The German Pedelec Naturalistic Cycling Study – Study Design and First Experiences

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ABSTRACT

This paper presents the study design and first experiences of a Pedelec Naturalistic Cycling study. There are 90 participants: 30 bicylists, 50 Pedelec cyclists and 10 E-bike cyclists. The bicycles are equipped with a data acquisition system that records among others speed data and videos on the traffic situation over a period of four weeks. Questionnaires assessing current travel and traffic behaviour and changes thereof, motives and experiences with Pedelecs / E-Bikes are used when recruiting participants, before and after the observation period. A one-week time use travel diary was used to collect qualitative information on the cycle trips and related activities. Despite a low modal share of bicycling in the study area there were no problems recruiting participants. Recruiting E-bike user proved to be a challenge as their market share in Germany is quite low. Participants are very cooperative even though the study procedure puts quite considerable demand on them. The data acquisition system provides reliable trip and video data, even though there are problems with the GPS data. Thus we expect an exceptional dataset that will improve our understanding of travel and traffic behaviour of E-Bike users.

Keywords: Pedelec, e-bike, naturalistic cycling study, travel behaviour, cycling behaviour, speed, traffic safety

1 INTRODUCTION

Motorised bicycles, so called Pedelecs or E-bikes, have recently become popular among cyclists. There are different types of motorised bicycles with the main difference whether they offer only assistance for pedalling up to a certain speed or unassisted power. In all cases they enable the cyclist to ride with less physical effort and / or on higher speed compared to traditional bicycles.

Currently there are a number of open questions regarding future travel mode share, travel mode shifts, potential user groups and usage patterns, the legal categorisation of the vehicles, related technical requirements, requirements for user protection devices (e.g. helmet), road infrastructure usage, potential safety risks etc. In Germany the current discussion about E-bikes focuses on the legal categorisation of the vehicles and traffic safety risks. The main concern about traffic safety risks is the higher average and maximum speed of the Pedelecs / E-bikes that may result in an increased injury severity, more heterogeneous speed, traffic conflicts among cyclists and between cyclists and pedestrians, underestimation of cyclist's speed by themselves and other road users, overconfidence to control the vehicles in critical situations etc. [1].

The discussion about Pedelecs and E-bikes should be based on sound empirical evidence. However, so far there is evidence mainly from research in China and America [e.g. 2, 3]. Given the differences in the legislation, transport infrastructure, types of E-bikes and travel behaviour the transferability of the results is questionable. In 2011 Switzerland has implemented a new police accident recording form that distinguishes between bicycles and bicycles with electric motor assistance. First accident data of E-bikes for 2011 reports two fatal and sixty-seven severe accidents. That corresponds to 35% of all E-bike accidents. For comparison the share of fatal and severe bicycle accidents amounts up to 25% for all bicycle accidents [4]. That indicates that E-bike accident may be more severe compared to bicycle accidents. However, there will be a few years until empirically sound accident data is available.

Therefore, the German Insurers Accident Research (UDV) together with Chemnitz University of Technology and TU Munich set up a large-scale Pedelec field study. The study aims at answering research questions concerning travel and traffic behaviour of Pedelec and E-bike cyclists. In particular we want to know:

- Who uses Pedelec / E-bikes and why?
- For which trips are they used?
- Which travel modes do they complement or replace?
- How does it change daily schedules and possibly create new cycle travel?
- Where do Pedelec / E-bike cyclist ride?
- How fast do Pedelec / E-bike cyclist ride?
- How many and what type of critical incidents and/or accident occur?

A field study approach was chosen to collect data in a realistic but still controlled setting. More specifically we have implemented a naturalistic observation approach where cyclist's behaviour is recorded during their daily life as unobtrusively as possible. This method has been successfully applied in driver behaviour research. Therefore, we have adapted the methodology to bicycle research. The Pedelec Naturalistic Cycling study is currently under way. Data collection will be finished in November 2012. The results are expected for spring 2013. Therefore, this paper presents the study design and first experiences gained during data collection.

The reminder of the paper is structured as follows. The next section provides background information about the market development of E-bikes, summarises the discussion about the legal categorisation of these vehicles in Germany and describes a previous study on safety-related aspects of Pedelecs / E-bikes. The third section introduces the conceptual framework describing the hypothesised impact of Pedelecs/E-bikes on individual travel and traffic behaviour. The fourth section describes the methodology of the Pedelec naturalistic cycling study, its procedure, sample and measurements. In the last section we summarise the lessons learned so far.

2 BACKGROUND

2.1 Market Development of E-bikes in Europe and Germany

Figure 1 describes the market development of E-bikes in Europe and Germany [5]. The number and the market share of E-bikes have constantly risen during the last five years. In Germany 310.000 bicycles with electric motor assistance were sold in 2011. That corresponds to 8% of the total number of bicycles sold. In the future these figures are expected to rise even further. For Germany the Two Wheeler Industry Association forecasts to sale 600.000 E-bikes per year corresponding to a market share of 10 to 15% [6].

The numbers in Figure 1 include all types of E-bikes. Precise figures about the numbers and market shares of different types of E-bikes are not available. However, the Two Wheeler Industry Association estimates that in Germany 95-98% of E-bikes sold are Pedelecs with electric motor assistance up to 25 km/h. 3-5% of the E-bikes are S-Pedelecs /E-bikes with electric motor assistance up to 45 km/h or unassisted power [7] (see section 2.2 for a description of the terms).

