# COPE1 – Taking Control over EV Range

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## ABSTRACT
A problem for electric vehicles (EVs) is that available battery technologies limit the driving range and might cause range anxiety, and as technology stands now, this problem will be present for many years to come. As a result, it is important to design tools that could easily help users overcome range anxiety issues. Design of such technology can take advantage of the experience accumulated by drivers who have already coped with this problem for many years. In this paper, we describe a coping strategy observed among some more experienced EV drivers, as well as, why this strategy is powerful, and demonstrate a first attempt to utilize it in design.

## Keywords
Coping strategies; electric vehicle information system; energy management; information visualization; interaction design; range anxiety.

## Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## 1. INTRODUCTION
In the electric vehicle (EV) use context, range awareness, or lack thereof, manifests itself through the phenomenon referred to as *range anxiety* [1, 4]. Range anxiety is an anxiety or fear of not reaching a target before the battery is empty, which can occur while driving or prior to driving as the user worries about later planned trips. The main cause for this problem is that EVs have a more limited driving range (e.g. Nissan Leaf has a claimed range of about 160 km (100 miles) in combination with charging times of approximately 8 hours in normal power plugs and a minimum of about 2 hours in fast charging stations for a fully charged battery. This is due to available battery technology and limitations of the electrical grid. This means that it might take hours to correct a trip-planning mistake, or even make the driver become stuck if discovered too late. While there is hope for improving battery technology in the future, current knowledge does not offer cheap manageable solutions for improving battery performance.

In earlier work we have been trying to address range anxiety by exploring how distance-left-to-empty information could be visualized in more accurate and intuitive ways, using maps and parameters of the world [2]. However, these types of calculations are problematic, as they tend to require knowledge about the future. Therefore, we are now researching alternative ways of dealing with range anxiety.

We address this problem by doing interaction design based on coping strategies developed among experienced drivers and reshape the user interface to meet the need of overcoming range anxiety. In this paper, we will describe the coping strategy we encountered with experienced drivers and why it is powerful approach, as well as, illustrate a first attempt to utilize it in design.



**Figure 1. Nissan Leaf EV driver demonstrate calculations of required energy efficiency for traveling 10 km using 1 battery bar (1,5 kWh).**


**Figure 2. COPE1. Circles represent locations, blue have been selected in a sequence connected with lines. Required energy efficiency is displayed in the lower right corner.**

## 2. OBSERVATION OF A COPING STRATEGY
When conducting field studies meeting experienced EV drivers, we encountered a range-anxiety-coping-strategy among one of them that appeared efficient to us, although yet relatively simple to perform. This driver had a few years experience through contacts, as a board member of the Swedish national EV interest group, and had also owned a Nissan Leaf for 3 months at the time.

The coping strategy can be described with the following vignette. The experienced EV driver was going to drop off the researcher at the airport and then drive home again. First, he looked up the distance back and forth to the airport (total distance). Secondly, he checked how many "bars" he had left in his Nissan Leaf user interface (Figure 1), each of those is worth 1.5kWh and there is a total of 12 (+2 hidden ones that provide sufficient security, as known by Nissan Leaf expert drivers [3]), which means he could approximate how much energy he got in the battery. Thirdly, he used his smartphone to do the following calculation:

[energy in battery(kWh)] / [total distance (km)] = [required energy efficiency (kWh/km)]

Lastly, he reset the "Energy Economy" (also kWh/km) figure in the existing Nissan Leaf interface. After this, he was ready to drive to the airport. In this particular case, he had calculated that he needed to drive with an energy efficiency of a maximum of 0.15kWh/km to be able to do the trip safely. When we arrived at the airport, he had 39km home and the cars own distance-left-to-empty estimation (often called the guess-o-meter) signaled 43km. This would normally be a typical cause for range anxiety, however, when we talked about this fact and range anxiety, he quickly replied:

*"as long as I stick to the 0.15 (kWh/km) I will make it…don't worry about it".*

In this situation, we believe that this strategy really demonstrated its potential in terms of easing range anxiety. It is also notable, that the strategy somewhat looks beyond the complexity of the world as in elevation, wind, number of passengers and so on, as the user can continuously adjust driving in relation to the required efficiency. In this sense, the strategy becomes a proactive and continuous tool, rather than a guess about how far one could reach (as the distance-left-to-empty meter) or our earlier work [2].

