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 produce 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

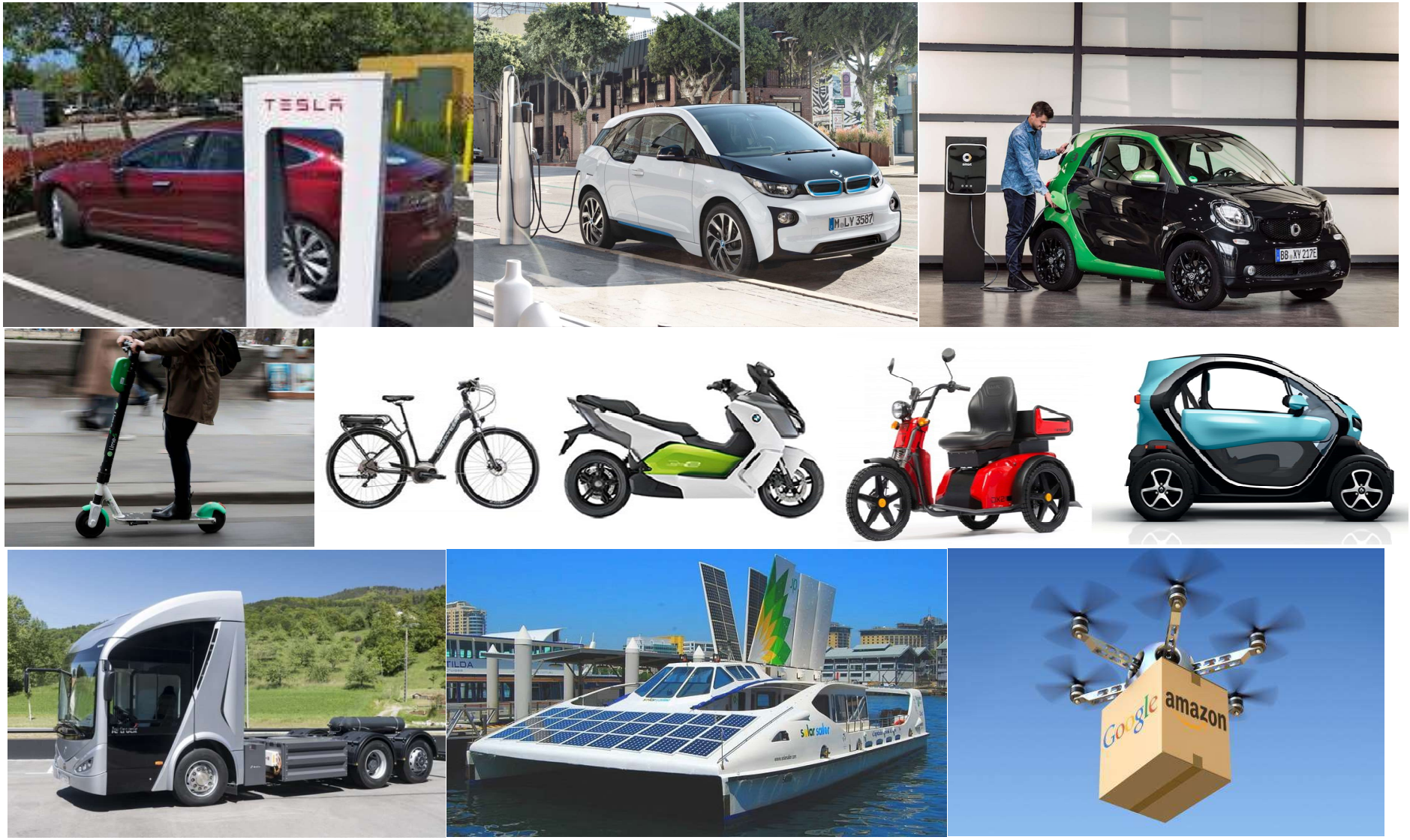
New mobility concept especially in urban area

- 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

EVs	**On the road**	Mainly widespread vehicles. There are different types and sizes.
	Water	Not very common as they can be used in the cities with waterways.
	Air	In the experimental phase, especially small and unmanned aerial vehicle (UAV)

