have logged distances between one and two thousands kilometer, see Fig 6.8, although the variation between the cars is large. Figure 6.9 shows the extrapolated logged distance in comparison to the yearly driving of the vehicles as stated by the owner/driver in the questionnaire. The variation in the fit between individual vehicles is large. However, the average of the extrapolated logged distances are somewhat shorter than what could be expected from the stated driving. It can be due to overstated yearly driving, non-representative logging periods, or missing data in the loggings.

The age of the main driver/owner of the logged cars are somewhat older than expected from car owner data as shown in Fig 6.10. Older people may thus be more willing than younger ones to participate in this type of investigations. No compensation for this effect was done in the recruitment, as it was not part of any predetermined strata. The in the questionnaire stated number of persons in the car when driving are shown in Fig 6.11. 60% of the driving have been done without passengers, in which here children younger than 10 years were not included. The Swedish Travel survey gives higher shares for driving with two or more passengers, but this figure form the travel survey includes also younger children, which contributes to the difference.

Half of the cars have been equipped with a towbar, see Fig 6.12. Over 20% of these have been towing a larger load for an estimated mean distance of 480 km during the logging period, see Fig 6.13.

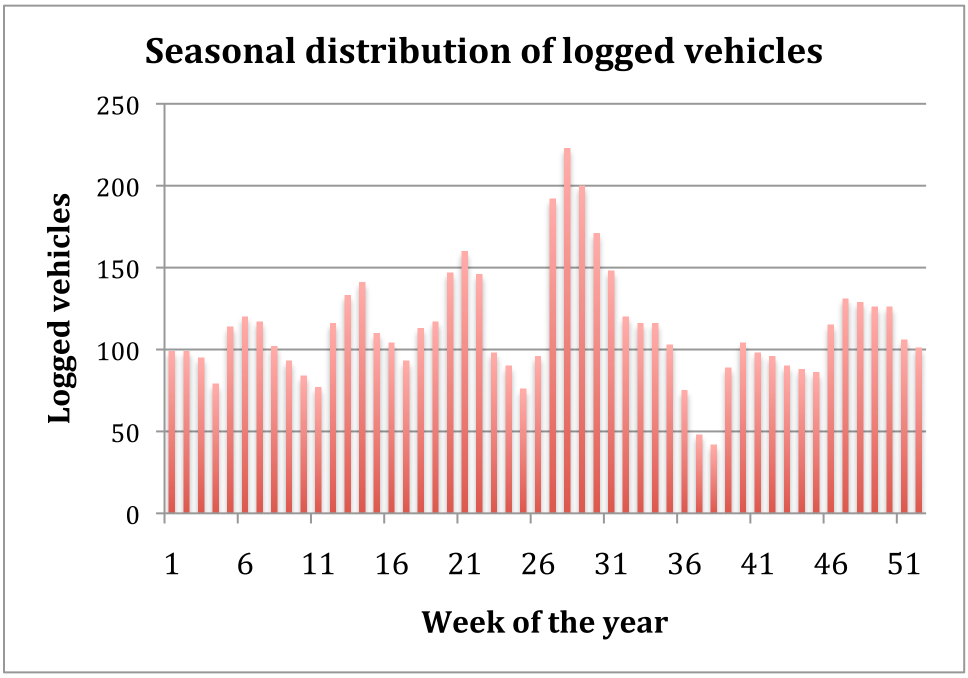

Figure 6.6 Distribution in time of the logging periods for the vehicles. Source: Data All Cars.

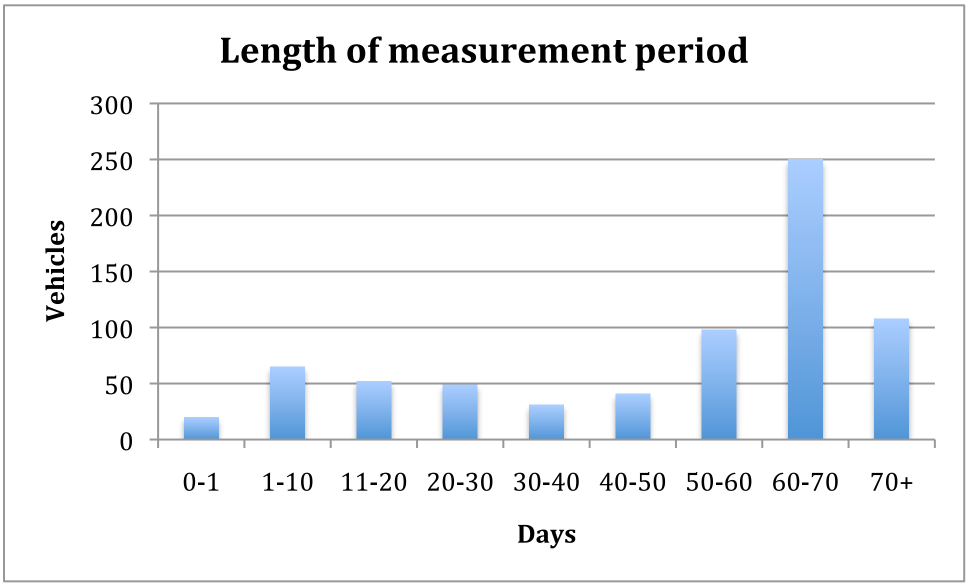

Figure 6.7 Distribution of the length of the measurement period for the different vehicles. Source: Data All Cars.

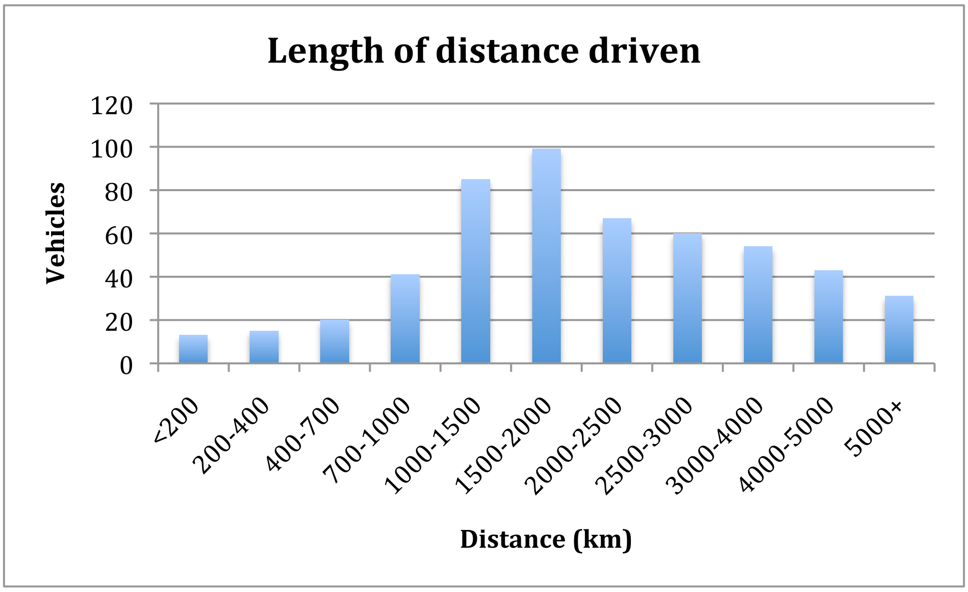

Figure 6.8 Distribution of the logged driving distance. Source: Data Cars 30d+.

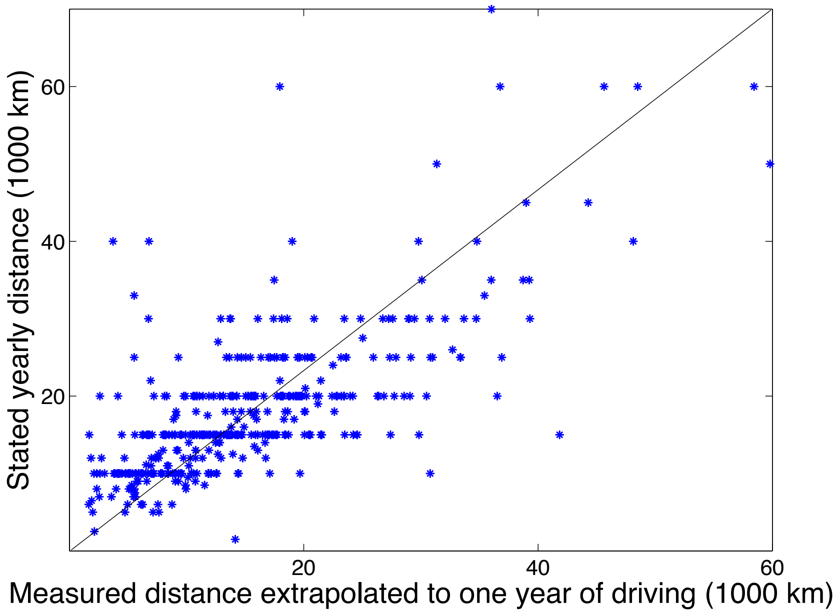

Figure 6.9 Yearly driving distances for the vehicles. Stated yearly driving (from Questionnaire) compared to logged data extrapolated to one year (Data Cars Corr 30d+).

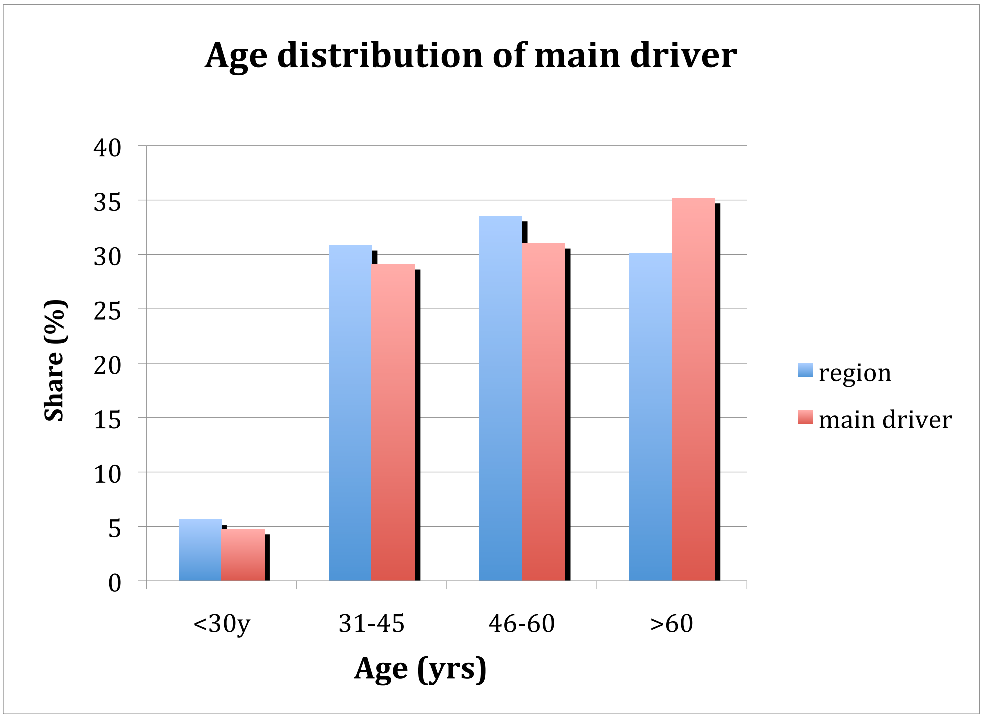

Figure 6.10 Age of the main driver compared to the owners/beneficiaries of comparable vehicles in the investigated region, weighted between juridical (estimated) and private cars in the same proportion as in the excerpt from the vehicle register (see Section 2.2.3). Source: Questionnaire and Swedish vehicle register.

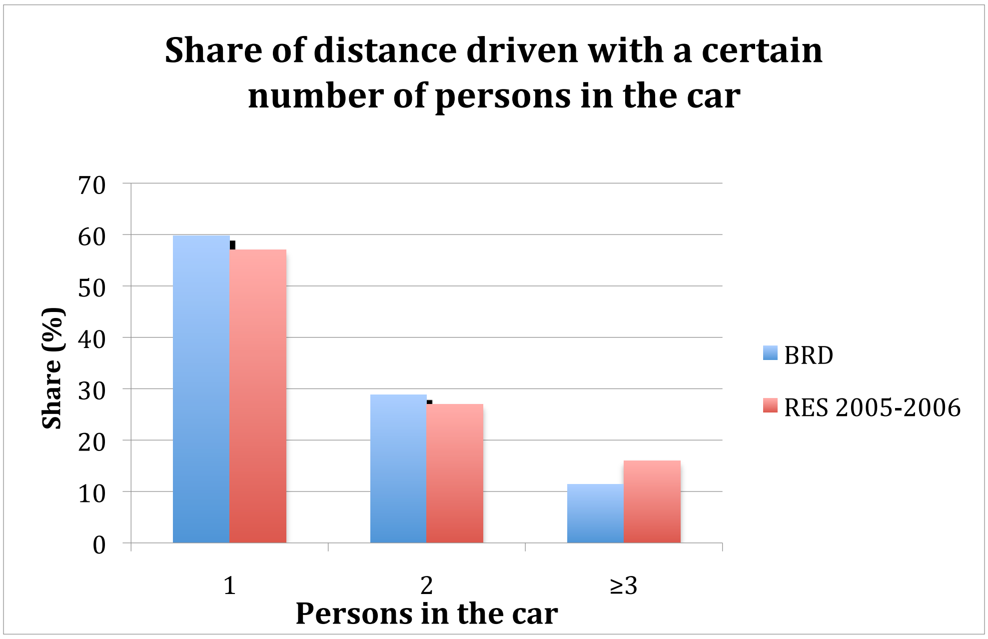

Figure 6.11 Stated distribution of the driving with different number of person in the car for this project compared to results from the Swedish national travel survey for the years 2005-06. Source: Questionnaire and SIKA 2007.

