ENEA

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

FOR SUSTAINABLE MOBILITY

Research and innovation for sustainable mobility

In the transportation sector, technological innovation could significantly contribute to both improving performance, consumption, versatility, eco-sustainability and efficiency, and reducing its environmental impact also in terms of polluting emissions.

With regard to sustainable mobility, ENEA is involved in the design of solutions and projects applicable to different types of transportation- individual; local public, and goods - and to infomobility, as described in this publication.

Some of the main activities concern electric and hybrid electric motors, storage, safety, localization of recharging stations and fast charge technology, also wireless.

At the ENEA Laboratories, systems (hardware and software) and components (batteries and powertrains for instance), for public low-emission vehicles are also designed, such as Mhybus, the first Italian methane-hydrogen bus, and Smartbus, for electric bus transportation on demand, as well as tools in support to administrations for planning policies of sustainable mobility and prevention of atmospheric pollution. Much effort is also devoted to ICT applications, with innovative software allowing to assess the economic, energy and environmental impact of home-work commutes, detect the position and speed of fleets of vehicles, estimate their consumption and emissions or optimize the management of goods. ENEA's reference department in this sector is the Energy Technologies Department. Actually, its Divisions – Energy Efficient Production, Conversion and Use; Smart Energy; IT and ICT Systems Development – host high-specialized facilities and infrastructure, such as the following Laboratories: Mobility and Storage Systems and Technologies; Battery Testing; and Development of Chemical and Thermofluid-dynamic Energy Processes.

ENEA

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

FOR SUSTAINABLE MOBILITY

INDIVIDUAL TRANSPORTATION

- HIZEV
- MICROCAR - Development of hybrid electric microcar prototypes
- HOWMOVE - Home-work Mobility Evaluation Tool Suite - A software to optimize home-work commutes
- PRIMO - PRIvate Mobility Observatory - A tool for monitoring private mobility
- ECOTRIP© - The software that measures consumption and emissions
- Optimum positioning of electric recharging stations
- Battery safety tests

GOODS TRANSPORTATION

- CITYLOG© - The software that optimises goods delivery
- EFRUD - Emissions Free Refrigerated Urban Distribution

LOCAL PUBLIC TRANSPORTATION

- SMARTBUS - Transport on demand
- MHYBUS - Methane-hydrogen mixtures for local public transport
- Ultrafast Battery Charging System
- Electrification of public transport in cities. Project validity and feasibility tested on a case study
- BEST - Better Electric Solutions for public Transport
- Test procedures for the study of battery ageing and second life

INFOMOBILITY

- STREET© - The software for traffic diagnostics
- SIMP© - SImulatore di Mobilità Pedonale (Pedestrian Mobility Simulator)
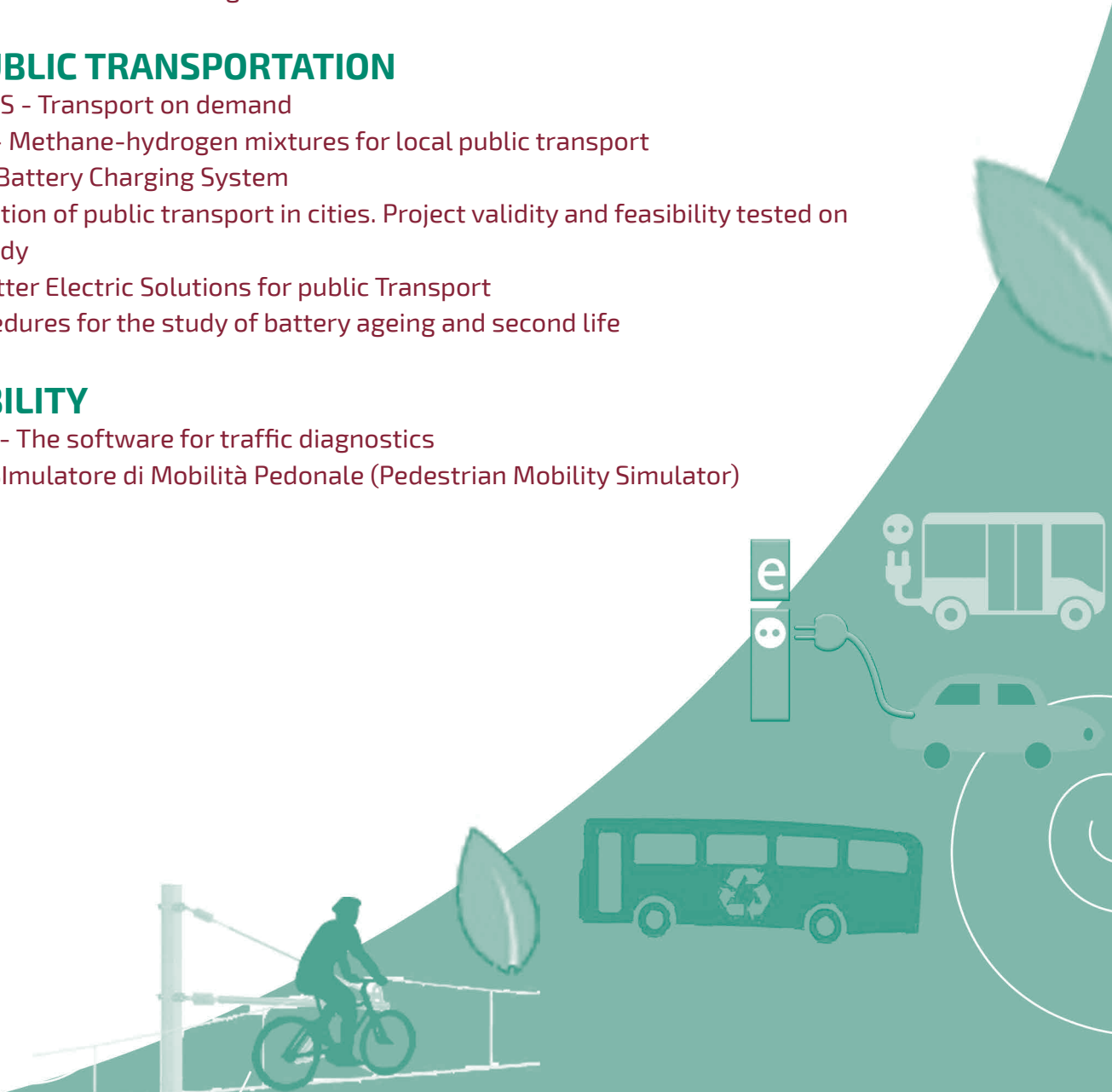
HIZEV
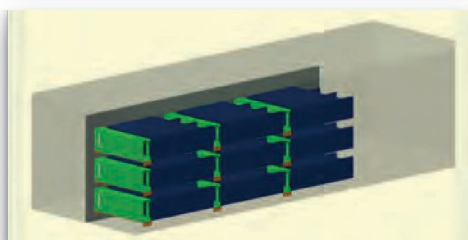
ENEA has conceived a high performance storage system based on OCCL modules, capable of delivering very high currents with the same capacity rating, up to 70 times the nominal capacity.

