Smartphone Applicatoin to Evaluate the individual possibilities for the Application of Electric Vehicles

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Abstract— **This paper deals with a mobile phone application that allows the user to analyse their driving habits and therefore recognize whether an electric vehicle would suit the users' requirements. The application analyses the daily trips and charging possibilities, recorded as per user input. The resulting demands are compared to available electric vehicles as well as extended range electric vehicles and plug-in hybrid electric vehicles. The vehicles that suit the requirements are presented to the user, taking not only the ideal range into account but also the realistic range in mild and cold weather conditions. Accordingly, the user receives reliable results, and therefore might utilize an electric vehicle sooner than originally envisaged.**

Keywords— ***android; consumption; cost estimateion; electric vehicles; extended range electric vehicle; new european driving cycle; plug in hybrid electric vehicles; smartphone;***

I. Introduction

In general, Electric Vehicles are highly favoured as a measure to decrease damaging emissions as well as present a viable mobility concept for the future. However, the sales figures remain low especially in countries without targeted grants. The main reason for this restraint is, despite the costs, the seemingly limited usability of battery electric vehicles (BEVs).

Despite many projects evaluating the usability of EVs in certain application fields there are only limited possibilities to access tools for individual evaluation. Two projects target the individual demands with the help of a mobile phone application. The first application is part of the project „colognE-mobil" which is a consolidation of a number of companies [1]. However there is limited information available about this application and the application is not yet available.

Another application for mobile phones is named "Check E" and provided by the organization "Austrian Mobile Power" [2]. This application is free of charge and offers a comparison of three real vehicles according to mobile recorded trips. There is limited information about the actual validation details and which data is recorded. All information available is, that the new European driving cycle (NEDC) data is used for the evaluation process, which therefore assumes a simple trip-length based evaluation process. However this application provides information about which percentage of the recorded trips would have been able to be covered by each of the three vehicles. Moreover a comparison with a conventional vehicle is implemented to state the potential savings by using EVs. The underlying data of the presented EVs is the (NEDC) and is therefore not realistic in most cases. According to current reviews the application also suffers under stability issues.

In contrast to these limited applications a new application is presented in this paper. This application does not use standardized data but rather calculates the individual usability details for all available vehicles in the database. Therefore experiences from previously undertaken projects, namely "Alltagstauglichkeit von Elektromobilität - Bausteine für eine Technologie Roadmap: Infrastruktur, Fahrzeug, Sicherheit" [3][4] and "Alltagstauglichkeit von Elektromobilität - Langstreckeneignung und –akzeptanz" [5][6] are used to transform the NEDC results into more realistic data. In addition, the individual driving behavior and trip details, such as acceleration and altitude profile are taken into account to allow accurate evaluations. However the results are aligned to worst case scenarios to ensure as good as possible the usability of any evaluated vehicle. As an additional feature it is possible to decide whether the vehicle is going to be used in mild or even in cold weather conditions as this also influences the consumption [7]. Moreover the application also considers the charging time and the inserted availability of charging options to not only analyse the trips but also the charging periods.

II. Project Target

The utilisation of EVs is subject to new challenges due to a new energy source, electricity, which is unlike the fuel

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of combustion engines. The energy density of fuel is very high and therefore allows a conventional vehicle to travel 500 km to 1000 km after a refueling process of five to ten minutes. A charging process with a domestic power socket and 2.5 kW leads (depending on the vehicle) to a range gain of 10 km to 20 km (values may differ depending on the vehicle's consumption) per hour. A maximum range of 100 km to 200 km in the first and second generation of EVs lead to a perceived restriction compared to conventional vehicles. Besides the resulting range anxiety, the required rethinking due to the new technology leads to reservations in sales figures.

To encourage the sales figures the public need to be properly informed and be reassured that EVs are able to cover their individual demands. The individual purchasing criteria are for example

- Possible Range
- Purchasing Costs
- Size
- Consumption
- Speed
- Interest

but are not restricted to those (see Figure 1).