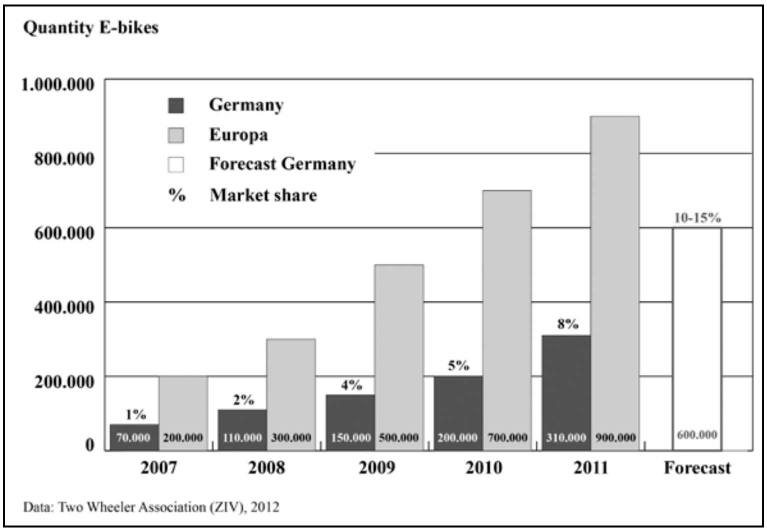

Figure 1. Market development of E-bikes in Europe and Germany

2.2 Legal classification of Pedelecs / E-bikes

The basis for the legal classification of Pedelecs and E-bikes is the EC Directive 2002/24/EC regulating the type-approval for two or three-wheel motor vehicles. Associated with that there are a number of specific directives regulating construction and safety devices for two or three-wheel motor vehicles [8].

This directive does not apply to:

….cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0,25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h, or sooner, if the cyclist stops pedalling, nor to the components or technical units thereof …[9].

By exempting certain cycles from type approval this directive sets the frame for the legal distinction of E-bikes in vehicles vs. non-vehicles. Vehicles and drivers of a vehicle need to comply with further requirements concerning the construction, driving licence or motor liability insurance.

In Germany the EC directive and thus the legal classification of E-bikes has not been implemented in national law yet. But a consensus has evolved among the legislator and interest groups to distinguish between two types of E-bikes: so-called Pedelecs with electric motor assistance up to 25 km/h and so-called S-Pedelecs or E-bikes with electric motor assistance up to 45 km/h or unassisted power [1]. Pedelecs with electric motor assistance up to 25 km/h are regarded as bicycles whereas S-Pedelecs / E-bikes are regarded as mopeds. However, the final legal classification is still pending. Table 1 summarises the main characteristics of these two types of motorised bicycles.

Pedelecs are bicycles with electric power up to 250 Watt and motor assistance up to 25 km/h. They can have a starting aid up to 6 km/h. They are regarded as bicycles and treated accordingly. As a consequence Pedelec cyclists do not need a driving license, motor vehicles insurance or a helmet. They are allowed to use the bicycle infrastructure. With a market share of up to 98% Pedelecs are currently dominating the German market.

S-Pedelecs and/or E-bikes are equipped with electric power up to 500 Watt and motor assistance up to 45 km/h or unassisted power. They are regarded as two-wheel vehicles. That means they need to comply with the 2002/24/EC directive and related regulations. Consequently S-Pedelecs /E-bike cyclists need a moped driving license, a motor liability insurance, a helmet and are only allowed to use the road infrastructure. Furthermore S-Pedelecs / E-bikes have to be equipped with e.g. certified brakes and tires. However, manufacturer often interpret legal rules in a different way in order to avoid most of the ambitious and expensive technical requirements. Therefore there might be a discrepancy between legal requirements and actual construction of S-Pedelecs / E-bikes.

Table 1. Characteristics of Pedelecs and S-Pedelecs / E-bikes in Germany

	Pedelec	**S-Pedelec / E-Bike**
Engine power	250 Watt	500 Watt
Motor assistance	25 km/h	45 km/h
Legal category	Bicycle	Moped*
Driving license	No	Yes
Helmet	recommended	mandatory
Motor liability insurance	No	Yes
Road usage	Bicycle infrastructure	Road infrastructure
Market share in Germany [7]	95-98%	3-5%

* Category L1e according to 2002/24/EC

2.3 Previous study on safety related aspects of E-bikes

The potential discrepancy between legal requirements and actual construction motivated a previous study on safety related aspects of E-bikes [8]. Five S-Pedelecs / E-bikes with different technical features (e.g. engine type, maximum speed) and one Pedelec were tested (among others) concerning operational safety and performance in different crash scenarios.

Concerning operational safety special emphasis was placed on the electric device and the braking system. Failures of the electric device such as a short-circuit in the engine may block wheels and may cause cyclist's falling. Electric devices were tested according to ECE-R100-01 [10]. The batteries were encapsulated appropriately and firmly mounted on the cycles. However, low-price E-bikes revealed lower safety standards concerning engine type, electronic battery monitoring system and cable routing.

