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# Potential demand and cost-benefit analysis of electric cars

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**Abstract**

In this study an analysis of electric family car performances is carried out. In particular, the aim of this research is to appraise the possibility of introducing electric cars in urban mobility and the evaluation of its economic feasibility. First of all, we determined the potential electric car demand, which was forecasted using a stated preference (SP) analysis. The survey was carried out at the University of Palermo considering a particular target of consumer: "the hybrid household". A logit demand model was calibrated using the SP technique to model the choice between the electric car and the conventional one.

In the second part of the work, the economic feasibility of the electric car is analysed by comparing the operating cost per kilometre of the internal combustion car with that of the electric one. Two options were analysed for electric cars: car purchase and car sharing.

*Keywords:* Cost/benefit analysis; Logit model; Electric cars.

## Introduction

The diffusion of electric cars for urban mobility is one of the possible strategies to reduce air pollution caused by road traffic in urban areas, thus realising more sustainable mobility. Road transport is one of the main factors responsible for pollutant emissions. In 1997, it was estimated that road traffic was responsible for about 72% of carbon monoxide, 46% of particulate matter, 53% of nitrogen oxide, and 24% of carbon dioxide emitted during that year. In all European urban areas the emission levels are increasing. Urban paths are often short so that the thermal engine does not have enough time to warm up and along with the repeated stop and go of the vehicle cause a major increase in consumption and pollutant emissions. It has been estimated that the cost for the Community due to diseases caused by pollutant emissions (like respiratory or cardiovascular disease) is about 1.7% of the GDP (Gross Domestic Product).

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Car factories have been obliged to reduce the emission levels of heat engines by increasingly stringent environmental standards determined by European laws.

In Italy 42% of the car fleet is not catalytic. This value is higher than the average recorded in the European Union countries, and it is much higher in the south of Italy.

## Electric car performances

Among new vehicles technologies, the electric one is more suitable than the conventional car for being used in urban areas for range, speed, energy saving and lower pollutant emissions. The limits of electric vehicles should be overcome by the introduction of new batteries, peak power units like the flywheel and super capacitors, or fuel cell technology. Vehicles based on fuel cell technology will permit energy saving, very low emission and a higher range.

Batteries are the main element of the propulsion system of the electric vehicle, but at the same time they are the main reason for the low performances and the limited range. Table 1 reports the main characteristics of new batteries for electric vehicles.

Table 1: Characteristics of batteries for electric vehicle [(*) prototype].

| | *PB – ACID* | *NI-CD* | *NI-MH* | *LI-ION* | *NA-NICL$_2$* | *NA-S* | *ZN-BR$_2$* |
|---|---|---|---|---|---|---|---|
| Specific energy [Wh/kg] | 35-60 | 40-60 | 70-95 | 80-130 | 90-120 | 150-240 | 70-85 |
| Specific power [W/kg] | 100-150 | 80-160 | 200-350 | 200-300 | 130-160 | 230 | 90-110 |
| Working temperature [C°] | 0 – 45 | 0 - 50 | -40 – 50 | -40 - 60 | 300-350 | 300-350 | 20-40 |
| Average life [$10^3$ Cycle] | 0,6-1 | 0,8 | 0,75-1,2 | 1 | 1,2 | 0,8 | 0,5-2 |
| Range [km] | 100-120 | 150 | 120 | 180 | 250 | 300 | 200 |
| Cost [€/kWh] | 50-75 | 80-115 | 65-115 | 65 | 75-110(*) | 80-144(*) | 65-80(*) |

The performances of electric vehicles seem to correspond better to the characteristics of the private transport demand in urban areas because over 80% of urban trips amount to less than 50 km per day. This datum is important for evaluating the range of electric vehicles, which is generally between 100 and 120 km (see table 2).

Table 2: Performances of some electric and hybrid cars.