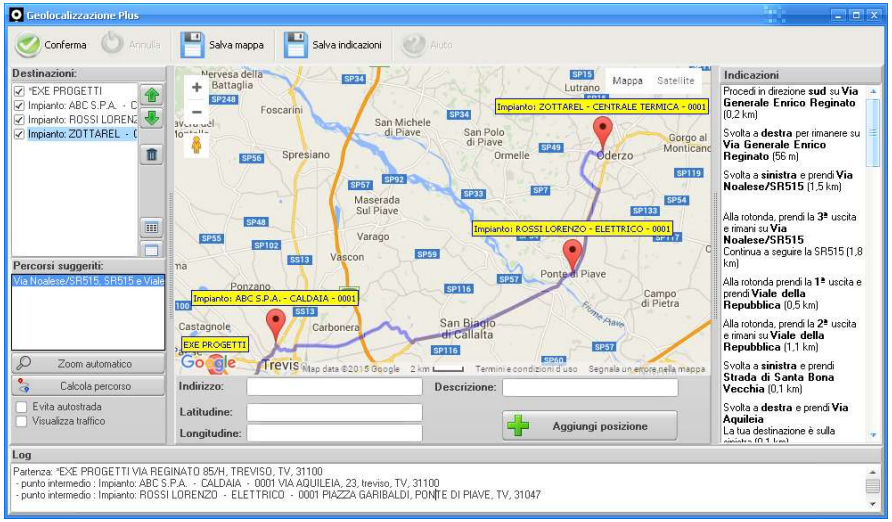
Electric Vehicles (EVs) in urban area

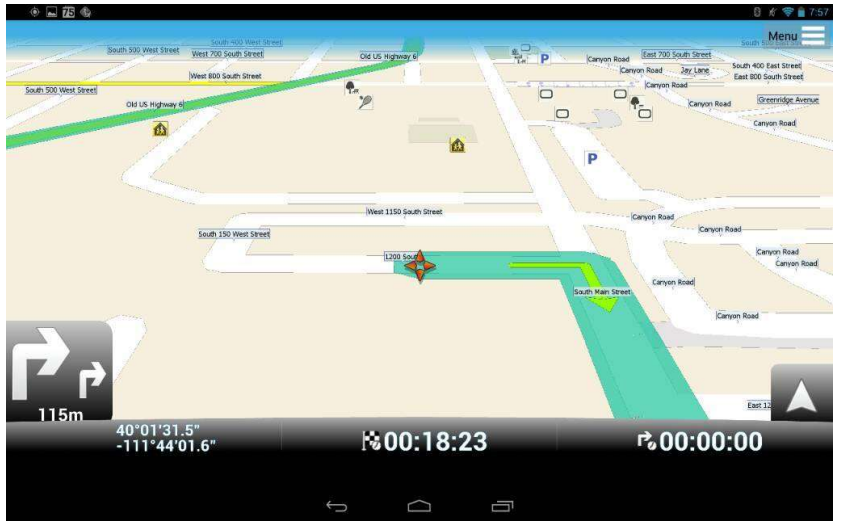
EVs	BEV	Battery Electric Vehicle (electricity only)
	HEV	Hybrid Electric Vehicle (electricity, petrol/diesel)
	PHEV	Plug-in Hybrid Electric Vehicles (electricity, petrol/diesel)
	E-REV	Extended Range Electric Vehicles (electricity, petrol/diesel)
	FCEV	Fuel Cell Electric Vehicles (electricity, hydrogen)

EVs on the road in urban area

EVs	**Pedalec**	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
	E-scooter, segway and hoverboard	New urban means of transport for passenger transport. Fast, agile, light and easy to carry.
	E-car	Different technologies developed for EVs for passenger transport
	E-Van	EVs for utility purposes
	ELVs (L1e – L7e)	**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)

