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From Traditional to Electric Free-Floating Car Sharing: Application and Case Study in the City of Milan in Italy

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Abstract

The main goal of the research is to analyze the benefits of Free-Floating Car Sharing (FFCS) combined with the benefits of electric mobility in an Italian metropolitan city like Milan. Milan, in fact, is among the European cities with the highest level of vehicular traffic and therefore congestion. In this perspective the work aims at defining and comparing two different scenarios: a current one, analyzing the data of the existing FFCS in Milan, and an evolutionary one, that foresees the renewal of the entire fleet of available cars with electric cars. The work represents a useful decision support tool for the planning and design of electric mobility in cities. The case study analyzed can be used as a starting point and extended to other contexts. Finally, using GIS tools, some evaluations are performed on the location of charging stations for vehicles.

Keywords: Free-floating carsharing; Vehicle relocation optimization; Electric vehicle; Transportation planning; Chargin Station; Cities.

1. Introduction

Car sharing - a service that allows you to use a shared car by paying for the time you use it is a completely new way of understanding and organizing mobility especially in urban areas. Today, there are two prevalent models of car sharing: (i) Station Based, where the user picks up the car in a pre-established place and must return it in the same place, subject to the possibility of leaving the vehicle in another place, with possible payment of a penalty; (ii) Free Floating, in which the user can pick up the car at a point (Origin) and have an entire pre-established area available without having to return it to the place of Origin. In the technical-scientific literature, several authors have studied how to evaluate the possible effects deriving from the use of car sharing by identifying parameters to define

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analytical calculation models (Baptista et al., 2014; Boyaci et al., 2015; Dowling and Kent, 2015; Firnkorn and Muller, 2011; Firnkorn and Muller, 2015; Jochem et al., 2016; Schulte and Vob, 2015; Wappelhorst et al., 2014; Weikl and Bogenberger, 2015).

In this prospective, there is a clear interest of the public authorities, responsible for safety, environmental protection, and traffic management, in encouraging the use and development of this alternative and sustainable transport system. Cultural change, which involves a transition from the logic of ownership of the vehicle to a logic of use (sharing), is for some population groups spontaneous (Barabino et al., 2012). For others, however, it should certainly be encouraged, and local authorities (e.g., municipalities) can play an important role in promoting and supporting the development of alternative, greener forms of car sharing by always providing an adequate mobility service (Boglietti et al., 2021). Within the broad context of shared services, to date, free floating car sharing is certainly the business model that most meets the transport demand for local mobility, but the fleet used by the operating companies is mainly made up of endothermic vehicles (Jochem et al., 2020). From a normative point of view, the European Council has approved an important target that concerns the countries of the European Union: the goal is to become climate neutral by 2050 and reduce Green House Gas (GHG) emissions by at least 55% by 2030. European Directive 2014/94/EC is also part of a regulatory framework aimed at achieving decarbonization goals by encouraging the development of mobility from alternative sources (European Commission, 2014; European Commission, 2017; European Commission, 2018). The main goal of the research is to analyze the benefits of free-floating car sharing combined with the benefits of electric mobility in an Italian metropolitan city like Milan. Milan, in fact, is among the European cities with the highest level of vehicular traffic and therefore congestion; 646 passenger cars per 1,000 inhabitants were surveyed in Italy in 2018 (Eurostat, 2020). Internationally and nationally, several studies have addressed new way of moving people in order to reduce congestion and the use of private car during the day (Neumann, 2021). In this view the work aims at defining and comparing two different scenarios: a current one, analyzing the data of the existing Free-Floating Car Sharing (FFCS) in Milan, and an evolutionary one, that foresees the renewal of the entire fleet of available cars with electric cars. The work represents a useful decision support tool for the planning and design of electric mobility in cities. The case study analyzed can be used as a starting point and extended to other contexts. Finally, using GIS tools, some evaluations are performed on the location of charging stations for vehicles.

2. Case study: the city of Milan

The challenge to the current model of mobility, due to a variety of factors such as, for example, global warming and the consequent push towards a low carbon economy, make car sharing and electric vehicles promising solutions towards a new concept of mobility (Pastorelli et al., 2020; He et al., 2013). In this perspective car sharing can be an incentive for the diffusion of BEVs (Battery Electric Vehicles) and vice versa: two innovations that together can facilitate their diffusion (Davidov, 2020). Therefore, the transition from traditional car sharing to Free Floating Electric Car Sharing (FFECS) may represent a natural evolution that develops over a few years. However, it must be considered that the proper operation of such a system will be mainly related to the management and operational choices of the companies providing the service. The problem that arises is that of understanding the factors that influence the adoption of a free-floating car sharing with electric vehicles, to be able to plan an efficient and effective service. It is important to identify the strengths and weaknesses of the system's development, to overcome any limitations, and to enhance with specific local policies the elements that bring added value. Comparing the numbers of car sharing in European and Italian cities, it emerges that Milan excels compared to other cities. The total number of car sharing vehicles in Italy increased significantly from 2013 to 2019 from about 1400 vehicles to about 8250 vehicles (Rotaris, 2021). The FFECS solution fits in perfectly with the goals of local and national policies on the environment and energy, the decarbonization of energy sources in the transport sector and the containment of pollutant emissions for public health. Some operators have already started to offer the FFECS service in the city of Milan, although the infrastructure component is still partial as shown in Figure 1.