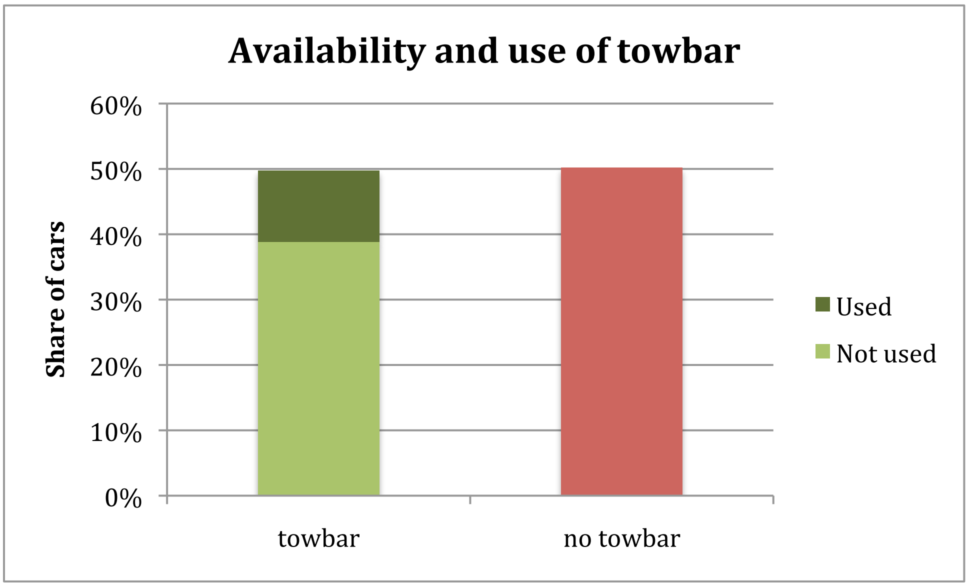

Figure 6.12 Availability and stated use of the towbar during the logging period. Source: Questionnaire.

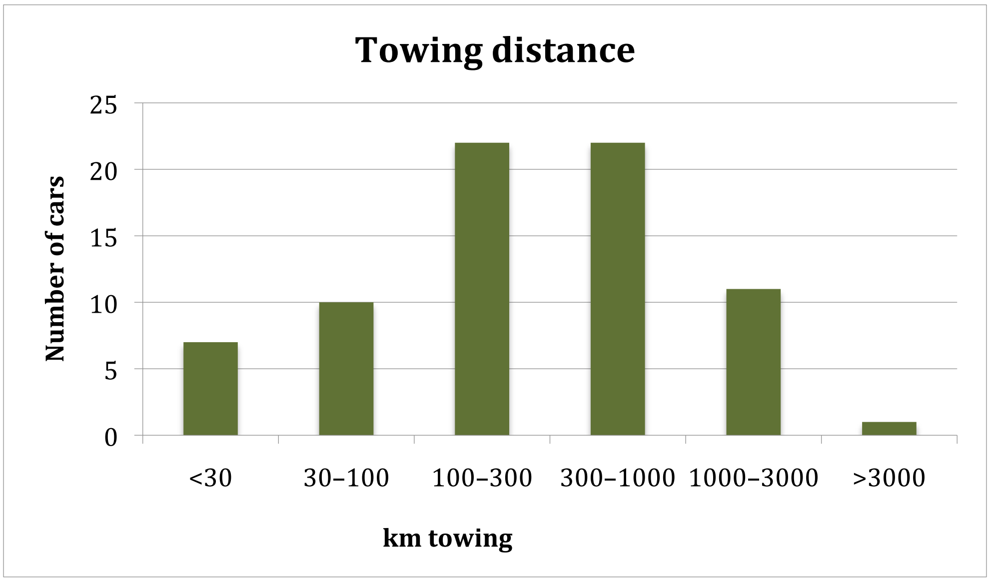

Figure 6.13 Stated towing distance during the logging period. Source: Questionnaire.

6.3 Data losses

The start up of the GPS involves an initialization delay of at least half a minute before logging data appears. Therefore most of the trips do not begin exactly from where the last one stopped. Loss of data can also give a division of the travel into several trips and introduce distances between trip stop and the next start. Also for instance ferry tours will contribute to these differences in stop and start position of successive trips. Including all cars, 71% of the trips have a difference in position between its start and the stop for the preceding trip shorter than 100 m, around 88% have less than 500 meters, and 93.4% less than 2 km, see Fig 6.14. Some of the losses are connected to cars that due to malfunctioning equipment got many of their trips divided into more broken trips. Some of these units are responsible for many broken trips.

Figure 6.15 gives the number of cars left for different tolerance of missing data. Here a trip is treated as a "potentially damaged trip" if the distance between its start and the stop of the preceding trip is larger than 2 km. Depending of the use of the data, different types of data losses are more or less important. When focus is not on second for second details but on for instance how long the trips are and when they occur, some data losses can be replaced with interpolated data. This can de done for instance, when missing data can be replaced with a good fit with interpolated data corresponding to a reasonable car speed on the actual type of road. Figure 6.15 also shows the effect of one such a simple repair technique. For instance, for a tolerance of 5% of the trips to have potentially lost data, this technique enables about 40% of the earlier filtered out cars to be accepted, giving a total of 460 cars left. This selection is here called *Data Cars Corr 30d+*.

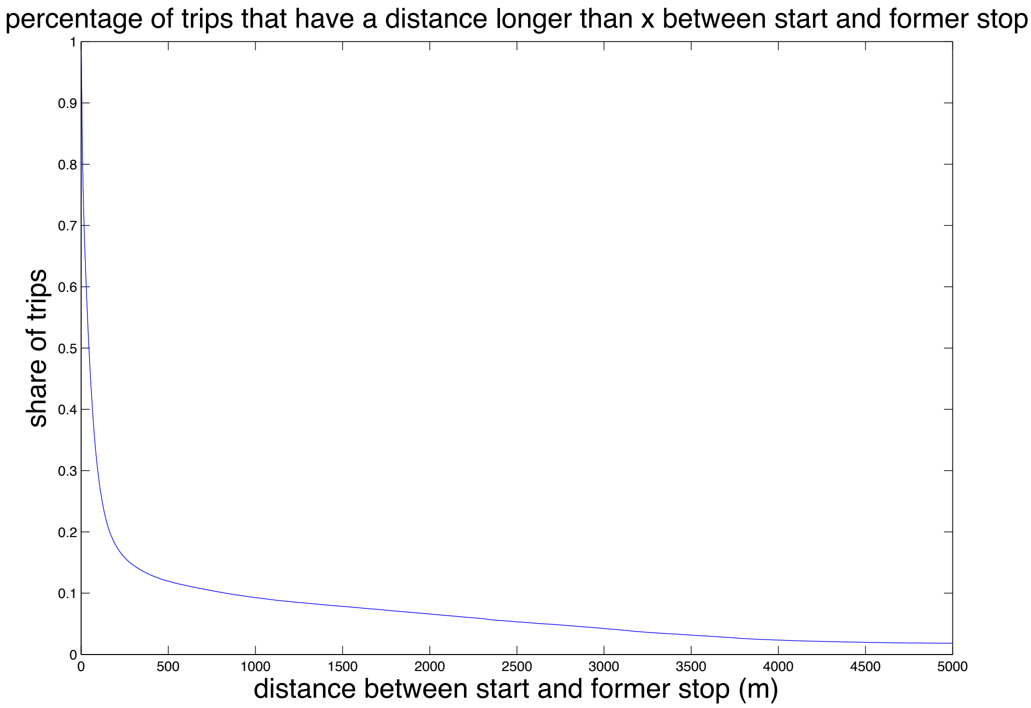

Figure 6.14 Distribution of the distances between first logging position and the last position before the stop. Source: Data Cars 30d+.

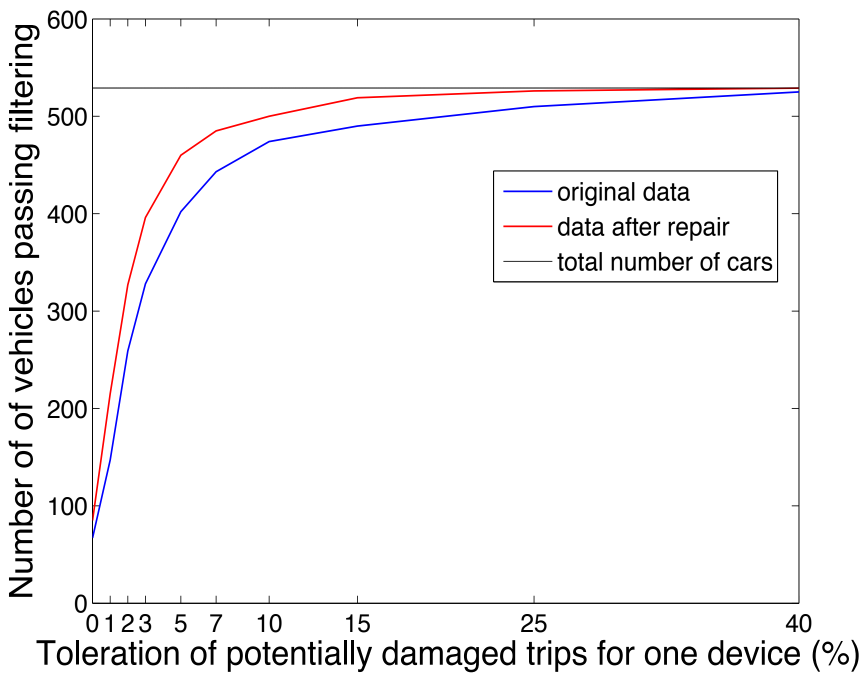

Figure 6.15 Number of vehicles left in data after filtering for different levels of tolerance of potentially damaged trips. With and without a simple repair technique. Source: Data Cars 30d+.

6.4 The car movements

We will here present some basic data of the logged driving and indicate some implication especially for electrification of vehicles.

Figure 6.16 depicts the distribution of the number and length of the trips. (Trips defined according the procedure described in Section 4.2) While the number of trips is dominated by short trips, the most common driving belongs to a trip between 30 and 50 kilometer. Not much more than 10% of the driving belongs to trips longer than 100 kilometer.

A similar relation holds for the pauses between trips, Fig 6.17. The number of pauses are dominated by short breaks, but at any time a random car not driving have probably stood there for a long time. The time between trips are totally dominated by longer pauses, almost 90% of the time a car is parked belongs to a pause longer than 8 hours.

Figure 6.18 gives the fleet average number of daily pauses longer than *T* hours, indicating for instance the opportunities for charging when a certain length of the pauses is required for a charging to possibly occur. In average only 0.7 pauses per day are 10 hours or longer. Many cars are not used every day and some drivers do not have a 10 h break over night, thus keeping the average down. If the time needed for charging is reduced to 4 hours this will roughly mean a possibility to 50 % more recharging opportunities on a fleet level. The potential occasions are again doubled if one allow for charging every half an hour.

Figure 6.19 depicts the distribution in time for pauses of different lengths. A clear pattern appears. Longer pauses (>10 hours) occur mainly during the night, while pauses of between 6 and 10 h length preferentially occur during around the middle of the day, and reasonably this is parking in connection to workplaces. Shorter stops also take place later into the evenings.

Figure 6.19 also gives the implied charging during these parking times, for an assumed specific charging pattern. The cars are assumed to be plug-in hybrids (PHEV), charging with a rate of 2 kW and have a battery of 10 kWh. The need for charging is dependent on the distance travelled since last charging occasion. With this kind of charging behavior most of the charging will for the 10 h case be conducted between 6 and 10 pm. This is still during hours of high load in the Swedish power grid. Increased possibilities to charge at the workplace could also lead to increased power need in hours with already high load, assuming many of the breaks of 6 to 10 h length occur at the workplace. The peak is in this case occurring between 7 and 9 am.