Developed at the ENEA Laboratory for Mobility and Storage Systems and Technologies for at the Casaccia Research Center, the system is at the core of HIZEV project, drawn up by "Industria 2015" a consortium of small, medium and microenterprises, research centers and universities coordinated by Picchio S.p.A., manufacturer of racing cars. The project is aimed at developing an electric supercar with a maximum power of 350 kw and 150 km of autonomy.

Made of high-power lithium-ion cells, with an autonomy of 180 km (NEDC, New European Driving Cycle), the storage system is centrally located in the rear side.

The thermal and electric behaviour of batteries was modelled under extreme racing conditions, validating performances through practical testing at the Casaccia facility for Batteries Testing. HIZEV provides for the development of two high-performance vehicles, one electric and the other hybrid. The latter can be used in three different modes: thermal only, electric only (with an autonomy of 30 km) or hybrid. The two engines, installed on identical frames derived from prototypes designed by Picchio S.p.A. for racing applications, were designed for dual use: road transport and racing.

CHARACTERISTICS OF THE VEHICLES	
Hybrid vehicles	Electric vehicles
Four-wheel drive	Four-wheel drive
Front end: 150kw electric engine	Front end: 150kw electric engine
Rear end: 2000 cc turbocharged internal combustion engine from 450 hp to 7000 rpm	Rear end: two electric engines of 150kw each Vector control differential
6 Kwh storage system: 400 V and 15 Ah OCCL Technology (Oxygen, Carbon, Cobalt, Lithium) positioned in the side dashboards of the vehicle	24kWh storage system: 400 V and 62 Ah, high-performance Lithium-ion technology, positioned at the back of the vehicle.

ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Division
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory
fernando.ortenzi@enea.it

4

MICROCAR
Development of hybrid electric microcar prototypes

ENEA has developed and makes available prototypes of electric and hybrid zero-emission city cars: Urb-e, with electric traction, and Spazia HPP (Hybrid Power Pack), a micro-vehicle demonstrating the possibility of applying the automotive hybrid technology on a small-sized vehicle, with a thermal-electric power-pack and a small-sized battery (3kWh).

The prototype Urb-e was initially conceived as a hybrid series with solely electric traction, on-board generator and electric storage system, with supercapacitors for testing power flow management strategies. The prototype was then used to develop other types of engine, like pure electric-powered vehicles with either lithium-ion batteries or two types of batteries and supercapacitors.

The Spazia HPP project proposes, instead, a conversion kit installed on a quadricyle which allows to turn a common microcar into a parallel hybrid vehicle, capable to operate in pure electric mode. The original engine (Diesel Lombardini) was integrated with an electric motor and a compact high-performance lithium-ion battery, implementing a power-pack entirely mounted under the hood, battery included. The prototype can operate in traditional diesel mode, pure electric mode or hybrid (with both engines), with better performances and reduced consumption and polluting exhaust emissions, at a cost lower than a pure electric microcar (a double-sized battery), thanks to the small size of the battery.

Compared to a diesel microcar, the additional cost is very limited, given a much greater flexibility of use thanks to the possibility of a zero-emission driving mode.

ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Division
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory

manlio.pasquali@enea.it

5

HOWMOVE

Home-work Mobility Evaluation Tool Suite
A software to optimize home-work commutes

HOWMOVE (Home-work mobility evaluation tool suite) allows to define Mobility Management strategies and measures for the optimization of home-work commutes of public and private workforce and evaluate its ex-post effects based on several performance indexes. This tool allows to collect large amounts of data through online questionnaires to build a robust and efficient database and provide synthesis and graphic representations of data. The software hosts an application capable of simulating routes on the road network, starting from the geographical area of the building specified in each questionnaire, and estimates fuel consumption and pollution levels depending on the type of vehicle and the type of road. The model utilizes the emission factors estimated by ISPRA for the national road transport emissions and consumption inventory, according to the vehicle classification indicated in the EEA-CORINAIR Guidelines for this type of data processing.
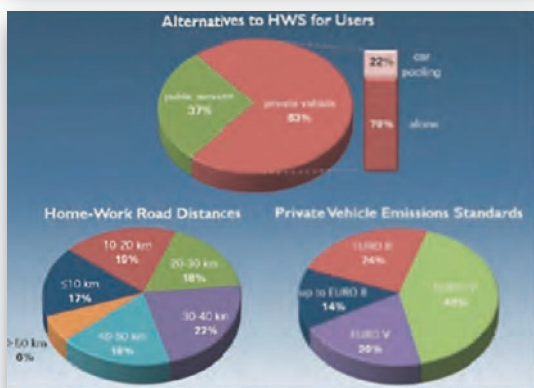
HOWMOVE also allows to calculate operating and investment costs (fuel, insurance, maintenance) and the external costs due to traffic congestion, safety and the value of the time spent commuting, on the basis of EU parameters. HOWMOVE has been successfully used, with reference to commuting, at the ENEA Casaccia Research Center, counting 1200 employees and over 300 visitors per day, located at about 25 km north-west of Rome. The bus service is organized in twelve lines, four days a week, from Monday to Thursday.

Using **HOWMOVE** has shown to provide a more sustainable home-work mobility, allowing :
- 37% cut in km/day travelled by private vehicles
- 600 kg of fuel saving per day
- 300 tonnes fuel saving and over 80 kg of particulate per year
- 1.3 million euro benefits for users and the community as a whole
- reduced traffic congestion and increased road safety.