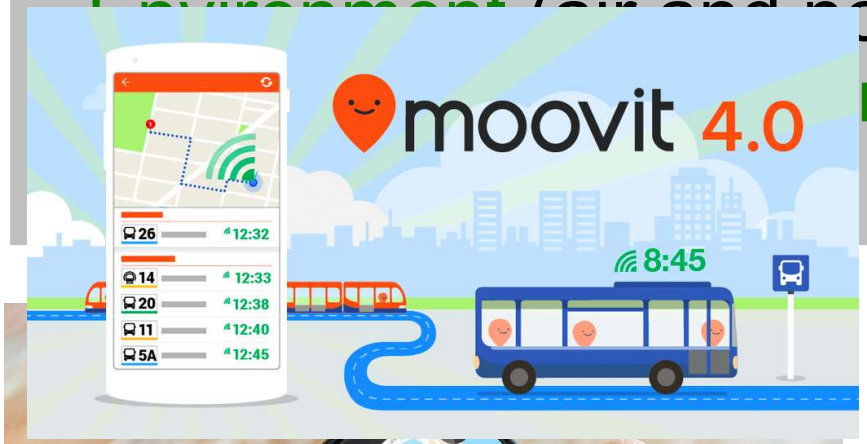
ICT systems and tools

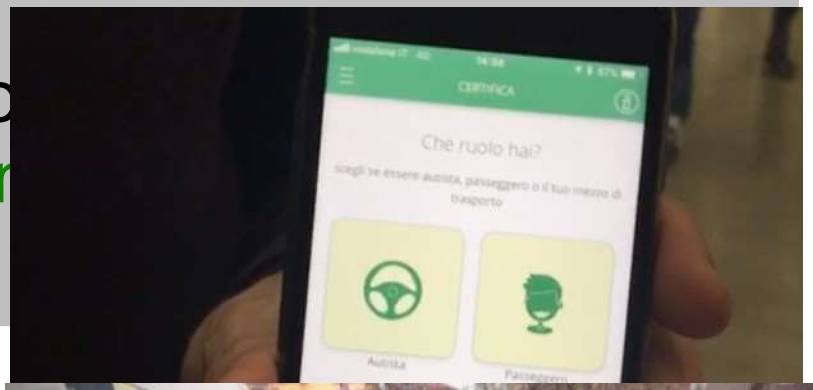




Smartphones

Several app

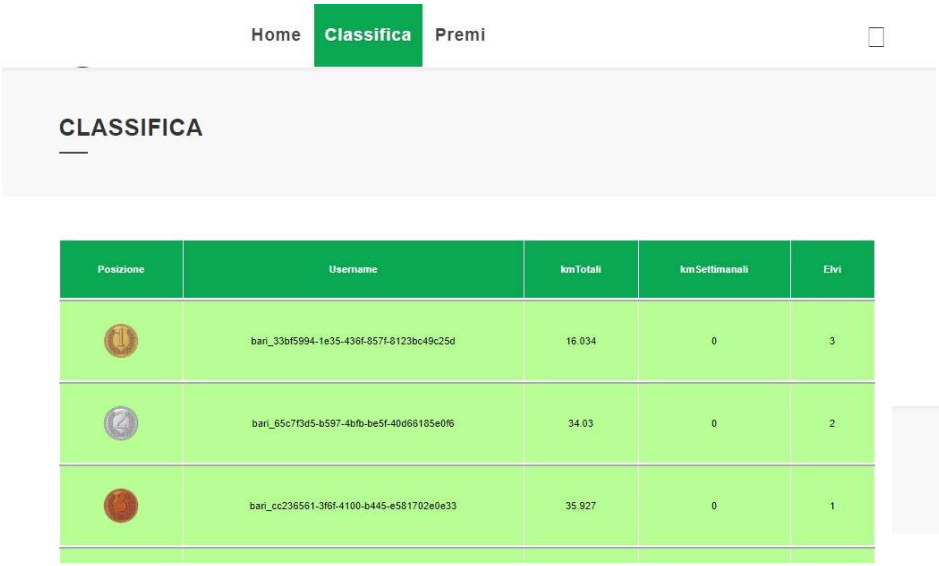


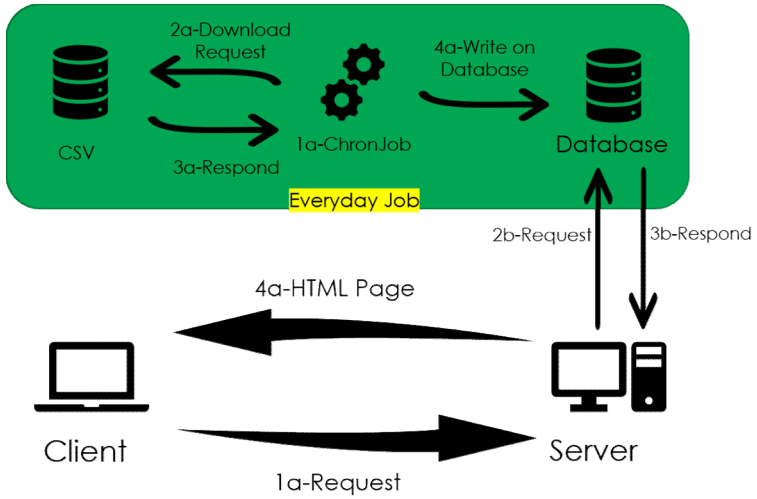


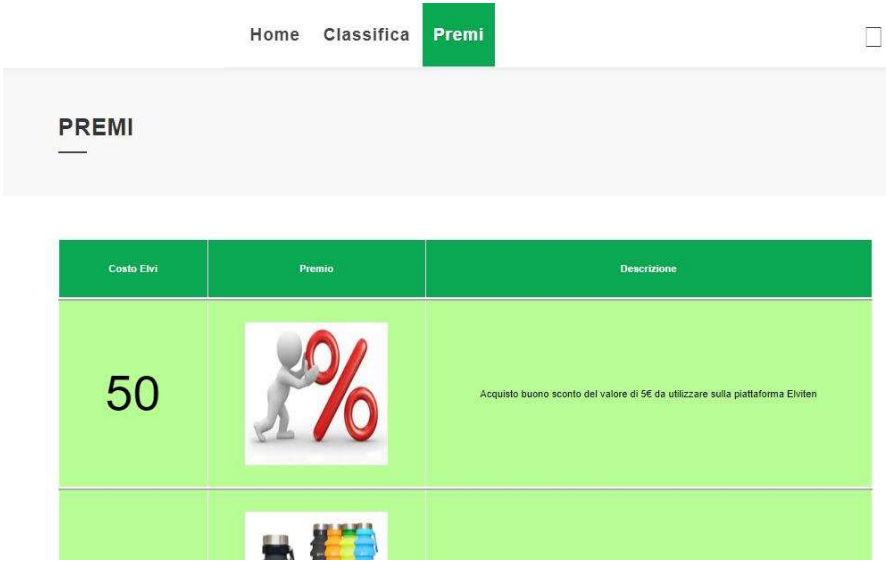
MaaS – Mobility as a Service

Sharing System

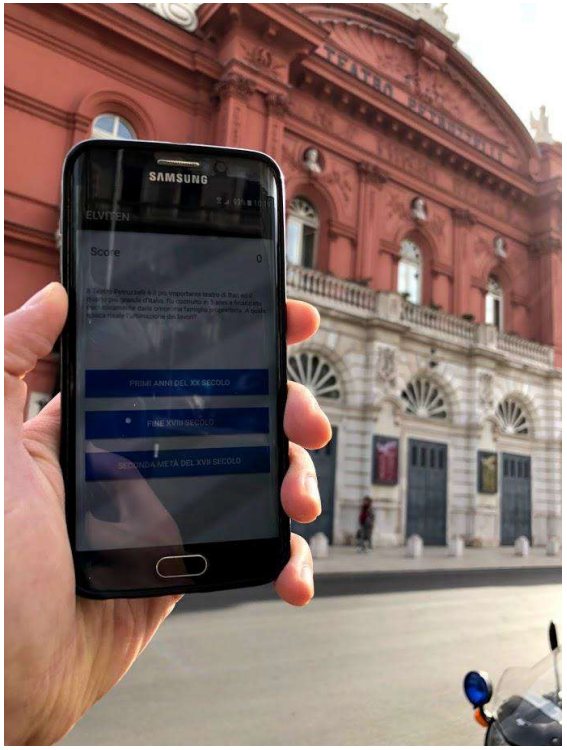
Incentive system

