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Green Move: an innovative electric vehicle-sharing system

Alessandro Luè[a,b,*], Alberto Colorni[a], Roberto Nocerino[b], Valerio Paruscio[b]

[a]*Dipartimento INDACO - Politecnico di Milano, Via Durando 38/A, 20158 Milano, Italy*
[b]*Poliedra - Politecnico di Milano, via Giuseppe Colombo 40, 20133 Milano, Italy*

Abstract

Vehicle sharing is one of the possible answers to the increasing demand of sustainable way of transport. However, the traditional management models of sharing services are not flexible enough to be a real answer to current and future mobility needs. Green Move, an ongoing project financed by Regione Lombardia that involves eight different research centers of Politecnico di Milano, has the objective to design and test a vehicle-sharing system, with different categories of electric vehicles. The service will have the following characteristics: multi-ownership, allowing single users, private companies, and associations to join the service both using vehicles provided by the service itself and sharing their personal electric car or fleet, this represents an application of a peer2peer approach in the field of sustainable mobility; the Green e-Box, a device that will be the bridge between user, vehicle and control center, potentially compatible with any vehicle; key-less-mobility, meaning that personal smartphones will be the access-key to the Green Move fleet, avoiding the use of smart-cards or physical keys. The design of a full scale service for the city of Milano will be carried out by a multi-criteria assessment of a wide number of possible alternative options in order to identify the most feasible and effective one. Indicators will be identified to measure the performance on relevant dimensions (i.e. economic and financial sustainability, social benefits, environmental effects). A trial to test the operating modes and the service efficiency will be carried out with electric vehicles and docking stations in a specific area of Milan, establishing a connection with the present traditional electric car sharing service owned by the Region. The performance of the service in term of accessibility and usability will be measured with a specific monitoring system. The paper aims to give a general overview of the project and a focus on the methodology in use for the full scale service design.

Keywords: vehicle sharing; electric vehicle; service design; social network; environmental assessment.

* Corresponding author. Tel.: +39-02-23992905; fax: +39-02-23992911.
E-mail address: lue@poliedra.polimi.it.

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1. Introduction

The general expectation, confirmed by the investments of the principal car producers, concerning personal mobility in western countries cities is a shift from internal combustion engine vehicles to electric ones. This shift gives a chance to avoid the local emission in urban area, since the energy needed for the car moving is generated by thermal power plants located in non urbanized area or, in the best scenario, by clean and renewable technology such as hydroelectric, wind, geothermic and solar power plants. If this prevision will be fulfilled, the shift towards electric cars will mean a significant fall of climate-changing emissions (on condition that the sources are zero-emission ones) and improvement of urban air quality.

In synergy with the decrease of vehicle weight, development of alternative forms of mobility (such as soft mobility measures, car pooling, bike-sharing, etc.) and spread of electric vehicles, Green Move represents a new idea of mobility as we are used to think, a new system based on small, electric and shared vehicles. Financed by Regione Lombardia and started in April 2011, the two years lasting project aims to face both the technological aspect and the service design in order to identify a successful model of vehicle-sharing. Eight different departments and research centers of Politecnico di Milano are involved in the project: DEI (information communication technology and electric vehicle expertise), DIG (economic and stakeholder analysis), DIAP (cost-benefit analysis and urban planning), DIIAR (geographical information systems), Fondazione Politecnico (administrative management and technological expertise), INDACO (service design and communication), MATE (mathematical models), and Poliedra (sustainable transportation and evaluation).