The braking systems were tested according to the specific directive 93/14/EC (2006/27/EC) [11]. On a dry surface all braking systems performed adequately. On a wet surface there were considerable differences in deceleration. Especially rim brakes did not meet the specifications according to 93/14/EC (2006/27/EC). Figure 2 shows the mean maximum deceleration and breaking distance of a S-Pedelec / E-bike for an initial speed of 30 km/h. In both cases the values exceed the limits. That means deceleration is lower and breaking distance is longer than requested by 93/14/EC (2006/27/EC).

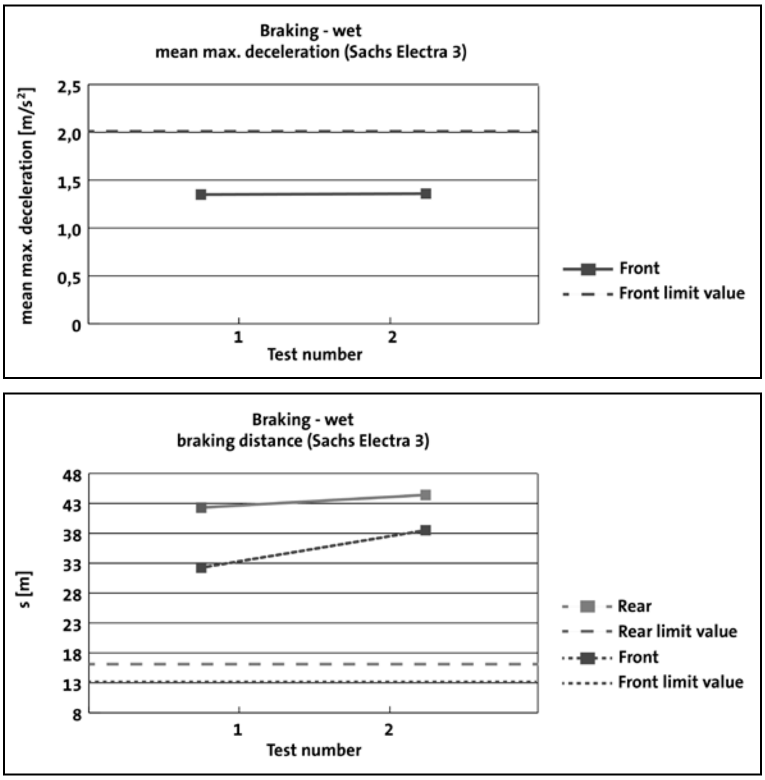

Figure 2. Braking system performance of a Sachs Electra 3 E-bike with mechanical rim brakes (top: mean max. deceleration, down: breaking distance) [8]

To test the performance of E-bikes in critical situations three different crash scenarios were investigated:

1. An E-bike with 44 km/h overtaking a bicyle with 22 km/h with an overlap of 0.2m
2. An E-bike with 44 km/h hitting a stationary passenger car orthogonally at the middle of the front passenger door
3. An E-bike with 25 km/h hitting a standing pedestrian from the side.

In all three scenarios a Hybrid III dummy was used in order to measure loads on head, neck, chest, pelvis and thigh. Selected results are summarised in Table 2. The table shows relevant load parameters and their thresholds according to ECE-R94 [12] – the frontal impact regulation for cars utilizing the same type of dummy, the dummy load values and an assessment whether or not they comply with ECE-R94.

Table 2. Selected crash test results

	Load parameter according to ECE-R94	Threshold according to ECE-R94	Load	meet criteria
Crash scenario 1*				
Head	HPC	1000	9477	No
	a_{3ms} [g]	80	83.53	No
Neck	F_Z [kN]	3.3	1.41	Yes
Chest	a_{3ms} [g]	60	37.43	Yes
	Deflection [mm]	50	5.49	Yes
	VC [m/s]	1.0	0.58	Yes
Pelvis	a_{3ms} [g]	60	15.80	Yes
Thigh	F [kN]	9.07	1.74	Yes
Crash scenario 2				
Head	HPC	1000	302	Yes
	a_{3ms} [g]	80	56.33	Yes
Neck	F_Z [kN]	3.3	2.36	Yes
Chest	a_{3ms} [g]	60	52.87	Yes
	Deflection [mm]	50	68.11	No
	VC [m/s]	1.0	1.93	No
Pelvis	a_{3ms} [g]	60	28.10	Yes
Thigh	F [kN]	9.07	9.29	No
Crash scenario 3*				
Head	HPC	1000	1774	No
	a_{3ms} [g]	80	21.32	Yes
Neck	F_Z [kN]	3.3	0.79	Yes
Chest	a_{3ms} [g]	60	21.37	Yes
	Deflection [mm]	50	1.79	Yes
	VC [m/s]	1.0	0.0	Yes
Pelvis	a_{3ms} [g]	60	11.65	Yes
Thigh	F [kN]	9.07	0.15	Yes

* measured at ground impact

In all three crash scenarios at least one parameter exceeded the respective threshold value. For the E-Bike / Bicycle and E-Bike / Pedestrian collision the head load parameter resulting from the dummy's subsequent fall exceeded the limit. For the E-bike / car collision it concerned the lower extremities at impact and the chest when hitting the bonnet. Loads exceeding the threshold will result more likely in severe injuries. Even though these results represent only a snapshot with specific vehicle types and crash test configurations they illustrate that higher speeds of Pedelecs or E-bikes may have severe consequences in case of an accident.