| *MODEL* | *VEHICLE'S TYPOLOGY* | *MOTOR'S TYPOLOGY* | *BATTERY* | *WEIGHT [KG]* | *PASSENGER* | *RANGE* | *MAX SPEED AND ACCELERATION* |
|---|---|---|---|---|---|---|---|
| Fiat Panda Elettra | Electric | d.c. motor | Pb-gel | 1050 | 2 | 100 km | 70 km/h 0 – 40 km/h in 10 s |
| Fiat 600 Elettra | Electric | a. c. induction motor | Pb-gel<br>Ni-MH<br>Li-Ion | 1240<br>1110<br>1020 | 4 | 100 km<br>120 km<br>180 km | 100 km/h 0 – 50 km/h in 8 s |
| Citroen Saxo | Electric | d.c. motor | Ni-Cd | 1087 | 4 | 75 km | 90 km/h 0 – 50 km/h in 8.3 s |
| Citroen Berlingo | Electric | d.c. motor | Ni-Cd | 1450 | 4 | 80 km | 95 km/h 0 – 50 km/h in 8.5 s |
| Peugeot 106 | Electric | d.c. motor | Ni-Cd | 1077 | 4 | 80 km | 90 km/h 0 – 50 km/h in 8.5 s |
| Toyota RAV4I-EV | Electric | a. c. P.M. synchronous motor | Ni-MH | 1460 | 4 | 200 km | 130 km/h 0 – 100 km/h in 17.5 s |
| Toyota Prius | Hybrid parallel | a. c. P.M. synchronous motor | Ni-MH | 1240 | 5 | 900 km | 160 km/h 0 – 100 km/h in 13.0 s |
| Honda Insight | Hybrid parallel | a. c. P.M. synchronous motor | Ni-MH | 850 | 2 | 1250 km | 180 km/h 0 – 100 km/h in 10.6 s |

[d.c. ⇒ direct current / a.c. ⇒ alternating current]

## Forecasting electric car demand by SP analysis

Carrying out an economic analysis on electric cars means facing some important problems like the absence of a real market for the electric car. The main reason for this absence is the high purchase price. Other reasons are the limited performance reached by an electric engine, especially if compared to a conventional one and the difficulties of recharging, due to the absence of recharging infrastructures.

In order to overcome some of these problems and to evaluate the market share and economic feasibility of electric cars, a demand sample analysis was carried out. A calibration of the demand choice model for the electric car was made using a stated preference technique (Pearmain et al., 1991) and carrying out a destination survey at the University of Palermo. To this purpose a questionnaire was constructed and submitted to the sample chosen. A part of the questionnaire was devoted to the decision maker's socio-economic characteristics, useful for identifying him or her, like: sex, age, ownership of two or more cars, ownership of a garage, average number of kilometres travelled per day and household income. The importance of the number of cars owned is related to the main characteristics of an electric car, which is more suitable for urban transport. Indeed, according to the literature (Kurani et al., 1996), it was expected that families which met criteria such as ownership of two or more cars and limited commuting distance, the so-called "hybrid household", should have a greater propensity to purchase and use electric cars. The lower electric vehicle performances can thus be overcome considering the target of the "hybrid household". The hybrid household, as mentioned, is a family unit which owns at least two cars: an electric one, used only within the urban area, and a conventional one used for longer trips.

In order to maintain the scenario realistic, the quantitative attributes able to explain the choice demand model and their values were also identified by a pilot survey. These attributes were: the annual cost for the electric (EC) and internal combustion car (ICC), the average time spent to travel by car per day and the average life of the car. In particular, the ICC running time from different origins to the University Campus was estimated elaborating a D.U.E. (Deterministic User Equilibrium) process of assignment of the private car O/D matrix (related to the rush hour and the average working day) to the urban network (Comune di Palermo, 1997).

The running time saved by using the electric car was calculated considering its possibility of entering reserved lanes and LTA (Limited Traffic Areas). The annual costs of EC and ICC were calculated considering not only the cost per year related to the average life of the car but also fuel or electric energy cost, maintenance costs, motor vehicle tax, civil liability and the number of kilometres travelled per year, which we supposed to be equal to 10,000 km. All the values were referred to the FIAT Seicento Elettra (EC) and to the Fiat Seicento SX (ICC). The EC annual cost includes the subsidies determined by the law in force (no motor vehicle tax for the first five years and 50% reduction of civil liability insurance). The subsidies for the EC purchasing price were assumed to be higher than those determined by the law in force. Finally, the average life of the EC was considered equal to that of the battery and it was estimated considering the number of charging/discharging cycles declared by FIAT. The ICC average life is seven years (ACI, 2002).

The identified levels of the EC purchasing cost were 19,446 and 15,831 euro, while the ICC purchasing cost was 8,551 euro. These costs were then transformed into annual costs related to the car's average life (Amoroso, 2002). The identified levels for the ICC's running time were 135 and 105 minutes per day, while the running time for the EC was 75 minutes per day. The average life levels for the EC are 6 and 10 years (for both the kinds of cars the characteristics are showed in table 3).