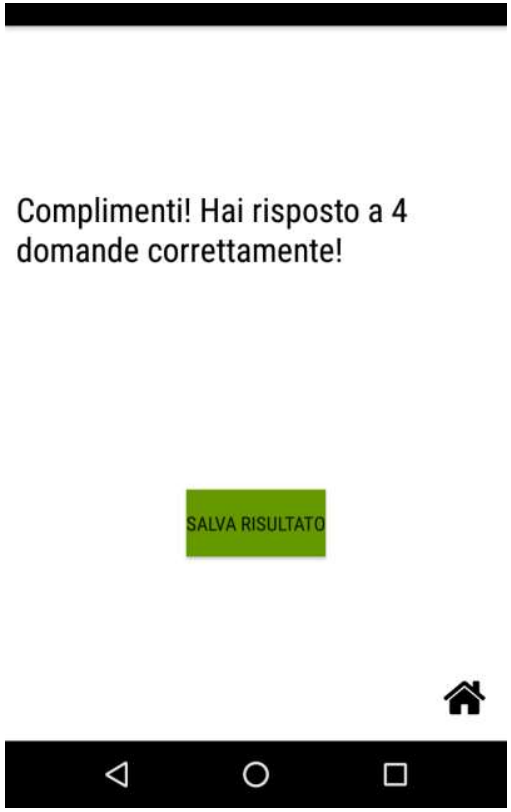






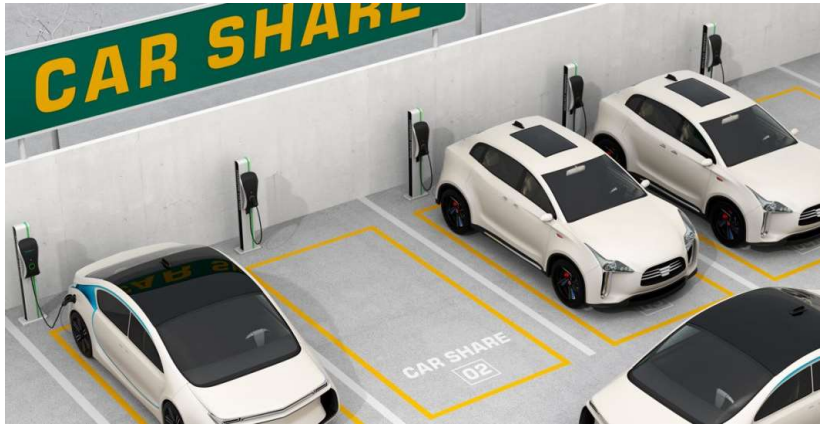
Gamification





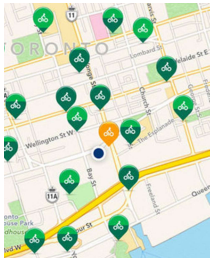
Sharing System with EVs

- 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

Use the app to conclude the trip

The EV is locked and payment is done electronically

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

