University of Applied Sciences and Arts of Southern Switzerland
Department for Environment Constructions and Design
Institute for Applied Sustainability to the Built Environment

SUPSI

Schweizer Forum Elektromobilität
Forum suisse de la mobilité électrique
Forum svizzero della mobilità elettrica

Territorial and climatic impact on the performance of electric vehicles

Shalako Baggi, Luca Pampuri*, Davide Rivola, Roman Rudel
University of Applied Sciences and Arts of Southern Switzerland (SUPSI),
Institute for Applied Sustainability to the Built Environment (ISAAC), CH-6952 Canobbio, Switzerland, www.supsi.isaac.ch
*Phone: (+)41 58 666 62 98, Fax: (+)41 58 666 63 49, E-mail: luca.pampuri@supsi.ch

Introduction

An electric vehicle (EV) has been equipped with a data logger, which allows to collect the data of the performances and the journeys of the car. An analysis of the data collected over a period of 19 months has been made. The goal was to cumulate know-how in the sector of electric vehicles. The analysis of the data allows to estimate which influence has the morphology of the territory and the climate on the performance of the EV. This knowledge can be used to promote the diffusion of EVs and propose a policy supporting the installation of new charging stations in the Southern Switzerland territory. The vehicle chosen for this test is a compact urban car from Mitsubishi. The model is an i-MiEV (Mitsubishi innovative Electric Vehicle).

EV-performance analysis

The cumulated data have been used to make two type of analysis. At first an analysis of the influence of the temperature on the car range has been made. Secondly the influence of the altitude gap on the range has been analyzed. High-resolution data cumulated over a period of nineteen months have been used to perform a statistical analysis. Thanks to a GPS tracker, the altitude profile of each travel has been rebuilt. The results cannot be applied to all electric vehicles because every typology of vehicle has a personal behavior, but the trend can be taken in consideration when making general observations.

