Electric Vehicles (EVs), Sharing System, Reallocation and Balancing of sharing EVs within a city through an incentive system

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Mobility issues
Transport Externalities

- Air pollution
- Climate change
- Congestion
- Noise pollution
- Accidents
- Infrastructure wear and tear
- Land use
- Oil dependence
Transport Externalities in Urban Areas

Different approaches to negative impacts proposed in some EU projects:

- Environment (air and noise), Energy (consumption) and Economy (transport efficiency, safety, land use and urban planning)
- Travel time, employment, road safety and environmental pollution
- Economic, environmental and social
- Environmental and quality life (air pollution, noise, traffic and road deaths)
Transport Externalities in Urban Areas

Mobility produces positive impacts and negative impacts (externalities).

These negative impacts are mainly related to:

- Number of km travelled
- Number of people
- Emission factors of i-th transport mean given transport speed (vehicle technology and driving behaviour influenced primarily the factor)
- Average speed
Innovations

New Technologies
- EVs
- ICT systems and tools
- Smartphones

New mobility concept especially in urban area
- Mobility as a Service (MaaS)
- Sharing systems

Innovative mobility strategies
- Incentive system
- Gamification
Electric Vehicles (EVs) in urban area
Electric Vehicles (EVs) in urban area

<table>
<thead>
<tr>
<th>EVs</th>
<th>On the road</th>
<th>Mainly widespread vehicles. There are different types and sizes.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Not very common as they can be used in the cities with waterways.</td>
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<td></td>
<td>Air</td>
<td>In the experimental phase, especially small and unmanned aerial vehicle (UAV)</td>
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</table>
Electric Vehicles (EVs) in urban area

<table>
<thead>
<tr>
<th>EVs</th>
<th>BEV</th>
<th>Battery Electric Vehicle (electricity only)</th>
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<tbody>
<tr>
<td></td>
<td>HEV</td>
<td>Hybrid Electric Vehicle (electricity, petrol/diesel)</td>
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<tr>
<td></td>
<td>PHEV</td>
<td>Plug-in Hybrid Electric Vehicles (electricity, petrol/diesel)</td>
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<tr>
<td></td>
<td>E-REV</td>
<td>Extended Range Electric Vehicles (electricity, petrol/diesel)</td>
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<tr>
<td></td>
<td>FCEV</td>
<td>Fuel Cell Electric Vehicles (electricity, hydrogen)</td>
</tr>
</tbody>
</table>
# EVs on the road in urban area

<table>
<thead>
<tr>
<th>EVs</th>
<th>Pedalec</th>
<th>E-scooter, segway and hoverboard</th>
<th>E-car</th>
<th>E-Van</th>
<th>ELVs (L1e – L7e)</th>
</tr>
</thead>
</table>
|     | Cycle with pedal assistance equipped with an auxiliary electric < 250 W, cut off when cyclist stops pedalling and/or vehicle speed reaches 25 km/h | New urban means of transport for passenger transport. Fast, agile, light and easy to carry. | Different technologies developed for EVs for passenger transport | EVs for utility purposes | L1e: L1e-A (powered cycle) and L1e-B (two-wheel moped)  

L2e: L2e-P (three-wheel moped for passenger transport) and L2e-U (three-wheel moped for utility purposes)  

L3e: L3e-A1 (low-perform.), L3e-A2 (medium-perform.), L3e-A3 (high-perform. motorcycle), L3e-AxE (enduro motorcycle) and L3e-AxT (trial motorcycle)  

L4e: two-wheel motorcycle with side-car  

L5e: L5e-A (tricycle) and L5e-B (commercial tricycle)  

L6e: L6e-A (light on-road quad), L6e-BP (light quadri-mobile for passenger transport) and L6e-BU (light quadri-mobile for utility purposes)  

L7e: L7e-A1 (A1 heavy on-road quad), L7eA2 (A2 heavy on-road quad), L7e-B1 (all terrain quad), L7e-B2 (side-by-side buggy), L7e-CP (heavy quadri-mobile for passenger transport) and L7e-CU (heavy quadri-mobile for utility purposes) |
ICT systems and tools
Smartphones

Several apps for Environment (air and noise), Energy (consumption) and Economy (transport).
MaaS – Mobility as a Service
Sharing System
Incentive system

## CLASSIFICA

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## PREMI

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<td>Acquisto transa scotto del caffè per 50 da utilizzare nella pasticceria Ginetti</td>
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**Diagram:**

1a-Request

1a-Respond

2a-Download Request

3a-Respond

4a-HTML Page

4a-Write on Database

CSV

Database

Everyday Job

2b-Request

3b-Respond

Client

Server
Gamification

Score 1

Le reliquie del patrono San Nicola furono trasferite nella cripta della basilica poco prima del suo completamento, da papa Urbano II. In che anno si è conclusa la costruzione?

1303
1103

Corretta!

Complimenti! Hai risposto a 4 domande correttamente!
Sharing System with EVs

- Station based
- Free floating
Sharing System with EVs

Check on the app the available EVs in a real time map

Booking the selected EV

Unlock the EV (often with a personal code)

Use the EV

YES

Are the data entered correct (personal data, licence, payment method)?

Use the dedicated app to register

Insert correct data

NO

Use the app to conclude the trip

The EV is locked and payment is done electronically

Use the EV
Issues of Sharing System with EVs

- Ensure the EVs availability in different city areas
- EVs charging activities
- Reallocation activities
- Stations location and permitted area of use
- Charging points location
- Charging time (EVs availability)
Reallocation activities in a sharing system with EVs

Reallocation activities

- Move EVs from one station/area to an other in order to ensure the availability in all the urban areas. It is important for an high level of service for users which alternatively they would not use it more.