However, to be able to execute such a strategy, the user needs to know a few things about the EV and the world.

1. Know about the strategy in the first place.
2. How long is the desired route?
3. How much energy do I have?
4. How do I execute the calculation?
5. Where to get energy efficiency for comparison?

All of which, could be easily supported by the EV user interface to support both new and experienced EV drivers.

# 3. DESIGN RATIONALE

Based on our observation, we decided to design a prototype to begin to explore how this coping strategy could be used in design, and to further explore the values of such a strategy in the EV UI. We also assume the following to help set a direction of the design:

a) People have a limited set of locations relevant for driving, and a good understanding of where they are.

b) Users do not want to spend time on planning for everyday driving; this type of tools should be effortless.

c) Planning can take place both in-car or elsewhere on an external device connected to the EV UI.

# 4. COPE1 – COPING STRATEGY PROTOTYPE 1

Our prototype COPE1 (Figure 2) is implemented using HTML5 and Processing.js and runs in any browser. In its current state we have mainly ran it in a browser on our computers to try out the idea, but it is intended for use on an iPad or similar tablet devices.

The prototype provides the user with the possibility to add locations important to them using a map. We imagine that important locations might be anything from the user's home, to workplace or charging stations. A circular area in the design represents each location and the distribution is loosely based on the real map location. With loosely we mean that we try to put them on the right location, but if two areas intersect they will slowly move away from each other, similar to the London Underground topological maps designed by Harry Beck in 1931. This is done to avoid "hidden" locations and thereby improve accessibility and the interaction with regards to our rationale: it should be effortless and quick to set up a plan.

When the user has added some locations it is possible to tap on a location to set a starting point that will be highlighted purple. When a starting point is set, the size of the other locations are updated in relation to the distance between the starting point and each location, in other words, the further away, the smaller location. This is to provide some feedback on the distances and thereby hint on the amount of energy required to reach them.

After the starting point is set, the user can begin to set a route by adding a sequence of locations. The end location will be highlighted yellow, and the route will be connected with a line that gradually shifts in color from purple (start) to yellow (end) to provide some feedback on directions. If the user wants to drive back and forth between locations, lines will be separated to maintain a clear visual of all fare-stages.

In the lower right corner, the prototype displays the energy efficiency required to complete the whole route based on the energy in the battery and the total distance of the selected route. In its current state, the EV is always fully charged, latter this will be updated with the actual state of charge of the EV.

All in all, setting up a route can be done in seconds, even more complex routes, and the system automatically computes the distance and required efficiency for the route.

# 5. DISCUSSION

The range anxiety coping strategy that we are considering in this paper shows an important potential in that current energy efficiency can be computed only with data coming from the car. This is a great advantage in relation to other forms of range anxiety help, which need to take into account data from outside the car to provide range information, such as map data, weather data, traffic data, etc. [2].

However, *planning* based on energy efficiency will not be accurate if it is only based on the driving distance and the current charge, as our drivers have done it. Indeed if our airport driver would have met a traffic jam in cold weather on his way back from the airport, his remaining energy (and therefore the energy efficiency he has planned for) would not have been enough, as energy needed for the headlights and car heating decrease the energy efficiency and they are also conflicting with the strategy of driving slow to spare energy. Still, even in adverse conditions as long-time traffic jams, the energy efficiency required to reach the target can be computed with in-car information, thus arguing for the efficiency of this coping strategy.

# 6. FUTURE WORK

We are currently investigating the placement of a moving object (the car) on the topological map without disturbing interaction. When this is done, the starting point will be automatically set based on the location of the EV. This also requires that the sizes (representing distance) of the locations updates as the EV moves.

Another challenge we are currently addressing is the lowest energy efficiency that is actually theoretically and practically manageable, taking into account factors that affect energy efficiency, such as heating, speed and lighting. For instance, a low energy efficiency might require that the user drive unacceptably slow, which may also be illegal on some roads.

# 7. REFERENCES

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