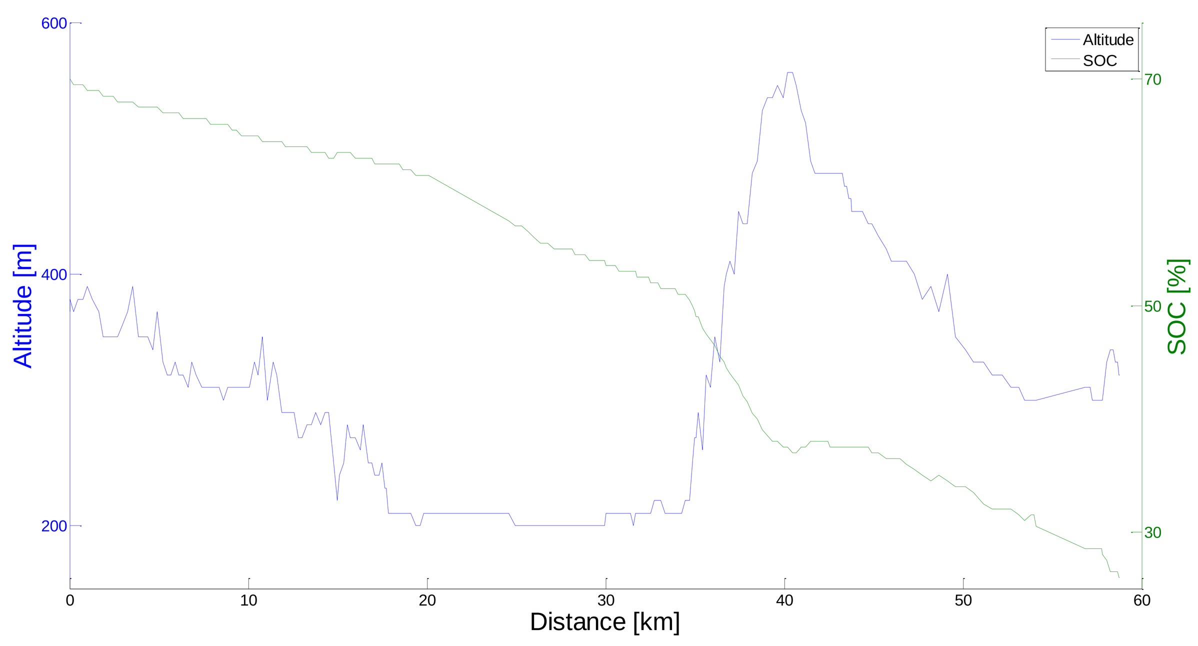

Figure 1: trend of the SOC in a typical travel with relative territory profile

Characteristics of the car

- **Battery**
  - Li-ion
  - 330 V
  - 16 kWh
- **NEDC[1] energy performance**
  - 135 Wh/km
- **Range (Manufacturer's declaration)**
  - 150 km
- **Maximum speed**
  - 130 km/h
- **Motor**
  - Permanents magnets
  - 49 kW
  - 180 Nm
  - 200 kg
- **Connection sockets**
  - Standard 230 V/10A
  - CHADEMO fast charging

1) New European Driving Cycle

Results

One of the benefits of an electric car is that it recovers a part of the potential energy when it goes downhill. As shown in the figure 1, in the descending phase the battery is recharged. The goal of the following analysis is to determinate if with a jagged journey the range of the electric car is greater than a regular journey thanks to the recovery of energy. To make this analysis we calculated an index that indicates the irregularity of the route. This coefficient has been arbitrarily call "coefficient of discontinuity". The formula used for the calculation of the index is the following:

$$ID = abs\left\{\frac{\Sigma CPG}{TG}\right\}$$

Where CPG is the cumulated positive altitude gap and TG the total altitude gap of the trip. In others words this index indicates how much altitude gap has been travelled in the trip in relation at the altitude gap between the start point and the end point. The figure 2 shows the estimated range of the EV in function f the index of discontinuity.