YES

NO

Insert correct data

Use the dedicated app to register

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

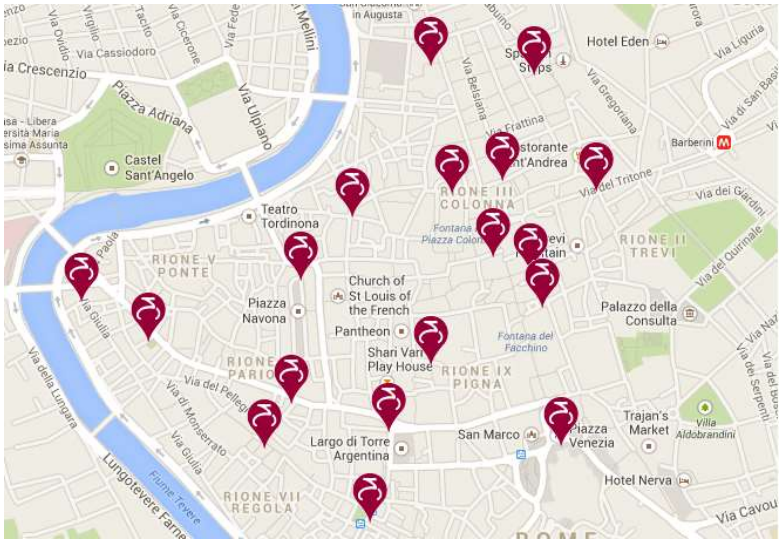
Goal

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



$C_{i,j}$

	1	2	…	n
1	-	5	4	9
2	5	-	7	10
…	4	7	-	3
n	9	10	3	-

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)

