Evaluation of a driver’s compatibility with electric, plug-in hybrid, and hybrid vehicles based on mobility patterns analytics

Supporting the transition to electric vehicles

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Abstract
Many potential buyers are hesitant to switch to an electric vehicle because of their shorter range between two full charging cycles. Creating an objective assessment to evaluate if switching to Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV), or Hybrid Electric Vehicles (HEV) respectively is favorable for an individual driver relies on multiple factors: the driving style (e.g., harsh maneuvers, anticipation), the typical daily distance traveled, the usual speeds at which the driver travels, the road environment (e.g., urban versus motorway), the availability of charging infrastructure nearby and the effective deliverable power (kW), and the typical stop times close to chargers, among other factors. Assessing the transition potential to BEV, PHEV, or HEV has various market applications: providing fleet analytics in terms of eco-efficiency and driver coaching, boosting electrified automotive sales, optimizing corporate fleets, minimizing carbon footprints, or selecting the vehicle type most suited to individual needs. This paper will shed light on how to assess electromobility transition by collecting, augmenting, and profiling driving trip data.

1. The current situation
Looking back at the history of passenger cars, traditional Internal Combustion Engines (ICE) prevailed in the automotive landscape. With the Paris Agreement entering into force in 2016 and aiming to limit global warming to a maximum of 2, preferably 1.5, degrees Celsius, the pressure to reduce carbon emissions is high [1]. To achieve this ambitious objective, emissions from transportation must be drastically lowered. A shift towards electric vehicles, in all its flavors, is the logical consequence.
With most governments granting subsidies for the purchase of BEVs, and in some countries also for PHEVs and HEVs, the share of electric vehicles should continue to grow within the European Union. According to the European Federation for Transport and Environment AISBL, it is estimated that by 2025, 172 new BEV models will be launched in Europe [2].

In the early years of electric vehicles, many had a bad reputation for the limited range they could reach between two full charging cycles. Even more, the availability of charging stations was a critical limitation for early adopters of EV (in particular BEV) models. Consumers may still be hesitant to switch to electric vehicles due to three main reasons:

- *Range anxiety*: worry on the part of a person driving an electric car that the battery will run out of power before the destination or a suitable charging point is reached.
- *Missing charging infrastructure*: lack of charging points at the trip destination.
- *Acquisition cost*: relatively higher prices for buying an EV compared to a combustion-powered vehicle, which requires strong fiscal measures from the national authorities.

Creating an objective assessment if the transition to EV is favourable for an individual driver relies on multiple factors: the driving style (e.g., aggressive driving, harsh acceleration,...), the anticipation and adaptation to the route topology, the average trip distance, the time between charging cycles, among other factors.

2. The technology used to create objective scores

The underlying idea of creating profiles from location data is not fundamentally new but has been used for many years in areas such as risk assessment in insurance telematics solutions. Motion-S developed in the past years a platform that can process mobility and trip data from moving vehicles and provide, in a matter of seconds, meaningful profiles on risk exposure, eco-mobility, and vehicle wear to serve business applications for various sectors.

Figure 1 shows the major components of the data processing pipeline, namely data collection, augmentation, and profiling.
The next sections will explain the phases of data transformation in detail.

Data collection
As a fundamental element for many telematics solutions, location data is crucial to derive mobility patterns and profile driving behavior. Latitude, longitude, timestamp, and vehicle heading as primary data input can be collected via various hardware solutions, either directly from the car’s telematics unit or via external devices such as dongles or even smartphones. Dongles (in particular OBD-based), connected to the vehicle, have been around for decades. Periodically submitted location data, transmitted via mobile networks, have been the basis for multiple fleets management or, in general, telematics solutions. However, in the past few years, fleet managers hesitate to use dongles because they are not recommended by car manufacturers since dongles could interfere with some vehicles. Furthermore, the integration effort, hardware, and communication costs are considered as limiting factors.

In more recent years, both smartphones and, more recently, car-data platforms, have been leading the trend of mobility data collection. In particular, with the booming of smartphones and affordable mobile communication networks with ever-increasing bandwidths and coverages, tracking solutions were developed based on mobile apps, using the phone’s integrated GPS sensor and gyroscope functionalities.