The basic idea behind Green Move is to create a flexible service of vehicle sharing, based on electric cars and open to a wide range of different typology of users. The system will be made easily accessible thanks to an add-on device, the Green e-Box, a bridge between the user, the vehicle and the control center, that allows the inclusion into the service to any vehicle and, consequently, to any user. The key characteristics of the service are:

- Intermodality: the service is defined as a vehicle-sharing system offering to users a multi-modal fleets. One of the more evident limitations of traditional sharing system is to offer to users a single typology of vehicle (usually car or bike). This approach is not flexible enough to supply a wide range of mobility needs.
- Multi-owner: an added value will be the opportunity for single users, private companies, associations, etc, to join the service not only using vehicles provided by the service itself but also sharing their personal electric car or fleet.
- Multi-business: the standardized way to join the system gives the chance to design alternative services and flexible mobility solutions (i.e. a mini-van used during the day as company vehicle and as collective taxi during the night).
- Green mobility credits: the opportunity to profile the user and to link his behavior to the effective consumption of energy makes possible to satisfy the personal will of low impact life style and to set up a credits system able to repay virtuous behavior.

The project aims to take advantage of the potentials of social networking to design a service fitting the real expectations of users, to understand dynamically the evolution of user's needs, to spread the service and to create solid and trusted users community and clusters, also thanks to feedback and rating systems. A structured social network community could be useful also in the self-management of part of the Green Move fleet.

After a preliminary phase necessary to design the vision and share it among the partners (Service Idea) and the analysis of territory, stakeholders and vehicle-sharing systems already in place (Context Analysis), the project faces the definition of several possible service options (Strategic Design) choosing

the ones with the highest level of sustainability (economic, social and environmental). The fourth phase (Option Analysis) will select, using a multi-criteria analysis, the most effective and efficient solution. The last phase concerns the implementation of the technology necessary to manage the physical system (System Development) and a trial to test it (Demonstrator).

2. Literature review

Car-sharing is attractive as a transportation service that fills the gap between public transit and private cars. Car-sharing is not suitable for long distances, one might use another household vehicle, air transport, rail, bus, or a rental car; neither for short distances, one might walk, bicycle, or use a taxi. But for intermediate distances a shared vehicle is a good option (Shaheen et al., 1998). Vehicle sharing systems have a decades-long history, beginning in 1940s in Switzerland (Shaheen et al., 1998). While central Europe remains the center of car-sharing activity, other growing markets have developed in northern Europe, North America, Asia, and Australia (Shaheen et al., 2007).

The concept of vehicle sharing had different evolutions, such as neighbourhood model, station cars, multi-nodal, depending on local approach (Barth & Shaheen, 2002), (Brook, 2004). Until the 90's, almost all car-sharing organizations resulted in failure (Shaheen et al., 1998): main factor of failure is the difficulties to reach a critical mass of users to guarantee an economical balance (Brook, 2004), thus the frequent need for a public support (Burlando et al, 2007). The most frequent barrier for many people to adopt car-sharing is the concern about not having a car always available when they need it (Katzev, 2003). Successful services have been implemented recently also thanks to the technological growth that allows an easier management and a more user friendly service (Fistola, 2007).

The recent spread of internet connectivity, web applications, such as social networks, and smartphones allows reconfiguring the idea of vehicle sharing with new big chance of success. Peer2peer (or social) car-sharing seems very promising and has some growing experience such as Buzzcar (France), Getaround (USA) and RelayRides (USA). Automakers are showing interest in this new car-sharing approach: General Motors recently has signed an agreement with RelayRides to produce cars that can be easily rented by owners.

The environmental benefit of the car sharing has been widely proved especially in a reduction of the number of car parked and circulating in the cities (Martin & Shaheen, 2011). In general, with the car-sharing, individuals become more mindful of the variable costs of each trip reducing their personal car use and then the overall level of kilometers driven (Katzev, 2003). Also given a low kilometers driven reduction, car sharing generally produce environmental benefits in terms of air quality since car sharing offer on average newer and cleaner cars (Iniziativa Car Sharing, 2005). Environmental benefits are often linked to cost savings, and this appears a strong driver for car-sharing diffusion (Katzev, 2003).

The use of electric cars for vehicle sharing is a recent application, thus few information about its success are available. Interesting applications concern the cycle involving renewable source of energy, smart grids, and the battery of electric cars that could represent a perfect storage for low price nightly produced energy (Bellifemine et al., 2009).