$\hat{S}$: 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:

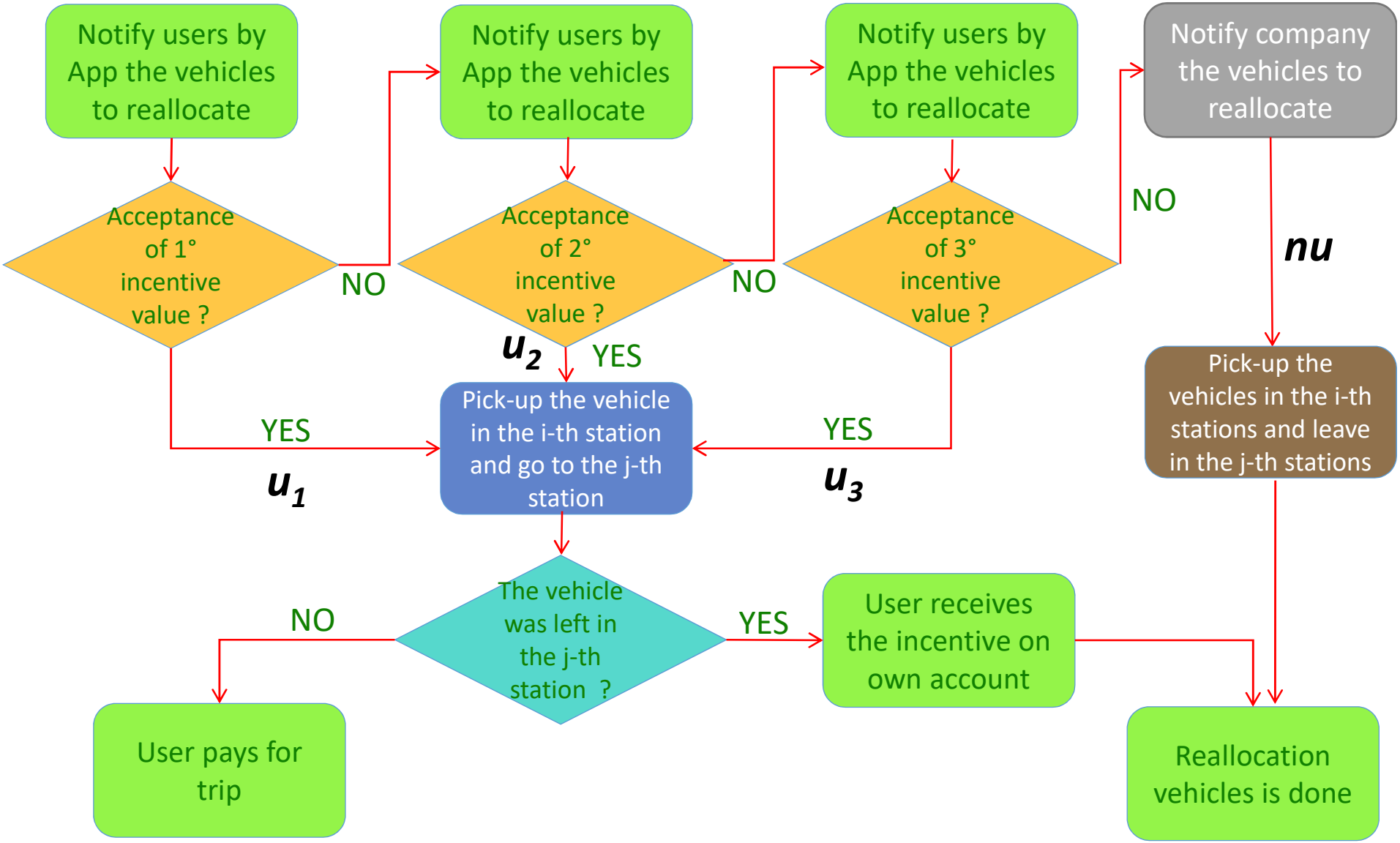
Minimization the total reallocation costs related to the distance to move the EVs from one station to an other

