European Green Vehicles Initiative – Expert Workshop

Testing of Electrical Vehicle Performance and Safety

Thursday 3 July 2014 - Fondation Universitaire, Brussels

Asterics – Ageing and efficiency Simulation & TEsting under Real world conditions for Innovative electric vehicle Components and Systems

SEVENTH FRAMEWORK PROGRAMME

Real world driving cycles for Electric and Hybrid Electric vehicles

Definition of a synthesis methodology and implementation on real-world case studies within the ASTERICS project

Lorenzo Berzi, Marco Pierini– Department of Industrial Engineering, Florence

Laura Borgarello, Claudio Ricci, Alessandro Piu, David Storer – Fiat Research Center, Turin

Hellal Benzaoui, Philippe Dutal, Florian Pereyron – Volvo, Lyon

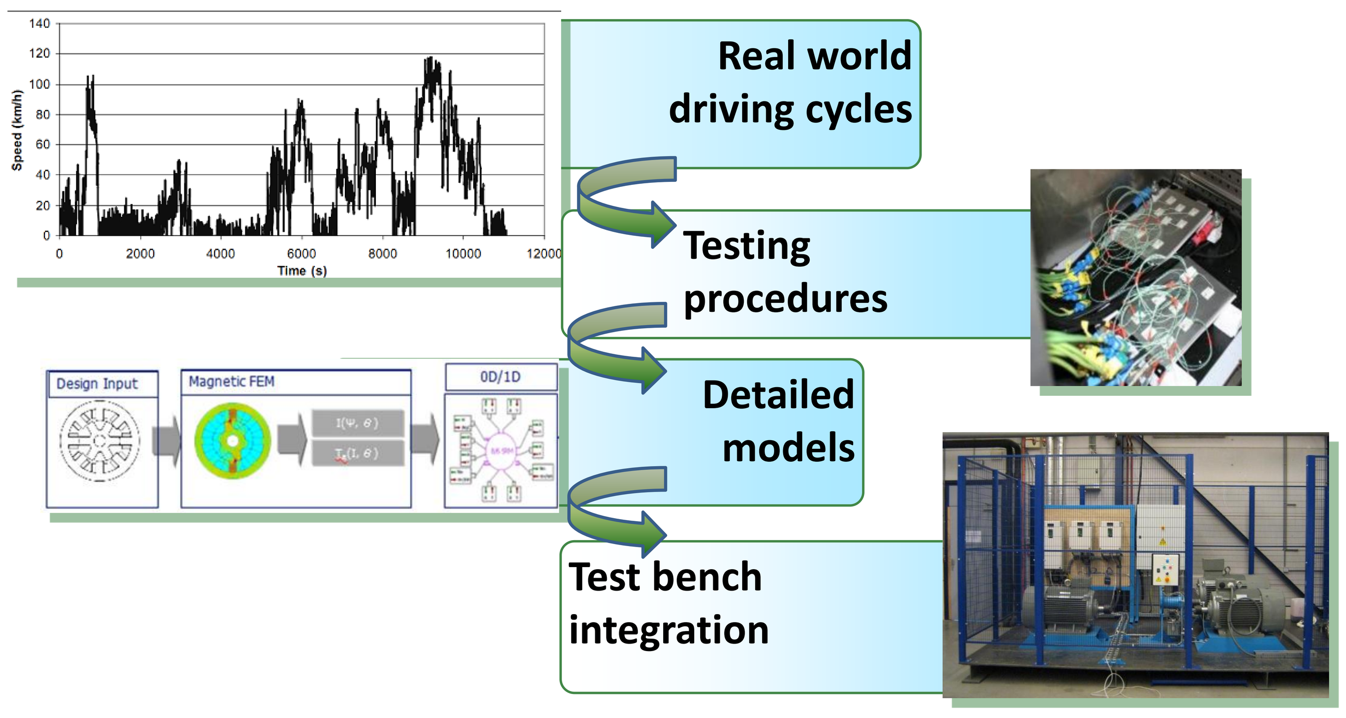
Horst Pfuegl – AVL, Graz

>> ASTERICS Project

Nowadays, there is a **strong demand for electrification of transport** in Europe, main drivers being the potential in primary energy saving and in the reduction of air emissions.

Overall performances of Fully Electric Vehicles (FEVs) have to be enhanced to **meet customers' expectations** on a broad basis. From an OEM perspective, **innovations are required in design, simulation and testing methodologies**.

