

Experiences from Data Collection in Living Labs- The Swedish National database for Car Movements

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Abstract

This paper reviews experiences from data collection in Living Lab projects that are parts of the Swedish National Database for Car Movements, managed by Test Site Sweden at Lindholmen Science Park. Discussions will include lessons learned from developing and running the database as well as from logging cars and data collection in living labs. Moreover, this paper will also introduce two on-going living labs (inductive charging and the replacement of a conventional car with an electric car in two-car households) within Test Site Sweden.

Keywords: Inductive charger, EV (electric vehicle), demonstration, battery, case-study

1 Introduction

The Swedish national database for car movements is a database managed by Test Site Sweden at Lindholmen Science Park that consists of data from vehicles used by both private users as well as organisations in so-called Living Labs. A Living Lab can be defined as user-centric innovation environments built on everyday practice and research with an approach that facilitates user influence [1].

The purpose of the database is to obtain a body of knowledge of how electric vehicles and conventional cars are used in everyday life. The national database for car movements was founded in 2008 and contains data from around 20 projects, corresponding to approximately 250 000 car trips. The data is gathered by loggers installed in the cars, which collect the driving patterns using GPS together with optional information, such as state of charge for electric vehicles. More information about this can be found in [2, 3]. The information can be complemented with other data such as road types, weather as well as answers from user questionnaires.

Test Site Sweden is a programme initiating and facilitating test and demo projects in the areas of vehicle and environment. The programme started 2007 and until today about 140 projects have been carried out.

2 Living Lab Projects at Test Site Sweden

Two examples of ongoing Living Lab projects in the Swedish national database for car movements are Wireless Charging of Electric Vehicles (WiCh) and Car Movement Data 3 (CMD3) both funded by the Swedish Energy Agency. The Swedish national database for car movements can be accessed through www.database.testsitesweden.com.

2.1 Wireless Charging of Electric Vehicles, WiCh

In WiCh, equipment for inductive charging of electric vehicles was installed in three cities in Sweden, the first Living Lab test of its kind in Europe. The users are mainly organisations, but also one private user.

Data gathered for the national database includes GPS coordinates as well as selected CAN-data, such as State of Charge. This in order to compare the data gathered from the charging stations with the purpose to investigate to what extent the inductive charger was used, i.e. if the car was charged more often, but for shorter periods, compared to when using conventional charging. The efficiency of the inductive charger was also measured.

2.2 Car Movement Data 3, CMD3

In CMD3, an electric car replaced one conventional car in a two car household by an electric car. GPS-position as well as CAN-data is gathered to see the change in the use of the cars. This Living Lab is based on the theory that two-car households more easily adapt to the restricted driving range of an electric vehicle. This argument relies on the fact that in two-car households, one car is generally used for shorter distances and the other one for longer distances. [4]

3 The National Database for Car Movements

3.1 The Data Collection Setup

Figure 1 shows the set up for the data gathering and storing. Loggers, powered using the cigarette lighter port, in the car send data using cellular mobile communication. The data is sent to a telematics data server and is collected in the first database with the raw data. Thereafter, the data is automatically filtered in the analysis database, after which it is presented in the Test Site Sweden homepage where it can be accessed by researchers and other non-profit organisations.