In summary there are several potential safety risks of Pedelecs and S-Pedelecs / E-bikes. Whether or not these potential safety risks translate into critical situations or even accidents in real life largely depends on user behaviour. Therefore, a Pedelec Naturalistic Cycling study was set up to investigate user behaviour under real-life conditions.

3 CONCEPTUAL FRAMEWORK

The conceptual framework of the Pedelec Naturalistic Cycling study is based on the assumption that individual mobility consists of a hierarchy of decisions by travellers where decisions at higher levels determine the scope of action at lower levels [13].

On the first level there are long-term decisions that determine the scope of action for individual travel behavior, for example choice of location for home and work, the purchase of travel modes (e.g. car, bicycle, PT season tickets), vehicles types, leisure activities etc. For example if people choose to live in the suburbs without public transport, they cannot choose public transport as an option for travel. These are infrequent decisions based on rational deliberations with long-term consequences for individual mobility.

On the second level there are medium-term decisions regarding the actual travel behavior such as planning of trips, destinations, travel mode choice, departure times etc. These are conscious decisions but largely determined by habits. Habits describe repeated behaviour in stable situations [14]. For example, for commuting trips the same travel mode, route and departure time is chosen every day without repeated deliberation due to nearly stable situational constraints for these trips.

On the third level there are aspects of the actual traffic behaviour such as driving style or speed. These are short-term, unconscious and automated decisions that are influenced by the traffic situation and vehicle characteristics.

Based on these assumptions we derived a conceptual model describing the influence of pedelec characteristics on individual travel and traffic behaviour (see Figure 3). On the first hierarchy level Pedelecs and S-Pedelecs / E-bike represent a new travel mode changing the scope of action for lower hierarchy levels. With additional electric power for cycling as core feature they enable cyclists to ride with less physical effort and / or on higher speed compared to traditional bicycles. Other characteristics such as driving license requirements or infrastructure usage potentially influence travel and traffic behaviour as well, but they are not inherent to the vehicle type but result from legal requirements. Therefore, in this study we focus on electric power as the core characteristics of Pedelecs and its consequences for individual travel and traffic behaviour.

Additional electric power for cycling may influence trip characteristics as well as the daily activity pattern in various ways:

- *More cycling trips / Differences in travel mode choice:* cyclists with limited physical power e.g. senior cyclists may be able to continue cycling or to cycle at all with additional electric power. This and the differences in other trip characteristics may also lead to the substitution of trips by car, public transport or by foot.
- *Shorter trip durations / later departure times*: additional electric power allows cycling at higher speeds and thus to cycle a given trip in less time. That also opens up the possibility for later departure times for a given trip.
- *Longer trips distances / farther destinations*: Shorter trips durations and / or additional power for cycling allow for longer trip distances overall and in a given time. Thus farther destinations overall and in a given time can be reached.
- *Differences in daily activity patterns*: Additional electric power and related differences in trip characteristics may allow for activity rescheduling on an individual level, e.g. grocery shopping on the way home, or on a household level, e.g. chaperoning children in a cycle trailer also for woman. But also new activities e.g. leisure activities seem possible given a wider scope of action for travel behaviour. Therefore, we may see a higher share of out-of home activities, different distributions of trip purposes and out-of home activities etc.

Concerning traffic behaviour we foremost expect higher trip speeds, on average and at maximum. We may also find higher individual speed variance given a potentially higher speed range. Furthermore, we expect steeper acceleration due to more power and steeper deceleration due to higher speeds.

The consequences for cyclists are twofold. There could be positive consequences such as higher satisfaction with travel, feelings of pleasure to cycle, improved physical fitness etc., but they are not in the focus of this study. There could also be negative consequences such as an increase in the number and /or severity of critical incidents and accidents due to an increase in exposition (number of trips), switching from protected travel modes to unprotected travel modes, higher speed levels etc. These aspects and their prevention are the main focus of this study.

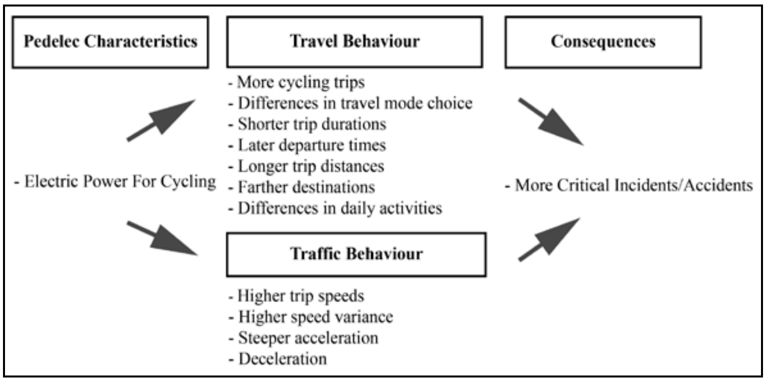

Figure 3. Pedelec Conceptual Model

4 STUDY DESIGN

The study employs a between design with three groups: i) cyclists using a Pedelec, ii) cyclists using a S-Pedelec / E-bike and iii) cyclists using a traditional bicycle. The bicycle group serves as a control group. The study design is described in detail in [15].

The study is carried out in the city of Chemnitz and the surrounding area. Chemnitz has got 249.500 inhabitants, a considerable share of commuting from the surrounding area into the city and a university with about 2.000 employees and 10.000 students. The study area covers urban and rural areas with the terrain being quite hilly. That makes it difficult for cycling but possibly attractive for motorised cycling. Currently, the share of cycling on the modal split is only 6% [16].