3. Context analysis

3.1. Best Practices

The Green Move project aims to design a new generation of vehicle-sharing that meets the peculiar needs of different type of users. In order to be really innovative, to avoid critical and inefficient choices in the designing phase and to modulate the service around effective experiences, the preliminary analysis

has considered a wide number of existing practices concerning traditional and innovative vehicle-sharing systems. Best practice preliminary survey shows the evolution of sharing services, from simple station cars for car rental to single-operator service to a peer to peer approach service. Currently the diffusion of electric car-sharing is still limited. Interesting models are vehicle-sharing services based on the use of a vehicle among defined user-cluster (a model close to household-sharing). Possibly the Green Move solution will be able to integrate all the opportunities of these models. The best practices have been reviewed considering a set of 39 parameters that can describe in detail the peculiarities of each vehicle sharing service (Table 1).

Table 1. The list of the parameters.

Capillarity	1. served area 2. capillarity
Intermodality	3. multimodality (matching with TPL stations) 4. interoperability (service integration with TPL)
Costs	5. registration fee 6. use fare 7. subscription
Incentives	8. incentives
Flexibility	9. spatial flexibility (one way, two ways trip) 10. temporal flexibility
Vehicles	11. type of vehicles (nr seats, boot size) 12. fuel distance
Ease of reservation	13. compulsory (yes/no) 14. type (car, departure station, arrival station) 15. technology (phone, web, …) 16. time (real time, n hours in advance)
Ease of use	17. vehicle accessibility (technology in use to open the vehicle) 18. service accessibility (24/7 or different) 19. number of vehicles (availability) 20. vehicle charge duration
Ease of payment	21. payment system
Extra services	22. type of extra services 23. service customization 24. info to user 25. info from user
Technology/service details	26. vehicles: type of engine/fuel 27. type of vehicles 28. tracking mode 29. insurance 30. charge technology 31. charge station technology 32. data collected 33. source of energy
Structure/management	34. vehicles ownership 35. infrastructures ownership 36. customer service modality 37. type of enterprise 38. credit facilities 39. vehicle property

Best practices are also being investigated in terms of social networking. As mentioned above, social networking is spreading out in mobility field. Three examples are:

- Waze: a system powered dynamically by users, able to provide free turn-by-turn navigation based on the live conditions of the road, that represent a good practice in terms of provision of info-mobility by users;
- Buzzcar: an example of peer-to-peer car-sharing system able to allow single car owners to join the service;
- Flinc: a social mobility network that promote carpooling within a trusted community.

3.2. Territorial Analysis

In this phase the analysis of strength, weaknesses, opportunities and threats of the territory reasonably included in the start up phase will be carried out (SWOT analysis). Particular relevance will be given to identify possible barriers (i.e. very dispersed architecture of traffic generators and attractors), synergies (i.e. areas with a high density of public transport stations) and the potentially best area to be included in the service launch and following developments, as well as the area for the field test. Data to be collected include both traffic and environmental indicators for a whole understanding of the present situation, including the main criticism to be taken into account.

According to AMAT (2002) data, every morning during the time lapse 7.30-8.30, from neighbouring municipalities enter in the city of Milano 70.000 cars while about 190.000 persons use public transport. During the same hour more than 90.000 users move inside the city with their private car and 260.000 use LPT. Further analysis including geo-location of these traffic fluxes will allow a better understanding of the potentialities of a vehicle-sharing spread around the city.

In the city of Milano the contribution of traffic to the air pollution is much more relevant than in the entire Lombardia region. In fact road traffic emissions represent in Milano city the 31% of CO_2 (Lombardy: 24%), 88% of CO (Lombardy: 48%) and 73% of NO_X (Lombardy: 48%) total emissions (AMAT, 2005).