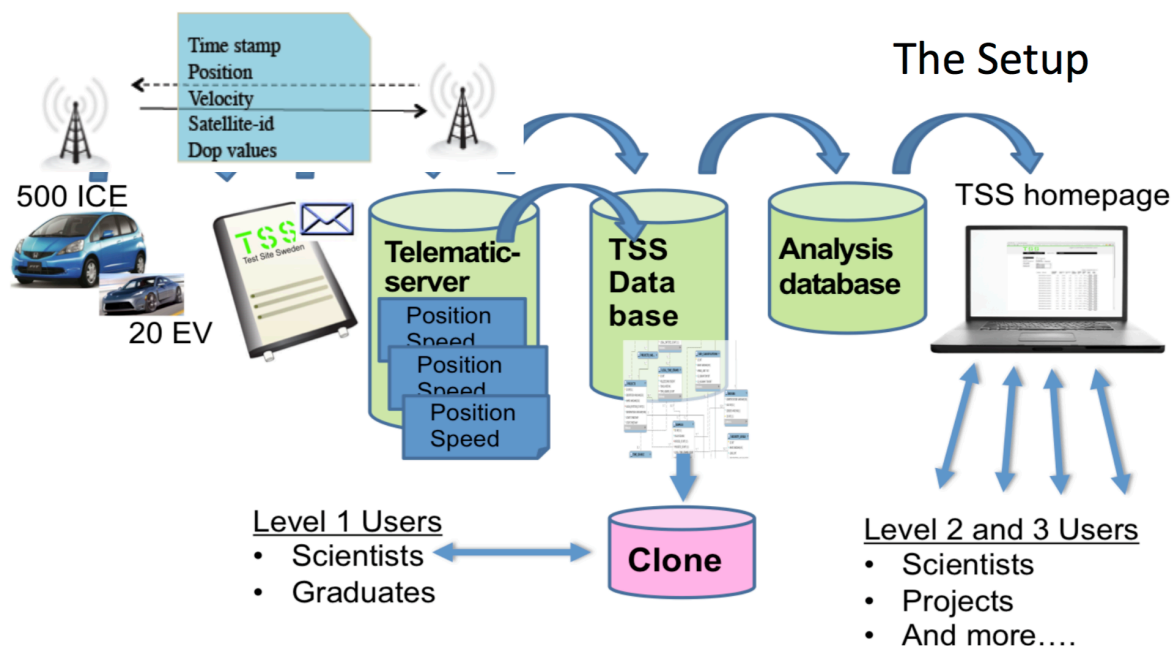


Figure 1: The set up for the national Swedish database for car movements.

3.2 Example of Results from some projects

In figure 2, data gathered from the database (from the project CMD that is the basis for CMD3, where conventional cars in households were logged and the project “EV range in cold climate”) is visualized. The figure shows the percentage of different distances the conventional cars are driven daily. The arrows describe the distance for the first generation Nissan Leaf tested according to different driving cycles with an average speed of 60 km/h (TÜV SÜD E-Car Cycle, TSECC) and with a speed of 33 km/h (New European Driving Cycle, NEDC) at different temperatures. The graph shows that if the door-to-door distance is 100 km, then the daily need of transportation using an electric vehicle is well covered. Similarly, Pearre et al. (2011) conducted a study where 484 instrumented gasoline vehicles were used to analyse daily driving patterns. They write that 9 % of the vehicles in the test never exceeded 100 miles in one day. Moreover, for drivers who were willing to make adaptations 2 days a year, 17 % would have their travel

needs met. If the drivers were willing to make adaptations six times a year, equivalent to once every two months, 32 % would have their travel needs met. [5]

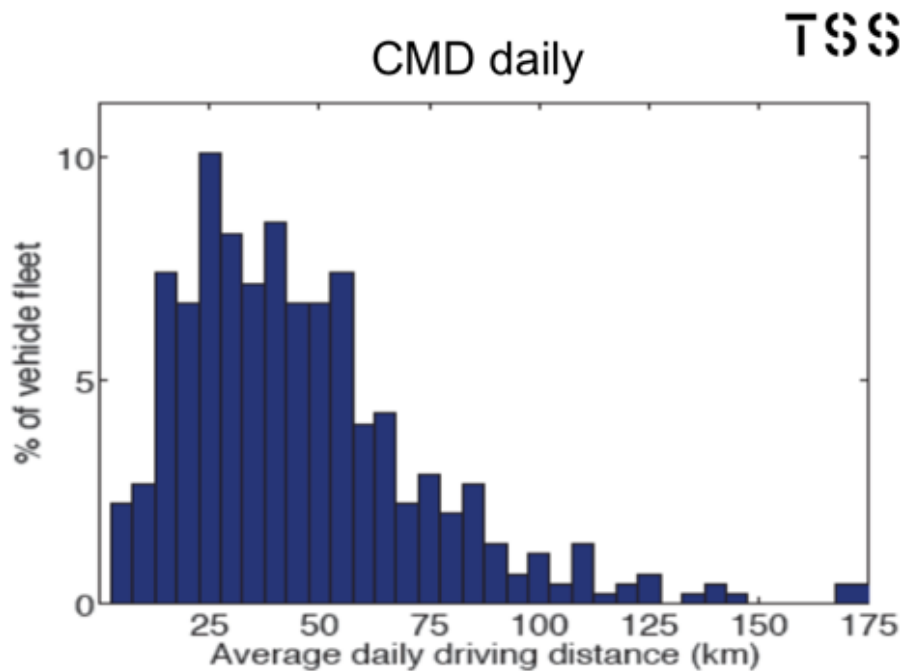


Figure 2: Percentage of the average daily driving distance for the travels gathered in the national database and different temperatures for NEDC and TSECC.