A significant advantage of these solutions is the possibility of providing immediate driver feedback to optimize driving behavior via coaching elements. However, in order to ensure that data is coming from a specific vehicle, a link between the driver and the car needs to be
guaranteed to assign a trip to a specific driver and car. This can be achieved via a Bluetooth connection with the vehicle’s onboard entertainment system or an external Bluetooth beacon.

With more and more cars being connected and providing rich information to car data platforms, new opportunities arise with high-quality car data ranging from failure codes to events. Platforms like High Mobility [3] or Otonomo [4] provide anonymized, cleared data which allows to profile and analyze vehicle status and driving behavior in near-to-real time for a large variety of automotive brands.

**Trip data augmentation**
To get meaningful insights about mobility data, location data is put into its particular spatio-temporal context.

![Timestamped location data as a basis for trip data augmentation](image)

Motion-S developed a platform that augments data in three consecutive phases:

1. Transmission of the map-based route of a raw trip to a secured platform
2. Extraction of all possible information layers for each segment of the trip route
3. Consolidation of results to get the augmented trip

During this process, more than a hundred different information elements are added to each location and road segment of the trip.

1. **General trip information**: raw and matched locations, distance and time, geocoded origin and destination, points of interest along the trip
2. **Driver actions**: illegal turns & U-turns, illegal directions
3. **Road environment**: speed limits for cars and trucks at each point of the trip, the possible speed at each location of the trip, specific road elements (roundabouts, tunnels, bridges), road types, lane categories, low mobility areas, controlled access locations, limited-access roads, type of divider and categories
4. **Road topology**: slope type and degree, road roughness index, road curvature radius
5. **Traffic information**: average speed of traffic, the average speed of traffic capped by the speed limit, free-flow speed, and jam factor

6. **Road signage**: all road signage information, including type, category, and specific location

7. **Weather information**: general weather information for the duration of the trip, including temperature, humidity, wind, surface conditions, sky status, and precipitation levels

### Profiling models

The platform can profile trips based on the augmented data, meaning calculate scores and metrics to conclude on a given mobility aspect. In particular, for the EV transition assessment, we consider the following elements.

1. **Fuel consumption estimation**: using fuel and electricity consumption models based on the driving profile and the road topology. These models are based on road slope and vehicle speed pattern [5]

2. **Eco score**: as an indication of the driver’s driving profile efficiency, compared to the average traffic flow of the same route

3. **EV score**: indicates the potential to switch to electric vehicles for a given profile

The profiling models are built on several assumptions regarding available infrastructure, driving dynamics, mobility patterns, and environmental factors, as illustrated in Figure 3.

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**Fig. 3: Influencing factors and rules for each motorization type compatibility**

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To assess the suitability of a specific motorization type, a minimal amount of trips is required, which should, in the best case, represent the usual mobility patterns of a driver. In principle, a
set of ten trips is sufficient to develop a reliable result. Still, the higher the number of trips provided, the more objective the assessment as outliers can more easily be identified.

For each driver, three scores are calculated: BEV, PHEV, and HEV compatibility score. Each score ranges from 0-100, with 0 being the lowest (complete incompatibility) and 100 being the highest reachable (perfect compatibility) score. The underlying algorithm calculates all scores, starting with the most electrified motorization type BEV, and ending with the least electrified type HEV.

Each trip is analyzed and a number of features per trip are calculated, at a later stage we also calculate some features over the aggregate of trips as well as using the information provided by the driver, such as whether or not they have a charger at home or their workplace. Since the conditions for compatibility for BEV and HEV vehicles are different, we consider different sets of features to assess the compatibility with each vehicle type. Figure 3 shows a list of such features.

A fuzzy logic inference system (FIS) has been developed to assess the compatibility of each vehicle type. Below is an example of the PHEV suitability score.

Fig. 4: Sample rules explaining the PHEV compatibility

For a given driver, we can predict a compatibility score. For example, we are comparing two drivers: one with a high compatibility score and one with a low compatibility score.
Table 1: Comparison of two exemplary PHEV compatibility profiles

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<tr>
<th>Driver 1: High compatibility score of 67.4</th>
<th>Driver 2: Low compatibility score of 24.1</th>
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For Driver 1, the green area, marking a high PHEV compatibility, is filled, meaning that at least one of the rules implying high compatibility was activated fully. This was the case since Driver 1 only drives about 17.8% of the total distance at low speeds (up to 50 km/h) and 37.6% of his distance at 90 km/h or more. Furthermore, at least one of the rules indicating medium compatibility was partially activated, leading to a limited orange area. This is because the profiler detected the availability of free charging infrastructure at the detected driver workplace.