- Charging the EVs in order to guarantee the minimum EV autonomy to reach the destination

- The sharing company ensures this service with its staff. This service is an operative cost.

- The reallocation activities are expensive because are proportional to the number of reallocation, but moving the EVs to the most demands areas, at different times of day, ensures an increase in profits.

- Innovative approach could increase profits and reduce costs.
Positive Incentive

Concept of “Nudge” defined in Behaviour Economics

“SET OF MATERIAL AND VIRTUAL OBJECTS THAT HELP MODIFYING THE MOBILITY BEHAVIOUR TO OBTAIN REDUCTION OF DRIVING AND/OR USE OF ALTERNATIVE MODES”
Advantages to introduce Incentive System to reallocate sharing vehicles with user involvement

- Reduction of reallocation costs for the sharing company
- Engage users to the sharing system with reward to be used for mobility services
- Reduction GHG emission and negative impacts (Externalities) due to vehicles involved in the reallocation service by company staff
Design of an Incentive System
Reallocation and balancing of shared vehicles through an incentive system

- Propose the reallocation service to users in exchange for an incentive

- Incentive based on 3 ranges of values (all values are lower than the reallocation cost faced by the sharing company)
  - User 1 -> 50% of company reallocation cost
  - User 2 -> 70% of company reallocation cost
  - User 3 -> 90% of company reallocation cost

- Acceptance of users based on probability
Innovative approach to the reallocation activities in a sharing system with EVs

**Goal**

Minimization of reallocation costs

**ASSUMPTION and DATA:**

- Consider a EVs (or ELVs) sharing system station based (or restricted areas as few blocks)
- **Distances and costs** in the reallocation service defined
- **Max and min number** of EVs (or ELVs) defined in each station to be balanced
- **Number of EVs (or ELVs) in charging** during the reallocation defined
- All the EVs (or ELVs) performing a trip during the reallocation are not considered
- Number of EVs (or ELVs) in each station before the reallocation is known
Data and decision variables

\[ C_{i,j} \]

- \( C \): reallocation cost to move one vehicle from the one station to an other station (data)
- \( X \): vehicle reallocated by the sharing company from a station/area to an other station/area (decision variables)
- \( S \): number of vehicles in a station/area before the optimization (data)
- \( S \): number of vehicles in a station/area after the optimization (decision variables)
Model of minimization of the reallocation costs service

Objective Function:

Minimization the total reallocation costs related to the distance to move the EVs from one station to an other

Subject to constraints:

- total number of EVs is the algebraic sum of the EVs leaving each station and those entering
- Min number of EVs in each station
- Max number of EVs in each station
- EVs in charge not considered in the reallocation process*

*This constraint is not present in the case of ELVs that are reallocated by van (such as: e-bikes, etc.)
Process of the reallocation vehicles through an incentive system

Notify users by App the vehicles to reallocate

Acceptance of 1° incentive value?

Notify users by App the vehicles to reallocate

Acceptance of 2° incentive value?

Pick-up the vehicle in the i-th station and go to the j-th station

Acceptance of 3° incentive value?

The vehicle was left in the j-th station?

User pays for trip

User receives the incentive on own account

Re allocation vehicles is done

Notify company the vehicles to reallocate

Pick-up the vehicles in the i-th stations and leave in the j-th stations

$u_1$, $u_2$, $u_3$, $nu$
Model of reallocation costs minimization with incentive system for users

Objective Function:

Minimization the total reallocation costs related to the distance to move the EVs from one station to an other, also considering the users reward

Subject to constraints:

- total number of EVs is the algebraic sum of the EVs leaving each station and those entering, also considering the reallocation by users
- Min number of EVs in each station
- Max number of EVs in each station
- Acceptance rate of users in the reallocation process
- EVs in charge not considered in the reallocation process*

*This constraint is not present in the case of ELVs that are reallocated by van (such as: e-bikes, etc.)
Simulation with electric car sharing system

Assumptions and data

6 stations
60 electric car

\[ i \in \{1,..,6\} \]
\[ j \in \{1,..,6\} \]
\[ k \in \{1,..,60\} \]

Distance costs

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User acceptance constraints:

\[ u_1 = 1 \]
\[ u_2 = 2 \]
\[ u_3 = 4 \]

Recharge constraint:

\[ X_{i,j,k,u} = 0 \quad \forall \ k = 2, 5, 7, 19, 30, 35, 36, 45, 47, 50, 56, 59 \]
Simulation with electric car sharing system

Reallocation process only by company staff

Solution without Incentive System:
F.O. = 34

Solution with Incentive System:
F.O. = 26

Reallocation process with user involvement
Simulation with electric bike sharing system

Assumptions and data

- 6 stations
- 60 electric bike

### Distance costs

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Recharge constraint:

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Recharge constraint is not applied in the case of reallocation by company staff.
Simulation with electric bike sharing system

Reallocation process only by company staff

Solution without Incentive System:
F.O. = 25

Solution with Incentive System:
F.O. = 17.4
Conclusions

- The innovative EV reallocation approach to minimize the relocation cost for the sharing company on the basis of user involvement by means of an incentive scheme is presented.
- The cost of reallocation with users involvement is always lower than that without users or at least is the same (in the simulation we observed about 20-30% of decreased).
- The problem with the use of ELVs that are reallocated by van (such as: e-bikes, e-scooter, etc.) has all feasible solutions.
- The problem with other ELVs or EVs can admit no solution.
- User acceptance is based on probability (human behaviour).
- Incentive can be economic (money) or awards (free minutes for mobility sharing, season ticket, etc.). The second choice increases the customer loyalty for this mobility service.
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