4 Results from Data Collection in WiCh and CMD3

This section will focus on some of the results from the data collection in the living lab projects WiCh and CMD3. Analysed results from the loggers and questionnaires as well as conclusions connected to that will not be included in this article. More information on these results can be found in ref [6, 7, 8].

4.1 Preliminary Results from Wireless Charging of Electric Vehicles

During the project, the efficiency of the inductive charger was measured. This was done using the precision power analyser Yokogawa WT 3000. The efficiency was measured between the grid connection and before the battery management system with a coil gap of between 105 to 100 mm (differs due to uneven ground). The charging cycle from 0 % to 100 % (taking about 6 hours) charging was measured and the overall efficiency was approximately 83 %, see figure 3. In figure 3, it can also be seen that the charging efficiency drops during the end of the charging cycle. The U.S. Department of Energy report a slightly higher result, ranging from a maximum 89% and a minimum of 85% depending on the coil gap [9], this is probably due to the fact that the U.S. Department of Energy has conducted their tests in a lab environment where as this test was conducted in the garage where the car is actually charged. There is a drop about 7200 seconds (2 hours) into the charging cycle, this is probably due to a software error of the charging equipment.

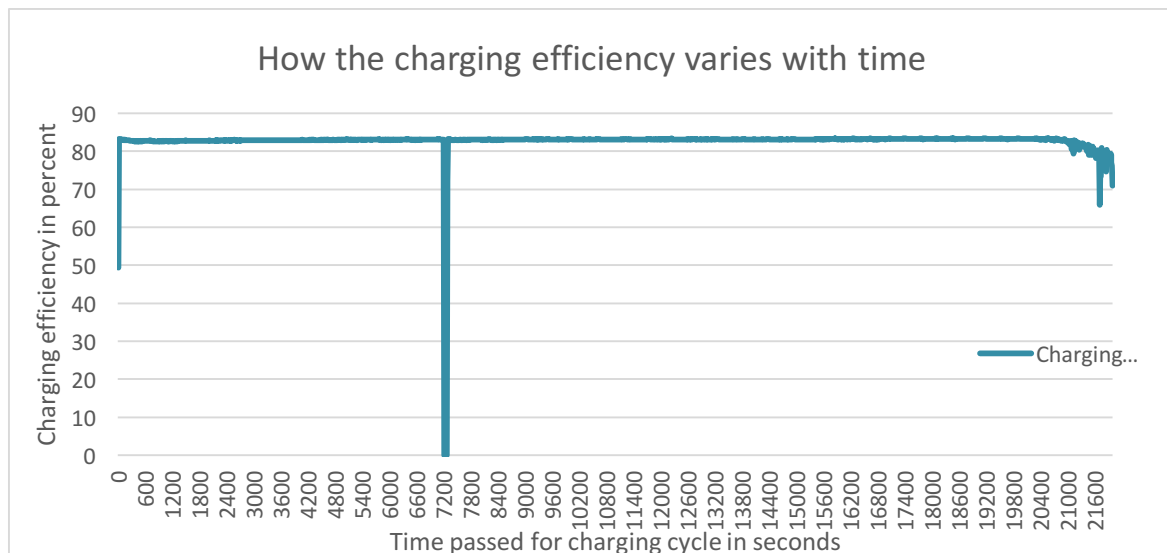


Figure 3: Charging efficiency over time, with the Y-axis corresponding to charging efficiency and X-axis time.

During the measurements, the charging plate was also moved in order to estimate how the charging efficiency varies with position as shown in figure 4. As a starting point, the left rear corner of the parking slot was chosen. The charging plate was moved to a chosen position and the charger was turned on for one minute. The power analyser was set to measure every ten seconds whereon the first and the last measured value of each position was excluded, and the average charging efficiency for the position was calculated based on the rest of the measured values. One can see that the efficiency is higher around the centre, and exhibits a doughnut-shaped pattern. The results correspond to the figures provided by the US Department of Energy [9].