Table 3: Characteristics of the electric car versus conventional car.

| CHARACTERISTICS: | CONVENTIONAL CAR: | ELECTRIC CAR: |
|---|---|---|
| range: | 315 km with a full | 100 km with a recharge |
| Fuel type: | Petrol | Electric energy |
| Purchase price: | 8,551 € | 19,446 € or 15,831 € |
| Fuel costs per year (taking into account 10000 km/year): | 921.3 € | 238 € |
| The average running time (minutes per day): | 2 hour and 15 minutes per day or 1 hour and 45 minutes per day | 1 hour and 15 minutes per day |
| Time of refuelling: | 5 minutes | 8 hours |
| Place of refuelling: | Filling station | Garage or Box (night recharge) |
| Speed max: | 150 km/h | 100 km/h |
| Motor vehicle tax: | 77.47 €/year | none |
| Civil liability insurance: | 620 €/year | 310 €/year |
| Average life of car: | 7 years | 6 years or 10 years |

Once all the levels 'n' for each attribute 'a' were established, the complete factorial plan was constructed according to the following relationship: $n^a = 2^3 = 8$.

Hence the complete factorial plan is made up of 8 scenarios only, so it was not necessary to divide them (Cascetta, 1998). Finally, all the scenarios were presented to each decision-maker who in his questionnaire reported the choice between the competitive alternatives. 469 questionnaires (3752 observations) were successfully carried out, so we analysed a sample of 0.11%. Actually the number of households in Palermo is 414,155 (ISTAT, 2002).

Let $U_{ICC}$ be the conventional car utility function; $U_{EC}$ the electric car utility function; cost the cost per year (€ per year); time the average running time (minutes per day); life the average life of the car (years); age the decision-maker's age (years); sex 1 if the decision-maker is a female, 0 a male; garage 1 if the decision-maker owns a garage, 0 none; $\beta_0$ a constant; $\beta_1$ the cost coefficient; $\beta_2$ the running time coefficient; $\beta_3$ the average life coefficient; $\beta_4$ the age coefficient; $\beta_5$ the sex coefficient; $\beta_6$ the garage ownership coefficient.
The utility functions of the competitive alternatives are:

$$U_{ICC} = \beta_1 \cdot cost + \beta_2 \cdot time + \beta_3 \cdot life + \beta_0 \quad (1)$$

$$U_{EC} = \beta_1 \cdot cost + \beta_2 \cdot time + \beta_3 \cdot life + \beta_4 \cdot age + \beta_5 \cdot sex + \beta_6 \cdot garage. \quad (2)$$

We expected who is younger (age), female (sex) and has got a garage (garage) should be mainly influenced by choice of the electric car. The calibration of the binomial logit model was made using the maximum likelihood technique (Ortùzar, 1996) with the Limpdep® 8.0 software.

The results of the calibration process are reported in table 4.

Table 4: Binomial logit car-choice model results.

| *Attribute* | *Coeff.* | *Value* | *Stand. error* | *t-student* | *p-value* |
|---|---|---|---|---|---|
| Cost | $\beta_1$ | -0.00163305 | 0.000142156 | -11.4877 | 0.00000 |
| Time | $\beta_2$ | -0.0122307 | 0.00239746 | -5.10151 | 0.00000 |
| Life | $\beta_3$ | 0.276977 | 0.019385 | 14.2882 | 0.00000 |
| Age | $\beta_4$ | -0.0805219 | 0.0373323 | -2.1569 | 0.0310 |
| Sex | $\beta_5$ | 0.209702 | 0.0815229 | 2.57231 | 0.0101 |
| Garage | $\beta_6$ | 0.147276 | 0.0759454 | 1.93923 | 0.0525 |
| ICC | $\beta_0$ | 0.411817 | 0.133113 | 3.09374 | 0.0020 |
| $\rho^2 = 0.12565$ | | V.O.T. = 60* $\beta_1/\beta_2$ = 2.07 €/h | | | |
| $\chi^2 [6] = 649.53437$ | | Significance ($\chi^2$) = 1,00000 | | | |

The results of the calibration process show the correctness of the signs and the p-value shows the significance of each attribute. The constant of garage ownership has poor significance, probably because other variables simulated the a priori preference of the decision-makers for the car. The overall significance of the demand model is shown by $\chi^2$ test.