An initial, evaluation of available vehicles can be undertaken using the test results of the new European driving cycle (NEDC) which are published with each vehicle. This also allows rough comparison of various vehicles. However the results are often escapist and

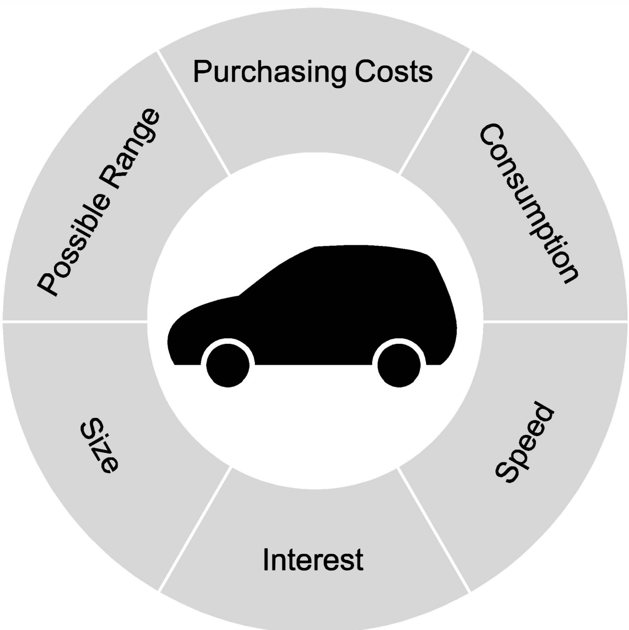

Figure 1 Typical purchasing criterias

therefore not reliable for individual utilization. This is also as no track specific influences, such as incline or decline, ambient temperature and individual user handling, are taken into account.

Even if the static routes to work or to the shops are compared to the possible NEDC range, the driving effort for finding a car park or other variations within the daily routes as well as variations in the possible charging time of EVs are not taken into account.

The sum of those issues and questions potential users have to face when thinking about purchasing an electric vehicle, deter future new car owners. Therefore the following presented project deals with these issues and supports users to evaluate the possible utilization of EVs beyond the possibilities of the NEDC.

The illustrated issues motivate the realization of a concept that allows potential buyers of EVs to evaluate and validate whether the daily requirements of range and consumption are fulfilled before buying an EV. This concept should take the user specific driving behaviour, trip characteristics as well as available charging possibilities into account. Despite these requirements of the concept it should be available to the consumer market to allow individual application for everyone.

In order to fulfill the requirements of the concept, it was implemented as a mobile phone application. This application is connected to an online database that allows use of up-to-date data of available BEVs, PHEVs and EREVs for the evaluation process. Due to the availability of sensors within mobile phones which are used within the application there is no need for the application of special and complex measuring equipment to record the driving details. The android based Application allows anyone to receive a basis for the verification and confirmation of their own possible utilization of EVs including a list of EVs that fulfill the requirements.

III. Application Details

The application allows the recording of trips that are undertaken with the currently available e.g. conventional vehicle. The user that is not yet convinced of EVs or who wants to find the most suitable EV for their usage can use this application to evaluate their own driving habits. After recording a suitable and representative amount of trips the application allows to crosscheck these with the available EVs and presents those that can manage these trips with the available range and recharge possibility in a table (see Figure 2).

This "EValuation" process leads to a result table with suitable EVs the "EVidence" that EVs can be used for the user demand is given. As the results are not only based on the driven trips but also on the user driving behaviour and