In order to give an alternative to private mobility, some experience of car sharing has been implemented in Milano, such as E-vai and Guidami. Since the end of 2008 is possible to hire a bicycle from BikeMi, the Milano bike-sharing, in one of the 190 docking station. The integration of these vehicle-sharing services represents an opportunity to be considered in the service design.

4. Service idea

At the beginning of the project a Service Idea is not fully established and defined yet. A project vision will be created using a step-by step approach, starting from the key service characteristics shared among the project partners: intermodality, multi-owner, multi-business and green mobility credits. A workshop focused on service idea generation has been performed involving researchers with different backgrounds as well as potential stakeholders. The aim of the workshop was a free and wide brainstorming that could produce some added value to the project in terms of innovation regarding many aspects such as business models, information management, interaction with users, collaboration dynamics, extra services and links with the energy production. To allow a free generation of ideas, somehow related to the vehicle sharing, a simple methodology has been set up. Three cross schemes have been showed, each containing two axis as combination of the variables: user experience (active/passive user vs. community/single user), technological scenario (relieving/enabling system vs. personal/shared technology) and energetic scenario (energy producers/consumers vs. business to business/business to consumer approach). Participants had to imagine services, not necessarily related to the car-sharing, that could represent good examples to fill the

proposed schemes. The workshop for the design of the Service Idea has proved a fertile activity that produced a large bulk of row ideas. A post-production activity has systematized the ideas collected to allow a merge of classical and innovative features (Maffei et al., 2011). Some of the most promising ideas are listed:

- Pricing/incentives (different fares to help cars relocation),
- Fleets management (use of firm fleets during night and/or weekends),
- Procurement/Consulting (specific offer for group of users and big attractive points),
- Education (through social network),
- Real time on the move (real time car pooling within the Green Move community),
- Feedback management (to allow a trusted community),
- Customization (for different categories of users),
- Micro community (e.g. condominiums),
- Coop (incentive users cooperation to the service management),
- Micro business (little companies offering extra services).

5. Strategic Design

According to the requests pointed out in the Context Analysis and the preliminary Service Idea, the Strategic Design phase is focused on the definition of specific requirements for the implementation of the Demonstrator (Savaresi & Alli, 2011) and the design of the Full Scale Service. The combination of different and reasonable options identified in this phase, concerning e.g. business model, services provided, technology chosen, etc., will give the dimensions of the options to be analyzed. The most promising service configurations are:

- Condominium vehicle-sharing that can supply a solution for short term and short distance mobility within the neighborhood for regular activities.
- Traveling to and from city center or other big attractive point.
- A vehicle sharing designed for the specific use of firms, with their peculiar characteristics.

Table 2 shows for each service configuration the typical use, the most important parameters for that kind of use and the most similar best practice among the ones investigated and classified. These three configurations show many different peculiarities that a generic vehicle sharing service cannot meet. In order to design a service customizing its offer for each possible usage it is necessary to start from the definition of the objectives of each possible use, such as those in the example. Besides a strategic design, further analysis is needed in order to prepare the option generation: a stakeholders analysis and consequently an objective and evaluation indicators' identification.

5.1. Stakeholder analysis

Even if the service will be designed around the user needs, a vehicle sharing service touch the interest of many stakeholders. The identification of possible stakeholders will be essential to include a wide range of prospects and different ideas concerning the service potentials and to avoid or mitigate possible contrasts and resistance. A stakeholder analysis will produce different point of view for an exhaustive options generation, as well as for the options evaluation. A main frame of stakeholders can be selected based on a general vehicle sharing service, while peculiar service configurations have some distinctive stakeholders as shown in the Table 3, based on two of the most promising service configurations.

Table 2.The three most promising service configurations.