The ASTERICS project will contribute **improving modelling and testing tools** that will be the base for **future developments of FEVs.**



>> ASTERICS Objectives and results

- Identification of **Real world environment and conditions** based drive cycles
- Development of **advanced testing methodologies** to automatically populate the component simulation models for **Battery, Inverter and E-Motor**
    - procedures for accelerated ageing of Battery, Inverter and E-Motor based in order to shorten the testing time
- Development of accurate **high fidelity models** for Batteries, Inverters and E-Motors
- **Total system (E-driveline) models integration** and validation on test bench.

>> Driving cycles and their development

A Driving Cycle (DC) is **a standardized procedure aimed to evaluate vehicle performances in a reproducible way** under testing conditions. It includes a time–vehicle speed signal as main input data; the test is significant if as far as **the DC is representative to typical vehicle use**. DCs can be obtained through «synthesis» of measured data.

Even if a large number of DCs is available in literature and vehicle regulation standards, there are still strong **reasons pushing for the development of new cycles, such as:**

- significant variations in driving patterns can be sometimes identified on a **local scale**
- **electric vehicles can induce a different driving pattern** from those adopted on conventional vehicles by the same users
    - **regenerative braking capabilities** can modify the driving style of the user and can significantly modify vehicle energy consumption
- recent literature work propose multi-varied simulation through the **use of a large amount of driving data** instead of "synthetic" cycles
    - a small database of **real-world trips for EVs** is needed.

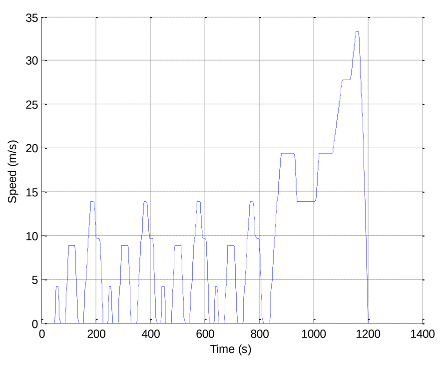


Fig. 1 - NEDC legislative cycle (time-speed profile)

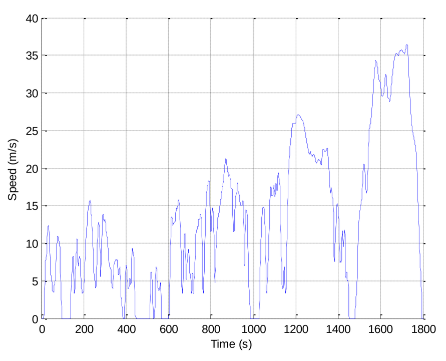


Fig. 2 – WLTC legislative cycle (v.5) -time-speed profile

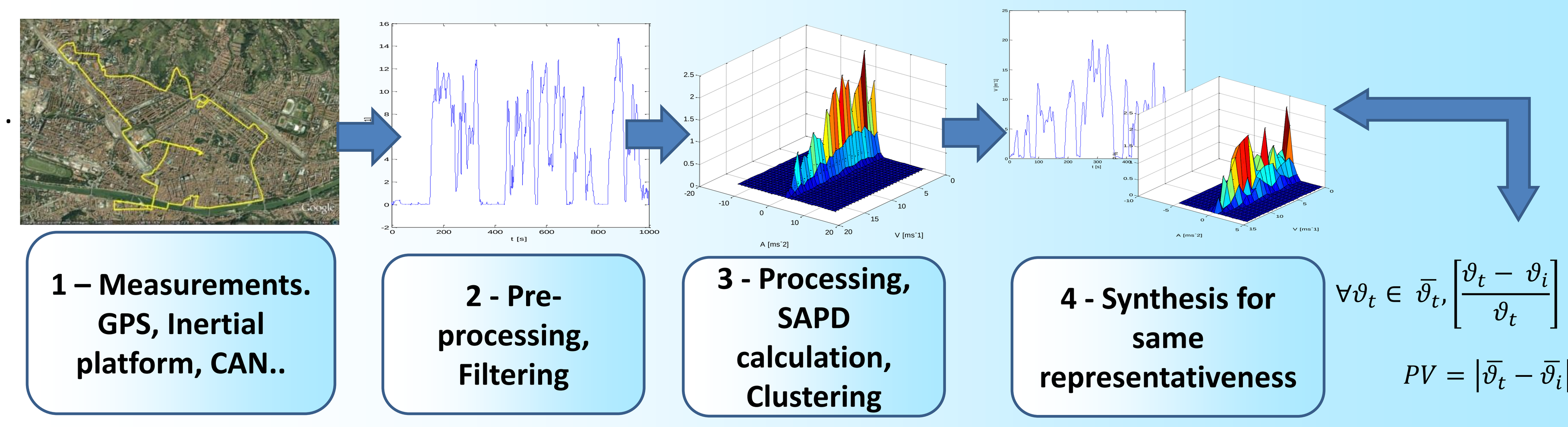
>> General methodology

Any process for the **definition of a driving cycle** is based on the following steps:

1. road/vehicle **data acquisition** in a predefined context
2. data **pre– processing** and preparation for analysis
    - filtering
3. **data processing, e.g.**
    - kinematic parameters calculation
    - Trips-Microtrip s recognition and grouping
4. **cycle synthesis**
    - data selection/randomization
    - verification

Example of Parameters used to describe driving cycles:

- **Set of indicators $\overline{\vartheta}_t$:**
  - **Time related** (duration, % acceleration, % cruise..)
  - **Speed related** (avg speed, avg moving speed..)
  - **Acceleration related** (avg positive/negative acceleration..)
  - **Stop related** (stops/km, avg distance between stops..)
  - **Dynamics related** (Relative Positive Acceleration, Positive kinetic energy..)
- **Distribution data**
  - **Speed distribution**
  - **Speed Acceleration Probability Distribution (SAPD)**



$$\forall \vartheta_t \in \overline{\vartheta}_t, \left[\frac{\vartheta_t - \vartheta_i}{\vartheta_t}\right] < threshold$$

$$PV = |\overline{\vartheta}_t - \overline{\vartheta}_i| \cdot W^T$$

>> Case study - 1: city of Turin

Data have been acquired from a Light Commercial Vehicle (LCV) Iveco Daily Electric, driven by professional drivers in repeated runs within the city of Turin over a pre-defined path.

Experimental plan includes:

- the use by 2 different professional drivers
- the adoption of 2 driving styles
    - Smooth/ECO; Aggressive/non ECO
- the experimentation of 2 different loading conditions
    - Unloaded and 80% of full load
- the use over different hours of the day, to experience different driving conditions

The synthesis method relies on CRF know-how and is coherent with general methodology

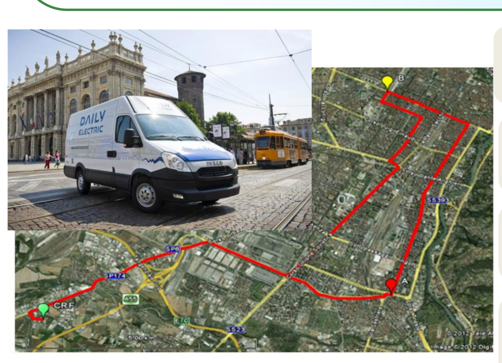


Fig. 3 – IVECO Daily and its route within the city of Turin

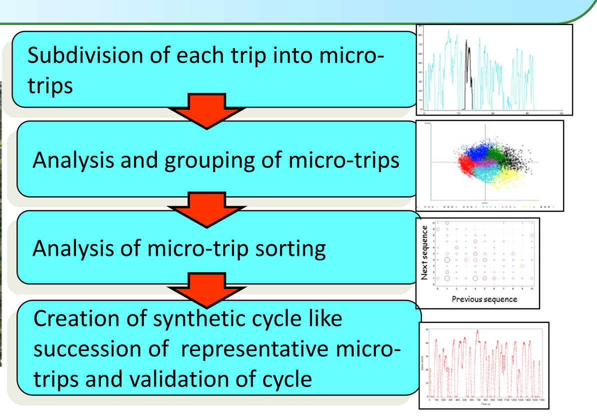


Fig. 4 – CRF approach for DC synthesis

The synthetic DC has been obtained using 20 different micro-trip belonging to 10 clusters of sequences; clusters have been identified through multivariate analysis methods. The sequences have been chosen as the most representative of each group.

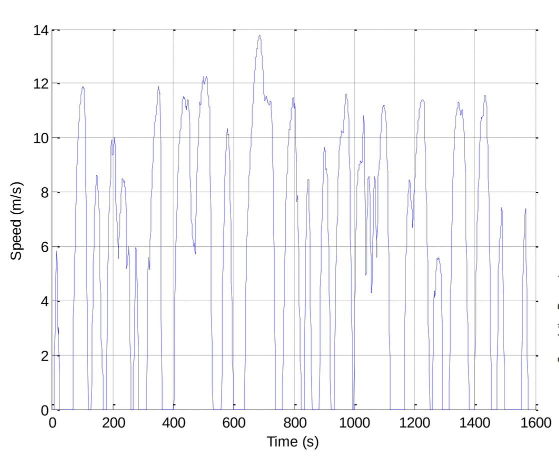


Fig. 5 – The representative cycle synthetized by CRF using Iveco Daily acquisitions.