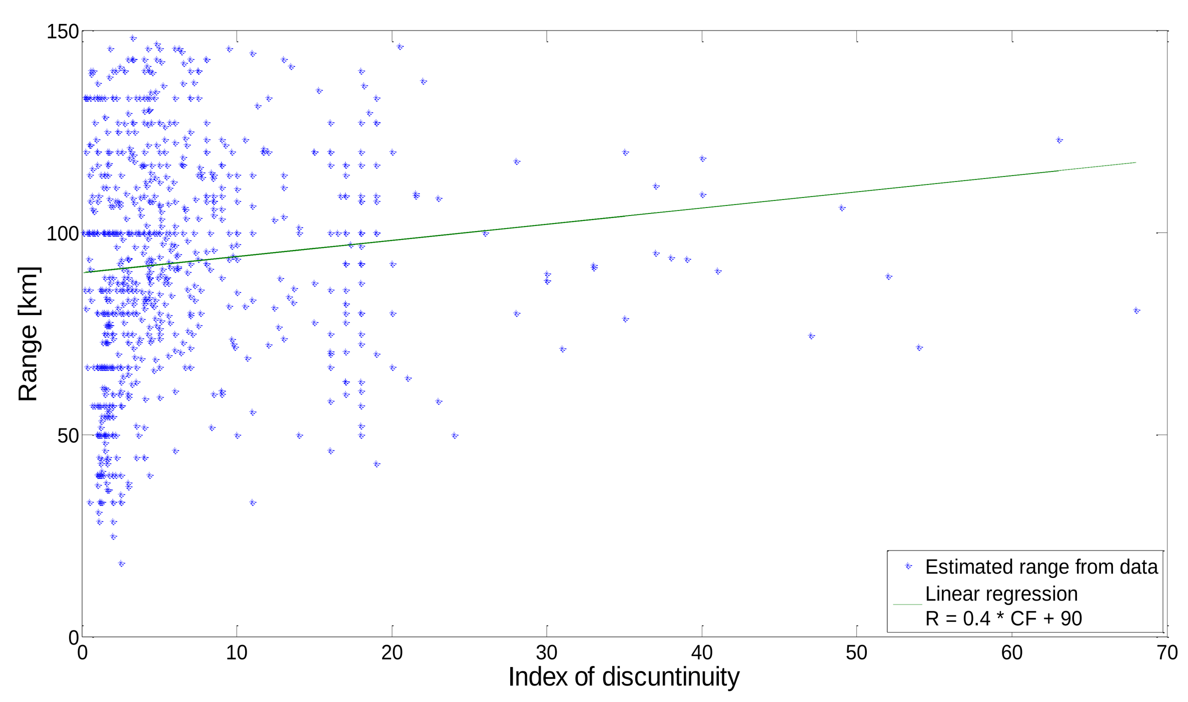

Figure 2: estimated range in function of the index of discontinuity

A relationship between the index of discontinuity and the range has been extrapolated with a linear regression. The Pearson product-moment correlation coefficient of this data is 0.12. This coefficient is a measure of the linear correlation (dependence) between two variables X and Y, giving a value between +1 and −1 inclusive, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation.[2] In our case the data are bound with a weak positive correlation. Consequently we can't affirm with certitude that a jagged journey allows to extends the range of the electric car.

The figure 3 represents a statistical analysis of the estimated range in function of the temperature. The data have been divided for each month. To show the relationship, an overlap with the average daily temperature has been made.

The red line represents the median, the box represents the likely range of variation (50% of the data) and the whiskers are the limits of the totality of the data. The outliers are plotted individually (red points). These outlier are probably due to the low resolution of the odometer (1km steps).

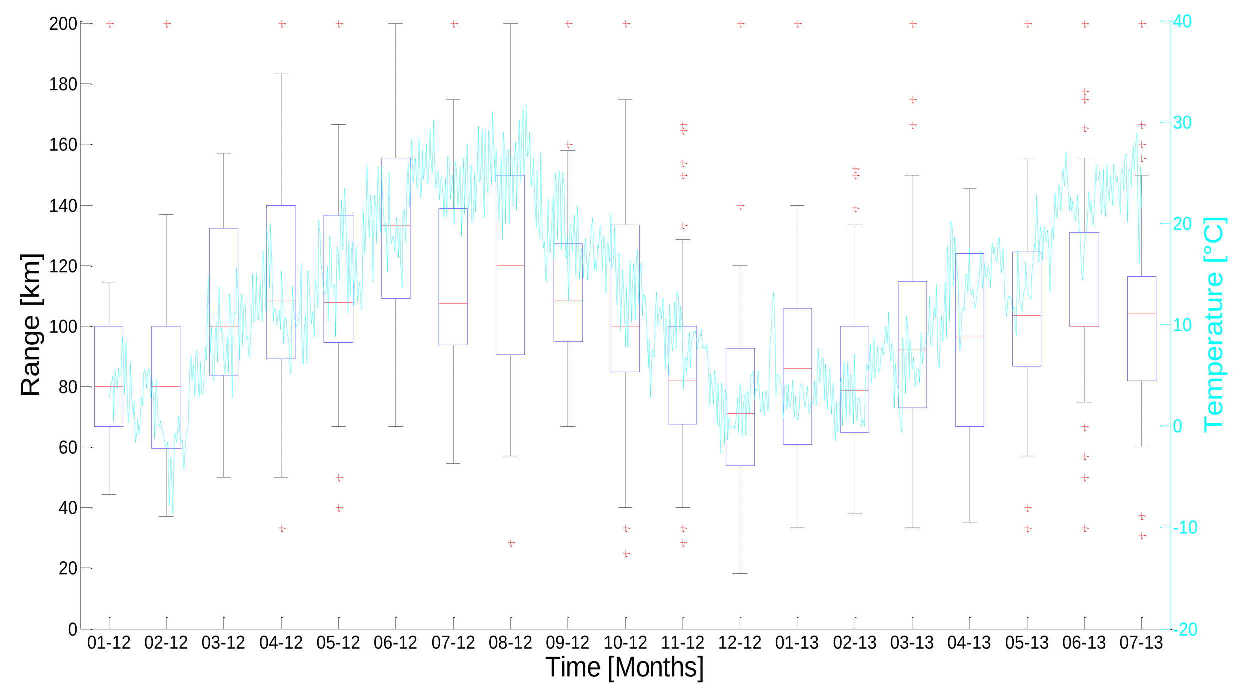

Figure 3: boxplot of the estimated range in function of the temperature

We observe that in general the decrease of the temperature is directly proportional with the decrease of the range, but during the warmest months this proportionality isn't respected. The figure 4 shows the dispersion of the estimated ranges in function of the temperature.