Service configuration	Typical use	Main parameters for the specific user	Similar best practice
Condominium vehicle-sharing	• shopping, • taking children to school	• capillarity, • type of vehicles, • ease of use.	• eVai, • Guidami, Getaround, • E-moving
Network of attractive point	reach attractive points such as • stations, • hospitals, • city center, • …	• fares, • incentives, • flexibility, • type of vehicles, • extra services.	• Greenwheels, • Yèlomobile, • Getaround, • E-moving.
Firm vehicle-sharing	use of firm vehicles typically during the weekend	• capillarity, • incentives, • type of vehicles.	• ICVS_Honda, • Greenwheels, • Car2go, • E-moving.

5.2. Service objectives

Objectives can be designed on two different levels. The first level concerns the satisfaction of potential user needs: the service has this primary objective to fill the lack of the current mobility systems. The second set of objectives is related to socio-economic and environmental performance of the service: sustainability is the reference point for the service design. In particular the focus will be on economic convenience, financial sustainability, social benefit and environmental effects.

Table 3.The stakeholders identified in the process.

General car-sharing stakeholders:
• Local authorities (road network and parking places owner, potential service promoter)
• Local Public Transport companies
• Automotive industry (original equipment manufacturer and aftermarket)
• Energy suppliers
• Local communities
• Press and other media
• Road users (walker, cyclists, ...)
• Taxi driver

Condominium car-sharing stakeholders
• Condominiums
• Real estate developers

Firm fleet sharing stakeholders
• Mobility managers

6. Option analysis

The option generation and evaluation will be a recursive process that will involve in the first stage the main parameters and will be extended consequently to detailed parameters, including management and technological aspects. The aim of the Option Analysis is to evaluate the different options defined as a combination of the parameters, and to compare them and to choose the most efficient one. Fig. 1

represents the steps of Option Analysis phase. Comparison will be performed based on criteria measured by specific indicators.

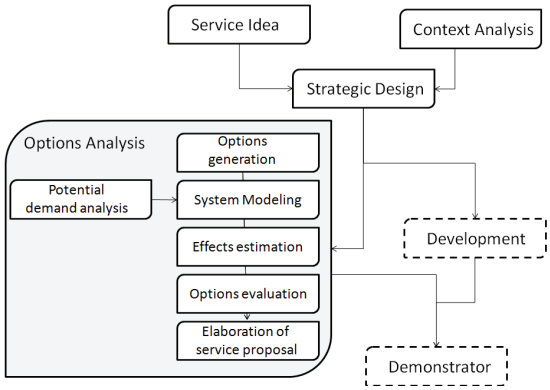

Fig. 1. Option analysis steps

The parameters are combined in order to define reasonable service options. As schematized in Fig. 2, the number of options is represented by the product of all the possible choices. A first screening of the options will eliminate those that are clearly dominated by other options or that show up some clear unfeasibility.

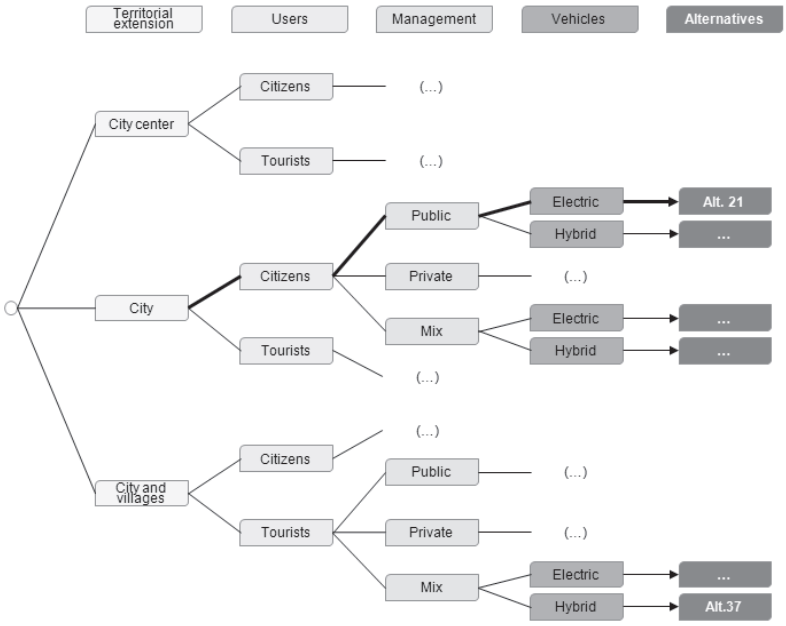

Fig. 2. Options generation. In this scheme the hypoteical Alt. 21 is generated by City as Territorial extension, Citizens as Users, Public as Management and Electric as Vehicles.

