# BRUSSELS EV EXPERIMENT ANNO X: ELECTRIC VEHICLES IN URBAN TRANSPORT

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## ABSTRACT

Brussels Free Universities (Vrije Universiteit Brussel and Université Libre de Bruxelles) started in 1979 with the development of a new urban transport system based on electric vehicles. A fleet of electric vehicles built by PGE has been set up since 1980.
During the development of the project a considerable evolution of the viewpoint has taken place due to the observation of vehicle technology and urban traffic environment.
This paper reports on the present situation of the fleet, the behaviour of the vehicles in urban traffic, the technology of electric vehicles currently available on the market and the European actions to promote their deployment in the cities.

## HISTORY

The Universities of Brussels (Vrije Universiteit Brussel (VUB), Flemish, and Université Libre de Bruxelles (ULB), French) started in 1979 with the development of a new urban transport system based on electric vehicles.
The scope of this project was to facilitate the urban traffic and to relieve the city centre. The users were to be provided with a sufficient number of vehicles, at their disposal by means of an automatic renting system, to cover local transportation needs normally carried out by thermal vehicles and not easily fulfilled by traditional public transport systems (tramcar, bus, metro).
Two types of electric vehicles built by PGE (Italy) were introduced:
- six PGE 3P: 3 persons + 50 kg capacity; 60 km/h max speed; 50 km range; 72 V battery.
- three PGE 5P: 5 persons + 50 kg or 2 persons + 350 kg; 60 km/h max speed; 50 km range; 96 V battery.

Initially two automatic renting and charging stations were installed, both at V.U.B. facilities in Brussels.

The first-phase development of the project was focused on the study of the rental system and related charging techniques [2,3]. This lasted until 1982.
The second-phase development was devoted to the exploitation of the electric vehicle fleet in order to study all technical aspects related to the integration of the vehicles in urban traffic and their acceptance by the users. At this moment (september 1990), it is still going on and will continue until withdrawal of the vehicles. The chosen electric vehicle technology shows the possibility of vehicle life spans of more than ten years.
The interest of an automatic electric rent-a-car system integrated in the urban tissue remains prevalent. Such a system can effectively relief traffic and pollution problems in cities.

## THE AUTOMATIC RENT-A-CAR SYSTEM

An automatic rent-a-car service permits moving around in the city avoiding all parking problems. The maintenance problems are concentrated by the system operator. Only a few simple rules have to be respected for making use of this service.
Automatic rent-a-car stations will be spread all over town. They are organised as battery charging posts and can be combined with taxi ranks.
The fleet of vehicles to be launched should be large enough to permit a decrease of the number of unused and actually unnecessary IC-engined cars. This is realisable by distributing the EV's over automatic rent-a-car stations not further apart than ca. 300 m. The number of vehicles per station depends on the local traffic density; this density can be derived from statistical studies of the movements in the station area.
Such a network covering the aimed area will allow the customers to move quickly and efficiently without having to walk large distances. The system has to be set up taking into account the existing means of communication.

### Objectives and characteristics

A rent-a-car system for use by town-dwellers must be designed to allow the users a number of advantages.
A day and night service is guarantied at reasonable cost, without the problems of private ownership of a (second) car:
- high purchase cost;
- maintenance problems;
- cost of insurance, taxes and parking;
- parking problems.

The system effectively complements the public transport network, which can not be made, economically spoken, sufficiently dense to cover all areas of a city; functions like the delivery of goods on small, very localized routes are difficult to realize.

The system can be accessed at each moment and the user is sure to find a place at the station where he leaves the vehicle. There is a complete freedom to choose the route and the privacy of the ride is preserved.
To integrate this system efficiently in the city, the following observations must be taken into consideration:
- the station network must be adequately built for its “territorial needs”;
- the vehicle types available have to cover all the usual necessities and the number of vehicles has to be proportioned to the town where the system is implanted;
- the maintenance has to be permanent and highly efficient;
- the conditions of the contract into which the hirer must enter have to be as easy as possible despite the fact it must still contain sufficient incentives to keep the user sensible of his economic responsibility;
- the automatic rent-a-car system must appear economically advantageous.

Some more general considerations can also be made:
- the hirer of a car has to submit to some restraints implicit in the rental system such as the obligation to book a place in an arrival station and the obligation to park in the appointed place. This implies another approach from the user, who should not regard the vehicle as his own;
- each electric rental vehicle can replace at least five private cars. When one estimates 2000 electric vehicles to be deployed in a city like Brussels, the number of private cars could diminish with about 10000.