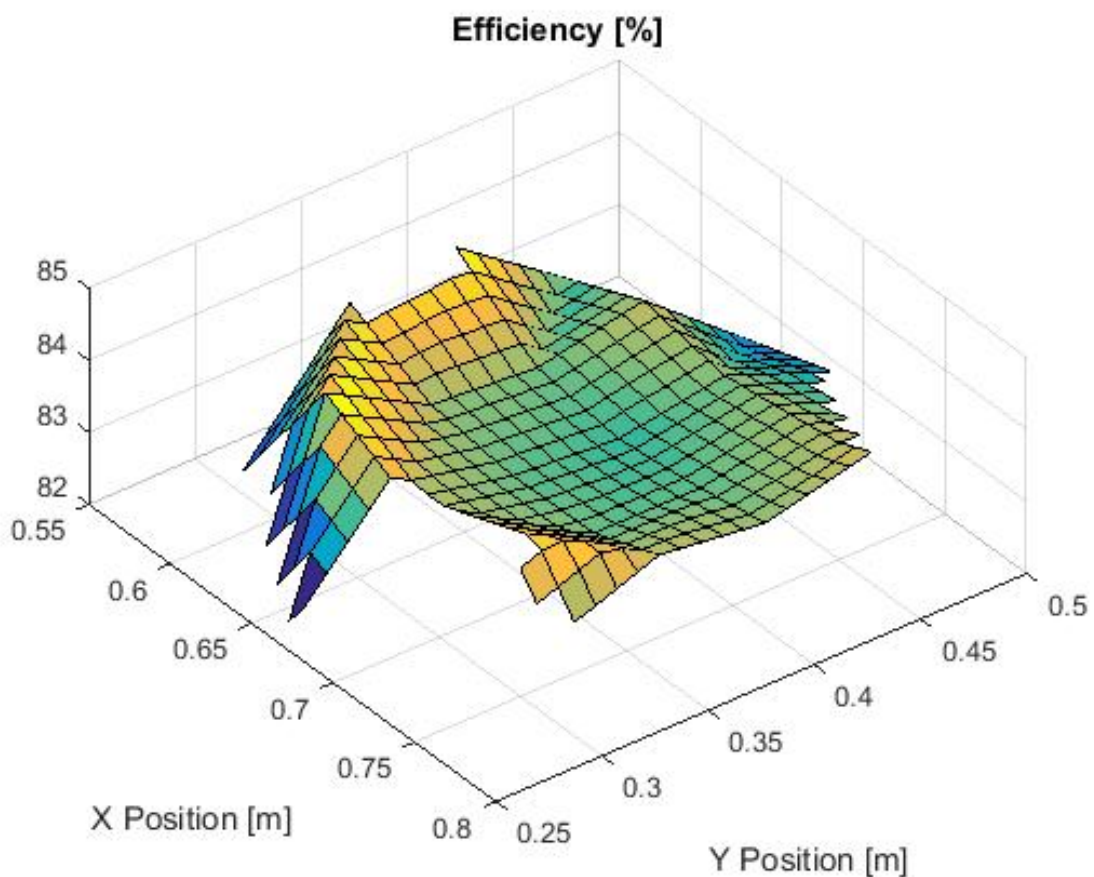


Figure 4: How the efficiency varies with position for inductive charging.

For more information on the living lab WiCh and results from the user study, see the articles *Large Scale testing of wireless charging in Sweden* [6], which will be presented during the EVS29 Symposium and *Introducing wireless charging for drivers of electrical vehicles in Sweden-effects on charging behaviour and attitude* [7], in proceedings of AHFE2016 affiliated conferences.

4.2 Preliminary Results from Car Movement Data 3

The results from CMD3 are mainly based on analysed results from the logger and questionnaires, that are outside the scope of this article. For more information, see the article *How are driving patterns adjusted to the use of a battery electric vehicle in two-car households?* [8], which will be presented during the EVS29 symposium.

5 Lessons Learned During the Procedure of Logging in Living Labs

In this section a selection of lessons learned from the Living Labs will be presented. A general lesson learned is the difficulty to estimate the budget for living labs caused by different unforeseen issues. Due to technical challenges, management of test persons and other administrative tasks.

This section is divided into lessons learned from the system set-up and in the living lab projects. Each section has a bullet-list describing some of the main lessons learned from the projects performed.

5.1 The Development of the Data Collection Set-up

The set-up of the data collection is described in 3.1 and shown in Figure 1.