Finally, Figures 6.20-23 gives some statistics for speed, acceleration, power, and energy needs in Swedish car driving. Different movement patterns have large differences in speed characteristics, Fig 6.20. There is also a large variation in the amount of power needed for acceleration for patterns with the same average speed, Fig 6.21. Also the average normalized power need at the wheels vary with movement pattern but is for most cars between 6 and 10 kW, Fig 6.22. The power need is calculated from the speed-acceleration pattern for the vehicles applied to a ”normalized” mid-size car with an assumed mass of 1500 kg, air resistance coefficient times frontal area of $c_d A = 0.66$ m^2, and rolling resistance coefficient $c_r = 0.01$. Some or sometimes much of the power going to acceleration is recovered to overcome air and rolling resistance when the car decelerates, the rest is lost when braking or in powertrain friction. The power need depicted in Figure 6.22 is thus an overestimate of the sum of these power needs in reality. On the other hand the given power need do not include the power needed for going uphill along the road. Also this later need is to a large extent recovered in real driving in deceleration or when going downhill, though.

The average normalized energy need at the wheels per distance driven for the different vehicles corresponding to the power need of Fig 6.22 is given in Fig 6.23. We can note that the comments made to Fig 6.22 are applicable also to this figure. The normalized specific energy need (as defined here) is around 1.5 kWh per 10 km for Swedish driving, while the ultimate losses in average are less than 1 kWh/10km. The variation in energy need gives an indication in the actual range for an electric vehicle due to this factor alone. (Other factors of importance can be the auxiliary energy need and energy conversion efficiency within the vehicle. Also energy recovery is of larger importance for electrified vehicles than for conventional ones.)

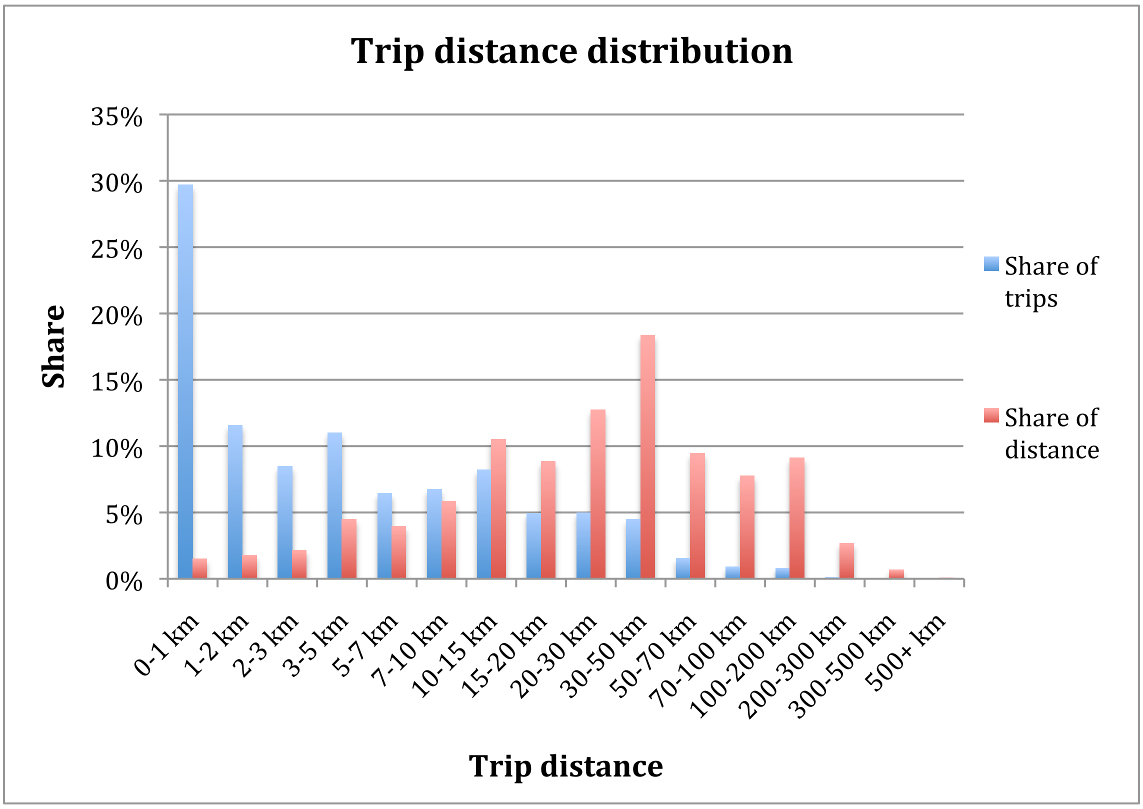

Figure 6.16 Distribution of trip distances. Source: Data Cars 30d+.

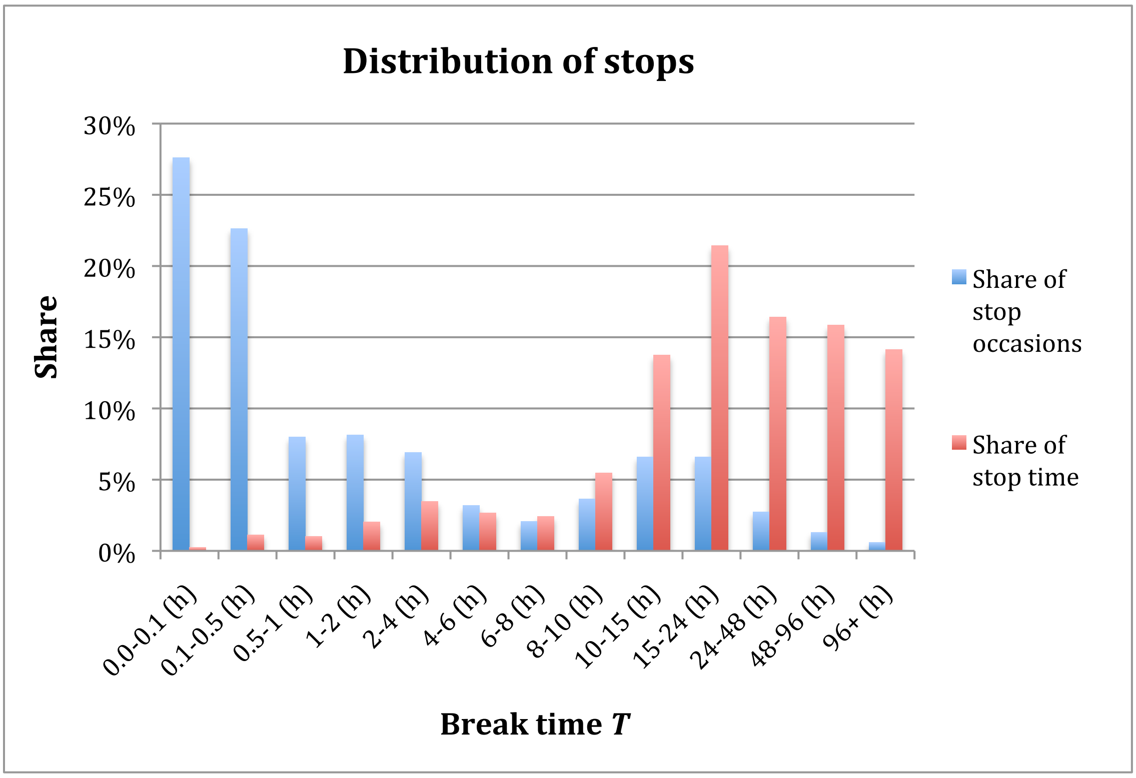

Figure 6.17 Distribution of the length of stops. Source: Data Cars 30d+.

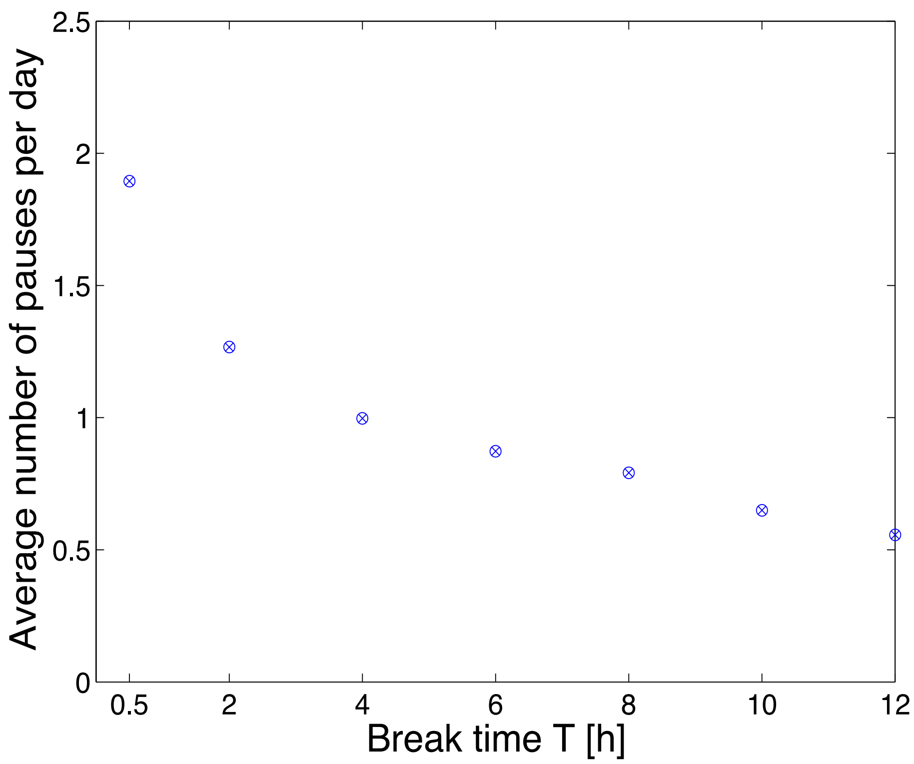

Figure 6.18 Fleet average number of stops per day longer than break time T. Source: Data Cars Corr 30d+.

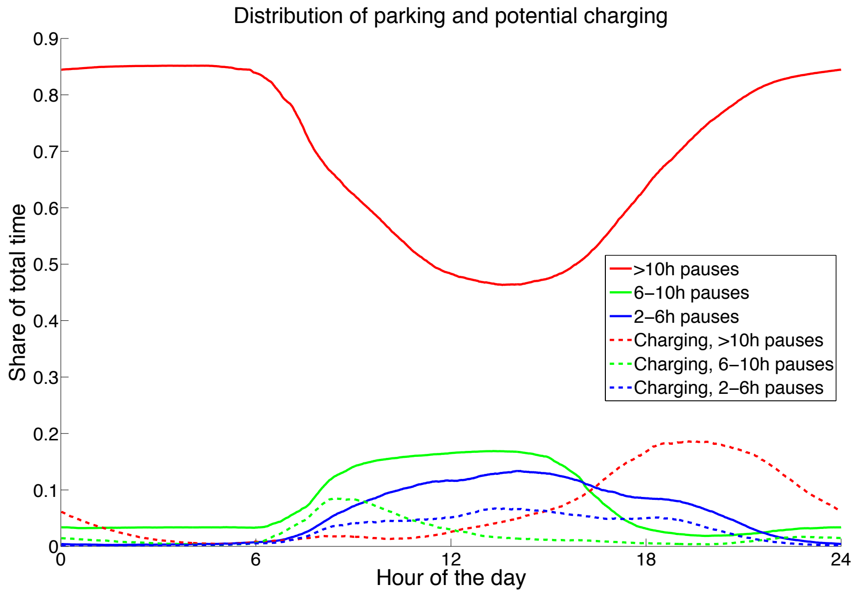

Figure 6.19 Distribution in time for parking of different lengths and potential charging during these pauses. Presented as shares of total measurement time for the vehicle fleet. Assumed: PHEVs with 2 kW charging immediately after parking which continue until battery is full (10 kWh) or pause ends. Energy use 0.2 kWh/km in CD mode. Source: Data Cars Corr 30d+.