PRIMO

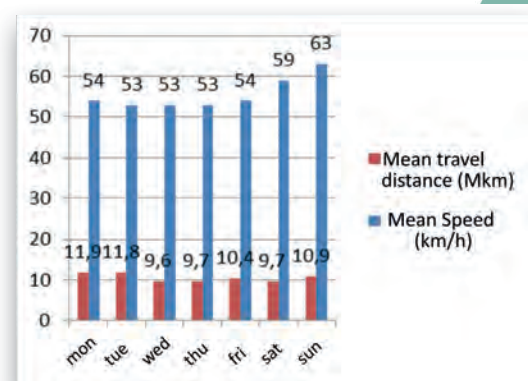## PRIvate Mobility Observatory
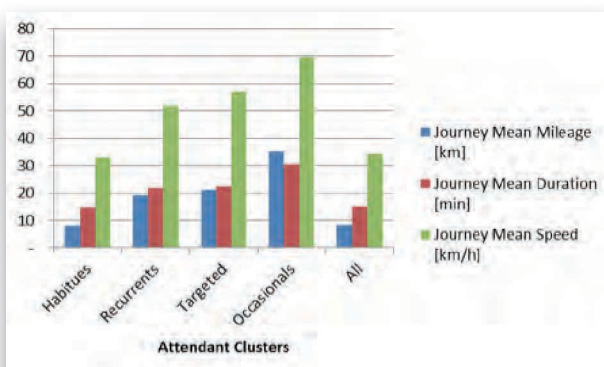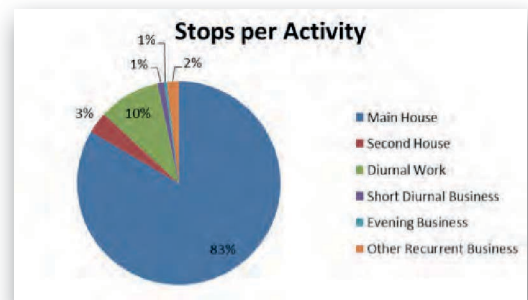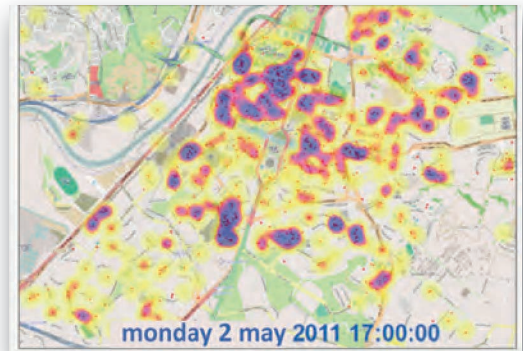## A tool for monitoring private mobility

PRIMO, PRIvate MObility Observatory, is a tool conceived to provide the local Administration with a wide, in-depth, constantly updated basis of knowledge for the definition of strategies and measures for mobility management.

Specifically, **PRIMO** allows to trace the behaviour of statistically significant samples of private road users with a better and more reliable spatial and temporal resolution compared to conventional investigation techniques. It is a suite of software modules capable of processing data from fleets of vehicles equipped with Floating Car Data-FCD, i.e. sensing systems of speed and position at regular time intervals. Developed on data from OCTO Telematics Italia S.r.l., it can be adapted to host the same content data from a different source.

PRIMO was developed in several integrated computing environments:
- SQL Server for monitoring data storage in a relational Database and extract important sub-populations
- ArcGis for visualizing and interpreting input and output data through thematic maps
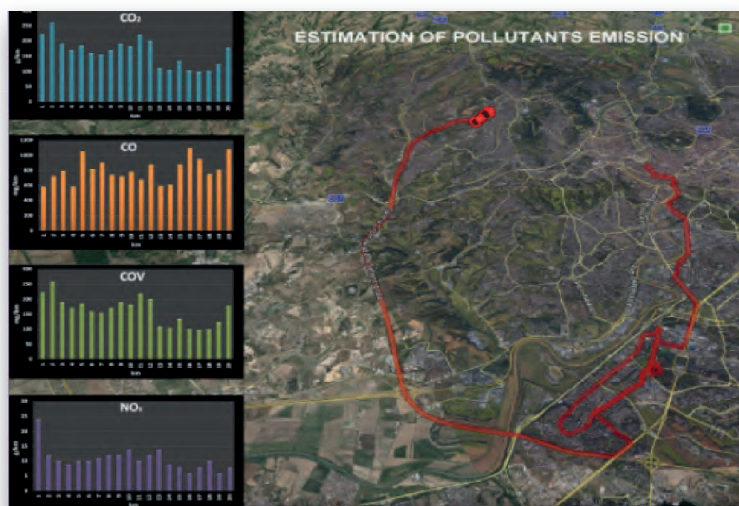- Java/C ++ for more complex processing.

PRIMO was tested on a monthly sample of surveys conducted within Rome's province to analyze systematic mobility, the stops and the potential diffusion of electric cars.

monday 2 may 2011 17:00:00

Stops per Activity

ECOTRIP

The software that measures consumption and emissions

ESTIMATION OF POLLUTANTS EMISSION

ECOTRIP© is a software that can accurately calculate fuel consumption and exhaust emissions (carbon dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds and particulate matter) thanks to on-board units connected to an operation centre.

Designed and manufactured in the Laboratory for Mobility and Storage Systems and Technologies, **ECOTRIP©** is part of PEGASUS Project, an Industria 2015 programme that aims to create an infotelematic platform for the sustainable and secure management of the flows of people, vehicles and goods within urban and extra-urban areas.

The peculiarity of this tool is its ability to operate both during initial heating (cold emissions) and at operation temperature (hot emissions), and with different levels of aggregation and detail.

It also allows to estimate the costs of externalities and the best strategies for managing mobility, also limiting the use of private vehicles (e.g., by means of road-pricing or mobility credits); furthermore it can be a valuable support for fine-tuning green insurance policies that provide discounts for less polluting vehicles.

Target and main users are Floating Car Data system companies that develop new applications for public administrations, local authorities, motorway/road operators and mobility agencies to improve and innovate traffic monitoring and management processes with regard to energy efficiency.

Optimum positioning of electric recharging stations

The ENEA Laboratory for Mobility and Storage Systems and Technologies has developed a methodology to support local administrations and industry operators in finding the optimal placement of electric recharging stations in urban centres.

Thanks to an innovative approach based on the construction of close-to-reality simulation models, this methodology makes it possible to identify locations for charging infrastructure based on the actual needs of users, according to the number of vehicles, potential users and areas involved.

Planning also takes into account elements such as interactions with the electrical system, the conformation of the territory and the need for business models that guarantee economic returns despite investments that are difficult to make solely by public funding.