According to the literature (Kurani et al., 1996), it was expected that SP respondents who met criteria such as ownership of two or more cars (85% of the sample), living in Palermo and having a limited commuting distance (94% of the sample), the so-called “hybrid household”, should have a greater propensity to purchase and use electric cars. The sample analysed shows these characteristics, but unfortunately it was not possible to have reliable data about household income because of the great resistance to answering about it.

The model’s predicted probability of the electric car choice is 54.61%, while 45.39% will probably choose the conventional one.

The importance of the variables cost and time in the demand model can also be analysed calculating the Value Of Time (VOT), which is equal to €2.07 per hour. It is interesting to note that this value is confirmed by the data obtained in the Urban Transport Plan of Palermo (Comune di Palermo, 1997). This confirms the reliability of the model here reported.

Useful information is given by the elasticity of the attributes annual cost and average time. The direct elasticity shows the effect due to a change in the value of the independent variable on the value of the dependent one. Table 5 shows the values related to the direct elasticity effect of the analysed attributes of transport supply on the probability of choosing between the two alternatives (ICC, EC), averaged over the set of observations.

Table 5: Direct elasticity split by choice alternative.

| *Alternative* | *Cost per year [€/y]* | *Average life [y]* | *Average running time [min/day]* |
|---|---|---|---|
| Conventional car | -2.205 | 0.885 | -0.669 |
| Electric car | -1.960 | 0.826 | -0.348 |

These data show how an increment in annual cost equal to 1% induces an average reduction of choice probability equal to 2.21% for the ICC and to 1.96% for EC. They also highlight a high cost-related demand elasticity. The average life shows perfect elasticity because this value is very near to the one for ICC and also for the EC. Finally, the average running time demand elasticity found for the calibrated model is inelastic, and indeed its value is lower than one. At all events, we have to remember that the average running time variable was expressed in minutes per day.

It should be stressed that the direct elasticity value found for the demand model calibrated is also due to the sample distribution among the two transport alternatives. The probability distribution is near to 50%, as mentioned before, and it highlights major indecision between the alternatives presented in the scenarios.

## Cost-benefit analysis of electric and internal combustion car

This analysis aims to compare from an economic point of view the individual use of a heat engine car with that of an electric one in specific applications. Indeed, although the cost involved in buying and keeping a traditional car is widely known, the same cannot be said for electric cars powered by batteries, which are built according to specific functional, constructional and legal requirements. Therefore, the cost analysis involves the life cycle of vehicles, and it is first and foremost a quality-oriented analysis, rather than a quantitative one. It will be focused on the identification of the new fixed and variable costs, which the individual use of these kinds of vehicles entail.

In order to compare these two different technologies, electric vehicles (EC) versus internal combustion vehicle (ICC), the study takes into account their operating costs per kilometre, obtained by the following equations:

$$OCK_{EC} = [(P - RV)/(n \cdot VKT)] + \left\{ [(1 + i)^n \cdot P - P]/(n \cdot VKT) \right\} + \frac{I}{VKT} + \frac{(L \cdot C)}{100} \quad (3)$$

$$OCK_{ICC} = \frac{(P - RV)}{(n \cdot VKT)} + \frac{[(1+i)^n \cdot P] - P}{(n \cdot VKT)} + \frac{(I + MVT)}{VKT} + \frac{(OM + EM)}{VKT} + \frac{(L \cdot C)}{100} \quad (4)$$

Let P be purchase price; RV residual value; n number of years since purchase; VKT kilometres travelled per year; ì interest rate (4.3%); I insurance cost; MVT motor vehicle tax; OM ordinary repairs; EM extraordinary maintenance; L energy and fuel price (€ per KWh or € per litre); C consumption per 100 km.

In particular, purchase price, insurance cost and motor vehicle tax are referred to the Fiat Seicento SX and to the Seicento Elettra. Of course, the electric vehicle purchase price includes the subsidies determined by the law in force. A 50% reduction was also considered for civil liability insurance and the absence of motor vehicle tax for the first five years.

The maintenance costs of the electric car are negligible because it does not need any mechanical assistance for the entire battery life cycle. This is due to the high reliability and robustness of the electric power train system.

The absence of a used car market does not make it possible to have a correct evaluation of the residual value of electric cars, which can only be hypothesised. On the basis of the efficiency of the electric engine, some authors believe that the electric car devaluation rate should be lower than that of the internal combustion one (De Carli, 1997). This hypothesis seems to be too optimistic, especially if evaluated in relation to the battery life cycle (see table 6) and its cost. The cost of the battery is equal to 16% of the electric car's purchase cost. In the analysis presented here the devaluation rate of the electric car was considered equal to that of the internal combustion one.