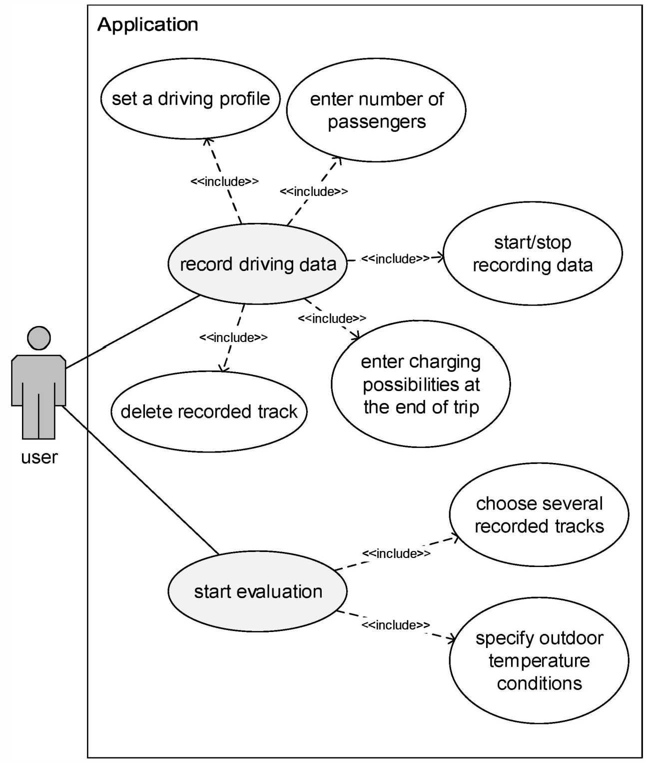

Figure 2 Use case diagram of the application

payload requirements, they become very reliable and individual. From this point the next step is to reach as many people as possible that either need confirmation or just initial proof of a reliable application of EVs. Once many people are convinced and change to EVs therefore allowing a reduction in climate influencing exhaust gases, an "Evolution" in the traffic sector is initiated.

To allow evaluation of a possible utilisation of EVs a user may record the usual trips undertaken with the current conventional vehicle. With the help of these individual driving details as well as the static information from a database, the individual resulting consumption for each available vehicle can be calculated correspondingly. Based on the calculations the results are presented to the user.

This concept results in the three steps of the project Title: "EValuation, EVidence, EVolution" and relates to the following aspects:

A. EValuation

Initially a scoring (EValuation) based on the recorded driving cycles (trip profile, user specific requirements) is undertaken

B. EVidence

Based on this analysis the application may provide "EVidence" that the individual requirements regarding the trip profile and driving behaviour of a user can be satisfied with currently available Vehicles. This also includes the proof of unnecessity of range anxiety or any other fear of the new technology of electro mobility.

C. EVolution

As a consequence, the long-term aim of the project is to present reliable and convincing results that are satisfactory for users to look for, and consequently buy an electric vehicle (EVolution). This should be a result of an informed, well-made decision rather than compromise.

Another part of the "EVolution" step is, to be part of the change and therefore support the mobile EVolution from combustion engines to electric.

The last meaning "EVolution" includes, presentation of the energy efficiency of the driving habits and therefore enforces a more ecological and therefore more economic driving behaviour of the user.

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IV. Evaluation Process

The evaluation process for the possible application of an EV takes place with the following steps. Initially the user records the driven trips with the help of the tool. Therefore the record can be initiated just before the start of the trip. Optionally the user can add further details like the actual payload and number of passengers. At the end of the trip the user concludes the record and can optionally add a charging opportunity where the car is parked.

When the user thinks they have covered all possible circumstances with the car, or just the general routine or intended purpose of the vehicle, the user can start an evaluation process. Based on the recorded trips that are supposed to be representative for general use, the available vehicles, downloaded from a frequently updated online database are evaluated with the usage.

The evaluation process is carried out by virtually letting the vehicles drive through the recorded tracks and letting them recharge where stated. After that the vehicle is stated as suitable if all recorded trips would have been able to take place. This means that for purely electric vehicles (BEVs) the state of charge must not reach empty state. For PHEVs or EREVs the additional fuel consumption is also calculated.

For all evaluation processes a worst-case scenario is taken into account as the required tracks must be fulfilled. Any fail would cause the requirement of a road side assistance service (RSAS) as a simple fill up of the tank is not possible.

All BEVs that passed the evaluation as well as all EREVs and PHEVs are presented in a list and can be sorted by various conditions like costs, consumption, number of passenger seats and other features. The user has the option to show more details about each vehicle and therefore find out about the estimated batteries state of charge throughout the recorded trips. This allows the user to see the degree of utilization of each vehicles range.