## Impact on urban traffic

The experiences with the electric vehicle fleet of Brussels Universities during ten years have proven the viability of electric vehicles in urban traffic. Electric vehicles can actually play a significant role in the solution of traffic problems.
Large towns are faced with a growing problem of traffic congestion. The largest part of this congestion is caused by the presence of numerous private cars, mostly owned and operated by commuters. During the working hours of these commuters, the cars are parked and perform no useful function; on the contrary, they occupy valuable space which could be used for other purposes, for instance by creating zones free of cars and pedestrian zones.
To increase viability of the urban living environment, the number of vehicles temporarily present in the city should be diminished. Access of private vehicles into the city centre should be discouraged, for example by modifying local traffic regulation or by imposing financial disincentives. An alternative for automotive commuters should be offered in the form of a "Park & Ride" system: parking lots at the borders of the agglomeration, combined with a fast, frequent

and reliable public transport system towards the city centre.
Most people arriving in the centre that way would spend the whole working day in their office and would have no need for transport. For those needing to make short, intra-urban trips such as business errands, which the arbitrary character makes less attractive the use of public transport means, the latter being confined for economical reasons to the axes where a major demand for transport is present, electric vehicles could be made available by means of an automatic rental system.
This proposal is illustrated in Figure 1.
Also the fleets of delivery vans, taxi cabs and buses operating in the city centres could be effectively electrified, wholly or partially.

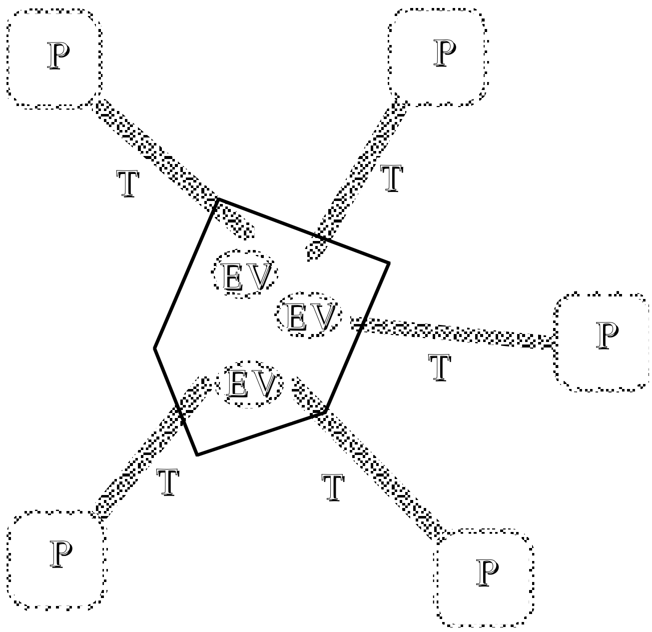


Figure 1: Urban traffic solution proposal

P: Dissuasive parking lots
T: Public transport axes
EV: Electric vehicles

## Description of the automatic rental system

The experiment with two rent-a-car stations on VUB facilities allowed to define the basic structure of an automatic rental system.

Each station is controlled by a microprocessor, which allows independent working of the station. However the station is always in contact with a central minicomputer, which has the full control of the whole system.

The functions of the central management are essentially:
- control the credit of each customer
- determine which car can be used, reserving parking lots
- control the state of charge of the batteries
- distribute vehicles between different stations
- communicate between stations
- manage user accounts.

The control unit of each station is somewhat likely to the control unit of an automatic filling station. The functions to be realized are:
- control of the user's card (which can be a credit card);
- dialogue with the user;
- control of the state of charge of the electric vehicles;
- release or acceptance of a vehicle depending on the decision taken by the central unit;
- control of the connection points of the vehicles;
- registration of the data recorded during the use of the vehicles (speed, distance, voltage, current, energy);
- control of the on- or off-board battery chargers.

## Access to the system

The user's identity card, which can be a regular credit card, gives admission to the system.
After identification, the following operations have to be carried out when renting a vehicle:
- choice of destination;
- choice of vehicle type;
- if the selected destination or vehicle is not available, offering alternatives.

Charging of the user's account starts from this moment.
When returning the vehicle, the connection of the charger stops tariffing.
During the complete rental period, the vehicle is assigned to one user, so all vehicles can be effectively followed up and monitored, and all irregular situations like accidents or breakdowns can be easily managed.
All operations are based on a clear dialogue between the system and the user, the latter being guided maximally in his decisions.