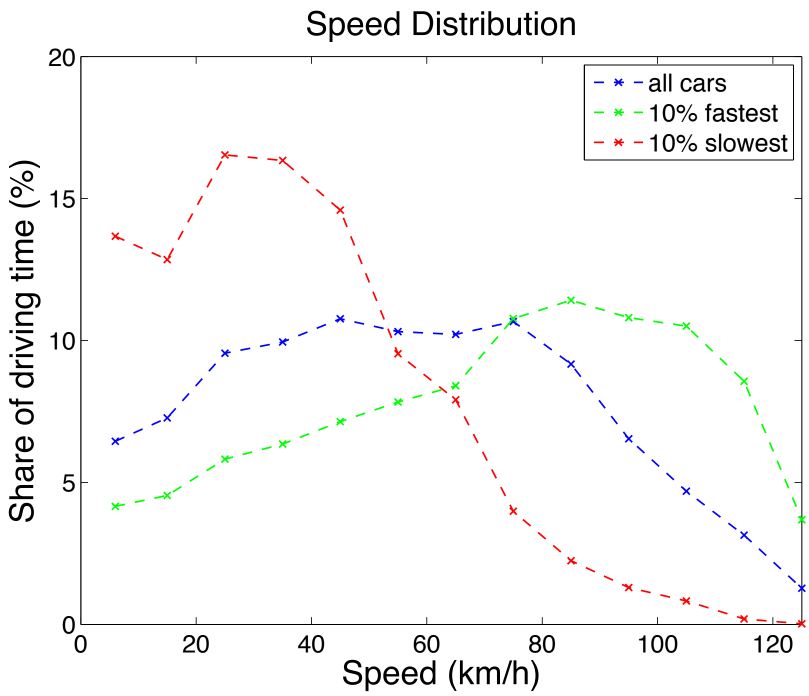

Figure 6.20 Speed distribution in 10 km/h intervals (first interval 2-10 km/h, though) when driving ≥ 2 km/h, given as average values for all cars and for the deciles with the highest and lowest average speed, respectively. From Kullingsjö and Karlsson [2012].

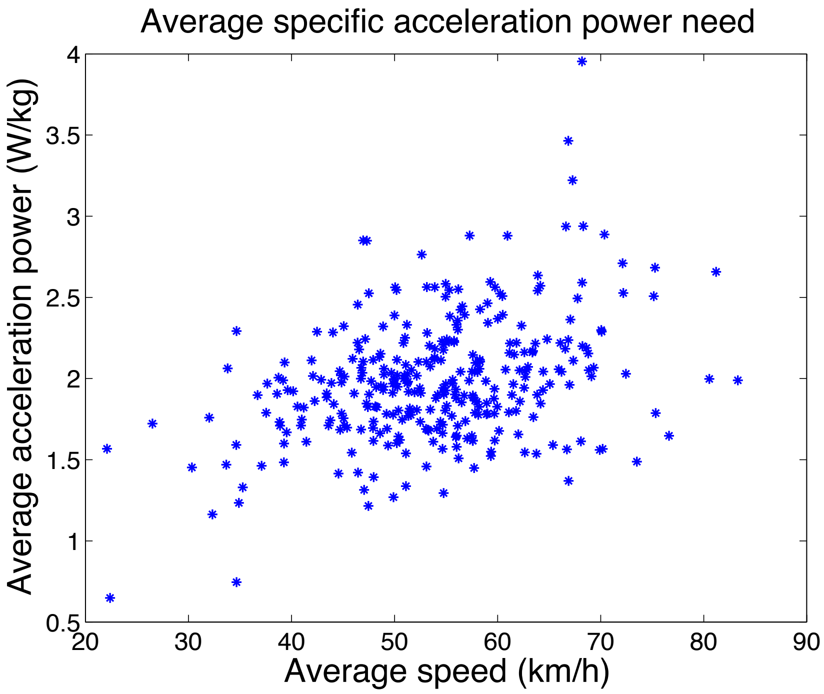

Figure 6.21 Vehicle average acceleration power need and average speed when driving ≥ 2 km/h. From Kullingsjö and Karlsson [2012].

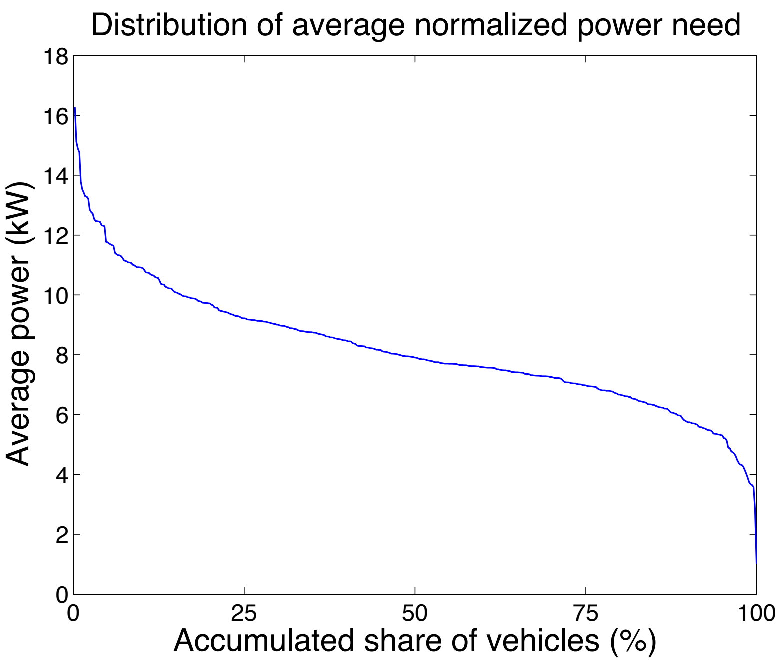

Figure 6.22 Vehicle average power need when driving ≥ 2 km/h. The power includes power need for overcoming rolling and air drag resistance and achieving the necessary

*acceleration. For comparison of movement patterns, the power need is for all the vehicles normalized to the properties of an assumed midsize car (mass M = 1500 kg, air resistance C_d *A = 0.70 m^2, and rolling resistance c_r = 0.01). (Source: Data Cars Corr 30d+).*

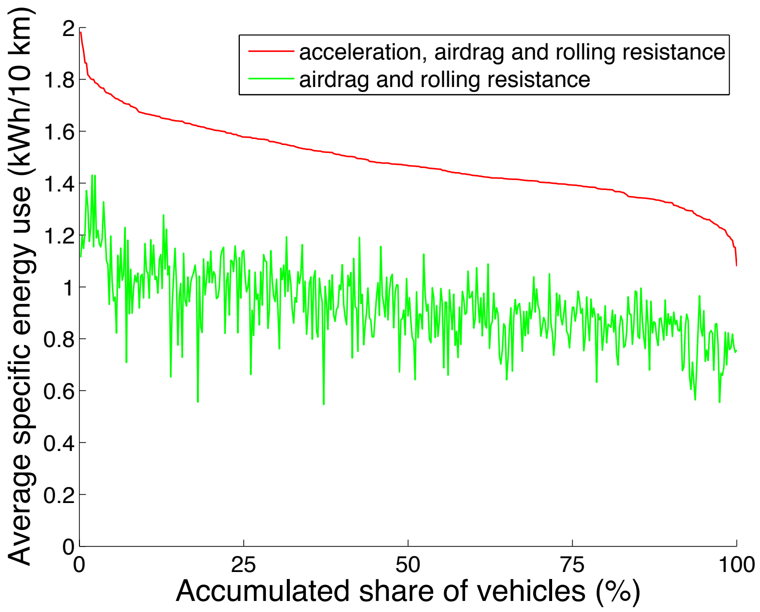

*Figure 6.23 Vehicle average specific energy need at the wheel when driving ≥ 2 km/h. The need is estimated as the sum of energy needs for overcoming rolling and air resistance and energy for achieving the positive acceleration. For comparison of movement patterns, the energy need is for all the vehicles normalized to the properties of an assumed midsize car (mass M = 1500 kg, air resistance C_d *A = 0.70 m^2, and rolling resistance c_r = 0.01). Source: Data Cars Corr 30d+.*

7. Experiences

7.1 Experiences from the administration of the campaigns

As the measurement was organized, the original time schedule for the campaigns was overly optimistic about the time necessary for changing between the campaigns. For a complete exchange a lot of people are expected to

- get an end-of-campaign signal
- recognize this signal (only recognizable when using the car)
- uninstall the equipment
- fill in the questionnaire
- pack the equipment in the earlier received envelope
- mail the equipment at a post office

The administration need then to

- get the equipment
- demount the equipment to extract and empty the memory card for any possible non-communicated data
- check the equipment for functioning and possible repair
- repack the equipment
- mail the equipment

All the next drivers are then supposed to

- get the equipment by mail
- install the equipment in the car
- use the car after the installation

The chain are not stronger than its weakest link and the total time elapsed is the sum of the times for each step. All these steps in each campaign with many persons and situations involved mean that the whole process realistically needs one month and also some spare equipment to compensate for some inevitable delays and losses along the chain.

Between the selection of cars and the actual measurement and during measurement some cars have been sold/exchanged. Also some equipment has deliberately been installed in other cars than the selected one. It has been an extra administrative burden to investigate and confirm which car has actually been measured.

7.2. Technical accomplishment of the measurement

To finally achieve data for about 500 vehicles for at least a month each, the project has needed the intention to measure over 700 vehicles. There have been losses for two main reasons. The equipment has not always been connected to the power outlet and the equipment has not always functioned as intended.

The loss of power is partly unintentional. During the use of the car the plug has occasionally been loose, unintentionally withdrawn from the power outlet, or even damaged. The fit of the connection plug may also have varied between different car brands. Sometimes the connection has been unplugged deliberately, most often to free the outlet for other uses. (As mentioned and further discussed in Section 3.1.4, to alleviate this a branching connector have been available on request or sent with the equipment.)

There have been three major malfunctions of the equipment. Different cars have different ways of dealing with the power to the power outlet when the car is turned off. Some disrupt the power, others not. The initial equipment software developed for handling the power when the car stopped did not work as intended in all situations. Some equipment did not turn off the logging, finally leading to a halt of all logging. This has led to a large tap of data in the first four campaigns. Later in campaign 5 a software error led to repeated losses of data packages for shorter periods for some of the cars. Both these malfunctions have been corrected. Still in the two last campaigns, extensive repeated losses of data occurred for many vehicles and the equipment have once again been updated.

We can conclude that the functional robustness of the equipment has not been enough tested and evaluated initially, and after hardware and software changes.

Complementary odometer readings and notes of installation and demounting points of time will facilitate in the control of equipment and obtained logging data.

7.3. Accomplishment of data handling

The transfer of data to the source database has been slow for several reasons. The database has been developed in parallel to the project and all routines were not there from the start. The data flux from the measurements has been large, and the pure computer time needed to transfer the data have been significant in comparison. The completion of the database has relied on manual handling and there has also been a large cost and competition with other projects both when it comes to man- and computer power. The analysis database and the statistics generated there facilitate to get an overview of the data. This instrument was not developed until late in the project, though, and also not as a part of the project. Altogether these peculiarities have hampered early scrutiny of the data and the feedback to any possible malfunction of the measurement equipment has been too slow. Work is now ongoing to automate the data handling and speed up the process.

7.4. Drivers' experiences

In the questionnaire the drivers/passengers were asked about their experience of the measurement campaigns. Very few have had problem with understanding the installation instructions and with the installation itself.

87% state that the equipment has worked flawlessly. Among the critical, the overwhelming part concerns a loose connection plug or the supplied branch connector. Others mention that the equipment often or occasionally beeps. A few have also argued that the battery has been discharged too quickly due to the equipment. (The drivers have not been able to recognize if the equipment works and are logging the car as intended. The only external sign is that the lights are on, when power is supplied.)

During use of the car some have experienced the equipment disturbing. It has mostly been connected to the antenna cord being in the way, the beeping and the loose plug mentioned above, and that the power outlet has been occupied. Some have also experienced problem with leaking water along the antenna cord.

8. CONCLUSIONS

The described car movement data project has resulted in a unique large dataset on the detailed movements of representative vehicles from the current fleet of privately driven cars in Sweden. The measurement project was initiated for the purpose of achieving appropriate data for various types of analyses connected to the electrification of cars. It is currently, as well as will be, used extensively for such purposes. However, it is a database freely available for all kinds of research devoted to vehicle movements, energy efficiency, and environmental performance as well as traffic safety and societal planning. Due to the privacy character of some of the data, the availability is further classified according to type.

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APPENDIX A. PAPERS, REPORTS AND PRESENTATIONS OF THE PROJECT

Papers

Karlsson S, 2010. The Swedish car movement data project – rationale, methodology and first results. In Proceedings to EVS25. Shenzhen. China. Nov 5-9 2010.

Karlsson S, E Jonson, 2011. The importance of car movement data for determining design, viability and potential of PHEVs. In: Proceedings of International Mobility Advanced Forum (IAMF), March 8-9, 2011, Geneva.

Karlsson S, and T Wiedemann. 2010. G4V: Impact and possibilities of a mass introduction of electrified vehicles on the electricity networks in Europe. In: Proceedings of EVS25. Nov 5-9, 2010, Shenzhen, China.

Kullingsjö L-H, S Karlsson, 2012. Estimating the PHEV potential in Sweden using GPS derived movement patterns for representative privately driven cars. In: Proceedings of EVS26. May 6-9, 2012, Los Angeles, USA.

Kullingsjö L-H, S Karlsson, 2012. The Swedish car movement data project. In: Proceedings of EEVC 2012, Nov 20-22, 2012, Brussels, Belgium.