In addition, a cost analysis and comparison to the current fuel based vehicle is possible. This also allows to find out about the point in time the EV will be more cost efficient than the currently used vehicle. This takes the cost of purchase as well as ongoing costs into account.

The details of the implemented evaluation process are shown in Figure 3. When the evaluation process is started, an actual vehicle database is downloaded. The user now has the option to choose trips to be considered for the evaluation process. Depending on the indicated charger availability at the end of each trip, the charging opportunities are also considered.

In the following step each vehicle of the list from the database is assessed in the order they are listed until the end of the list. Each vehicle is now processed on the selected trip list in chronological order. According to the trip specific data the consumption of the current vehicle is estimated and the remaining energy is calculated from the original capacity. Initially each vehicle is assumed to be fully charged for the first trip. If the remaining energy is positive, it is examined whether the vehicle can be charged, and if so, how much energy could be charged. The charging processes are assessed depending on the available charging standards at the destination and the currently active vehicle to ensure compatibility. The chargeable energy is then added to the remaining energy, obviously allowing a maximum of 100% State of Charge (SoC).

This process is repeated for all selected trips, however if the remaining energy is not sufficient it is checked if the vehicle allows additional fuel based traction as with a plug in hybrid electric vehicle (PHEV) or extended range electric vehicle (EREV). If so the expected fuel consumption is calculated from the moment when 0% SoC is reached. If the vehicle is neither of both, but reaches theoretical negative SoC, the vehicle is discarded and will not show up in the result table.

After all trips are evaluated the electrical consumption as well as possible fuel consumption is given for both the complete amount of the selected trips as well as per 100