In the case of Driver 2, mainly the low compatibility category was triggered and the two others to a much lower extent, driving the centroid (the black line) to the left. In particular, this driver declared the impossibility of installing a charger at home, and the profiler did not detect any free charging station at work nor near the destinations of her or his trips. On top of that, the time between consecutive trips is too short to effectively charge the battery.

3. Application fields & potential solutions

Use case 1: Fleet analytics and optimization in terms of eco-efficiency and driver coaching

With fleet vehicles being renewed regularly to reduce maintenance costs and limit possible downtimes, fleet operators and managers need to have deep insights into their fleet's mobility patterns, such as average trip distances, idle times available for charging, charging infrastructure at trip destinations and along the most common routes, among others.
This information is crucial to optimize the fleet’s composition in terms of regular combustion, hybrid or electric vehicles. With more and more regulations in force, limiting $CO_2$ emissions on corporate levels, reducing the environmental footprint through switching to sustainable mobility modes is a must already today. Calculating compatibility scores on a per-driver level allows fleet managers to optimize their fleet composition.

![Fig. 5: Visual analytics to identify the best fleet composition](image)

**Use case 2: Automotive Pre-Sales Support**

In the past years, the number of electric vehicle models has continuously grown. Still, consumers are confused about alternative motorization and miss guidance in selecting their next car. Analyzing day-to-day mobility patterns, such as average trip distances, idle times available for charging, charging infrastructure at trip destinations and along the most common routes, enables assessing the individual potential of the transition to electric, plug-in hybrid, or hybrid vehicle.

When targeting end consumers, the automotive sector needs to convince them that alternatives to traditional combustion engines are competitive. The car dealer can objectively recommend a vehicle type with the most compatible specification based on reference data sets.
Use case 3: Specific insurance for environmental-friendly vehicles

With more and more electric vehicles being launched, insurance companies have become conscious of this new customer group. Liverpool Victoria [6] and Bâloise Group [7], to give some examples, launched specific insurance programs covering specific risks for electric vehicles, e.g., breakdown assistance and towing to the nearest charging point. Thinking further and using driving behavior analytics not only for risk but also for rewarding eco-efficient driving styles, is just the next step. To improve customer retention, positive communication channels with the clients are essential. Trip logbooks integrated into a mobile app, for example, allow customers to keep track of all trips they did in the past and how good they have been driving in terms of risk and eco-efficiency. Insurance companies can implement rewards programs based on the scoring methodology, granting cash pots for green benefits, e.g., EV charging discounts, discounted premiums for EV cars, or soft mobility services.

Case Study: AskLee

FEBIAC, the representative of car manufacturers and importers in Belgium and Luxembourg, strived to overcome the hurdles of mass adoption of electric vehicles and promote eco-efficient mobility. What needed to be done was to ensure that the consumers understood that range anxiety is a thing of yesterday as new-generation vehicles and batteries have strongly evolved. Recently, many car manufacturers launched new EV models - nevertheless, sales of electric vehicles were only taking up slowly. FEBIAC, as the organizer of the yearly Brussels Motor
Show, got in contact with Motion-S, to launch a mobile app that helps car buyers evaluate whether an electric car would satisfy their needs.

AskLee, a mobile app, was developed based on the platform of Motion-S: integrating the mobile Android and iOS trip detection software (SDKs) in the mobile app and using the platform to calculate accurate eco and EV transition profiles. The app has collected more than 208 thousand trips covering over 3.4 million km during the past months. It has been a real added value for potential customers in their decision-making process.

Fig. 7: Mobile app frontend of AskLee

**Conclusion**

The decision to buy a new car has always been difficult, even when only combustion engines were available. Today, it is even more complex, with hybrid and full-electric vehicles coming to the market in many variations and with different battery capacities. With more and more car manufacturers bringing new models to the market, the gap between high-performance cars and short-range electric vehicles will hopefully be closed shortly, allowing more people to choose an environmentally friendly individual transport mode.

Data analytics for explaining the compatibility of engine types can surely help individuals and corporations assess the suitability of BEVs, PHEVs, or HEVs.
References


[3] High-Mobility, Website: https://high-mobility.com