Karlsson S, L-H Kullingsjö, 2013. GPS measurement of Swedish car movements for assessment of possible electrification. In Proceedings of EVS27 Symposium, Barcelona, Spain, Nov 17-20, 2013.

Reports

Jonson E, S Karlsson, 2010. Möjligheter att utnyttja data från databasen LUNDAvISA för analys av laddhybrider. Fysisk resursteori. PRT Report 2010:5. Chalmers Tekniska Högskola. Göteborg. (in Swedish)

Karlsson S, 2013. The Swedish car movement data project. Final report. PRT report 2013:1 Rev 2. Nov 2013. Division of Physical resource, Theory Dep of Energy and Environment, Chalmers University of Technology, Gothenburg, Sweden.

Presentations

Karlsson S, 2009. *Climate relevance, risks and pitfalls in systems design*. Invited presentation at IEA End-Use working party: Workshop on electricity in the future transport system. Sept 17, 2009, Stockholm.

Karlsson S, 2009. *Electrification of Transport in Energy Scenarios – With a focus on plug-in hybrids*. Invited presentation at Uppsala Energy 2009. Oct 21, 2009, Uppsala.

Karlsson S, 2010. *Laddhybriders laddmöjligheter – Analys av bilars verkliga rörelsemönster.* Presentation at Sveriges Energiting March 16-17, 2010. Stockholm. (in Swedish)

Karlsson S, G Zettergren, 2010. *Mätning och analys av bilrörelser i den svenska bilparken av relevans för framtida elektrifiering.* Presentation at Energirelaterad fordonsforskning 2010. May 18-19, 2010, Skövde. (in Swedish)

Karlsson S, 2010. *Är din bil med? Bilrörelseprojektet – ett underlag för elektrifiering.* Presentation at Chalmers Energidag. Nov 4, 2010, Göteborg. (in Swedish)

Karlsson S, 2010. *Bilrörelseprojektet – ett underlag för elektrifiering.* Presentation at Göteborg Energis Forsknings- och utvecklingsforum. Dec 8, 2010, Göteborg. (in Swedish)

Karlsson S, 2012. *Driving patterns matter*. Presentation at Chalmers Energy Conference, March 28-29, 2012, Gothenburg.

Kullingsjö L-H, S Karlsson, 2012. *The Swedish car movement data project*. Presentation at The first national Swedish transport conference, Oct 18-19, 2012, Stockholm.

Kullingsjö L-H, S Karlsson, 2013. Mätning och analys av fordonsrörelser som underlag för elektrifiering. Presentation at Energirelaterad fordonsforskning 2013. April 10-11, 2013, Örebro. (in Swedish)

Personnel from Test Site Sweden have also made several oral and poster presentations of the project in various contexts.

E-media

Karlsson S, L-H Kullingsjö, 2013. Electric vehicles and driving patterns. Ch10 in Sandén B, (ed) System Perspectives on Electromobility, Chalmers Univ of technology. http://www.chalmers.se/energy

www.chalmers.se/brd The project has from early on had a webpage at Department of Energy and Environment at Chalmers University of Technology, Sweden.

http://www.goteborgenergi.se/Privat/Projekt_och_etableringar/Forskning_och_utveckling/Forskningsstiftelsen The project has from early on been presented at Göteborg Energi Forskningsstiftelse. (in Swedish)

TSS
Test Site Sweden

Vill du medverka i en studie för att mäta bilars körmönster?

Detta brev är en förfrågan om du vill vara med i ett forskningsprojekt där vi ska mäta hur bilar används. Att just du tillfrågas beror på att vi har gjort ett slumpmässigt urval av bilar i Västra Götaland och Kungsbacka med hjälp av bilregistret.

Forskningsprojektet leds av Test Site Sweden (TSS) inom Lindholmen Science Park i samarbete med Chalmers Tekniska Högskola och Consat AB. Data från mätningarna ställs samman och analyseras vid Institutionen för Energi och miljö, Chalmers Tekniska Högskola.

Projektet finansieras också av Energimyndigheten inom programmet Fordonsstrategisk forskning och innovation (FFI), Göteborg Energis stiftelse för Forskning och Utveckling, Vattenfall, Lindholmen Science Park samt Telenor.

Studiens Syfte

För att göra bilar mer energisnåla pågår det utveckling för att driva dem med el. Mätningen från studien kommer att ge viktigt underlag till forskning och industri för att bättre förstå och kunna dimensionera och planera t.ex. batteristorlek och laddinfrastruktur mm.

Hur långt och hur ofta, var och när bilar kör kommer att vara viktiga faktorer för hur mycket elbilar eller så kallade laddhybrider kan ladda och utnyttja batteriet. Detta påverkar exempelvis den enskilde bilägarens ekonomi, hur bilen ska dimensioneras och hur infrastrukturen i form av laddmöjligheter kan behöva byggas ut. Data över bilars rörelsemönster finns idag inte att tillgå, vi vill därför samla in data för hur olika bilar rör sig under en längre tidsperiod.

Läs gärna mer om projektet på följande sidor och på www.chalmers.se/brd

Tycker du att det här låter spännande och gärna deltar? Skicka in ditt godkännande av deltagande så snart som möjligt i det bifogade svarskuvertet. Vi skulle uppskatta att ha ditt svar inom 10 dagar efter att du mottagit denna förfrågan.

Med vänliga hälsningar

Sten Karlsson
Energi och Miljö
Chalmers Tekniska Högskola

Peter Lindgren
Test Site Sweden
Lindholmen Science Park

LINDHOLMEN SCIENCE PARK · CONSAT · CHALMERS
Energimyndigheten · Göteborg Energi · VATTENFALL · telenor

TSS
Test Site Sweden

Beskrivning av studien

Rörelsemönstret av ett antal bilar kommer att loggas under en mätperiod av två månader.
Vi kommer att logga position (latitud, longitud, altitud), hastighet och tidpunkt.
Totalt planerar vi att genomföra studien på 500 bilar, fördelat på 7 olika mätperioder med upp till 100 bilar i varje period. Projektet kommer att pågå under två år med start i mitten av juni, 2010.
Det är viktigt att vi får tillräcklig bredd i undersökningen, så oavsett om du är ung eller gammal eller om du kör mycket eller lite är din medverkan betydelsefull.

För de bilägare som vill delta i studien går det till på följande sätt:

- Du skriver under och skickar in det bifogade dokumentet ”godkännande av deltagande” i det bifogade svarskuvertet. Du kan endast delta med det efterfrågade fordonet.

- Vi skickar en liten loggningsutrustning till dig som du själv mycket enkelt installerar i fordonet. Instruktioner följer med loggern. Med hjälp av GPS-positionering sänds mätdata om hur fordonets framförs. Du ska köra bilen precis som vanligt.

- Utrustningen skickar kontinuerligt data till vår server under hela mätperioden.

- Det statistiska underlag som blir resultat av studien kommer att visa hur körmönstret ser ut idag för svenska bilar på olika typer av vägar.

- De insamlade uppgifterna användas endast i forskningssyfte och hanteras enligt personuppgiftslagen. All mätdata hanteras konfidentiellt.

Vi hoppas att du vill vara med i den spännande utveckling som pågår!

TSS • Lindholmen Science Park • Box 8077 • SE-402 78 • Göteborg • Sweden
Tel. +46 (0)31-340 00 76 • Fax +46 (0)31 764 70 49 • www.testsitesweden.eu

TSS
Test Site Sweden

Frivilligt deltagande

Ditt deltagande i studien är helt och hållet frivilligt.

Rätt att avbryta

Du har rätt att när som helst begära att insamlingen av data avbryts utan att ange något skäl.

Eventuella risker

Vi vill att du kör precis som vanligt och därför innebär denna studie inga andra risker utöver vad som är förknippat med vanlig körning. Det är alltså du som förare (alternativa förare) som fortfarande har det fulla ansvaret för ett säkert framförande av fordonet.

Informationsplikt

Du är skyldig att informera alternativa förare om datainsamlingen.

Behandling av personuppgifter och data

När du deltar i denna studie kommer vissa personuppgifter att samlas in om dig. Utöver det som insamlas automatiskt i fordonet, kommer vi att be dig om vissa uppgifter om dig och eventuellt andra förare, t.ex. ålder och kön på förare och deras ungefärliga andel av totala körningen. För behandlingen av alla uppgifter som går att härröra till dig som person gäller reglerna i personuppgiftslagen (1998:204), PuL.

Kontakt och support

Om du har några frågor eller kommentarer gällande studien har du möjlighet att besöka vår hemsida www.chalmers.se/brd. På hemsidan kan du fylla i din fråga i ett frågeformulär så hör vi av oss. Alternativt kan du ringa vår supporttelefon 031-340 00 76 (telefonsupporten går via Consat AB).

TSS • Lindholmen Science Park • Box 8077 • SE-402 78 • Göteborg • Sweden
Tel. +46 (0)31-340 00 76 • Fax +46 (0)31 764 70 49 • www.testsitesweden.eu

Godkännande av deltagande

Om studien

Lindholmen Science Park AB (”**Lindholmen**”) bedriver tillsammans med Chalmers Tekniska Högskola och Consat AB ett forskningsprojekt innefattande en studie som syftar till att mäta bilrörelser (”**Studien**”). Studien är tänkt att utgöra ett underlag till forskning och industri för att bättre förstå och kunna dimensionera t ex batteristorlek och laddinfrastruktur. Studien genomförs i enlighet med de regler som anges i personuppgiftslagen (1998:204), med Lindholmen som personuppgiftsansvarig. Insamlade personuppgifter kommer enbart att användas i forskningssyfte samt behandlas konfidentiellt, såvida inte informationen måste lämnas ut enligt lag, förordning eller myndighetsföreskrift.

Deltagarna har rätt att en gång om året, kostnadsfritt, få information om vilka personuppgifter Lindholmen har om dem samt om hur dessa används. Sådan begäran från deltagare ska göras skriftligen. Deltagarna har också alltid rätt att skriftligen begära rättelse av felaktiga personuppgifter och att återkalla lämnade samtycken. Kontakta Lindholmen för begäran om information, rättelse etc., på följande adress:
TSS, Lindholmen Science Park AB, Box 8077, 402 78 Göteborg.

Om mitt deltagande

Jag godkänner att följande villkor gäller för mitt deltagande i Studien.

1. Jag har läst och förstått den information som jag har fått om Studien och jag samtycker till att information om min bils rörelsemönster (och därmed, indirekt, information om mig eller andra förare av bilen) samlas in, lagras och analyseras. Jag samtycker också till att uppgifterna sparas och återanvänds i framtida forskningsprojekt som rör bilars rörelsemönster, energieffektivitet, miljöegenskaper, trafiksäkerhet och/eller samhällsplanering.
2. Jag förbinder mig att, i enlighet med bifogade instruktioner, installera den loggningsutrustning som skickas till mig, inklusive GPS-enhet, kablar, dator och sändare. Jag åtar mig att vårda loggningsutrustningen varsamt samt inom en vecka efter Lindholmens begäran avinstallera utrustningen och returnera den i bifogat kuvert. Om problem uppstår med loggningsutrustningen under Studien kommer jag så snart som möjligt kontakta Lindholmen och följa de ytterligare instruktioner som jag då får.
3. Jag är införstådd med att bilen förväntas framföras på samma sätt som vanligt och att det är den som kör bilen som är ansvarig för körningen.
4. Jag förbinder mig att informera eventuella andra förare av bilen om Studien och att loggningsutrustningen kommer att registrera även deras körning. Jag kommer även att informera eventuella passagerare om Studien och inte tvinga någon att köra eller åka med i bilen som på grund av Studien inte vill det.
5. Jag förstår att mitt deltagande i Studien är frivilligt och att jag när som helst kan välja att avbryta det.
6. Jag accepterar att jag inte är berättigad till någon ersättning för mitt deltagande i Studien.

* * *

☐ Nej, jag vill inte delta i Studien och vill inte ha mer information eller påminnelser

Motivera gärna kort varför du inte vill delta i studien: ___________________________________

Dina kontaktuppgifter: telefon:__________________ e-post:___________________________

Bilens registreringsnummer:_________________________

Datum och plats:___________________________________

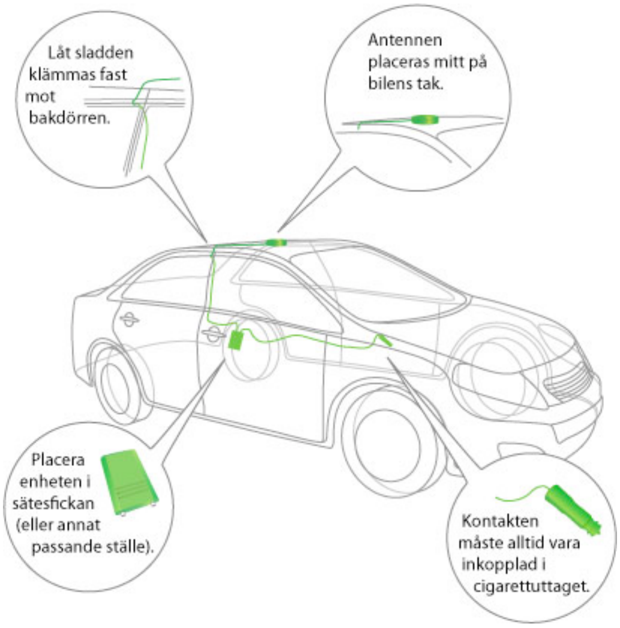
Signatur:_____________________ Namnförtydligande:________________________________

Instruktioner för deltagare i projektet Bilrörelsedata

Bästa deltagare!