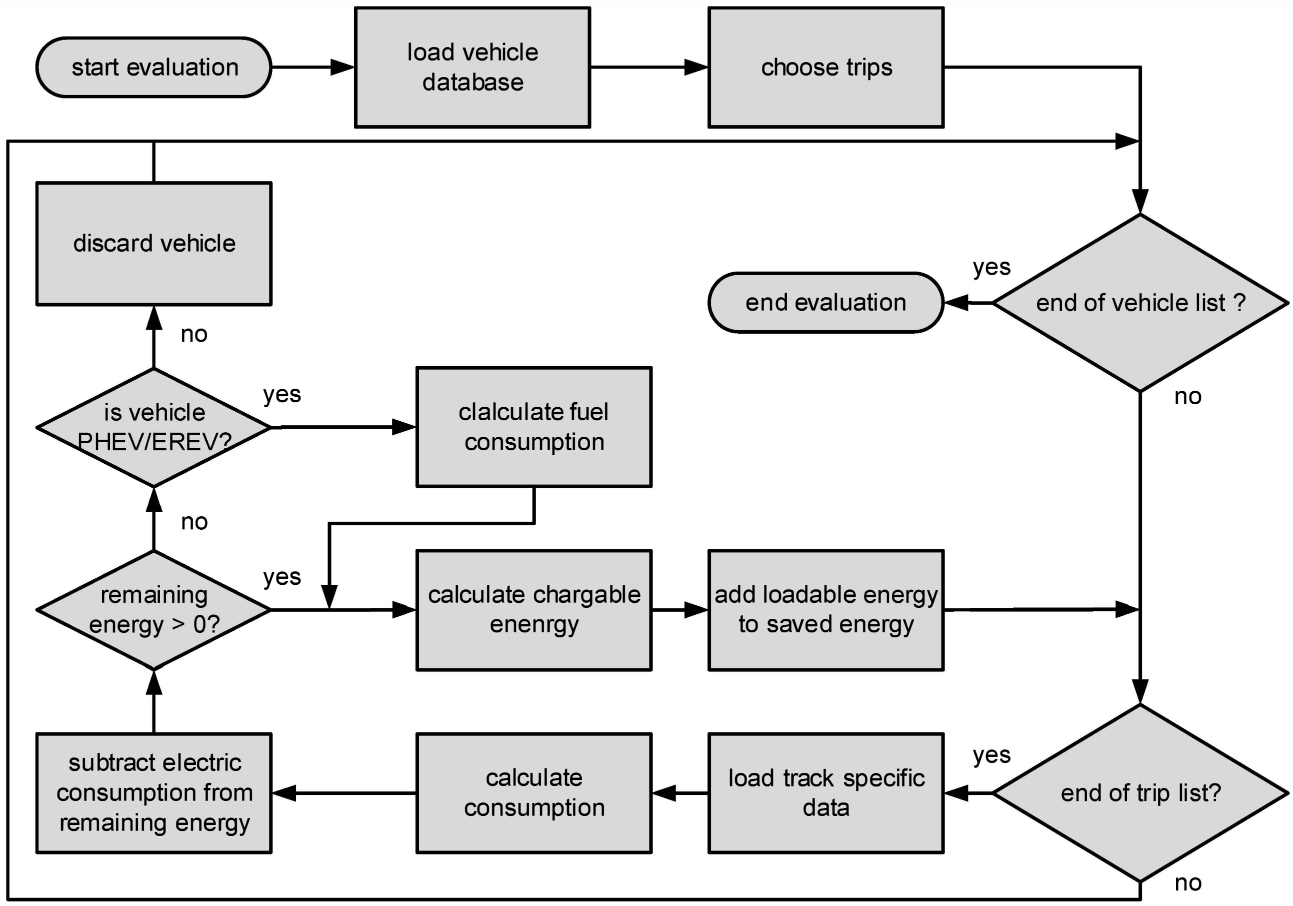

Figure 3 Flowchart of evaluation algorithm

km. This allows a comparison of the expected consumption and resulting costs for each vehicle.

A. Measurement Details

For the evaluation process there are two categories of data being gathered by the application. These include the trip data, which are automatically recorded after a manual user initialization, and additional information entered manually by the user. The latter include basic buying criteria such as

- Price
- Luggage space
- Number of seats
- Maximum speed
- Maximum Payload

Despite those criteria the range demands, consumption and therefore resulting ongoing costs are the main issues for the decision making process for or against a vehicle.

B. Influences on the consumption

The energy consumption of a vehicle is based on the sum of the driving forces as well as the vehicle parameters such as weight, friction factors and others. Many of those parameters are not available directly but are included in the NEDC results. Based on the NEDC results, the individual driver and trip profile factors are superimposed to allow the individual calculation of the consumption. The main apparent forces are (see Figure 4)

- F_B Force of inertia
- F_L Air drag
- F_S Climbing resistance
- F_R Rolling resistance

Most up to date smartphones include sensors for the global positioning system (GPS) [8] and acceleration.

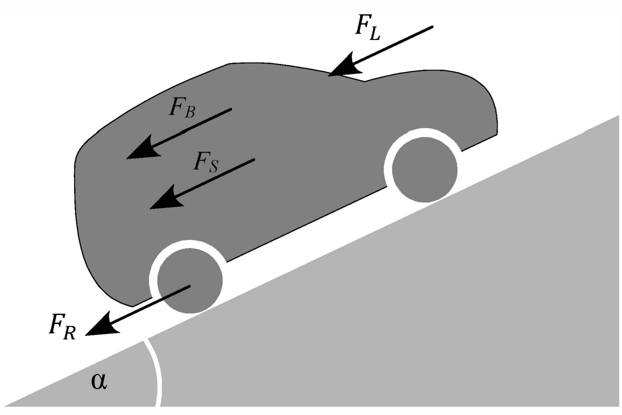

Figure 4 Agent driving resistances

These sensors are accessed by the application via the Android application-framework [9]. Nearly all available Smartphones are equipped with the necessary sensors. The application itself is usable on 86,3 % of all devices with the operating system android [10].