The project started in March 2012 with the design of the study and the design of the measurements. In May 2012 we started recruiting participants. Data collection started in July and will run until November 2012. Results are expected for spring 2013.

4.1 Procedure

Figure 4 describes the study procedure. After recruitment, selection and assignment to the respective study group each participant receives a questionnaire asking for current travel and traffic behaviour (see section 4.2). Then a data acquisition system is mounted on participants' bike collecting data about their cycling behaviour over a period of four weeks (see section 4.3). During these four weeks the participants are asked to keep a time use travel diary over a period of one week (see section 4.4). After four weeks the data acquisition system is dismounted and participants receive another questionnaire. The four-week observation period and related measurements are scheduled between July and November 2012 depending on participant's preference.

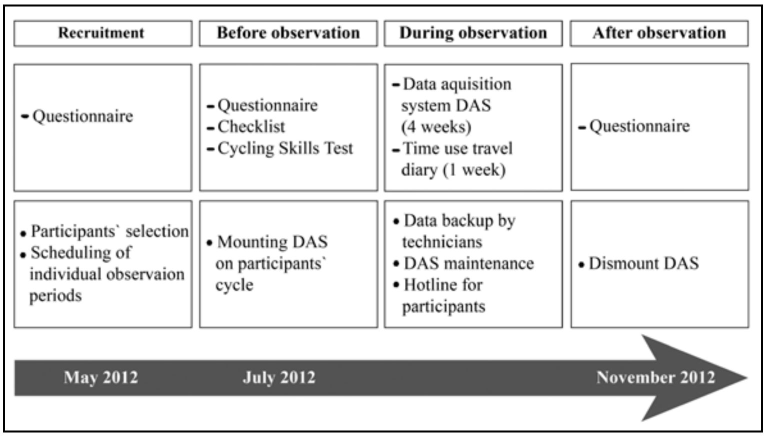

Figure 4. Procedure of the Pedelec Naturalistic Cycling Study

4.2 Sample Description

We recruited voluntary participants via different communication channels, e.g. flyers in bicycle shops, announcements at the institute's website and the local newspaper. Potential participants filled in a recruitment questionnaire asking for contact details, basic socio-demographic variables and the selection criteria for participation. These were:

- *Bicycle type*: Basic technical data about the bicycle was required to assign the participants to the three study groups.
- *Availability during test period*: Participants were required to be continuously available over four weeks where the data acquisition system was mounted on the bicycle. The aim was to exclude holiday periods to get data about participants' daily cycling.
- *Age*: We aimed to get an equal distribution across different age groups to account for age-related differences in cyclist's behaviour.
- *Main trip purpose:* For the Pedelec cyclists we further distinguished between main trip purpose 'work' and 'leisure' to account for the diversity of usage patterns.
- *Frequency of cycling*: We focused on frequent cyclists to get as much data as possible during the observation period.

Table 3 presents the sample distribution by bicycle type, age and main trip purpose as planned. Given the low market share of S-Pedelecs / E-bikes in Germany and related problems to recruit those cyclists we decreased the sample size in that group from 30 to 10 participants. We reallocated this sample share to the Pedelec group increasing the sample size from 30 to 50 participants respectively. The final sample distribution by E-bike type corresponds to the market share in Germany.

Table 3. Sample distribution by bicycle type, age and main trip purpose

	Bicycle	**Pedelec**		**S-Pedelec / E-Bike**	**Overall**
Age		**Work**	**Leisure**		
<= 40 years	10	13	4	3	30
41 to 64 years	10	5	10	5	30
>= 65 years	10	2	16	2	30
Overall	30	20	30	10	**90**

At this stage, we have full datasets of 55 participants, 61% of whom are male. The mean age is 52 years, the youngest rider being 16, the oldest 75. 24% of the participants reported a daily use of their bicycle, Pedelec or E-Bike. 69% of the Pedelec group used it predominantly for leisure purposes, 31% for commuting.

4.3 Measurements

Table 4 gives an overview over the measures and data collected during the study (see [15] for details). Questionnaires were used to collect data when recruiting, before and after the actual observation period. They have been implemented as paper/pencil- and online version of which participants could choose. We used standard scales as well as adapted or self-developed measurements. The focus was on current travel and traffic behaviour; perceived changes in this behaviour when using Pedelecs or S-Pedelecs / E-bikes; attitudes towards travel mode choice and different aspects of cycling and the history of critical incidents and accidents while cycling. Since there have been questions only relevant for Pedelec and S-Pedelec / E-Bike users there are two versions of each questionnaire, one for bicyclists and one for Pedelecs, S-Pedelecs / E-Bikes.

While the technician mounted the data acquisition system on the bicycle he also collected detailed information about the technical specification using a checklist. Furthermore, a cycling skills test was conducted, disguised as equipment test. The aim was to control for difference in cycling skills especially among elderly cyclists. All participants were asked to start cycling and to stop at a given point. The performance was judged as “no problems”, “small problems” or “severe problems”. The technician received a video-based training on typical mistakes in these two tasks.

The data acquisition system and the time use travel diary are described in the following sections (section 4.3 and 4.4).