Du får här mätutrustningen som ska användas i projektet Bilrörelsedata. Var vänlig att installera utrustningen enligt anvisningarna nedan så snart som möjligt, och senast 7 dagar efter leverans. När mätningen är slut kommer enheten att börja pipa; det är då dags att skicka tillbaka utrustningen. Vi tackar vänligast för din medverkan.

Du kan följa projektets utveckling på hemsidan: www.chalmers.se/brd, där finns även ytterligare information och kontaktuppgifter. Maila i första hand dina frågor till supportbrd@consat.se, i andra hand kan vi även bistå med hjälp på supporttelefonen: 031-340 00 76.



1) Torka bort grus och smuts och placera den magnetiska GPS-antennen mitt på taket.
   - Har du tyg, glas eller plasttak får antennen placeras inne i bilen så nära taket som möjligt.
   - Tänk på att plocka in antennen vid biltvätt!

2) Låt sladden från GPS-antennen klämmas fast i bildörren, förslagsvis på passagerarsidan.
   - Sladdarna kan vara känsliga, har du barn i bilen placeras enhet med sladdar lämpligen utom räckhåll för barnet.

3) Placera enheten i sätesfickan.
    - Har du andra lämpliga ställen att lägga enheten på går det lika bra, tänk dock på att sladden inte får vara i vägen och att enheten inte får utsättas för sparkar eller smuts.

4) Kontakten ska alltid vara inkopplad i 12volts-uttaget (cigarettändaruttaget). Välj det uttag i bilen som passar dig bäst.
    - När enheten får ström skall lamporna lysa/blinka.
    - Behöver du använda cigarettuttaget till annat, efterfråga en förgreningskontakt av oss.
    - Om lamporna på enheten lyser även när tändningen är av och bilen förväntas stå stilla mer än 10 dagar bör kontakten kopplas ur för att undvika att bilbatteriet laddas ur.

5) Fyll i bilens mätarställning vid mätperiodens början på etiketten som sitter på enhetens ovansida. När mätperioden är slut fylls mätarställningen vid den tidpunkten i. Anledningen till att detta är viktigt är för att vi ska kunna analysera om enheterna har fungerat bra under mätperioden och tagit upp all data vi behöver.
6) Kör som vanligt. Om vi inte skulle få någon signal kontaktar vi dig och ser om det är något som gått fel.
7) Efter ungefär två månader börjar utrustningen att pipa. Det betyder att mätningarna är klara. Koppla ur utrustningen och packa den varsamt i det medföljande bubbelkuvertet. Fyll även i enkäten och lägg i kuvertet. Lägg kuvertet direkt i brevlådan, det är förberett med frankering och adress.

APPENDIX E. THE ROAD CLASSIFICATION

Table E.1. The ID for road classification categories connected to each data point.

ID	NAME	SPEED_LIMIT	IS_URBAN	IS_HIGHWAY
1	Testsite_Sweden50	50	1	0
2	Sverige10051270	70	0	0
3	Sverige10051250	50	1	0
4	Sverige1005120	0	1	0
5	Sverige10051230	30	1	0
6	Sverige10051230	30	0	0
7	Sverige10051280	80	0	0
8	Sverige10051260	60	0	0
9	Sverige10051250	50	0	0
10	Sverige1005120	0	0	0
11	Sverige100512110	110	0	1
12	Sverige10051250	50	0	1
13	Sverige10051270	70	0	1
14	Sverige10051270	70	1	0
15	Sverige10051290	90	0	1
16	Sverige10051250	50	1	1
17	Sverige1005120	-120	1	1
18	Sverige10051230	30	1	1
19	Sverige10051270	70	1	1
20	Sverige10051280	80	0	1
21	Sverige10051290	90	1	1
22	Sverige1005120	0	0	1
23	Sverige10051290	90	0	0
24	Sverige10051240	40	1	1
25	Sverige10051230	30	0	1
26	Sverige1005125	5	1	0
27	Sverige10051240	40	1	0
28	Sverige10051260	60	0	1
29	Sverige10051260	60	1	1
30	Sverige100512110	110	1	1
31	Sverige10051260	60	1	0
32	Sverige1005125	5	1	1
33	Sverige100512120	120	0	1
34	Sverige100512120	120	1	1
35	Sverige100512100	100	0	1
36	Sverige100512100	100	0	-20
37	Sverige10051280	80	1	1
38	Sverige10051280	80	1	0
39	Sverige10051290	90	1	0
40	Sverige100512120	120	0	0
41	Sverige1005120	0	1	1
42	Sverige100512100	100	1	1
43	Sverige100512110	110	0	0
44	Sverige100512100	100	0	0
45	Sverige10051240	40	0	0
46	Sverige100512100	100	1	0
47	Sverige10051220	20	1	0
48	Sverige100512110	110	1	0

This is a documentation of the BRD.jar application, source code and the calculations that are done, as well as an overview of the surrounding database structure.

1 The source and destination databases, and the BRD.jar application.

The source database (tss_ev) is where data is stored in raw format, and the destionation database (tss_calc) is where data is stored after calculations are completed. The purpose of BRD.jar is to read data from the source database, divide it into trips, make calculations and write the results back to the destination database.

1.1 Source database (tss_ev)

The structure of the source database is not discussed here.

1.2 Destination database (tss_calc)

The destination database conatains the following tables.

Table name	Description
device_data	Contains all the logged data. One row per logged set of data.
trip_stats	Contains information on the trip level. One row per trip.
device_stats	Contains data on the device level. One row per device.
arrays	Complement to the device_stats table. Contains 2D data for devices that not are suitable to store in the device_stats table (currently only acceleration vs. speed histogram).

1.2.1 The device_data table

A single row in the device_data table contains the following columns. (Note that each ROW in this table corresponds to a COLUMN in the device_data table)

Column name in database table	Unit/format	Description	How this is calculated by BRD.jar
iddevice_data	-	Unique id.	-
project	-	Project id as specified in tss_ev.PROJECTS	Manualy entered into the BRD application at calculation.
device	-	The device this device data belongs to.	Transfered from the DEVICES_ID that is associated to each sample in the source database.
trip	-	The trip this belongs to. Counts from one and up for each device.	The TripBundle divides all data from a single device into a set of ordered trips. This number reflects to which trip in that order this device data belongs to.
timestamp	milliseconds	UNIX timestamp. (Uncertain if leap seconds are included or not)	Copied from the milliseconds value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
timestamp_string	"YYYY-MM-DD HH:MM:SS.d"	Timestamp on the format "YYYY-MM-DD HH:MM:SS.d".	Converted from the milliseconds value.
altitude	m	Altitude in m. (Unknown how reliable this value is).	Copied from the altitude value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
latitude	degrees	Latitude	Copied from the latitude value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)

longitude	degrees	Longitude	Copied from the longitude value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
speed	km/h	Speed in km/h.	Copied from the speed value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
direction	degrees	Direction in degrees.	Copied from the direction value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
last_valid_timestamp	milliseconds	Last valid timestamp in milliseconds (precission is down to seconds, so two and three entries alternating are equal to each other even when everything is alright.)	Copied from the milliseconds value in the source database. (In case the satellites, Xdop values are zero, this is an interpolated value between the the last and next device data with non zero satellite and Xdop values.)
satellites	-	Number indicating which satellites where used to measure these values.	Copied from the satellites value in the source database. (In case the satellites, Xdop values are zero, this value belongs to a device data for which values have been interpolated between the last and next device data with non zero satellite and Xdop values.)
pdop	-	Positional (3D) dilution of precision. (Multiplied by a factor ten).	Copied from the pdop value in the source database. (In case the satellites, Xdop values are zero, this value belongs to a device data for which values have been interpolated between the last and next device data with non zero satellite and Xdop values.)
hdop	-	Horizontal dilution of precision. (Multiplied by a factor ten).	Copied from the hdop value in the source database. (In case the satellites, Xdop values are zero, this value belongs to a device data for which values have been interpolated between the last and next device data with non zero satellite and Xdop values.)
vdop	-	Vertical dilution of precision. (Multiplied by a factor ten).	Copied from the vdop value in the source database. (In case the satellites, Xdop values are zero, this value belongs to a device data for which values have been interpolated between the last and next device data with non zero satellite and Xdop values.)

1.2.2 The trip_stats table

A single row in the trip_stats table has the following structure. (Note that each ROW in this table corresponds to a COLUMN in the trip_stats table)

Column name in database table	**Unit/format**	**Description**	**How this is calculated by BRD.jar**	**The function in BRD.jar that returns this value.**
idtrip_stats	-	Unique id	-	-
project	-	Project id as specified in tss_ev.PROJECTS	Manualy entered into the BRD application at calculation.	-
device	-	the device this trip belongs to.	Transfered from the DEVICES_ID that is associated with each device data that belongs to this device in the source database.	-
trip	-	A from 1 monotonely increasing id that uniqly identifies the trip for this device.	The TripBundle divides all data from a single device into a set of ordered trips. This number reflect which number in this order this trip has.	-
final_velocity	km/h	The velocity at the end of the trip (km/h). (To be able to identify trips that has ended because the data stream stoped for some reason other than that the car stoped. That is, if the end velocity not is close to zero.)	Speed value for the last data points.	Trip::getAveragedFinalVelocity()
start_latitude	degrees	The latitude at the start point.	Taken from the latitude coordinate for the first device data in this trip.	Trip::getStartLatitude()
start_longitude	degrees	The longitude at the start point.	Taken from the longitude coordinate for the first device data	Trip::getStartLongitude()

			in this trip.	
stop_latitude	degrees	The latitude at the stop point.	Taken from the latitude coordinate for the last device data in this trip.	Trip::getStopLatitude()
stop_longitude	degrees	The longitude at the stop point.	Taken from the longitude coordinate for the last device data in this trip.	Trip::getStopLongitude()
average_velocity	km/h	Average velocity. (km/h)	Calculated as the sum of the speed values for each device data in this trip, divided by the number of device data in this trip.	Trip::getAverageVelocity()
average_velocity_squared	km/h (not km^2/h^2)	The square root of the average of the squared velocity. (km/h)	Calculated by summing the squares of the speed values for each device data in this trip, then dividing by the total number of device data in the trip, and finally taking the square root of the whole expression.	Trip::getAverageVelocitySquared()
average_velocity_cubed	km/h (not km^3/h^3)	The cube root of the average of the cubed velocity. (km/h)	calculated by summing the cube of the speed values for each device data in this trip, then dividing by the total number of device data in this trip, and finally taking the cube root of the whole expression.	Trip::getAverageVelocityCubed()
distance	km	The distance traveled during this trip. (km)	Calculated by integrating the speed values over all device data.	Trip::getDistance()
pause_before	seconds	The number of milliseconds between the end of the last trip and the start of this, and then divided by 1000. Zero if this is the first trip. (seconds)	Calculated as the difference in the milliseconds value for the first device data in this trip and the last device data in the previous trip. Or zero if there is no previous trip.	Trip::getPauseBefore()
pause_after	seconds	The number of seconds between the end of this trip and the start of the next. Zero if this is the last trip. (seconds)	Calculated as the difference in the milliseconds value for the first device data in the next trip and the last device data in this trip, and then divided by 1000. Or zero if there is no previous trip.	Trip::getPauseAfter()
duration	seconds	The duration of this trip in seconds. (seconds)	Calculated as the difference in milliseconds between the first and last device data for this trip, and then divided by 1000.	Trip::getDuration()
start_time	milliseconds	UNIX timestamp for the start of this trip.	Taken from the milliseconds value in the first device data for this trip.	Trip::getStartTime()
stop_time	milliseconds	UNIX timestamp for the stop of this trip.	Taken from the milliseconds value in the last device data for this trip.	Trip::getStopTime()
start_time_string	"YYYY-MM-DD HH:MM:SS"	Start time for this trip in the format "YYYY-MM-DD HH:MM:SS".	Converted from the milliseconds value for the first device data in this trip.	Trip::getStartTimeString()
stop_time_string	"YYYY-MM-DD HH:MM:SS"	Stop time for this trip in the format "YYYY-MM-DD HH:MM:SS"	Converted from the milliseconds value for the last device data in this trip.	Trip::getStopTimeString()
num_corrected_speed_values	-	Number of speed values that was corrected with Trip::correctBadSpeedValues() for this trip.	Incremented each time a speed value is corrected by the function Trip::correctBadSpeedValues().	Trip::getNumberOfcorrectedSpeedValues()
num_interpolation_regions	-	Number of regions where trips have been merged together and data has been interpolated by the function TripBundle::mergeShortPauseTrips.	Incremented each time two trips are merged in TripBundle::mergeShortPausetrips().	Trip::getNumberOfInterpolationRegions()
num_interpolation_points	-	Number of points that was interpolated when trips where merged with TripBundle::mergeShortPauseTrips().	Incremented each time an interpolated value is added in the function TripBundle:mergeShortPauseTrips().	Trip::getNumberOfInterpolationPoints()