Table seven shows the costs per kilometre of the owned electric and conventional car calculated considering a different number of years since purchase.

The analysis is made considering a utility car used in the urban area. It is assumed that a vehicle runs for 10,000 kilometres per year in the ECE urban cycle (around 38 km per day 24 days per month 11 months per year).

Table 6: Battery's life cycle.

| *Km/year* | *Battery life Pb-gel [year]* | | |
|---|---|---|---|
| | High | Low | Average |
| 6000 | 17 | 10 | 13 |
| 7000 | 14 | 9 | 11 |
| 8000 | 13 | 8 | 10 |
| 9000 | 11 | 7 | 9 |
| 10000 | 10 | 6 | 8 |
| 11000 | 9 | 5 | 7 |
| 12000 | 8 | 5 | 7 |
| 13000 | 8 | 5 | 6 |
| 14000 | 7 | 4 | 6 |
| 15000 | 7 | 4 | 5 |

Table 7: Cost per kilometre of electric and conventional car

| *Year* | *OCK IC [€]* | *OCK EC [€]* |
|---|---|---|
| 1 | 0.425 | 0.625 |
| 2 | 0.362 | 0.481 |
| 3 | 0.327 | 0.402 |
| 4 | 0.321 | 0.387 |
| 5 | 0.309 | 0.360 |
| 6 | 0.301 | 0.356 |
| 7 | 0.296 | 0.344 |
| 8 | 0.292 | 0.336 |
| 9 | 0.290 | 0.330 |
| 10 | 0.288 | 0.326 |
| 11 | 0.287 | 0.323 |
| 12 | 0.286 | 0.321 |
| 13 | 0.285 | 0.319 |

Table 8: Annual cost for 10,000 km/year.

| *Year* | *IC cost per year [€]* | *EC cost per year [€]* |
|---|---|---|
| 1 | 4251.62 | 6249.57 |
| 2 | 3618.28 | 4809.26 |
| 3 | 3270.19 | 4017.68 |
| 4 | 3207.38 | 3874.84 |
| 5 | 3087.81 | 3602.91 |
| 6 | 3011.24 | 3557.79 |
| 7 | 2959.37 | 3439.83 |
| 8 | 2923.04 | 3357.20 |
| 9 | 2897.16 | 3298.35 |
| 10 | 2878.70 | 3256.37 |
| 11 | 2865.71 | 3226.84 |
| 12 | 2856.93 | 3206.86 |
| 13 | 2851.44 | 3194.39 |

As is highlighted in table 8, there is no economic feasibility for electric car purchase if we consider 10,000 kilometres travelled per year. Moreover, if we consider the battery life cycle it is not possible to evaluate the results reported after the eighth year.

It is very interesting to evaluate the annual cost for electric and internal combustion cars related to the battery life cycle and to a different number of kilometres travelled per year (VKT). The data obtained (table 9) highlight the economic feasibility of the internal combustion car, if we consider the actual purchase price and the subsidies determined by the law in force.

Table 9: Annual cost related to different VKT and average battery's life cycle.

| Km/year | Average Battery life | IC Cost per Year [€] | EC Cost per Year [€] |
|---|---|---|---|
| 15000 | 5 | 3526.31 | 3721.91 |
| 14000 | 6 | 3362.04 | 3652.99 |
| 13000 | 6 | 3274.34 | 3629.19 |
| 12000 | 7 | 3134.77 | 3487.43 |
| 11000 | 7 | 3047.07 | 3463.63 |
| 10000 | 8 | 2923.04 | 3357.20 |
| 9000 | 9 | 2809.46 | 3274.55 |
| 8000 | 10 | 2703.30 | 3208.77 |
| 7000 | 11 | 2602.61 | 3155.44 |
| 6000 | 13 | 2500.64 | 3099.19 |

If we consider a higher level of subsidies equal to 30% of the electric car purchase price, like the one determined by the regional law in force in Emilia Romagna (Regional Law 13th November 1995), the electric car becomes economically feasible at the fifth year after the purchase date, considering 10,000 km travelled per year.

Table 10 shows the data for the annual cost of electric and internal combustion cars related to a different number of kilometres travelled per year and to the average battery life, considering a purchase price subsidy equal to 30% of the electric car's cost. It is interesting to highlight the fact that the electric car becomes economically feasible at 10,000 km travelled per year.