The geographic distribution, the power dimensioning and users of the recharging columns were estimated on the basis of georeferenced data collected by OctoTelematics in a month of observation of home-to-work and occasional travel in Rome's territory. In particular, the number of trips, the distances covered and the geographical distribution of the points of arrival were estimated.
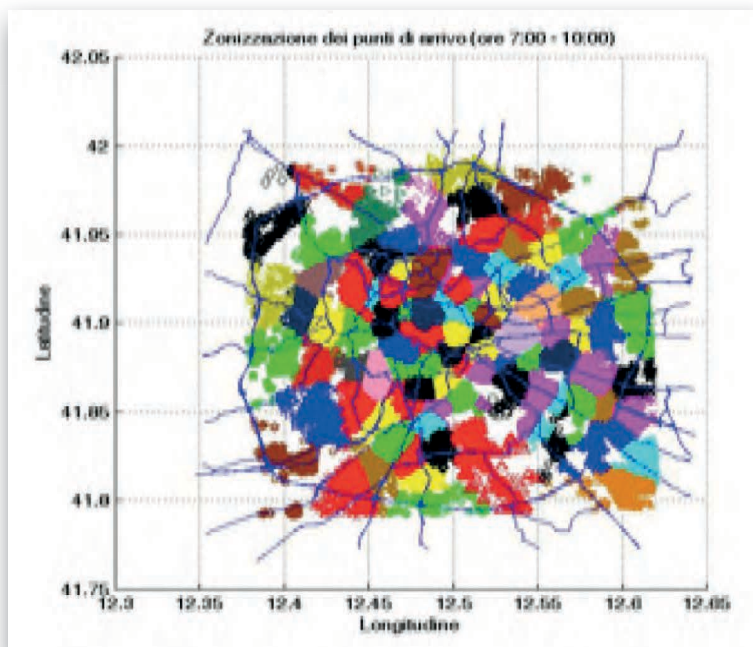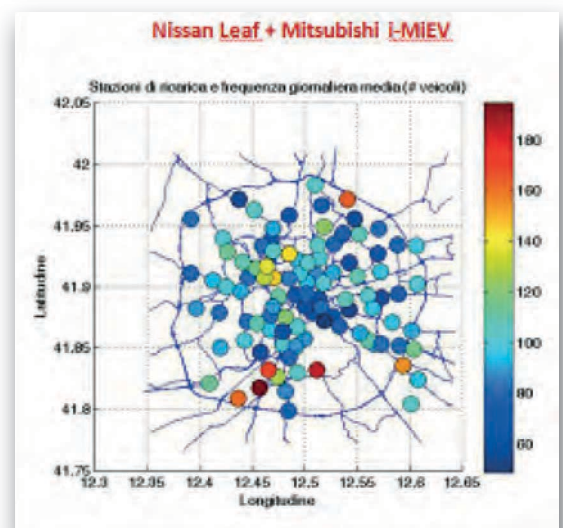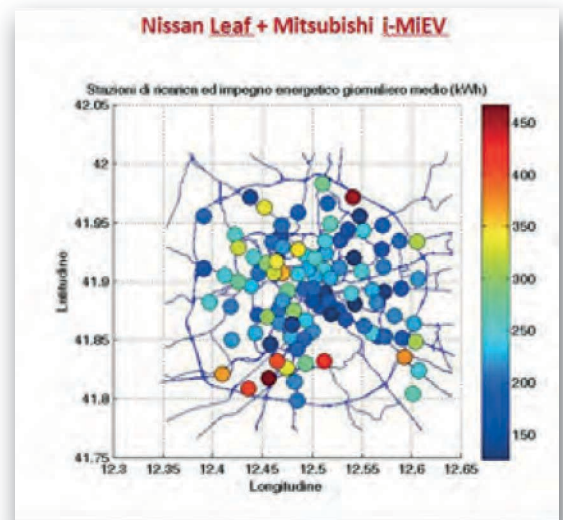
Battery safety tests
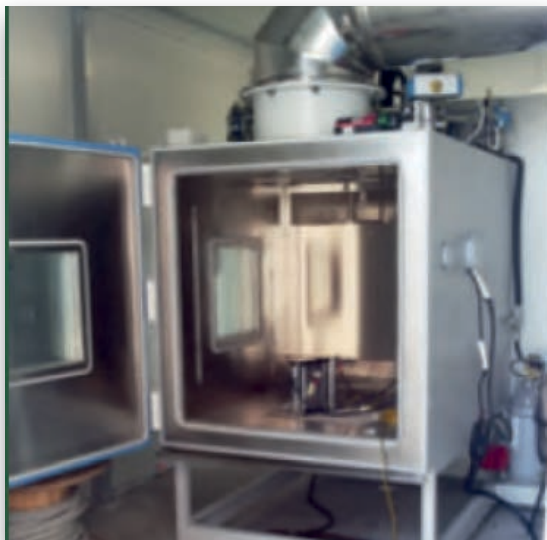
Tests on safety and prevention of possible accidents caused by unwanted battery reactions (loss prevention) are of particular interest on the research front when considering the growing spread of electrochemical storage technologies with lithium-ion batteries for mobile phones, laptops, tablets, ebooks and electronic cigarettes, but also in electrical mobility and systems for storage and redistribution of energy from alternative renewable sources. In this field, ENEA has advanced laboratories and infrastructure to research on: study of the conditions in which batteries may explode and/or ignite; analysis of substances that develop in case of an accident; prevention systems; emergency and management procedures, with particular reference to the means to be used in case of fire.

In particular, the Laboratory for Mobility and Storage Systems and Technologies has been recently equipped with an explosion-proof climatic chamber and, in partnership with the Casaccia Research Centre, with an outdoor testing field, the FARO facility - the first in Italy and one of few in Europe - for destructive testing on large storage systems and for testing the various extinguishing systems.

Activities are funded by the Ministry of Economic Development's Electric System Research to provide data and information useful for the creation of storage or recharging rooms for electric vehicles and to help to regulate these sectors.


ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Division
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory
cinzia.dibari@enea.it

CITYLOG©

## The software that optimises goods delivery

CITYLOG© is a software, developed by ENEA and the Department of Transport of the University of Rome "La Sapienza", which can indicate optimal goods delivery solutions even in case of random arrivals. The software is a useful support to companies that run goods distribution centres to improve efficiency and quality of service by scheduling - and possibly rescheduling in case of anomalies - timetables, loads and routes and may be of interest to companies that produce industrial software.