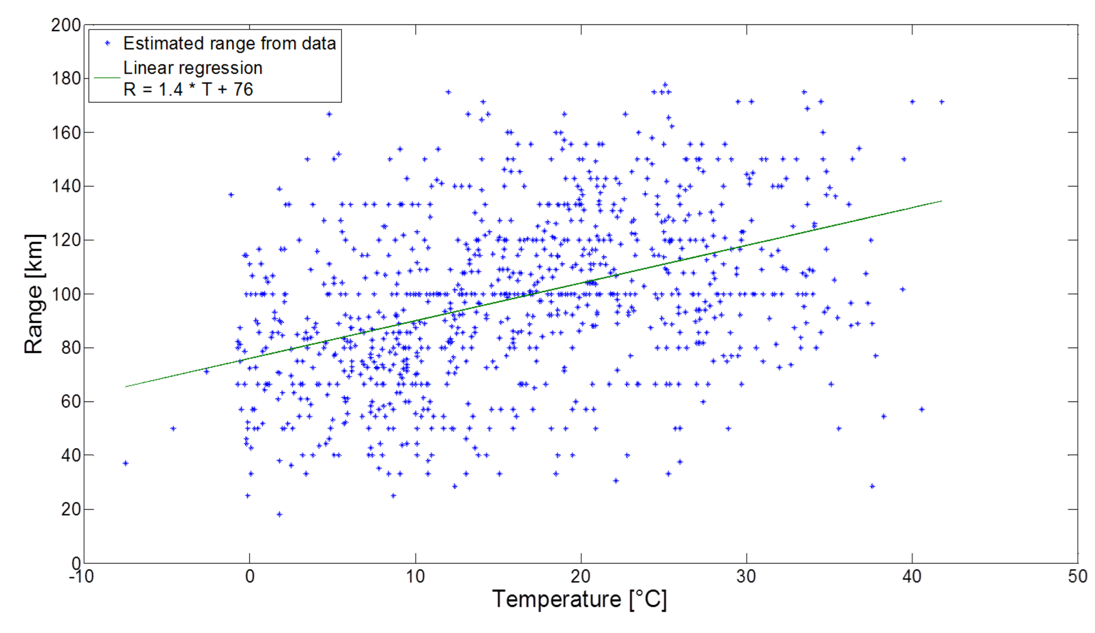

Figure 4: dispersion of the estimated range data in function of the temperature

Also in this case the relationship between the temperature end the range has been extrapolated with a linear regression. The correlation factor of this data is 0.34. This means that the data are bound with a moderated positive correlation. We can affirm with sufficient certitude that the temperature affects the range of the EV.

Conclusions

- Our analysis indicates that a territory with jagged profile allows to better exploit the characteristics of an EV. An EV, in respect to a traditional vehicle, can recover energy in the descending phase. Thank to the recovered energy, the range of the electric vehicle augments if the territory is jagged. As consequent an electric vehicle that travel a jagged route consume less energy than a traditional vehicle. This difference is less significant in a flat route. Additional analysis are anyway required in order to exclude effects due to high driving speed and low resolution of distance measurements.
- The results of this research show that a low temperature causes a decrease of the range and temperatures over 27°C, as recorded in the summer months, has the same effect. This behavior is due to the fact that the battery has an ideal range of operational temperature and their capacity decrease if the temperature is out of this range. However it is important to note that these seasonal variations of the battery capacity are affected by the use of the accessories of the EV: the heating during winter and the air conditioning during summer. In general all this factors of influence cause a seasonal variation of the range of the EV. Therefore we can affirm that the thermal insulation plays an important role in electric vehicles.
- This analysis represents the point of departure for the development of an equation that allows to determinate the range of the electric vehicle in function of the temperature, the previewed altitude gap and the driving style of the user. For this last parameter a separated study has been previewed in order to increase the reliability of these results thanks to an additional analysis . The analysis of data from other vehicles and the extension of the period of observation are the goals of our future work.

2) Kendall, M.G., Stuart, A. (1973) The Advanced Theory of Statistics, Volume 2: Inference and Relationship, Griffin. ISBN 0-85264-215-6

ACKNOWLEDGEMENTS: Swiss Federal Office of Energy, Repubblica e Cantone Ticino, Città di Mendrisio, Azienda Elettrica Ticinese (AET), Infovel, Aziende Industriali Mendrisio (AIM) and EcoVelClub.