Table 10: Annual cost related to different VKT and average battery's life cycle (with subsides of 30%).

| *km/year* | *Battery's average life [year]* | *Annual cost EC [€]* | *Annual cost IC [€]* |
|---|---|---|---|
| 15000 | 5 | 3203.02 | 3526.31 |
| 14000 | 6 | 3163.68 | 3362.04 |
| 13000 | 6 | 3139.88 | 3274.34 |
| 12000 | 7 | 3018.15 | 3134.77 |
| 11000 | 7 | 2994.35 | 3047.07 |
| 10000 | 8 | 2901.95 | 2923.04 |
| 9000 | 9 | 2829.30 | 2809.46 |
| 8000 | 10 | 2770.65 | 2703.30 |
| 7000 | 11 | 2722.34 | 2602.61 |
| 6000 | 13 | 2671.60 | 2500.64 |

The analysis reported on before highlights the fact that the high purchase cost of the electric car, along with battery life, have a major influence on economic feasibility. We can guess that a household will only substitute a conventional car with an electric one with a subsidy equal to 30% of the electric car purchase cost.

These reasons, together with the evolution of new ways of using private cars (like leasing or car pooling) that are alternatives to ownership, led us to evaluate a different possibility of electric car boosting: car sharing.

In order to compare the economic feasibility of electric car sharing, its annual cost was evaluated calculating the operating cost per kilometre and the annual cost related to the number of kilometres travelled per year. For this analysis the following equation was adopted:

$$OCK_{CS} = FK \cdot VKT + HF \cdot \frac{VKT}{AS} + SR \quad (5)$$

Let FK be cost per kilometre; VKT kilometres travelled per year; HF hourly cost; AS average speed; SR subscription rate per year to the sharing club.

The annual subscription rate to the car sharing club is equal to €77.47, the hourly cost is €1.65 and the cost per kilometre is equal to €0.20. The total cost of electric car sharing is due to the cost per kilometre and to the hourly cost. So it was necessary to forecast not only the number of kilometres travelled per year but also the time taken for travelling, which depends on the average speed. The average speed was obtained from the data reported in the Urban Traffic Plan of Palermo (Comune di Palermo, 1997), also considering the running time saved thanks to the possibility of using electric cars in reserved lanes and in Limited Traffic Areas (LTA). The average speed obtained is 28 km/h.

As highlighted in table 11, the electric car only becomes economically feasible for a high number of kilometres travelled per year (over 14,000 km/year); by contrast, car sharing is suitable for a number of kilometres travelled per year lower than 14,000 km/year, which is more realistic if we think of its use in urban area.

Table 11: Annual cost of electric car sharing compared to electric car owned related to battery's average life and kilometres travelled per year

| *km/year* | *Battery's average life [year]* | *Annual cost of EC Sharing [€]* | *Annual cost of EC owned [€]* |
|---|---|---|---|
| 15000 | 5 | 3961.40 | 3721.91 |
| 14000 | 6 | 3702.47 | 3652.99 |
| 13000 | 6 | 3443.54 | 3629.19 |
| 12000 | 7 | 3184.61 | 3487.43 |
| 11000 | 7 | 2925.68 | 3463.63 |
| 10000 | 8 | 2666.76 | 3357.20 |
| 9000 | 9 | 2407.83 | 3274.55 |
| 8000 | 10 | 2148.90 | 3208.77 |
| 7000 | 11 | 1889.97 | 3155.44 |
| 6000 | 13 | 1631.04 | 3099.19 |

It could be interesting to compare all the alternatives considered in order to evaluate their economic feasibility. Figures 1, 2 and 3, shown below, compare the three hypotheses of electric car sharing, electric car purchase and conventional car purchase considering three different numbers of kilometre travelled per year.

The comparison points out the clear economic feasibility of car sharing with regard to electric and conventional car purchase considering 9,000 kilometres travelled per year. This advantage becomes lower if related to 11,000 kilometres travelled per year. It is possible to notice that economic feasibility is attained in both cases presented before the limit imposed by the average battery life.

If we consider 13,000 kilometres travelled per year it is possible to note that conventional car ownership is more profitable than electric car sharing and purchase starting from the fourth year (see figure 3).

Fig. 1: Annual cost of electric car sharing , electric car owned and internal combustion car owned related to 9,000 kilometres travelled per year.