- *Database set-up*
In the beginning, there were too much manual handling of data in order to get the result presented in the Test Site Sweden webpage. Today the process is automated, which is a necessity for projects with many test-persons and a large amount of data.
- *Connectors and cables*
A large source of error was the cigarette lighter contact where the logger was powered. In many cases the cigarette lighter in the car was loose. Many users also used the cigarette lighter for other purposes. Splitter cables were used but these were also a source of error. Moreover, the functionality of the cigarette lighter varies in different car. Some cars have them active all the time, leading to the logger never being turned off which can give the car battery problems if parked for too long. This problem was addressed by turning the logger off after a certain period when the car did not move.
The GPS-antenna is a magnetic puck that is put onto the roof of the vehicle. The cord from the antenna then needs to go through the door, which in some cases has lead to the cable breaking, also the cord that is pressed into the antenna can come loose, which leads to the unit not logging. Another issue with the GPS-antenna was that many of the test persons didn't want it installed on the roof of their cars, but put it in the glove compartment or on the dashboard, leading to the GPS antenna getting GPS lock late or not at all. The GPS lock is also a problem in urban areas where it can take a long time. This leads to the trips being shorter than in reality and analysing the problem afterwards is difficult.
- *Bad cellular coverage*
Data transfer often defaulted when the coverage was low and the logger had to resend data. This caused the logger to be overloaded and forced it to restart, which resulted in lost data during a period of about 15 minutes. This problem was addressed by demanding better signal strength in order to initiate transmission of data.

5.2 Lessons Learned in the Living Labs

5.2.1 Lessons Learned from logging

- *CAN logging*
In order to get more information from the car, the logger was connected to the OBD port in the car and CAN some of the data was read. Reversed engineering to be able to read the CAN data needs to be done for each car model and it is time-consuming. The CAN data should not be read to frequently as this might also cause the logger to be overloaded. This of course depends on the processor in the logger.

- *Discharge of 12 V battery in some electric cars*

In some of the car models (noticed in Nissan Leaf 2012 and 2013), the 12 V battery is only charged when the high power battery is charged. If the car only is used for shorter distances, the charging of the 12 V battery never initiates and it is after some time completely discharged. This problem has shown to be even more significant during the winter.

5.2.2 Lessons Learned from administration

The administrative part of the Living Lab includes the management of test-persons, cars (in case of CMD3, where a conventional car was exchanged with an electric car), mobile broadband connection and the loggers.

- *Management of test persons*

Appropriate test persons are to be found, loggers distributed and collected, the logging rounds need to be monitored etcetera. This was shown to be a more time-consuming task than expected (the user needed to disconnect and post the logger, the logger needed to be emptied and serviced and sent to the new user where it needed to be connected to the car). Many times the users needed to be reminded several times to disconnect and post the logger. In the early stages of the logging projects there were exactly as many loggers as test persons, this was obviously too little and extra loggers had to be ordered.

- *Cars*

In the living lab CMD3 the parked conventional car (being parked for about four months) had the 12 V battery discharged in some cases. This was solved by disconnecting the battery. The management of the replacement of cars was very time-consuming. The cars needed to be exchanged, washed, serviced and in some cases changing to/from winter-tyres.

- *Loggers*

The chosen loggers had to be programmed in order to collect and send the correct data at a predefined rate, which is good in order to have a more flexible functionality. The cost for programming, fixing bugs and general support of the logger has been high and a more simple solution would be recommended if possible.

6 Discussion

This paper focuses on lessons learned in living labs and data collection, rather than the results of the living labs themselves.

All in all, the main lesson learned from living labs is that much time is needed for the management and administration. Managing test persons/users often takes more time than expected. This is often due to the human factor and nature. Firstly considerable time is needed to find suitable test persons and when planning for logging in living labs with several consecutive rounds, there need to be a generous amount of time in between these rounds. It is important to make the test persons feeling involved in the project and that they understand why the project is important. A suggestion is to reuse test persons in several living labs to more strongly connect to them and make they feel responsible and appreciated. Information before, during and after is another key for success and it can be done by arranging general information meetings. Many of the test persons are members of social networks, which is another good mean of keeping them informed about progress in the projects.

As mentioned above, the estimation of budget for the living lab has been difficult as many unforeseen issues have appeared. In order to reach a better estimation of the budget a detailed risk analysis is recommended and a fixed price should be negotiated with all partners. This is especially important with the partner providing the logging equipment or doing the development and support of the loggers and the database. All involved partners should be involved in the development of the risk analysis.

In order to get the most out of the logging questionnaires are needed before and after the test-period. This has been done in some of the living labs. To get the most from the data, the answers should be connected with the right data-stream to make filtering on behaviours and different conditions for the test persons possible.

It is important to keep the system set-up as simple as possible. Today the logging possibilities have developed and it is possible to find loggers that you can connect directly to the OBD port without cables. This will decrease the risk of having problems with cables. These loggers will read CAN and also transmit

the data via cellular network. If the living lab is for a shorter period, the best way is to hire the equipment and have support included in the price to minimise the risk of additional cost.

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