Table 4. Overview of measures

	Time			
Instrument	**Recruitment**	**Before observation**	**During observation**	**After observation**
Questionnaire	Sociodemographics Bicycle usage Bicycle make / model	Sociodemographics Attitudes Personality traits Travel behaviour History of cycling accidents		Cycling Behaviour Experiences with NCS *only Pedelecs & E-bikes*: Travel behaviour changes Cycling behaviour changes
Checklist		Technical specifications of the bicycle		
Cycling Skills Test		Performance start cycling & stop at a given point		
Data acquisition system (DAS)			Trip characteristics	
Time use travel diary			Daily activity pattern Trip characteristics	

4.4 Data acquisition system (DAS)

First we described the requirements of a data acquisition system for the NCS. The following requirements were defined:

- Recording of the traffic situation with video cameras, in the direction of cycling, wide angle sidewards, backwards if appropriate

- Measurement of cyclists' horizontal movements with additional sensors (e.g. wheel sensor), calculation of speed, acceleration and deceleration
- Measurement of cyclists' position with GPS; calculation of speed, acceleration and deceleration, sloop; description of routes on geographical maps
- The different data sources need to be synchronised
- No interference with electric devices of the Pedelecs, S-Pedelecs / E-bikes
- Weather protection
- Battery life times for cameras / GPS similar to battery life time of Pedelec, S-Pedelec / E-Bikes for coordinated charging
- Data storage capacity similar to battery life time
- Simple and self-explaining handling for attachment /detachment, battery charging procedure and data backup
- Price per unit max. 1.000 € (for total quantity of 30 units)
- Weight max. 1.000 g
- Vibration-resistance of measures, data storage and batteries
- Operational also in bad visual conditions (e.g. twilight, rain)
- System components are available for purchase on short notice

Following a market analysis three self-compiled systems were selected for pre-testing, consisting of video cameras, GPS sensor and wheel sensor, altimeter and accelerometer if necessary Table 5 describes each DAS and its advantages and disadvantages in relation to the requirements listed above (see [15] for details).

Table 5. Comparison of pre-selected data acquisition systems (DAS)

	DAS 1	**DAS 2**	**DAS 3**
Front camera	Drift® Innovation HD720	Oregon Scientific ATC9K	ACME FlyCamOne eco V2
Back camera	Drift® Innovation HD720	Oregon Scientific ATC9K	ACME FlyCamOne eco V2
GPS	Garmin Edge® 800	Oregon Scientific G-ATC9K	SM Modellbau GPS-Logger
Wheel sensor	Garmin GSC™10	SIGMA Rox 9.1	SM Modellbau Unilog2
Accelerometer	-	Oregon Scientific ATC9K (built-in)	-
Altimeter	Garmin Edge® 800 (built-in)	SIGMA Rox 9.1 (built-in)	SM Modellbau Unilog2
Pros	Smallest video file Wide-angle lens fast reaction to changing light conditions	Best video quality Wide-angle lense fast GPS start	Synchronised data measurement 1 step for switching on/off 1 battery to charge
Cons	3 batteries to charge 3 devices to attach / detach 5 steps for switching on/off proprietary software	2 batteries to charge Remote control for synchronising video cameras not working proprietary software	no wide-angle lens biggest video file poorest video quality

The DAS 3 was selected because of its advantages for user handling, synchronisation of the single data measurements and more flexible options for data processing.

The final DAS is pictured in Figure 5. The system was firmly mounted on participant's cycle by technicians. The system is independent from the bike's electric or drive system. Participants start / stop data recording by switching on / off one flip switch. Two LEDs display the status of the DAS. We decide to carry out maintenance and data backup by technicians. In that way participants are only required to monitor the DAS, to keep individual maintenance appointments (at their home or university) and to contact technicians in case of malfunctioning. Participants received instruction for monitoring the DAS while it was mounted on their bicycle.

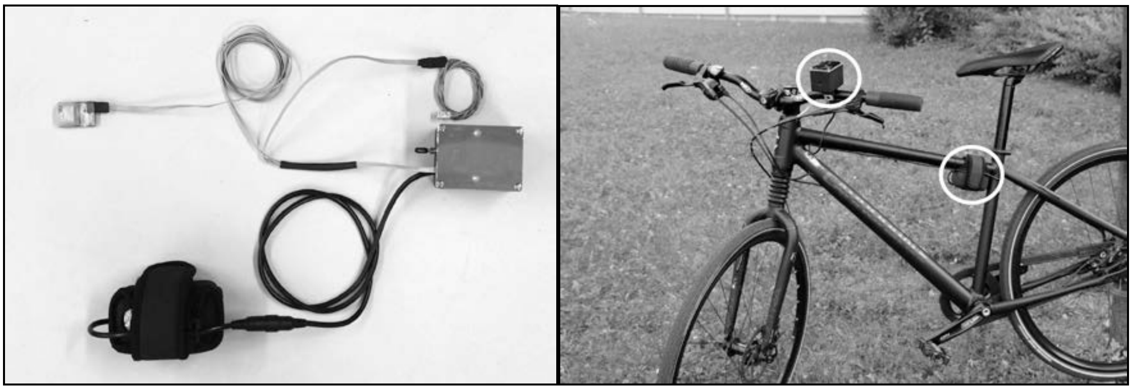

Figure 5. Data acquisition system for the NCS (right: DAS components, left: DAS mounted on a bike)

4.5 Time use travel diary

In addition we asked participants to fill in a one-week time use travel diary. In that diary participants are requested to record all trips, not only cycling trips, as well as their in-home and out-of-home activities.