The project has a potential wide target that shares some common needs: low impact mobility, low cost car availability, cars suitable for different needs and opportunity to earn money sharing the own car or

fleet. In order to create a service able to meet the needs of commuter and occasional traveller, students and businessman, single user and companies, all the potential users will be considered in the service design. An ongoing specific survey will estimate demand and supply curves related to a number of potential service configuration. The survey aims to show the peculiarity of each user profile investigated. In particular the survey will be designed in order to understand the sensitivity of different target users with respect to the main parameters that define alternative service configurations.

7. Option evaluation

In order to evaluate the options generated, the first step will be to measure their performances, using a set of simulation models, with respect to the set of indicators elaborated for this purpose. A better decision-making process should consider several feasible options, identified and evaluated also with the participation of the stakeholders and the public. For each option, the impacts will be estimated in order to eliminate successively all the options that are inferior because they are Pareto-dominated or too conflicting, or because they have critical impacts on a particular sector. This will gradually narrow the problem and will allow a more significant definition and evaluation of the remaining options, so that the actual entity of the conflicts involved will become more evident. The procedure does not aim at finding automatically the best option, but is a decision-making process, where a continuous participation of all the stakeholders involved optimize the satisfaction of subjective and contrasting interests (Keeney & Raiffa, 1976).

The estimation phase will associate an indicator to each criterion. The instances assumed by the indicators, will be organized in a score matrix of dimension $m \cdot n$, expressing the effects of the n options on the m criteria: for instance, the criterion “air quality” can be expressed by the indicator “daily emission of NO_X by transport system”. The indicators will be estimated by using the same methods among the stakeholders. Therefore one score matrix will be generated.

The peculiarities of each stakeholder will be expressed in the preferences phase with criteria weights, which express the relative importance of the criteria for a stakeholder, and value functions. One value function will be associated to each indicator to represent the satisfaction of the stakeholder about the instances of this indicator. The value functions will be applied to the score matrix in order to calculate normalized values and to convert each indicator into an objective that every stakeholder wants to maximize. The result is a matrix, called value matrix. For each stakeholder, a value matrix will be generated. The global performance of each option for each stakeholder will be calculated as weighted sum of the values of the option as regards to each criterion. In this way, the rankings of the options usually are different for each stakeholder. The choice of the best option, or the best set of options, will take into account the satisfaction of each stakeholder (Colorni & Luè, 2008).

8. Conclusion

The design of a new service that customizes its offer for different users profile is an ambitious objective. The analysis conducted shows promising innovative aspects that can bring to more successful vehicle sharing model. The innovations of current vehicle-sharing systems are complex, because they usually involve both administrators and stakeholders with different opinions and interests and with a resistance to change their “business as usual” approach. In order to enlarge the prospective and to avoid or mitigate possible resistances, identification and participation of interested subject represents an important added value to take into account.

The design of an innovative mobility service not only cannot ignore the environmental dimension and the sustainability but also starts from the need to decrease human impact on the natural resources. In fact

economy and society have always been key factors of discussion but, in the last decades, environmental concerns and sustainability issues as well have come to the fore.

Finally, the decision to consider a wide range of options instead of a unique possible solution extends the project duration but it's effective in order to design a service that fits the real needs of potential users, decreases the chances of failure, contributes to decrease air pollution and has a sensible impact to alternative mobility level of service.

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