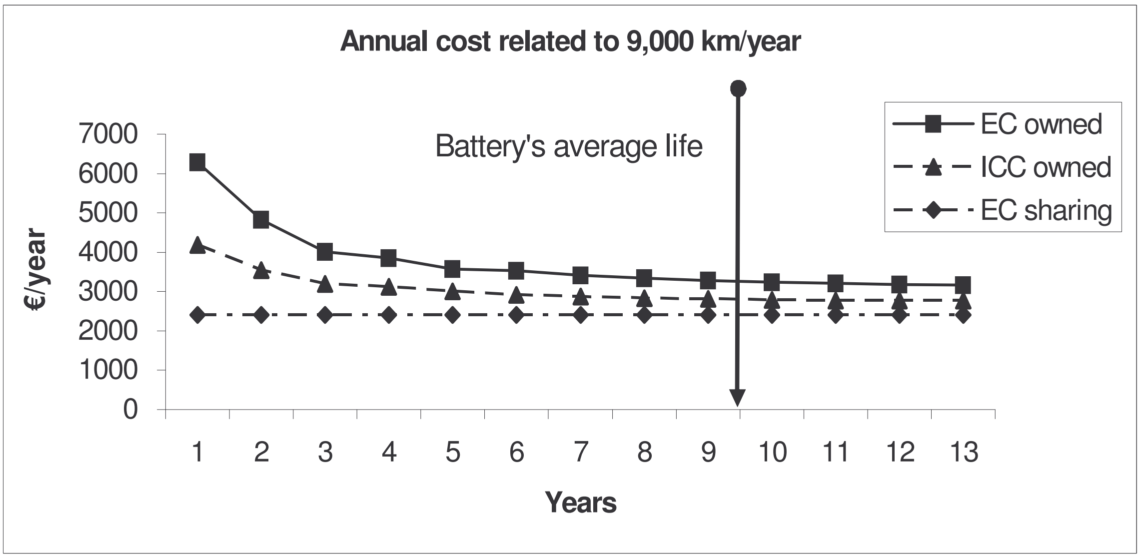
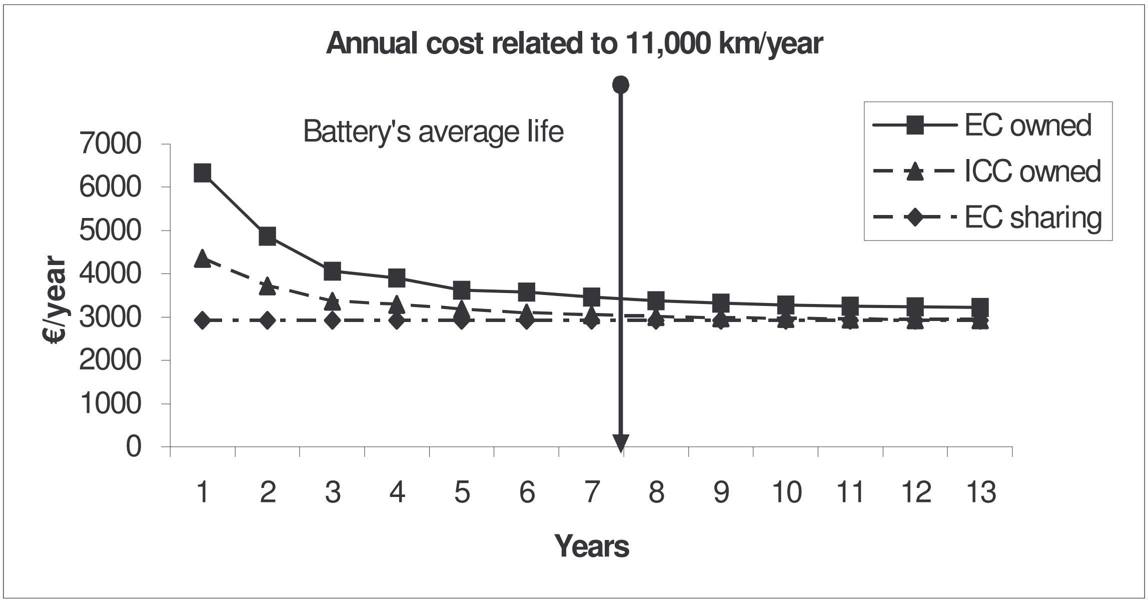
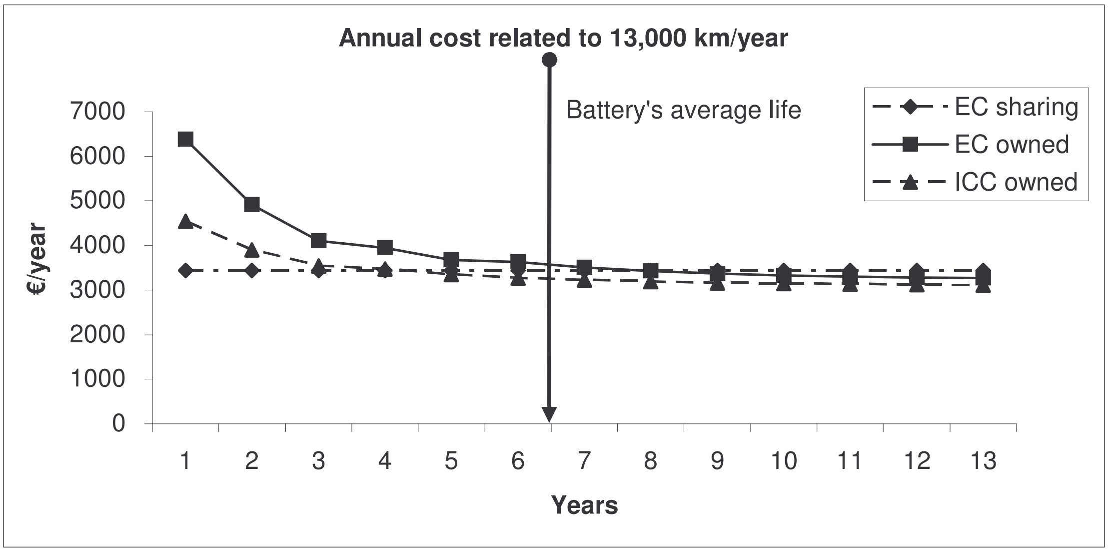