Traditional travel diaries ask about the next trip undertaken by the respondent and then collected various information on that trip. In contrast time use diaries focus on activities and treat trips as an activity. Research consistently shows that time use diaries reveal higher travel times [17] and trip rates [18] in comparison to travel diaries. For example, comparing the German national travel survey MiD ("Mobility in Germany") 2002 and the German time use survey 2001/2002 the difference in overall daily travel time amounts up to 10 min [19]. That is because recording trips in the context of the day's activities seems to provide a closer correspondence to the natural storing of information and the planning of activities and trips. Furthermore for assessing the likely consequences of Pedelecs for activity rescheduling and hence transport demand, a time use diary is the preferred choice. On the negative side time use diaries place considerable higher response burden on participants.

To account for the advantages and disadvantages of time use diaries we use an adjusted time use travel diary [20] and adapted it to the data needs of this study (see Figure 6 for an example). The time use travel diary is based on the design of the time use diary. For each activity and trip participants are asked to indicate:

- start /end time,
- main activity or trip,
- any secondary activity and
- address for activities and transport mean for trips.

An open time interval was chosen in contrast to a preset time interval in time use surveys in order to reduce response burden and the likelihood of trips being omitted from the diary because they are shorter than the preset time interval. Specific for the Pedelec NCS participants are asked to indicate for each trip:

- Planning horizon (from 1=routine to 4=spontaneous)
- Accompanying persons (E = adult, K= child (>10 years), G=luggage, how many?)
- Time pressure (yes/no)
- Alternative travel mode for that trip (if available)
- Description of critical situations during the trip

Beispiel: **Datum: Mo 4.6. 2012** **Wetter:**

Uhrzeit (von 04:00 bis 03:59)		**Hauptaktivität** *nur eine Aktivität pro Zeile*	**Gleichzeitige Aktivität** *wichtigste gleichzeitige Aktivität*	**Ort der Aktivität/ Verkehrsmittel** *genauer Ort der Aktivität (Adresse)/ bzw. das Verkehrsmittel für Wege*	**Fragen nur zu Ihren Wegen**				
von	**bis**				**Planung der Fahrt*** *1/2/3/4**	**Begleitung**** *Wer/Wieviele?*	**Zeitdruck** *Ja/Nein*	**Alternatives Verkehrsmittel**	**Beschreibung kritischer Situationen während der Fahrt**
04:00	08:30	Schlafen		zu Hause (Musterstraße 1, 01011 Musterstadt)					
08:30	08:32	Weg zum Bäcker		zu Fuß	2	0	N	k.A.	
08:32	08:35	Brötchen/Zeitung gekauft		Bäckerei (Musterstraße 1, 01011 Musterstadt)					
08:35	08:37	Rückweg nach Hause		zu Fuß	2	0	N	k.A.	
08:37	09:30	Frühstücken	Zeitung lesen	zu Hause					
09:30	10:15	Hausarbeit	Telefonieren	zu Hause					
10:15	10:40	Weg zum Arzt	Gespräche	Auto	2	1, E	J	Taxi	
10:40	12:00	Arztbesuch		Ärztehaus (Musterstraße 1, 01011 Musterstadt)					
12:00	12:15	Weg zum Restaurant		Auto	2	1, E	N	zu Fuß	
12:12	13:20	Mittagessen	Gespräche	Restaurant (Musterstraße 1, 01011 Musterstadt)					
13:20	13:45	Rückweg nach Hause		Auto	2	1, E	N	Taxi	
13:45	14:30	Mittagsschlaf		zu Hause					
14:30	15:00	Weg zum Garten		Elektrofahrrad	3	0	N	Auto	
15:00	17:00	Gartenarbeit		Gartensparte (Musterstraße 1, 01011 Musterstadt)					
17:20	17:50	Rückweg nach Hause		Elektrofahrrad	3	0	J	Auto	Korb auf Gepäckträger verrutscht, Probleme Gleichgewicht zu halten, wäre fast gestürzt
17:50	19:00	Abendessen	Gespräche	zu Hause					
19:00	20:00	am Schreibtisch gearbeitet	Telefonieren	- " -					
20:00	21:45	Fernsehen		- " -					
21:45	22:00	Körperpflege	Waschbecken geputzt	- " -					
22:00	03:59	Nachtruhe		- " -					

*__Planung:__ **1** = regelmäßig, Routine / **2** = ein oder mehrere Tage vorher / **3** = im Laufe des Tages / **4** = gerade eben/spontan
** **Begleitung Wer: K** = Kind bis 10 Jahre / **E** = Erwachsener ab 11 Jahre / **G** = schweres Gepäck

Figure 6. Example for a Time use travel diary

5 LESSONS LEARNED

After having carried out about two third of the study we can draw some preliminary conclusion regarding the data collection, some relating to the experience with the participants, quite a few also relating to the technical equipment.

Despite the overall low share of motorised bicycles in the bicyclist population, it proved not too difficult to acquire a substantial subject sample (S-Pedelec / E-bike riders were hard to find, though). However, as Pedelecs currently seem to appeal mainly to elder people, it was much easier to find older riders, compared to their younger counterparts. The opposite is true for the regular cyclists, which illustrates the special role of electric bicycles among different modes of transport.