1.2.3 The device_stats table

A single row in the device_stats table has the following structure (Note that each ROW in this table corresponds to a COLUMN, or a set of columns in the case of a histogram, in the device_stats table)

Column name in database table	Unit/format	Description	How this is calculated by BRD.jar	The function in BRD.jar that returns this value.
iddevice_stats	-	Unique id.	-	-
project	-	Project id as specified in tss_ev.PROJECTS	Manualy entered into the BRD application at calculation.	-
device	-	The device this trip belongs to.	Transfered from the DEVICES_ID that is accosiated with each device data that belongs to this device in the source database.	-
num_trips	-	Number of trips for this device.	The number of trips that the TripBundle divides the DeviceLog into.	Trip::getNumberOfTrips()
first_time	milliseconds	UNIX timestamp for the first logged value for this device.	Taken from the milliseconds value for the first device data in the first trip.	TripBundle::getFirstTime()
last_time	milliseconds	UNIX timestamp for the last logged value for this device.	Taken from the milliseconds value for the last device data in the last trip.	TripBundle::getLastTime()
first_time_string	"YYYY-MM-DD HH:MM:SS"	Time for the first logged value for this device in the format "YYYY-MM-DD HH:MM:SS".	Converted from the milliseconds value for the first device data in the first trip.	TripBundle::getFirstTimeString()
last_time_string	"YYYY-MM-DD HH:MM:SS"	Time for the last logged value for this device in the format "YYYY-MM-DD HH:MM:SS".	Converted from the milliseconds value for the last device data in the last trip.	TripBundle::getLastTimeString()
total_length	km	Total distance traveled by this device. (km)	Calculated as the sum of the individual trips distances.	TripBundle::getTotalTripLength()
mean_trip_length	km	Average trip length. (km)	Calculated as the total trip length, divided by the number of trips.	TripBundle::getMeanTripLength()
max_trip_length	km	Maximum trip length. (km)	Calculated by finding the max of the individual trip lengths.	TripBundle::getMaxTripLength()
num_defect_entries_discarded	-	Number of entries that was discarded because not all values for that device data existed.	Each time a device data that misses one or several values is filtered away in DeviceLog::filter(), this value is incremented.	TripBundle::numberOfDefectEntriesDiscarded()
num_early_entries_discarded	-	Number of entries that was discarded because they had a timestamp that was before the UNIX timestamp defined by Parameters::DISCARD_ENTRIES_BEFORE.	Each time an early entry (as defined by having a UNIX timestamp that is earlier than Parameters::DISCARD_ENTRIES_BEFORE) is encountered by the function DeviceLog::filter(), that value is discarded and the counter is incremented.	TripBundle::numberOfEarlyDiscardedEntries
num_late_entries_discarded	-	Number of entries that was discarded because they had a timestamp that was larger than the UNIT timestamp defined by Parameters::DISCARD_ENTRIES_AFTER.	Each time a late entry (as defined by having a UNIX timestamp that is later than Parameters::DISCARD_ENTRIES_AFTER) is encountered by the function DeviceLog::filter(), that value is discarded and the counter is incremented.	TripBundle::numberOfEarlyDiscardedEntries
num_overlapping_entries_discarded	-	Number of entries that was discarded by DeviceLog::filter() because they were multiples of an already existing device data.	Each time a multiple of a device data is encountered by DeviceLog::filter, the value is discarded and a counter incremented.	TripBundle::numberOfOverlappingEntriesDiscarded()
num_zero_speed_entries_discarded	-	Number of entries that was discarded by DeviceLog::filter() because they where part of a continuous stream of zero-speed-values that	When a continuous stream of more than 10 minutes of device data with speed values smaller than 0.1 is encountered by the function	TripBundle::numberOfOverlappingEntriesDiscarded()

		was longer than 10 minutes. (The first 10 minutes are not discarded)	DeviceLog::filter(), the entries after the initial 10 minute period are discarded until a value with larger velocity is encountered. Each time such a value is discarded a counter is incremented.	
trip_length_histogram_(x)	-	16 columns that together form a histogram over trip lengths. Each column in order contains the number of trips that falls within the following intervals (The value (x) at the end of each column name being the right hand limit for the interval): 0-1, 1-2, 2-3, 3-5, 5-7, 7-10, 10-15, 15-20, 20-30, 30-50, 50-70, 70-100, 100-200, 200-300, 300-500, 500+. (km)	Calculated by stepping through all the trips for this device and incrementing the pile which corresponds to the trips length.	TripBundle::getTripLengthHistogram()
total_travel_time	seconds	Total time this device have measured data. (seconds)	Calculated by adding the duration for each each trip.	TripBundle::getTotalTravelTime()
max_speed	km/h	The maximum speed. (km/h)	Calculated by finding the device data with largest speed value.	TripBundle::getMaxSpeed()
average_velocity	km/h	Average velocity. (km/h)	Calculated by adding the average velocity for each trip multiplied by the duration of that same trip, and finally dividing the ansver by the total travel time.	TripBundle::getAverageVelocity()
average_velocity_squared	km/h (not km^2/h^2)	Square root of the average velocity squared. (km/h)	Calculated by adding the average velocity squared for each trip multiplied by the duration of that same trip, and finally dividing the answer by the total travel time and taking the square root.	TripBundle::getAverageVelocitySquared()
average_velocity_cubed	km/h (not km^3/h^3)	Cube root of the average velocity cubed. (km/h)	Calculated by adding the the average velocity cubed for each trip multiplied by the duration of that same trip, and finally dividing the answer by the total travel time and taking the cube root.	TripBundle::getAverageVelocitySquared()
speed_histogram_(x)	seconds	14 columns that together form a histogram over speeds. Each column contains the number of seconds that has been been spent in the corresponding speed interval (The value (x) at the end of each column name being the right hand limit for the interval). Intervals: 0-0.1, 0.1-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120, 120+. (km/h)	Calculated by stepping through all the device data for this device and incrementing the pile which corresponds to the speed value, and finally dividing by the sampling frequency (2.5Hz).	TripBundle::getSpeedHistogram()
average_positive_acceleration_times_speed	m^2/s^3	The average value for the positive acceleration*speed (sum of positive values, divided by the total travel time). (m^2/s^3)	Calculated by summing all positive acceleration*speed values, and then dividing by the total travel time. (Note that summation only occurs for a subset, while division occurs by the whole set.)	TripBundle::getAveragePositiveAccelerationTimesSpeed()
average_negative_acceleration_times_speed	m^2/s^3	The average value for the negative acceleration*speed (sum of negative values,	Calculated by summing all negative acceleration*speed values, and then dividing by	TripBundle::getAverageNegativeAccelerationTimesSpeed()

		divided by the total travel time). (m^2/s^3)	the total travel time. (Note that summation only occurs for a subset, while division occurs by the whole set.)	
num_corrected_speed_values	-	Number of speed values that fell outside of the interval +/-Parameters::VALID_SPEED_CUTOFF and was corrected by TripBundle::correctBadSpeedValues().	When correction of bad speed values is done by TripBundle::correctBadSpeedValues(), a counter is incremented each time a value outside of the allowed interval is corrected.	TripBundle::getNumberOfCorrectedSpeedValues()
num_interpolation_regions	-	Number of regions where interpolated values have been inserted.	When trips are merged and intermediate values interpolated in TripBundle::mergeShortPauseTrips(), a counter is incremented each time two trips are merged and points are inserted in between.	TripBundle::getNumberOfInterpolationRegions()
num_interpolation_points	-	Number of points that where interpolated with TripBundle::mergeShortPauseTrips().	When trips are merged and intermediate values interpolated in TripBundle::mergeShortPauseTrips(), a counter is incremented each time an interpolation point is inserted.	TripBundle::getNumberOfInterpolationPoints()
average_num_trips_per_day	-	Average number of trips per day.	Calculated as the total number of trips divided by the length of the measureing period. Where the length of the measuring period is defined as the time between the first and last logged value + one average pause time. ()	TripBundle::getAverageNumberOfTripsPerDay()
max_num_trips_per_day	-	Maximum number of trips per day.	Calculated as the maximum number of trips that has occurred between 03:00-03:00 two days in a row. Note that the day in this calculation not is defined to be 00:00-24:00 because it can be expected that some trips home after a late evening will start after 24:00 but still most intuitively is counted as belonging to the previous day.	TripBundle::getMaxNumberOfTripsPerDay()
pause_time_histogram_(x)	-	13 columns that together form a histogram over pause times. Each column contains the number of pauses that has the corresponding pause length (The value (x) at the end of each column name being the right hand limit for the interval). Intervals: 0-0.1, 0.1-0.5, 0.5-1, 1-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-24, 24-48, 48-96, 96+. (hours)	Calculated by stepping through the trips (except the last) and incrementing the pile that corresponds to the pause length of the pause after that trip.	TripBundle::getPausetimeHistogram()
travel_time_point_histogram_(x)	seconds	24 columns that together form a histogram over the times at which the device has been turned on. Each column contains the number of seconds that the device has been on in the corresponding time interval (The value (x) at the end of each column name being the right hand limit for the interval). Intervals: 00:00-01:00, 01:00-02:00, 02:00-03:00,	Calculated by stepping through each device data and incrementing the pile that corresponds to the hour (converted from the milliseconds value) of that data and finally dividing the result by the sampling frequency (2.5Hz)	TripBundle::gettravelTimePointHistogram()

		03:00-04:00, 04:00-05:00, 05:00-06:00, 06:00-07:00, 07:00-08:00, 08:00-09:00, 09:00-10:00, 10:00-11:00, 11:00-12:00, 12:00-13:00, 13:00-14:00, 14:00-15:00, 15:00-16:00, 16:00-17:00, 17:00-18:00, 18:00-19:00, 19:00-20:00, 20:00:21:00, 21:00-22:00, 22:00-23:00, 23:00-24:00.		
trip_length_per_day_histogram_(x)	-	17 columns that together form a histogram over daily trip lengths. Each column contains the number of days that the trip length fell in the corresponding interval (The value (x) at the end of each column name being the right hand limit for the interval). Intervals: 0, 0-1, 1-2, 2-3, 3-5, 5-7, 7-10, 10-15, 15-20, 20-30, 30-50, 50-70, 70-100, 100-200, 200-300, 300-500, 500+. (km)	Calculated by stepping through the trips and adding the trip lengths for trips that start between 03:00 one day and 03:00 the next day, and then incrementing the pile which corresponds to the trip length achived. Note that the day starts at 03:00 instead of 00:00 because it's more natural to count trips that starts in the early parts of the day as belonging to the previous day.	TripBundle::getTripLengthPerDayHistogram()
num_trips_per_day_histogram_(x)	-	11 columns that together form a histogram over number of trips per day. Each column contains the number of days that had the corresponding number of trips (The value (x) at the end of each column name being the right hand limit for the interval). Intervals: 0, 0-1, 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9+.	Calculated by stepping through the trips and incrementing a counter each time a new trip that starts the same day as the previous trip and resetting the counter to 1 each time a trip starts at the next day. Thus calculating the number of trips in a day. Before resetting the counter when a trip from a new day is encountered the pile that corresponds to the number of trips just counted is incremented by one. If the trip that restarts the counting is several days after the last trip, the number of days between these to trips (not counting the days of the current or previous trip) is added to the zero pile that counts the number of days there were no trips. Note that the day starts at 03:00 instead of 24:00 because it's more natural to associate trips that starts in the very early hours with the previous day.	TripBundle::getNumberOfTripsPerDayHistogram()

1.2.4 The arrays table

The arrays table has a different structure than the other tables, and it is a complement to the device_stats table for storing two dimensional structures. Currently only the acceleration vs. speed histogram. Each row in this table corresponds to an entry for a specific coordinate in a specific 2D array. The device row identifies which device the data belongs to, while the type column defines what array it belongs to (currently only type=1 which is acceleration vs speed histogram). The three other columns are the x and y coordinate and the value at that coordinate. The values that fall outside of the diagram falls into the boundary. That is, the rows with extreme (max or min) coordinates contains values that are the sum of the entries that falls outside the boundary at that x or y value. (Note that each ROW here corresponds to a COLUMN in the arrays table.)