The GPS-data available for the application is given by the "location-object" based on the Android Framework [11]. This "location-object" includes the following details

Table 1 Properties and content of an android location-object

Information included in location-object	**unit**
Timestamp	ms
Latitude	°
Longitude	°
Altitude	m[1)]
Distance to a given location-object	m
Current speed	m/s

1) The altitude is calculated with the help of the world geodic system established and last revised in 1984 (WGS 84). It is a standard used for e.g. cartography and navigation including GPS. The WGS 84 describes the surface of the earth in relation to which the altitude is calculated using the coordinates of a GPS-receiver. [12][10]

Within the application the following details are extracted from the information for the evaluation process

- Acceleration (m/s^2)
- Gradient (°) (course of the altitude)
- Driven distance (m)
- Velocity (m/s) (velocity profile)

To compensate for the signal loss of the GPS sensor, e.g. in tunnels or in urban canyons, the acceleration sensor is used to calculate the driven distance. Even though the accuracy is not as precise as the accuracy of the extracted signal from the GPS-Sensor, it allows covering of short term signal losses of the GPS-Sensor and calculation of the driven distance.

Moreover it is possible to compute the additional energy consumption based on the user driving dynamics with the help of the acceleration sensor. This allows a further individualization of the evaluation process. In later versions of the application it is also planned to give feedback to the user, based on the efficiency of their driving behaviour to allow the user to improve the efficiency and therefore reduce the consumption.

C. *Evaluuation Concept*

The tractive energy demand E_V is a result of the integral over the tractive force F_V (1) [13][14][15].

$$E_V = \int F_V ds \tag{1}$$

also simplified as

$$E_V = F_V \cdot s \tag{2}$$

where the parameter s represents the driven distance. F_V can be calculated with the balance of forces (3)

$$F_V = F_B + F_S + F_R + F_L \tag{3}$$

The Force of inertia is calculated by

$$F_B = m_V \cdot a_V \cdot c_m. \tag{4}$$

Where c_m is an additional factor for rotating masses which takes respect of rotating drive train components. This factor is approximated as constant [14]. m_v is the vehicles mass and a_v the acceleration.

The rolling resistance F_R is calculated with the help of

$$F_R = m_V \cdot g \cdot \cos\alpha \cdot c_r. \tag{5}$$

With $g = 9.81 m/s^2$ being the acceleration due to gravity, α the climbing angle and c_r the rolling friction coefficient. This factor is generally dependent on the speed, pressure in the tires, tire material, road surface and weather conditions. However with limited speed and constant tire pressure, this coefficient can be assumed constant [14].

The climbing resistance is

$$F_S = m_V \cdot g \cdot \sin\alpha, \tag{6}$$

and with the help of the specific gravity ρ_L, the vehicles facial surface A_V, the specific aerodynamic drag coefficient c_d and the speed v, the air drag can be calculated as follows.

$$F_L = \frac{1}{2}\rho_L \cdot A_V \cdot c_d \cdot v^2 \tag{7}$$

D. *Result Presentation*

Based on the previously shown calculations, a diagram is created for each vehicles of the list that is generally suitable for the assessed trips. This diagram illustrates the course of the energy level throughout the assessed trips (see Figure 5). Optionally this diagram can be extended with details regarding the fuel consumption of the current vehicle and fuel and electricity prices. This allows the user to access economic calculations and evaluate possible savings with the EVs.

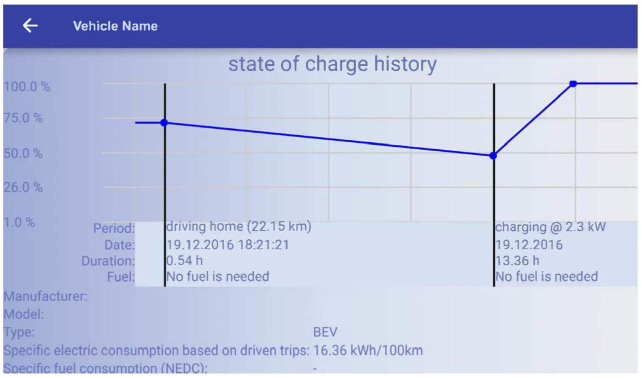

Figure 5 Application screenshot for the estimated state of charge for an evaluation process.