At operative level, **CITYLOG©** uses heuristic procedures that do not guarantee an exact result but approximate it through the use of genetic algorithms. It consists of a user interface and modules for optimisation, real-time simulation and medium-term route planning. This makes it possible to reduce delivery times and energy and environmental impact, improving controllability and traceability.
The software is also set up to store GPS data on vehicle tracking.
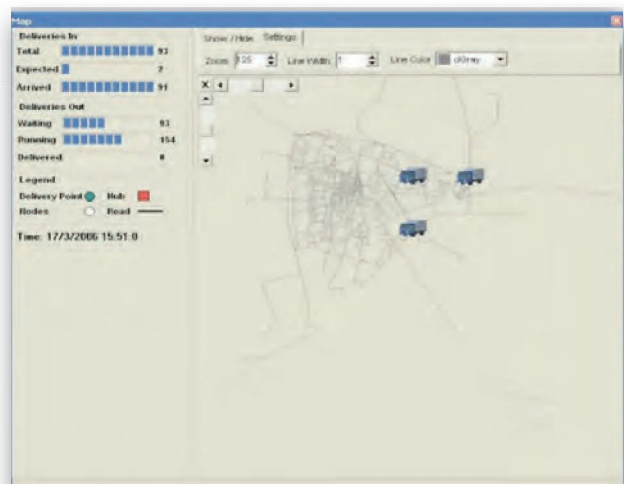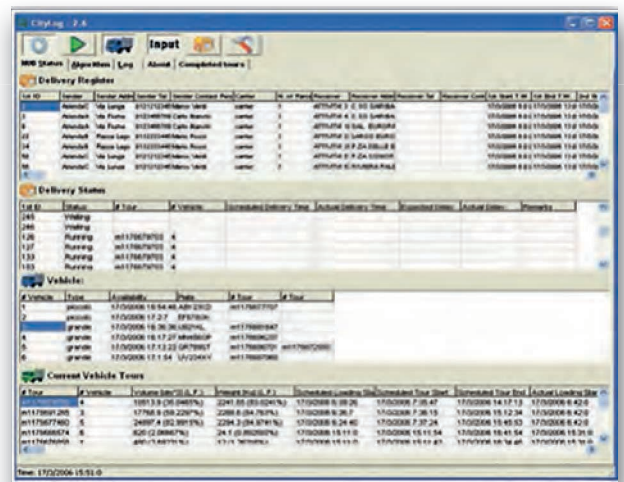
EFRUD
Emissions Free Refrigerated Urban Distribution
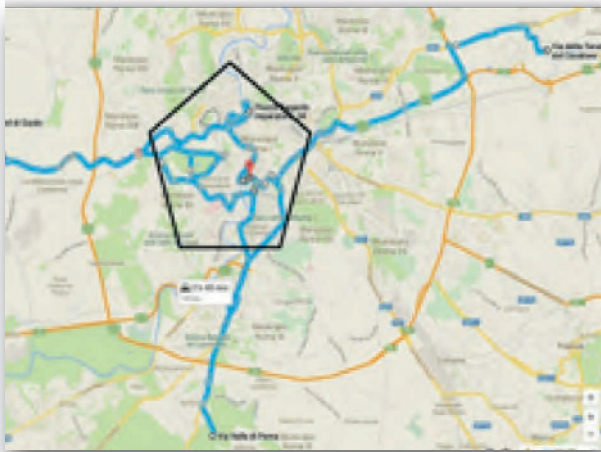
EFRUD is an innovative transport system for perishable goods that reduces the environmental impact and improves the energy efficiency of this business. Financed under the European Commission's LIFE + programme, it uses a refrigerated cell based on the storage of frigories (without the use of a compressor) and mounted on dual mode vehicles (electric/diesel) that can operate using the thermal engine in the extra-urban areas and the electric traction within the city.

EFRUD also includes:

- an on-board diagnostic system (HW/SW) for real-time acquisition, management and transmission of kinematic and environmental data
- a frigorie storage refrigeration cell (RafTM technology) that is pre-cooled at the departure station using about 14 KWh of electricity per day
- an operation control centre that collects data on the cell temperature and humidity and allows extrapolation of control parameters to estimate the driving style of the driver
- a display where transient and fully operational engine conditions are highlighted and an e-learning platform equipped with a cabin display providing the driver with real-time indications to the benefit of a more ecological driving style.

ENEA has developed instrumentation and on-board sensors (door opening/closing, temperature and humidity, ventilation to stratify the air inside the refrigerator cell), an HW/SW data acquisition and transmission system (OBU), a display for the driver and a ground operation control centre for coordination and management.

During experiments carried out in Rome's city centre for a total of 8,500 km, over the course of several days and schedules it was found that drivers who had been appropriately trained achieved a significant reduction in fuel consumption and pollutants.

The frigorie-storage refrigeration system was always able to keep the temperature below 7-8°C without interruption of the cold chain, delivering the fresh goods provided by the operators involved (Tenuta del Cavaliere, producer of organic milk, dairy products and cheeses, and Agricoltura Nuova, producer and distributor of organic fruits and vegetables and other local branded products) to street markets, cafés, restaurants and shops.

For all deliveries within the limited traffic zone (LTZ) or pedestrian areas, electric traction was used with benefits in terms of emission reductions and zero noise. Overall, tracking the vehicles making deliveries showed a significant drop in consumption and pollution compared to a conventional vehicle as well as a financial benefit for those making the deliveries.

In addition to ENEA, the project involved TRAIN Consortium, ROMA Capitale, METES Foundation and ITENE of Valencia.
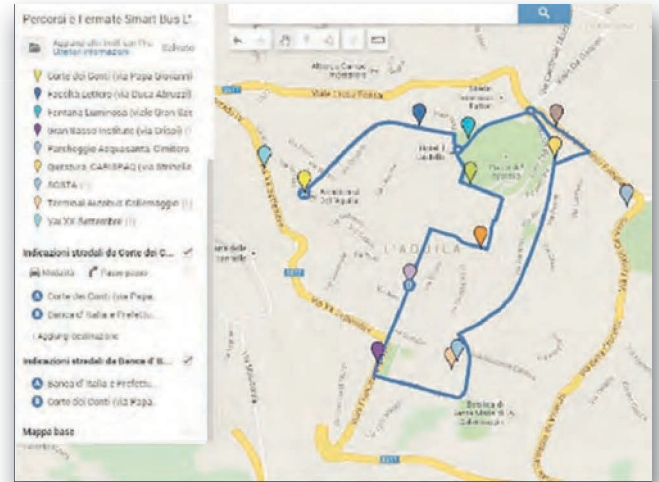
ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Division
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory
antonio.lioi@enea.it

SMARTBUS
Transportation on demand

SMARTBUS is a "bus on demand" system for improving public transport and increasing the number of passengers. The system was designed by ENEA on the basis of an algorithm that optimises the service in terms of route, charge autonomy and transport capacity. Smartbus has been experimented in L'Aquila with a bi-modal bus (diesel or electric) connected to an operation centre to handle transport requests sent by people using a dedicated website. The system communicates the users their request Acceptance/Refusal and pickup time (also via SMS), and the bus driver the route, the stops and the users booked.

The electronic system bi-directionally and wirelessly connects the on-board sensors, the GPS satellite navigation system and an operation centre.

The prospects are that these technologies will allow quick and partial "on-the-road" recharging at preset spatial intervals and, hence, the use of "minimum" electricity storage: the size of the battery is no longer based on the total daily travel (e.g., 200 km), but rather on the distance between a partial charge and the next one (e.g., every 5-10 stops, or at the terminus).