## EXPLOITATION OF THE BRUSSELS EV FLEET IN DAILY URBAN USE DURING 10 YEARS (1979-1989)

Different electric vehicle related problems (mechanical, electrical and electronical) were investigated for several years in the laboratories of the Universities of Brussels.
In particular battery charging techniques were studied.
A low weight high frequency battery charger, equipped with power transistors [4,5] was developed and used for the first time in June 1984 for the famous Brussels-Paris-Versailles

trip by a V.U.B. electric vehicle in the occasion of EVS-7 conference; the distance of 360 km was covered in 20 hours, with intermediate boost charging sessions about each 30 kilometres.
Research has also been done in the field of theoretical vehicle behaviour. A mathematical model for electric vehicles (including trolleybuses and also applicable on thermal vehicles), based on cinematic and energetic equations of movement, was designed and applied on electric vehicles and dual-mode trolleybuses [6,7,8].

## Actual state of the fleet

The PGE vehicles were acquired in 1979 and put into service in 1980. They are still in use today. Since 1985 however the usage of the fleet was extended: the vehicles are nowadays available to members of the university community , against a small fee. Since then a growing number of external drivers make use of the electric vehicles to suit their needs for local transport in the Brussels urban area; most of them are satisfied with the performances of the electric vehicles in urban traffic and become regular patrons.
Tubular-plate lead acid batteries have been used; they have proven that their low energy density (35 Wh/kg) is not a fundamental handicap in operating electric vehicles.
To enhance the flexibility of electric vehicle fleet exploitation all vehicles have been fitted with on-board battery chargers. A special charger was developed for this purpose, according to the following guide-lines: easy and safe operation, safe treatment of the battery, being able to use any standard power outlet in Belgium (220 V, 50 Hz single-phase, 16 A). These on-board chargers use a constant current / constant voltage characteristic. The formerly developed high-frequency chargers are still used for special purposes and mainly for rapid charging.
The presence of these on-board chargers has enabled a new operation mode for the fleet: beside the departmental use within the framework of the experiment, and the revenue-earning use by externals, the electric vehicles are now used for commuting purposes between Brussels and the surrounding area: some electric vehicles are covering 60 km round trips daily, and are able, by the use of opportunity charging, to cover an extra 40 km during the day. The users concerned charge overnight at home; the low energy consumption during charging makes the electric vehicles very economical for this purpose, and their slower speed in comparison with thermal vehicles is in some degree compensated by the ability to avoid traffic congestions.

## Current EV usage

Since their introduction, the electric vehicles of Brussels University have covered over 120000 km together; the most part of which were done after 1985 with the introduction of fleet exploitation. This means an average of 13000 km per vehicle, which may not seem much but which is a considerable amount compared with other EV experiments [9].
Some characteristic data of the fleet operation are presented here. The average trip length is 14,3 km.
It is interesting to show the distribution of trip length versus number of trips made.
The largest number of trips are shorter than 10 km; this corresponds to local urban services. The peak for long trips (>40 km) stands for interurban commuting journeys with intermediate charging and should not be considered in the framework of urban transport.

The distribution of cumulated kilometres versus trip length, excluding the interurban journeys shows that the most significant contribution comes from the intermediate journeys (10-15 km).
Such an use pattern is thus typical for electric vehicle fleet operation in a city such as Brussels(cf. [10]). These short distances generally covered in urban traffic are easily coped with by currently available lead-acid batteries; the possibility of opportunity charging using the on-board charging facility creates an enhanced flexibility in vehicle operation and makes the maximal daily coverages much greater than the theoretical maximum range on a full charge, the latter being about 50 km; in fact daily coverages of 100 km, or 2000 km/month, are not uncommon with some electric vehicles of the Brussels fleet.

## Charging techniques

The limited amount of energy in the batteries makes it necessary to adopt fast or semi-fast charging techniques. In the framework of the Brussels experiment both techniques have been investigated.
An on-board charger makes the electric vehicle more independent. Such charger should be easily connectable to the electric mains. It also must be compact to be installed aboard, it must withstand the shocks and the vibrations of the vehicle and it must be suitable for the control procedures of fast charging techniques.

The fast charging techniques have been demonstrated on June 24, 1984, by the trip Brussels-Paris-Versailles (and back on June 29) at the occasion of the EVS-7 symposium.
Fast charge permits a rapid energy transfer between the electric mains, “infinite” energy source, and the vehicle traction system.