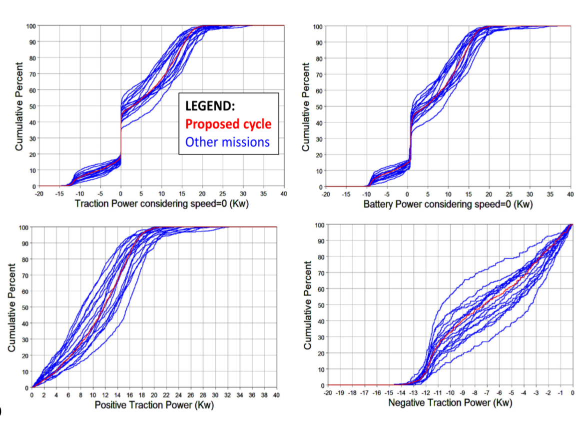


Fig. 6 – Cumulative percentage distribution of main power parameters for the proposed cycle and the other missions

>> Case study - 2: city of Florence

Data acquisition on the city of Florence has been performed on a small number of light vehicles, and in particular:

- electric quadricycles (Renault Twizy), used both for light freights delivery and commuting
- electric vans (Renault Kangoo ZE, under 3.5t class), used for light freights delivery
- electric passenger cars (Peugeot iOn), used by various private and commercial users for general purpose trips.

The acquisition took place on vehicles which were used during their normal service; the detail of the acquisitions had to be limited (e.g. sometimes GPS not allowed for privacy reasons). The main advantage of such approach is that data are supposed to be representative of the use to which the vehicles are subjected, the city of Florence being affected by intense traffic within its historical center.

Data treatment includes microtrips grouping throughk-means algorithm application on kinematic indicators. Various driving cycles have been prepared, their difference being based on:

- the source of the measured data (quadricycle; full power vehicles)
- the groups used for cycle generation (e.g. including or not "aggressive" sequences)

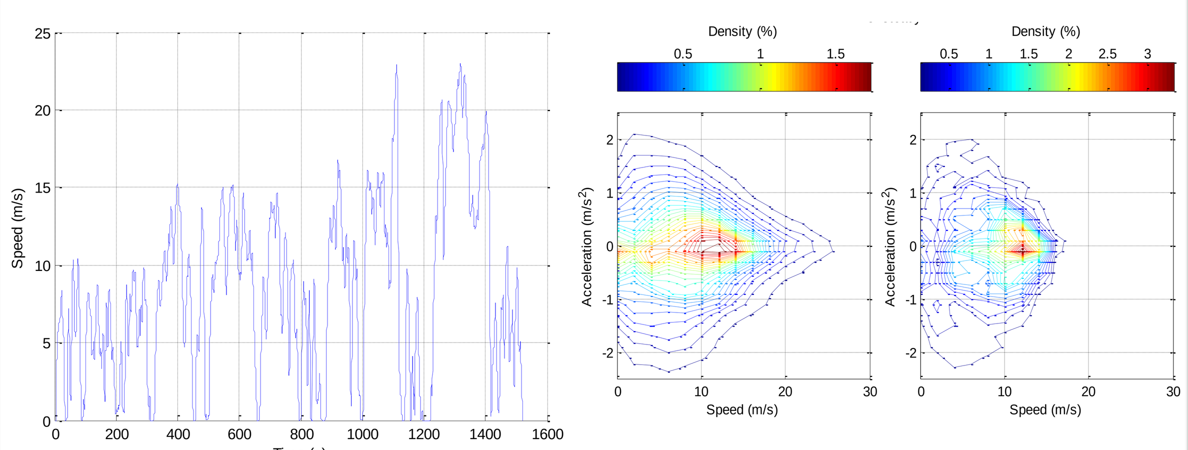


Fig. 7 – Left: the representative cycle obtained using Kangoo and iOn acquisitions. Right: a comparison between full data SAPD and synthetic cycle SAPD

>> Case study - 3: city of Lyon

Data acquisition on the city of Lyon is performed on an Heavy Vehicle equipped with an innovative hybrid powertrain.