Fig. 2: Annual cost of electric car sharing , electric car owned and internal combustion car owned related to 11,000 kilometres travelled per year.




At all events, it is worth stressing that 13,000 kilometres travelled per year means covering 50 kilometres per day. It is difficult to imagine that people who exclusively travel within an urban area will cover 50 kilometres per day.

Fig. 3: Annual cost of electric car sharing , electric car owned and internal combustion car owned related to 13,000 kilometres travelled per year.




## Conclusion

As highlighted by the operating costs per kilometre, the main problem about the introduction of electric cars is the high purchase price. The high cost of battery increases the initial cost of the electric car and also replacement costs are a significant component of the total lifecycle of EC (Delucchi et al., 2001). Our question is whether the government should finance by subsides the introduction of the electric cars on large scale. According to the analysis carried out by Carlsson (2003) the answer was negative, due to the substantial loss in tax revenue that the government would face if a consumer switched to EC. Nevertheless the lower electric vehicle performances can be overcome considering the so-called target of the “hybrid household”. As mentioned, the hybrid household is a family unit which owns at least two cars, one used only within the urban area and the other for longer trips. We have to remember that electric vehicle performances seem to correspond better to the characteristics of private transport demand in urban areas. Indeed, over 80% of urban trips amount to less than 50 km per day.

The cost-benefit analysis allowed to identify the level of incentives to be adopted in SP analysis highlighting as the decision maker was interested in the EC. Therefore the electric car can be economic under some conditions, such as the level of incentives and subsidies introduced in Emilia Romagna, or notably for commercial fleet vehicles or different transport services like car sharing and car pooling. Actually, the high purchase price and the low incentives do not allow us to forecast a market share for the electric car. For this reason in the demand analysis two different levels were taken into account for the cost of purchase attribute: one considered the actual level of subsidies for electric car purchase; the other considered a double level of subsidies for electric car purchase.

However, the market share found in the demand analysis reflects people's willingness to pay and their sensitivity concerning health and environmental themes. Of course, the electric vehicle in particular and low emission vehicles in general give major environmental benefits compared to existing vehicles. Thus market penetration of the electric car could depend on pricing of environmental benefits. New fiscal, regulatory, planning and policy instruments which reflect environmental benefits (such as vehicle purchase taxes, fuel taxes, road pricing and so on) should be addressed in the urban areas where the damage due to road transport emissions is greater.

Another policy that should be addressed to introduce electric cars in urban areas is car sharing. The cost-benefit analysis pointed out the economic feasibility of electric car sharing. Anyway, we believe that for a real development of electric car sharing in urban private transport some further advantages should be offered, like free parking and a door-to-door service.

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