Using of fast charging involves a loss of efficiency from 80 % by $C_5$ down to 60-60 %, taking some cautions and using auxiliary equipment, otherwise several phenomena can occur: electrolyte stratification and consequential differential degradation of the electrodes, capacity reduction due to more sulphatation caused by higher temperature and partial recharging and destruction due to overcharge.
Fast recharging technique is characterized by a constant recharging current corresponding to up to three times $C_5$. Beside the effects already cited care has to be taken to stop the charging procedure in due time. Naturally the battery cannot be fully recharged and after a certain number of fast charging cycles (an indication can be after ten cycles) an equalizing charge is applied. This can be done during night hours and aims to restore the homogeneity of the different battery parts.
For an 170 Ah battery, 120 Ah can be used in rapid charging. Five cycles in a working day (0800 to 1700) allow for 240 km/day.
In spite of the faster degradation of the battery (without auxiliary equipment), the energy transfer obtained can be higher than the energy transfer corresponding to the guarantied number of cycles using a $C_{20}$ current. Tests on maintenance-free batteries showed an augmentation of the extracted Ah with 25 %.
The possibility of using fast charging techniques is an important element in the choice of carried battery capacity and available range. For a strictly urban use, the carried battery weight can be considerably reduced.
However, fast charging is not always necessary; without fast charging the strain on the electric distribution system is reduced.
The use of semi-fast on-board chargers following a constant current/constant voltage characteristic allows for range extension without putting too much constraints on the electric distribution system.
All this refers to lead acid batteries with a specific energy of about 30-35 Wh/kg. Every other battery which has a higher specific energy and which can be charged the same way can only increase the opportunities for deploying electric vehicles

## EUROPEAN ACTIONS

Several European actions are being developed to allow the deployment of electric vehicles.

## AVERE-ASBE

Since 1978, an European Association for Electric Road Vehicles was set up. It aims to promote the technical development of electric vehicles and participates in the organization of the EVS symposia.

ASBE, Belgian section of AVERE, was also set up in 1978.

## COST 302

In the framework of the Scientific Cooperation between the European Community and non-community European countries, experts from 11 countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Sweden, Switzerland and the United Kingdom) were working together from 1982 to 1986.
The final report of this study showed the following facts:
- the Western European market of electric vehicles can be estimated, taking into account the use of the vehicles, at 6 million private cars and 1 million vans (respectively 7 % and 12 % of the total fleet);
- the reduction of the pollution in the cities would be 25 to 30 %.
- the impact on the production of electric energy would be an increase of 2,5 %.
- the oil economy for “Western” Europe would be 3,5 % of the total oil consumption of the transport sector.

One can add that the deployment of large numbers of electric vehicles within an automatic rent-a-car system would allow a substitution of one to five vehicles (one to one in the COST report); this would even increase the beneficial effects on pollution.

## The 12 Electric Hours

As a follow-up to the COST 302 action, a test demonstration called the “12 Electric Hours”, is organized in different European cities to show the opportunities of electric vehicles. The VUB, ASBE and CITELEC are the promotors of this events.
Urban traffic being the "natural environment" of electric vehicles, an electric vehicle demonstration should take place in live urban traffic. This is the basic thought of the "Twelve Electric Hours": let the electric vehicles operate during twelve hours inside normal urban traffic, and show that they are able to cover proper distances during this twelve hour period at a speed which would justify their normal integration in the urban circulation. It should be a "test demonstration" run showing the performances of electric vehicles in urban traffic.
Up to now three editions took place: Brussels, Belgium, October 1987; Bruges, Belgium, september 1989; La Rochelle, France, september 1990.
Several vehicles covered from 150 to 250 km during these events.
The next event is planned in Padova, Italy, in February 1991 and other cities are willing to organize it: Châtellerault, France; Strasbourg, France; Monaco; Namur, Belgium.

### CITELEC

During the seminar organised parallel with the “12 Electric Hours” in Bruges, a memorandum was signed, calling for the creation of an association of cities interested in the use of electric vehicles to solve their traffic and pollution problems.
CITELEC was officially created on February 2, 1990, patronized by the European Community. At the moment, more than 30 cities are members.
Its action programme contains the following points:
- information
- definition of needs
- user training
- demonstration
- impact on traffic
- impact on town planning.

### EDS programme

The European Parliament has asked the European Commission for a study about “Advanced electric drive systems for buses, vans and passenger cars to reduce pollution”, also known as “EDS”.
The aim of this study is to define future technologies for automotive vehicles, using an electric motor as traction motor and several methods of on-board electricity generation.
Furthermore, market and environmental studies will be performed.
The EDS programme should allow the European Parliament to trace future development paths in road transport technology.

## Conclusion

The real breakthrough of electric vehicles is more a political problem than an economical or technical problem. In fact, social and ecological benefits must be included in the cost calculations to show the advantage of transforming the current road transport technology in an “electric” way, and to make the electric vehicle the mainstay of urban road transport in the next century.

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