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



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

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

User acceptance constraints:

$u_1 = 1$

$u_2 = 2$

$u_3 = 4$

Recharge constraint:

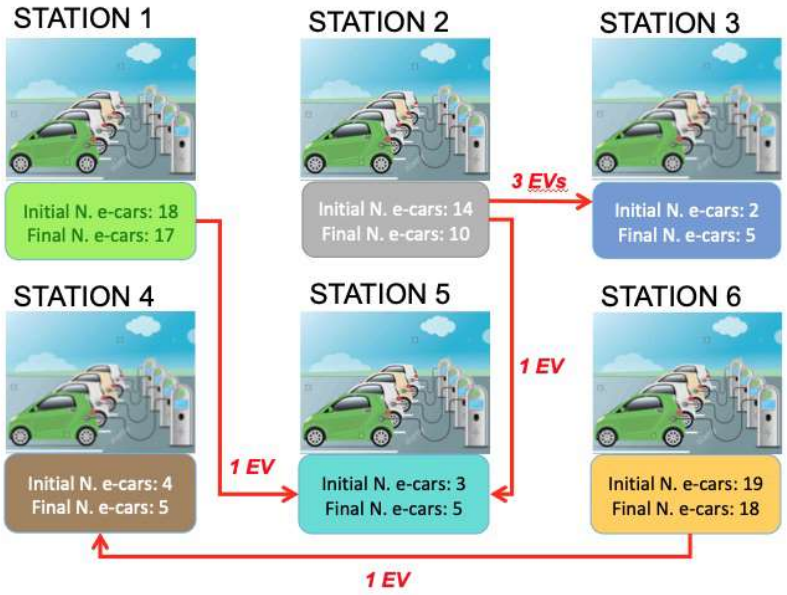
$X_{i,j,k,u} = 0 \quad \forall\ k = 2, 5, 7, 19, 30, 35, 36, 45, 47, 50, 56, 59$

Distance costs

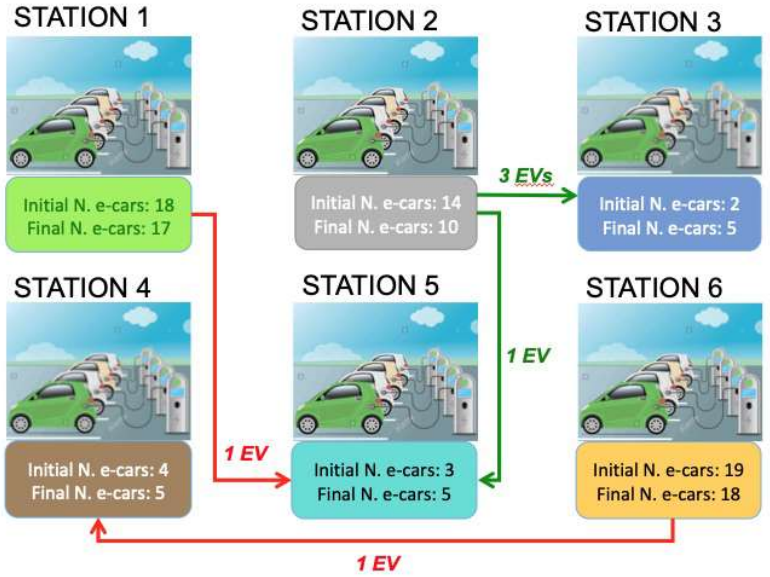
	1	2	3	4	5	6
1	-	5	8	4	4	9
2	5	-	6	7	10	10
3	8	6	-	3	8	5
4	4	7	3	-	3	2
5	4	10	8	3	-	4
6	9	10	5	2	4	-

Simulation with electric car sharing system

Reallocation process only by company staff



Reallocation process with user involvement



Solution without Incentive System:

F.O. = 34

Solution with Incentive System:

F.O. = 26

Simulation with electric bike sharing system

Assumptions and data

6 stations

60 electric bike

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

User acceptance constraints:

$u_1 = 1$

$u_2 = 2$

$u_3 = 4$

Recharge constraint:

$X_{i,j,k,u} = 0 \quad \forall\ k = 2, 5, 7, 19, 30, 35, 36, 45, 47, 50, 56, 59$

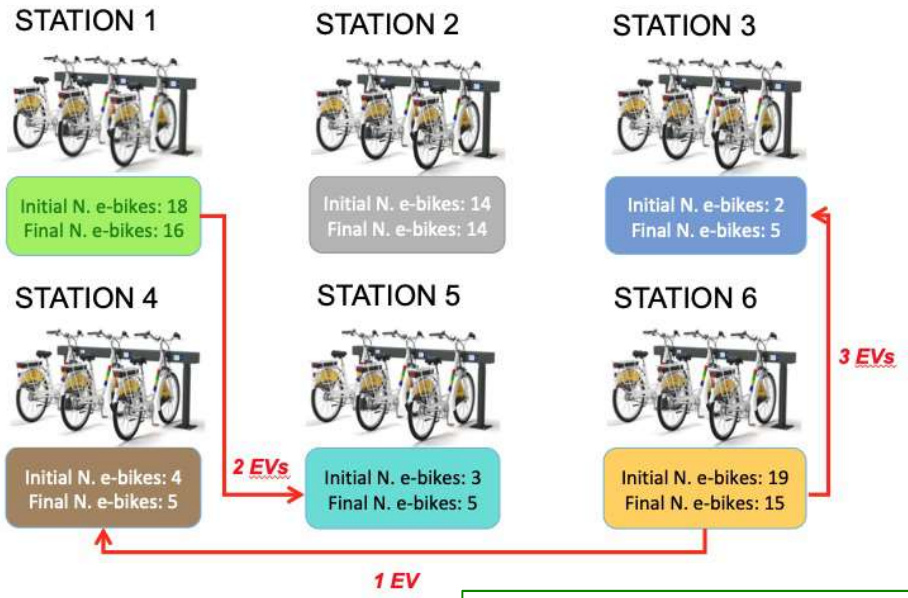
Distance costs

	1	2	3	4	5	6
1	-	5	8	4	4	9
2	5	-	6	7	10	10
3	8	6	-	3	8	5
4	4	7	3	-	3	2
5	4	10	8	3	-	4
6	9	10	5	2	4	-

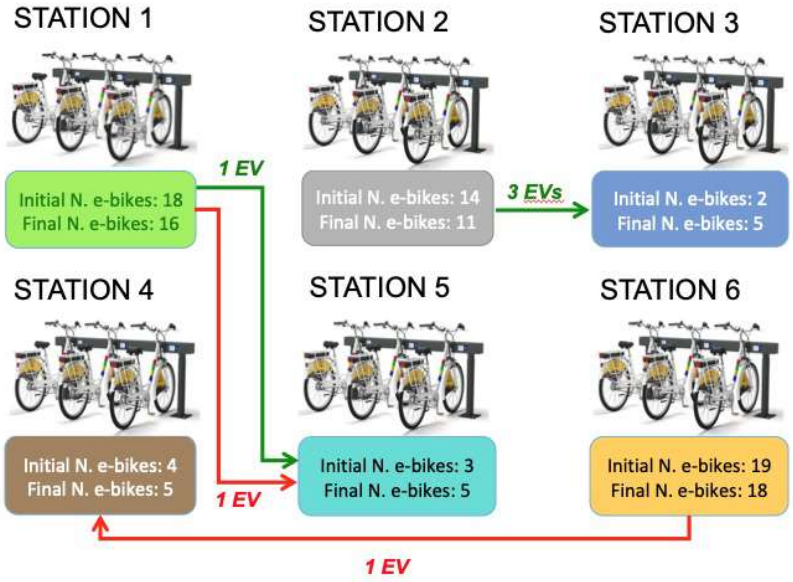
Recharge constraint is not applied in the case of reallocation by company staff

Simulation with electric bike sharing system

Reallocation process only by company staff



Reallocation process with user involvement



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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