SMARTBUS is equipped with the NASUS system developed by ENEA, capable of capturing real-time data and of analysing position, battery charge, speed, passengers, etc., and the air quality (NO_2, SO_2, H_2S, CO) thanks to the wireless transmission along the route.
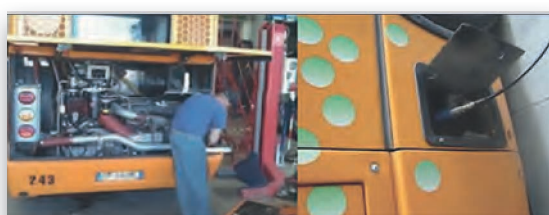
MHYBus

Methane-hydrogen mixtures for local public transport

Within the framework of the **LIFE+MHYBUS** European Project managed by the Emilia Romagna Region for reducing consumption and emissions of local public transport, ENEA has been involved in research and experimentation on -methane-hydrogen mixtures, an internal combustion technology that has proved to be very promising.

In particular, in the engine test room of the Low Environmental Impact Vehicle Laboratory of the ENEA Casaccia Research Centre, the mapping of the engine management control unit has been redesigned, based on the specific characteristics of the fuel.

After the very positive results certified by the homologation test at the Institute for Research on Engines in Naples, the engine was mounted on board **MHYBUS**, a bus that provides public transport in Ravenna using a 15% hydrogen mixture available at the SOL plant, using an easily transportable gas compression station (an 8-meter container) owned by ENEA.

Periodic measurements carried out by ENEA have shown that performance in terms of fuel consumption and emissions has remained unchanged over time and the engine does not experience any alterations within the combustion chamber.

Advantages

The addition of hydrogen to methane improves combustion and engine power efficiency and allows full use of the fuel, reducing fuel consumption and CO_2 emissions.

H_2-CH_4 blends also offer an excellent cost/benefit ratio (both environmental and energetic) compared to the engine powered solely by H_2 or fuel cells. Actually, an internal combustion engine fuelled by pure hydrogen obtained through the steam reforming of methane produces higher amounts of CO_2 emissions than the same engine fuelled by methane. This happens because CO_2 was previously emitted at the plant during the process to produce hydrogen itself (separation of the two elements from the CH_4 molecule).

On the other hand, with the CH_4-H_2 blend there is a "leverage effect" equal to two, that is, twice a reduction of CO_2 than that obtained by simply replacing carbon atoms in the fuel with hydrogen atoms, which, in terms of hydrogen use, equals to double its specific efficacy.

This brings the system performance almost to the same level as that of a fuel cell, while the costs remain much lower than those of traditional systems.

Thanks to the widespread use of methane storage and transport systems, blends can be a flexible way to gradually develop the hydrogen system. Reduced amounts of hydrogen can be initially introduced into the network and then gradually increased as, for example, more hydrogen from renewable sources becomes available.

Ultrafast Battery Charging System

ENEA has developed and tested an innovative lithium battery system that allows full recharge in 20 minutes and partial recharge in 5-10 minutes during stops at a terminus, sufficient to replenish the energy consumed while driving. Thanks to the "active" cooling system it is equipped with, this technology is particularly suitable for small buses used for public transport, as demonstrated by Tecnobus's "Gulliver" Minibus provided by the Transport and Logistics Research Centre of the University of Rome "La Sapienza".

The battery system developed in the Laboratory for Mobility and Storage Systems and Technologies consists of 24 units (a module 12 V - 60 Ah). In order to reach the vehicle's 72 V nominal supply voltage, the modules are arranged in series, forming six-piece strings, and the two containers in which the original lead-acid batteries were housed can accommodate four of them placed in parallel. Since the batteries are far more "dense" energetically, the overall weight of the system is reduced to ¼ of the original system weight.
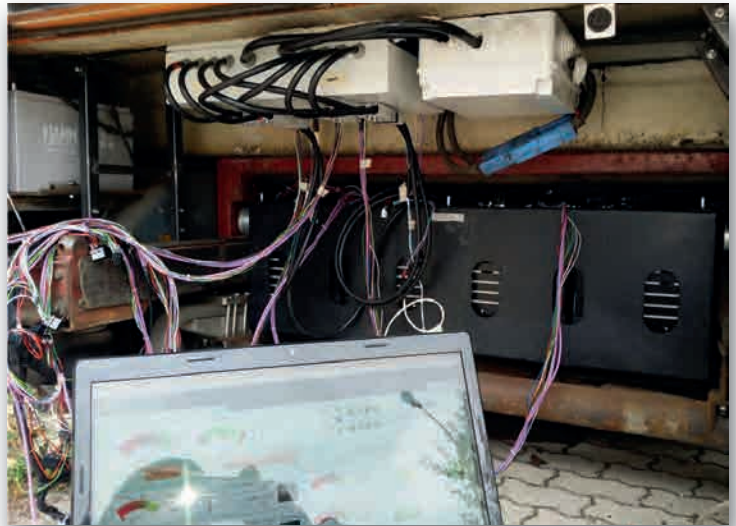
The battery module (three sizes are available: 30Ah, 60Ah, 100Ah) consists of four cells connected in series, an electronic management and control system called BMS (Battery Management System) and an intelligent module, i.e., a forced air cooling system capable of working in stand-alone mode or in serial/parallel combinations to build complete battery systems that can be managed with a programmable "supervisor".

In this way it is possible to obtain the voltage/capacity levels required for many applications in the field of electric vehicle drives and auxiliary start-up/power also for the nautical sector.

The electronic management and control system consists of two cards developed in collaboration with the Department of Information Engineering of the University of Pisa: the first printed board provides for the monitoring, protection and active balancing of the recharging status of the single cells of the module, while the second card handles power connections and the wireless signal.

The ultrafast battery charging system is developed within the Project "ENEA-CNR for the Development of Manufacturing in Southern Italy", funded by the Ministry of Economic Development - Electrical System Research.

Main characteristics of the "Gulliver" minibus	
Weight (without drive batteries)	2,800 ± 100 kg
Length	5.1 m
Passengers	27 (of which 10 seated)
Drive power	25 kW (peak) 20 kW (nominal)
Average consumption	500 Wh/Km

Electrification of public transport in cities

Project validity and feasibility tested on a case study

Electrification of the Local Public Transport service can contribute to the transition towards more sustainable mobility. In this context, ENEA has carried out a study to verify the possibility of electrification of public transport, without changing the service, thanks to the use of vehicle technologies and innovative recharging. Advances in storage and recharging systems make it possible to overcome problems such as driving autonomy and recharging duration, and to increase the chances of success of electrification projects.