V. Conclusion

The presented mobile phone application allows users to evaluate a possible utilisation of EVs. Therefore, this application takes individual user data into account to allow a precise evaluation. In this context the driving habits and trip profiles are analysed as well as the distance and general vehicle requirements, such as the number of seats, luggage space and purchasing costs. The latter are also sorting criteria for the results table in which all suitable EVs are presented after the evaluation process. Moreover the user has the possibility to see details for each possible EV in order to estimate the extra energy available at each stop of the recorded trip list.

References

[1] "E-mobil check," in cologne-mobil - Elektromobilitätslösungen für NRW, 2017. [Online]. Available: http://cologne-mobil.de/e-mobil-check.html. Accessed: Feb. 5, 2017.

[2] ">> CHECK-E <<," 2017. [Online]. Available: http://www.austrian-mobile-power.at/check-e. Accessed: Feb. 5, 2017.

[3] Ruhr-Universität Bochum and Delphi Deutschland GmbH, Wuppertal, "Alltagstauglichkeit von Elektromobilität Bausteine für eine Technologie Roadmap: Infrastruktur, Fahrzeug, Sicherheit," Technische Informationsbibliothek (TIB), 2011. [Online]. Available: https://www.tib.eu/de/suchen/id/TIBKAT%3A683200054/Alltagstauglichkeit-von-Elektromobilit%C3%A4t-Bausteine/?tx_tibsearch_search%5Bsearchspace%5D=tn. Accessed: Feb. 5, 2017.

[4] P. Spichartz, M. Schael, B. Ni, A. Broy and C. Sourkounis, "Fleet test of electric vehicles regarding their suitability for daily use," *International Symposium on Power Electronics Power Electronics, Electrical Drives, Automation and Motion*, Sorrento, 2012, pp. 1396-1400.

[5] C. Sourkounis, P. Spichartz, P. Dost, et. al., "Alltagstauglichkeit von Elektromobilität - Langstreckeneignung und -akzeptanz," Technische Informationsbibliothek (TIB), 2015. [Online]. Available: https://www.tib.eu/de/suchen/id/TIBKAT%3A86383762X/Innovationen-f%C3%BCr-eine-nachhaltige-Mobilit%C3%A4t-Elektromobilit%C3%A4t/?tx_tibsearch_search%5Bsearchspace%5D=tn. Accessed: Feb. 5, 2017.

[6] P. Spichartz, P. Dost, N. Becker and C. Sourkounis, "Experiences with long distance electromobility in metropolitan areas," *IECON*

2015 - 41st Annual Conference of the IEEE Industrial Electronics Society, Yokohama, 2015, pp. 003626-003631.

[7] P. Dost, P. Spichartz and C. Sourkounis, "Temperature influence on state-of-the-art electric vehicles' consumption based on fleet measurements," 2015 International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS), Aachen, 2015, pp. 1-6.

[8] G. Xu, "GPS: Theory, algorithms and applications," 2nd ed. Berlin: Springer-Verlag Berlin and Heidelberg GmbH & Co. K, 2003

[9] T. Künneth, „Android 5 - Apps entwickeln mit Android Studio," 3rd ed. Rheinwerk Verlag, 2015

[10] "Dashboards," in Android Developers. [Online]. Available: https://developer.android.com/about/dashboards/index.html. Accessed: Feb. 5, 2017.

[11] "Location strategies," in Android Developers. [Online]. Available: https://developer.android.com/guide/topics/location/strategies.html. Accessed: Feb. 5, 2017.

[12] "Department of Defence World Geodic System 1984", 3rd ed. St. Louis, Missouri: National Imagery and Mapping Agency, 2004.

[13] A. Karle, „Elektromobilität: Grundlagen und Praxis." Carl Hanser Verlag GmbH & Co. KG, 2015.

[14] M. Mitschke and H. Wallentowitz, „Dynamik der Kraftfahrzeuge". United States: Springer Vieweg, 2015.

[15] P. Spichartz, P. Dost and C. Sourkounis, "Examination and measurement of range extension using different recuperation modes in electric vehicles," *2014 IEEE Industry Application Society Annual Meeting*, Vancouver, BC, 2014, pp. 1-9.