Overall participants were quite willing to follow the study procedure, but expressed reluctance to complete the seemingly labour-intensive time use travel activity diary. That corresponds to previous experiences where a similar activity diary generated the initial questioning of the relevance, but nevertheless, all respondents cooperated [18].

Also, despite best efforts to keep the data acquisition system as simple as possible, participants still encountered some difficulties in handling the system. Many forgot to switch off the system occasionally, resulting in a substantial amount of video material with the bike standing still.

Wheel sensors, while overall a reliable data source, malfunctioned when participants used bike racks. However, since maintenance was carried out regularly, this issue was usually discovered and resolved quickly.

GPS data proved to be a bigger problem as it regularly produced erratic and implausible tracks. We think that this is because the system provided only raw data, without any further processing. Fortunately, speed, trip duration or trip length can also be drawn from the wheel sensor data.

Overall, despite several issues that are quite familiar to all naturalistic driving/riding studies, we expect an exceptional dataset that will improve our understanding of travel and traffic behaviour of E-Bike users.

REFERENCES

[1] Deutscher Verkehrsgerichtstag (ed), *50. Deutscher Verkehrsgerichtstag [50th German Council on Jurisdiction in Traffic*], Wolters Kluwer, Köln, 2012.

[2] C. Cherry, R. Cervero, "Use characteristics and mode choice behavior of electric bike users in China", *Transport Policy* **14** (2007), pp. 247-257.

[3] J. Dill, G. Rose, "E-bikes and Transportation Policy: Insights from Early Adopters", *Transportation Research Board 91th Annual Meeting*, Washington DC, US, January 22-26, 2012.

[4] Bundesamt für Straßen ASTRA, *Verunfallte Fahrradfahrende nach Unfallfolgen, 2011 [Cycling accidents, 2011]* http://www.astra.admin.ch, retrieved 26.10.2012.

[5] Two Wheeler Industry Association (ZIV), *Annual Report 2011*, Bad Soden a. Ts., 2012.

[6] S. Neuberger, "Pedelecs – Neue Chancen für den Radverkehr [Pedelecs – new chances for bicycle traffic]" in Deutscher Verkehrsgerichtstag (ed), *50. Deutscher Verkehrsgerichtstag [50th German Council on Jurisdiction in Traffic]*, Wolters Kluwer, Köln, 2012.

[7] S. Neuberger, Two Wheeler Industry Association (ZIV), Personal communication, 17.10.2012.

[8] M. Kühn, "Safety Aspects of High-Speed Pedelecs", *Compact Accident Research*, German Insurers Accident Research (UDV), Berlin, 2011.

[9] European Parliament and the Council of the European Union, *Directive 2002/24/EC relating to the type-approval of two or three-wheel motor vehicles and repealing Council Directive 92/61/EEC*, 18 March 2002.

[10] ECE-R 100/01(WP.29/2010/52) Approval of Vehicles with Regard to Specific Requirements for the Electric Power Train, Nov./Dec. 2010.

[11] The Council of the European Union, *Directive 93/14/EC (2006/27/EC) on the braking of two or three-wheel motor vehicles*, 5 April 1993.

[12] UNECE, *ECE R 94 Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a frontal collision*.

[13] B. Schlag, S. Schade, "Psychologie des Mobilitätsverhaltens", *Aus Politik und Zeitgeschichte* **29/30** (2007), pp. 27-32.

[14] B. Verplanken, H. Aarts, A. van Knippenberg, "Habit, information acquisition, and the process of making travel mode choices", *European Journal of Social Psychology*, **27** (1997), pp. 539-560.

[15] S. Schleinitz, S. Schwanitz, T. Petzoldt, M. Kühn, T. Gehlert, *Pedelec-Naturalistic Cycling Study – Part 1*, Research Report, German Insurers Accident Research (UDV), Berlin, 2012.

[16] A. Ahrens, F. Ließke, R. Wittwer, S. Hubrich, *Sonderauswertung zur Verkehrserhebung ‚Mobilität in Städten – SrV 2008': Städtevergleich [Statistical analysis of the Household Mobility Survey for Cities – SrV 2008: Comparison of Cities]*, Dresden University of Technology, November, 2008.

[17] A. S. Harvey, "Time-space diaries: Merging traditions" in P. Stopher, & P. Jones (eds), *Transport survey quality and innovation,* pp. 152-180, Elsevier, Oxford, 2003.

[18] T. Arentze, H. Timmermans, F. Hofman, N. Kalfs, "Data Needs, Data Collection, and Data Quality Requirements of Activity-Based Transport Demand Models", *TRB Transportation Research Circular E-C008: Transport Surveys: Raising the Standard*, Proceedings of an International Conference on Transport Survey Quality and Innovation, Grainau, Germany, May 24-30, 1997.

[19] R. Gerike, T. Gehlert, *Time Use in Travel Surveys and Time Use Surveys – Insights for data collection and analysis*, Manuscript submitted to the Special Issue on "Sustainable Mobility: The role of consumers, current trends, policy approaches and future challenges", Journal of Environmental Policy and Planning.

[20] R. Gerike, T. Gehlert, H. Twaddle, "Time use in time-use surveys and transport surveys", *3rd International Time Use Observatory Workshop*, Santiago, Chile, 21-23 March, 2012.