L'Aquila was chosen as the "laboratory", where the traditional diesel buses of two low-traffic public transport lines connecting the centre with the nearby suburbs were replaced with two battery-powered electric vehicles equipped with detectors of location, speed, load, and even transfers from and to the depot. The study was developed on the basis of the data collected on board the bus. Through data filtering and smoothing, the seasonal profile was then extracted for each bus used, correlating them with the energy consumption data.

Cost-benefit analysis showed very positive results in terms of energy and cost savings, as well as how the correct positioning of recharging stations in the strategic nodes of the public transport network is crucial to assessing the economic feasibility of the project.

The results so achieved and the relevant methodology led to the decision to develop a Decision Support System (DSS) that allows local public transport managers to verify the technical-financial feasibility of electrification.

The DSS was conceived as a simulation tool to evaluate the performance of an electric bus based on actual driving data previously gathered to determine, second by second, the power consumption and the battery charge status, given the initial charge available.

Transport company technicians interested in the electrification of a bus line can therefore check whether it is possible to switch to electric vehicles, simulating the operation of buses with increasing battery sizes and then issuing specifications for calls for tenders specifying the minimum battery characteristics required.
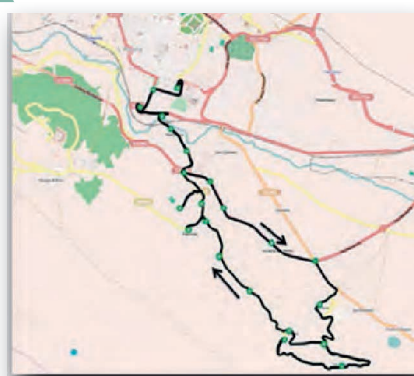

Basic scenario	Company	Collectivity
Net Current Value (NCV)	€ 9.095	€ 3.473
Benefit/Cost Ratio (B/C)	1,05	1,02
Internal Rate of Return (IRR)	7,5%	4,3%

ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Divi-
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory
mariapia.valentini@enea.it

BEST
Better Electric Solutions for public Transport

BEST is a software program for the technical, financial and environmental assessment of the electrification of a local public transport line, as a support tool for local public transport companies seeking to identify the most suitable lines for the possible use of vehicles powered by electric batteries. The software was developed as part of the national programme "Ricerca di Sistema Elettrico" (i.e., Electric System Research) and allows to evaluate the technical and financial feasibility of some possible technological solutions for electrification, comparing the environmental and cost aspects of the chosen solution with two conventional alternatives (diesel and compressed natural gas).
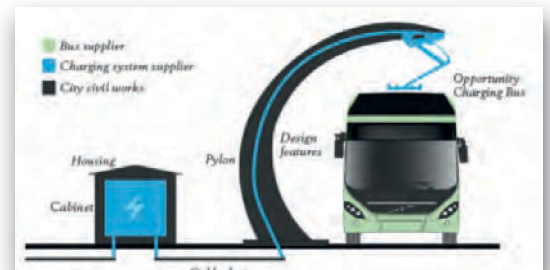
BEST is an innovative tool that integrates specialist knowledge ranging from vehicle technologies to methodologies for estimating financial and environmental performance indicators. It uses Open Data in GTFS format made available by local public transport operators, in compliance with the current European and national regulations.


The software consists of four calculation modules that can, respectively:

- estimate energy consumption and emissions of greenhouse gases and pollutants in the air of the various technological alternatives
- verify the technical feasibility of electrical architectures and dimension the on-board battery storage and the related recharging system
- compare the various solutions, electrical and conventional, from an economic point of view through the analysis of investment and operation costs
- estimate the external costs generated by harmful emissions and vehicle noise for the various energy alternatives.

BEST can be applied to any urban context thanks to its input data standardisation: it has already been tested on some bus lines of ATAC network in Rome and will be applied to two more medium-sized cities in order to examine the potential for electrification of local public transport.
In addition, by the end of 2017, it will be further expanded in collaboration with the University of L'Aquila, taking into account other electrification solutions for local public transport, like hybrid buses and electric trolleys. The possible electrification of the local public transport network as a whole will also be assessed, taking into account any economies of scale
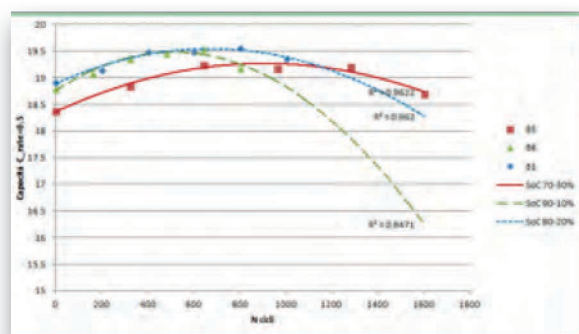
Test procedures for the study of battery ageing and second life
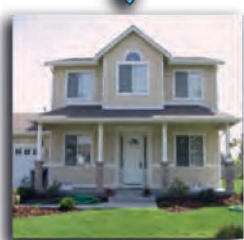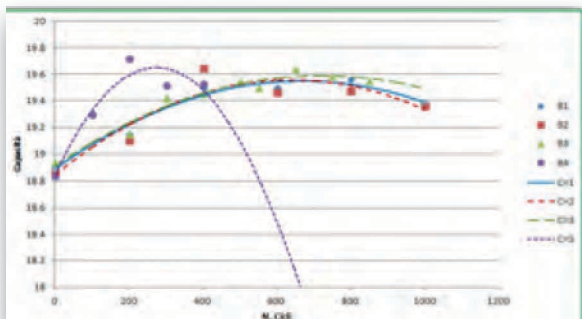
ENEA has developed advanced testing procedures for the study of ageing and the second life of rechargeable batteries. These energy storage systems are particularly important for their field of application is wide-ranging: predicting their degradation and failure whilst improving their durability and reliability is a complex but crucial issue as the mechanisms that lead to deterioration are many and selecting stress factors, test conditions and battery chemistry can significantly influence test results.

ENEA researchers have also studied the reuse (or second-life) of lithium-ion batteries for power applications for different uses such as, e.g., stationary storage, with a view to develop more energy efficient and cost-effective systems. The main criticalities lie not only in the assembly of homogeneous cells and, hence, in the definition of homogeneous criteria for cells collection and characterization, but also in the need for tailor-made electronics for performance optimisation and safety management. Studies have highlighted that determining the criteria for cells collection and reuse necessarily depends on the intended use of the batteries made with second-life cells. Once the characteristics of the degraded cell have been identified, it is necessary to identify the maximum values of continuous and "impulsive" currents that do not cause the cell to degrade rapidly, and then develop a set of work profiles that the cell can withstand successfully. By so doing, applications can be eventually identified that are compatible with these profiles.