Column name in database table	**Description**
idarrays	Unique id.
project	Project id as specified in tss_ev.PROJECTS
device	The device this array belongs to.
value	The value at the coordinate given in the x and y columns.
type	Type of array (= 1 for acceleration vs. speed histogram)

x	x coordinate.
y	y coordinate.

The Paramters class

All calculation are dependent upon the values define in the Paramters class. The values in this file are summarized in the following table.

Parameter	Description	Current value	Used in
DEBUG_MODE	If true, only a small subset of values for a single device will be loaded from the source database. To allow quick testing of code.	false	Database::loadDevice()
WRITELESS_DEBUG_MODE	If true, no data will be written to the destination database.	false	BRDCalculator::run()
FORCE_ESTABLISHED_CONNECTION	Will make the program quit if a connection to the source or destination database not can be established.	true	Database::connectToDatabases(int port)
DISCARD_ENTRIES_BEFORE	Defines a UNIX timestamp for which device data will be discarded if their timestamp is less than. (To get rid of bad values)	1100000000000l (about year 2005)	DeviceLog::filter()
DISCARD_ENTRIES_AFTER	Defines a UNIX timestamp for which device data will be discarded if their timestamp is larger than. (To get rid of bad values)	1400000000000l (about year 2014)	DeviceLog::filter()
DEVICE_DATA_PAGE_SIZE	Number of device data stored on a single page. (Used to be able to page in and out subsets of the data to avoid memory usage running high)	350	DeviceDataStorage
PAGES_PER_DEVICE_DATA_PAGE_OUT	Number of pages that are paged out each time the maximum pages in memory is reached. (Used to be able to page in and out subsets of the data to avoid memory usage running high)	25	DeviceDataStorage::pageOut()
MAX_NUM_PAGES_IN_MEMORY	Maximum number of pages in memory before data is paged out. (Used to be able to page in and out subsets of the data to avoid memory usage running high)	4000	DeviceDataStorage
MYSQL_PAGE_SIZE	Maximum number of rows that are read from the source database at a time. (A different paging than	500000	Database::loadDevice()

	the other three values are related to)		
SAMPLING_FREQUENCY	Number of samplings per second.	2.5	Trip, Trip::getSpeedHistogram(), Trip::getTravelTimePointHistogram(), Trip::getAccelerationVsSpeedHistogram(), trip::calculateMinMaxAccelerationTimesSpeed().
SAMPLING_INTERVAL	Number of milliseconds between two consecutive logged values. (= 100/SAMPLING_FREQUENCY)	400	TripBundle::mergeShortPauseTrips()
TRIP_DIVISION_INTERVAL	Maximum number of milliseconds between two consecutive device data that is allowed without making a breakpoint between two trips in the first division into trips.	400	TripBundle::TripBundle(DeviceLog deviceLog)
VALID_SPEED_CUTOFF	+/-VALID_SPEED_CUTOFF (km/h) is used as a window for acceptable speed values. Used to identify bad speed values.	500	Trip::correctBadSpeedValues()
SHORT_PAUSE_CUTOFF	Two consecutive trips with a pause between that is smaller than this (in milliseconds) are merged into a single trip with linearly interpolated values where the pause was.	10*1000 (10 seconds), or 60*1000 (60 seconds) depending on version. So far BRD been run with 10 seconds to prioritize minimal amount of interpolated data, while project 6,7,8 has been run with 60 seconds to prioritize that trips not get divided into multiple trips because of short periods of lost data.	TripBundle::mergeShortPauseTrips()
FINAL_VELOCITY_AVERAGING_INTERVAL	Number of device data entries that are used to average over when calculating the velocity at the end of the trip.	5	Trip::getAveragedFinalVelocity()
INFINITY	Large number used to represent infinity in the histogram limits.	0xFFFFFFFF (= 4294967295)	Paramters
TRIP_LENGTH_HISTOGRAM_INTERVALS	Array of right hand values for trip length histogram intervals in km. (Left hand limit in the column before, and first left hand limit is 0)	1, 2, 3, 5, 7, 10, 15, 20, 30, 50, 70, 100, 200, 300, 500, INFINITY	TripBundle::getTripLengthHistogram()
SPEED_HISTOGRAM_INTERVALS	Array of right hand values for speed histogram intervals in km/h. (Left hand limit in the column before, and first left hand limit is 0)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, INFINITY	Trip::getSpeedHistogram(), TripBundle::getSpeedHistogram()
PAUSE_TIME_HISTOGRAM_INTERVALS	Array of right hand values for pause time histogram intervals in	360000, 1800000, 3600000, 7200000, 14400000, 21600000,	TripBundle::getPauseTimeHistogram()

	milliseconds. (Left hand limit in the column before, and first left hand limit is 0)	28800000, 36000000, 54000000, 86400000, 172800000, 345600000, INFINITY	
TRAVEL_TIME_POINT_HISTOGRAM_INTERVALS	Array of right hand values for travel time point histogram intervals in hours of the day. (Left hand limit in the column before, and first left hand limit is 0)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	Trip::getTravelTimePointHistogram(), tripBundle::getTravelTimePointHistogram()
NUMBER_OF_TRIPS_PER_DAY_HISTOGRAM_INTERVALS	Array of right hand values for number of tips per day histogram intervals. (Left hand limit in the column before. First column is exactly 0)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, INFINITY	tripBundle::getNumberOfTripsPerDayHistogram()
TRIP_LENGTH_PER_DAY_HISTOGRAM_INTERVALS	Array of right hand values for trip length per day histogram intervals in km. (Left hand limit in the column before. First column is exactly 0)	0, 1, 2, 3, 5, 7, 10, 15, 20, 30, 50, 70, 100, 200, 300, 500, INFINITY	TripBundle::getTripLengthPerDayHistogram()
AVERAGED_FINAL_VELOCITIES_HISTOGRAM_INTERVALS	Array of right hand values for averaged final velocities histogram intervals in km/h. (Left hand limit in the column before, and first left hand limit is 0)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, INFINITY	TripBundle::getAveragedFinalVelocitiesHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_SPEED_MIN	Minimum value on speed axis for acceleration vs speed histogram in km/h.	0	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_SPEED_MAX	Maximum value on speed axis for acceleration vs speed histogram in km/h.	150	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_SPEED_INTERVALS_PER_UNIT	Speed interval size for acceleration vs speed histogram in 1/(km/h).	1/2	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_ACCELERATION_MIN	Minimum value on acceleration axis for acceleration vs speed histogram in m/s^2.	-10	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_ACCELERATION_MAX	Maximum value on acceleration axis for acceleration vs speed histogram in m/s^2.	10	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
ACCELERATION_VS_SPEED_HISTOGRAM_ACCELERATION_INTERVALS_PER_UNIT	Acceleration interval size for acceleration vs speed histogram in 1/(m/s^2).	40	Trip::getAccelerationVsSpeedHistogram(), TripBundle::getAccelerationVsSpeedHistogram()
DAY_BREAK_POINT	Defines what hour of the day a trip is counted to belong to one or another hour. (To make sure that trips that starts after 24:00, but is home trips for late evening events are counted as belonging to the	3	Trip::getStartDay()

	previous day.)		
ZERO_SPEED_CUTOFF	Value used in DeviceLog::filter() to identify when the car is standing still. (km/h)	0.1	DeviceLog::filter()
MAX_ZERO_SPEEDS_IN_A_ROW	How many zero-speed entries to accept in deviceLog::filter() before starting to throw away the values. To get rid of data collected when the car was turned of, but the device still continued to work. (Should not be too small because data collected while in queues, at red lights, and other normal stops should not be thrown away).	5*60*SAMPLING_FREQUENCY (= 5 min)	DeviceLog::filter()
MAX_SPEED_AVERAGING_INTERVAL	Number of device data that are averaged over when max speed is calculated.	10	Trip::getMaxSpeed()
KNOT_TO_KM_H	Conversion factor from knot to km/h.	1.852	DeviceLog::loadDevice()

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Enkät för deltagare i projekt Bilrörelsedata

Det här är en mindre enkät som vi vill att alla bilägare som deltagit i projekt Bilrörelsedata ska fylla i och sända tillbaka tillsammans med utrustningen när mätningen är slut. Den behandlar fyra områden: Bilen och hushållet, körningen och förarna, laddmöjligheter samt erfarenheter av undersökningen. Vid frågor om enkäten, hör gärna av dig.

Tackar på förhand

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A. Bilen och hushållet

a) Bilens registreringsnummer? ________

b) Antal personer i hushållet över 18 år? ________

c) Antal personer i hushållet under 18 år? ________

d) Antal körkort i hushållet? ________

e) Antal bilar i hushållet? ________

Om fler än en bil i hushållet: På vilken plats i rangordningen av dessa (1:a, 2:a, 3:e, …) kommer bilen vad gäller:

e.1) Körsträcka (längst körsträcka = 1:a) ________

e.2) Ålder (yngst = 1:a) ________

e.3) Storlek (störst = 1:a) ________

B. Körningen, förarna och lasten under mätperioden

a) Ungefärligt antal mil som bilen körs per år? ________ mil/år

b) Användes bilen under mätperioden regelbundet för pendling till arbete/studier?

☐ Ja, bilen stod då oftast parkerad på följande adress/området:

____

☐ Ja, men bilen stod inte parkerad på någon särskilt plats under arbetstid (den användes oftast i arbetet, på olika arbetsplatser, etc.)

☐ Nej

c) Uppskatta hur stor andel av körsträckan under mätperioden som olika personer har varit förare. Markera även respektive förares ålder med ett kryss i tabellen.

	Andel av körsträcka:	Ålder: 16-30 år	31-45 år	46-60 år	> 60 år
Förare 1	%				
Förare 2	%				
Förare 3	%				
Övriga	%				
Totalt	*100 %*				

d) Uppskatta hur stor andel av körsträckan under mätperioden som bilen framfördes *utan passagerare*, med *en passagerare* samt med *fler än en passagerare* (passagerare äldre än 10 år):

Ingen passagerare:	%	av körsträckan under mätperioden.
En passagerare:	%	av körsträckan under mätperioden.
Fler än en passagerare:	%	av körsträckan under mätperioden.
Totalt:	*100 %*	

e) Har bilen dragkrok?

☐ Ja, men den användes inte för att dra någon större last under mätperioden.

☐ Ja, och bilen drog en större last (t ex husvagn eller tyngre släpkärra) under delar av mätperioden, motsvarande en sträcka på ________ mil.

☐ Nej, bilen har ingen dragkrok.

f) Var körningen under mätperioden "mycket onormal" i relation till hur det brukar vara? Ja ☐ Nej ☐

*Med **ja** avser vi verkligt udda händelser som under en längre period påverkade hur bilen användes, exempelvis: Bilen stod på verkstad tre veckor (några dagar anses normalt) eller föraren var sjuk en månad och körde inte till arbetet som han/hon brukar (en enstaka vecka, eller semester är normalt).*

f.1) Du får gärna, men behöver inte, ange vad som var "onormalt" och vilken tidsperiod:

____

____

____

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C. Möjligheter att ladda en eventuell elbil/laddhybrid

a) Finns det idag ett eluttag tillgängligt där bilen parkeras/skulle kunna parkeras större delen av dygnet?

- ☐ Ja, eluttag finns nära
- ☐ Nej inte nu, men jag skulle kunna installera
- ☐ Nej inte nu, men jag kan enkelt ha en förlängningskabel
- ☐ Nej, inget av ovanstående

b) Används bilen regelbundet för pendling till arbete/studier (inte bara under mätperioden)? Ja ☐ Nej ☐

b.1) Om ja, ungefär hur lång sträcka enkel väg? __________ km/dag

b.2) Om ja, parkeras bilen regelbundet på ett ställe? Ja ☐ Nej ☐

b.2.1) Om ja, finns det på detta ställe tillgång till eluttag, t ex uttag för motorvärmare? Vet ej ☐ Ja ☐ Nej ☐

D. Dina och andras erfarenheter av mätningen

a) Tycker du/ni att utrustningen var lätt att installera? Ja ☐ Nej ☐
Om nej, vad skulle kunna förbättras?

____

b) Har utrustningen fungerat klanderfritt? Ja ☐ Nej ☐
Om nej, vad har krånglat?

____

c) Har utrustningen fungerat utan att störa förare eller passagerare? Ja ☐ Nej ☐
Om nej, vad har varit irriterande?

____

d) Tycker du/ni att informationen har varit tillräcklig? Ja ☐ Nej ☐
Om nej, vad skulle kunna förbättras?

____

Var vänlig att skicka tillbaka enkäten tillsammans med utrustningen när mätningen är slut.

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