The vehicle is used in real condition in the area of Lyon city and is equipped with data logging system for the powertrain and with GPS system for georeferencing; thus also data related to altitude variation will be included in the analysis.

Due to the high mass of the vehicle, significantly different values are expected on parameters calculation in comparison with lighter ones, thus being well differentiated from the other case studies.

Fig. 8 – VOLVO vehicle and some routes

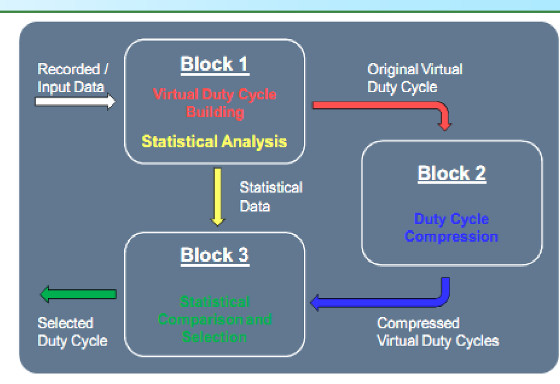


Fig. 9 – VOLVO approach for DV synthesis

Compression algorithm relies on VOLVO know how; it doesn't simply select portions of the long cycle (micro-trips selection) but rather generates a new cycle from scratch, according to the characteristics of original cycle. Final cycle include altitudes information

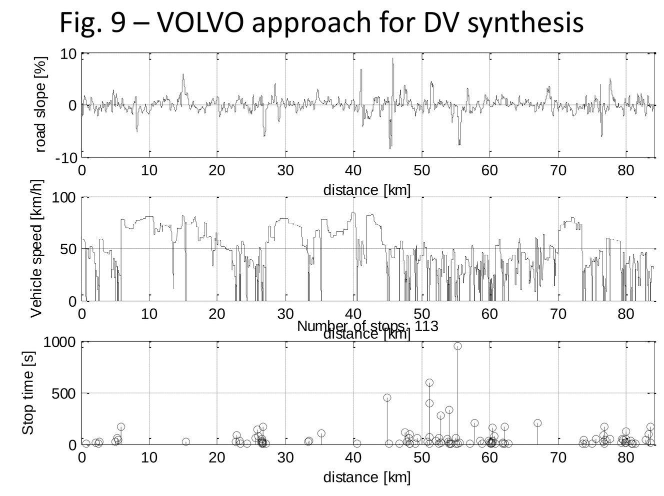


Fig. 10 – VOLVO proposed cycle.

ASTERICS partner have access to a simple tool for DCs data management. The tool can be used to build new DCs from raw data, according to user input, and/or to "bind" together existing and newly generated cycles.

It can be used also by command-line for batch simulations (e.g. system tuning), proposing a different DC for each simulated event.

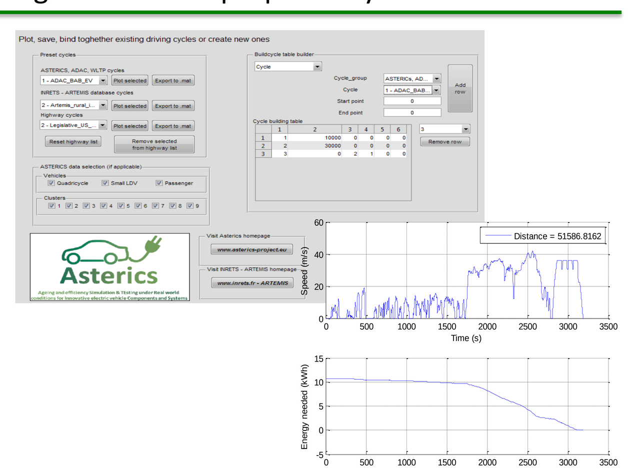


Fig. 11 – ASTERICS tool and its typical output, that includes an approximated assessment of the energy needed to run the cycle.

Website: http://www.asterics-project.eu/ - Contacts for Driving Cycle analysis: lorenzo.berzi@unifi.it; marco.pierini@unifi.it

AVL · CRF Centro Ricerche Fiat · FH Joanneum University of Applied Sciences · GK · SIEMENS · THIEN eDrives · Università degli Studi Firenze, Dipartimento di Ingegneria Industriale · University of Ljubljana · VOLVO

This project is co-funded by the 7th FP (Seventh Framework Programme) of the EC - European Commission DG Research http://cordis.europa.eu/fp7/cooperation/home_en.html http://ec.europa.eu