ENEA - Energy Technologies Department
Energy Efficient Production, Conversion and Use Division
Technologies and Systems for Sustainable Mobility and
Energy Storage Laboratory
natascia.andreacci@enea.it; francesco.vellucci@enea.it;
manlio.pasquali@enea.it

STREET
The software for traffic diagnostics

STREET© (Short-term TRaffic Evolution forEcasting Tool) is a software program for road traffic diagnostics and the prediction of its evolution in the immediate future, meaning a 15-60 minutes time span. Designed and developed in the ENEA Laboratory for Mobility and Storage Systems and Technologies under the PEGASUS Project (Industria 2015 programme), it can operate using both the data collected from networks of fixed traffic sensors and estimates based on the Anonymous GPS positioning data transmitted by fleets of vehicles in motion.

STREET© incorporates a set of "data-driven" models (regressive, pattern-matching and neural networks) with different degrees of theoretical and computational complexity.

Two key approaches - *univariate* and *multivariate* - can be applied to **STREET©** to specify the prediction model and the choice of the most significant variables. In the *univariate* approach, the models are defined and estimated for each road section, and predictions of future traffic conditions are based solely on the current and most recent measurements/estimates made on the road section being examined. For the *multivariate* approach the models have a structure that can also consider the most recent traffic fluctuations as input variables, measured/estimated on the related sections upstream and downstream of the road segment being monitored. This model property is particularly important as it strengthens their ability to capture/learn the evolution dynamics of traffic in space and time, and therefore to predict the different modes of propagation/dissipation of congestion that can occur due to sudden variations in the demand and/or network capacity.


STREET© includes a calibration/training function for the numeric values of the model parameters that is applied both during the initial tuning phase of the models starting from a set of historical data, and for periodic updates, which are particularly necessary when significant changes occur in traffic patterns due to modifications in the physical and functional characteristics of the road network.

STREET© also includes a testing function that allows one to check the predictive capacity of the different models while offline and monitor their performance over time in the various traffic situations by computing appropriate forecasting accuracy indicators for a targeted section of the road network, for example a neighbourhood, and the full network, i.e., the whole city.
This function makes it possible to identify the strengths and critical points of the models proposed in real conditions of use, and to obtain useful information for any possible corrections that might constantly increase accuracy and reliability. The testing function also allows to define the "optimum" combination of the predictions from the different models in order to get higher performance than individual forecasts

STREET© also provides an online analysis of current traffic estimates that makes it possible to identify anomalous conditions and improve the accuracy of forecasting models over time and space.
Equipped with a user interface that allows access to individual functions, the software is completely written in JAVA to ensure its independence from the platform on which it will run. It has been installed and made operational on Octotelematics's Floating Car Data platform for forecasting traffic on Rome's road network.
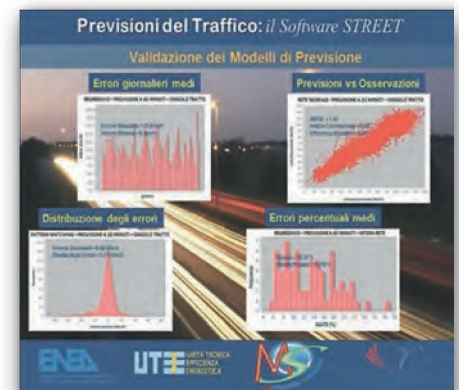
SIMP©

SImulatore di Mobilità Pedonale (Pedestrian Mobility Simulator)

SIMP© is a software program that simulates pedestrian flows within structured environments, such as subway stations, in order to improve their level of safety. The simulator addresses pedestrians' behaviour by considering the simulation environment as a complex system, where users' risk varies over time and real emergencies can occur, reaching the point of mass stampedes with consequent trampling and crushing resulting in injury and death.
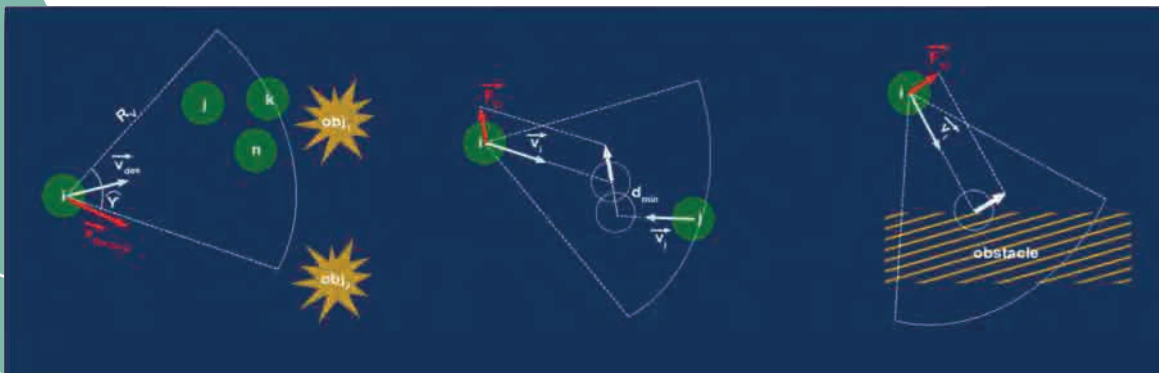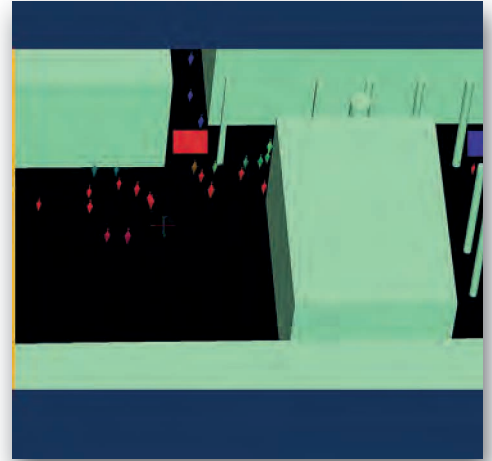
SIMP© was developed using autonomous agent simulation tools: computational units endowed with perception (information received from the environment based on particular sensory properties), reasoning (data processing) and autonomy (performing actions to achieve certain goals), starting from the layout of the environment and people flows.

Starting from the site map, the study of the direction of flows and average numerical data on the flow of people, **SIMP©** is able to:

- model emerging collective behaviours starting from the study of the single individual's behaviour
- characterise pedestrians' dynamics as surrounding conditions change, both in ordinary management situations and in critical conditions
- test the planimetry of the environment during the design phase.

SIMP© is useful for:

- improving mobility control and supervision
- diagnosing any critical issues or turbulence in pedestrian flows in advance
- effectively managing any emergencies
- obtaining geometric and structural adjustments of the environment being studied
- testing safety criteria in high people traffic areas.