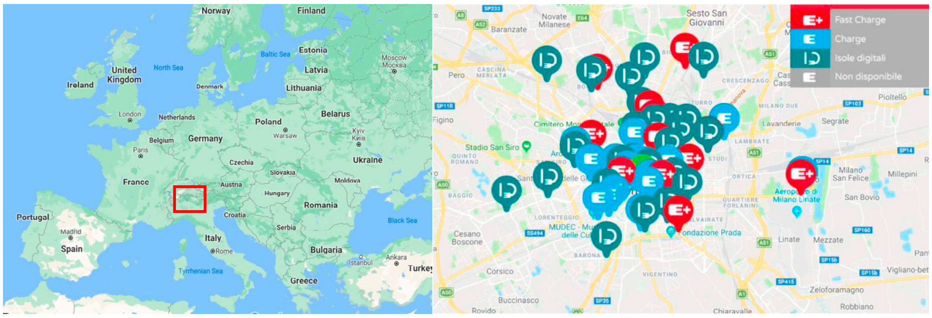


Fig. 1. Map of Milan with indication of Charge, Fast Charge and digital islands charging points.

The operator who provides the car sharing service, in view of the few average kilometers travelled by users, takes charge of periodic recharging, through agreements with garages and parking lots, private points, or at digital islands, operated by the energy supply utility of the territory. However, if a wider diffusion of vehicles in FFECS is to be hypothesized, it is necessary to focus on a key element: the electric recharging infrastructure. Normal power systems (slow recharging) are preferred for recharging near residential areas (in particular, those where the lack of private parking/boxes does not allow recharging in private spaces) or within exchange parking lots that provide a long stop; otherwise, high power systems (fast recharging) are to be favored on stretches of road with high vehicular traffic where a short stop is expected. The first step of the analysis is to examine the data relating to the main roadways characterized by important traffic flows and a high number of fuel stations. In this way it is possible to identify which areas of the city to serve mainly with a free-floating car sharing service with electric cars. The next step is to analyze the available data and create thematic maps using QGIS software. Figure 2 shows an example of maps implemented for the Milan metropolitan area where it is possible to observe:

- traffic flows greater than 24,000 vehicles/day that represent useful indicators for the location of fast charging stations suitable to enable FFECS, but also to contain range anxiety, proposing to user's recharge points along the routes;
- location of petrol stations, mostly distributed along high mileage links, and possible points where to physically place the recharging station;
- parking lots and garages, with priority given to those in correspondence with modal interchanges, or long-stay locations, in which to place slow recharging infrastructures;
- settled activities, where a medium-long stay is foreseen (stadiums, universities, supermarkets, hospitals and cinemas);
- hotels and tourist accommodation, long-stay locations, where slow recharging points are to be installed.

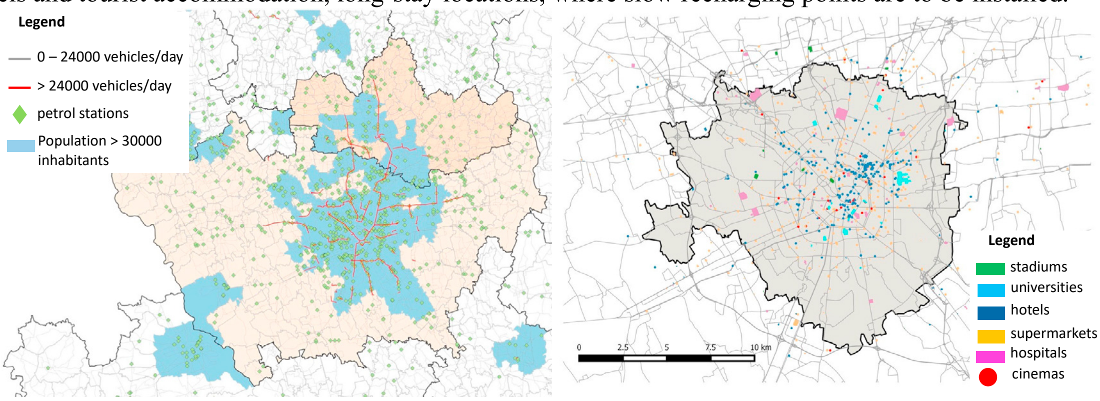
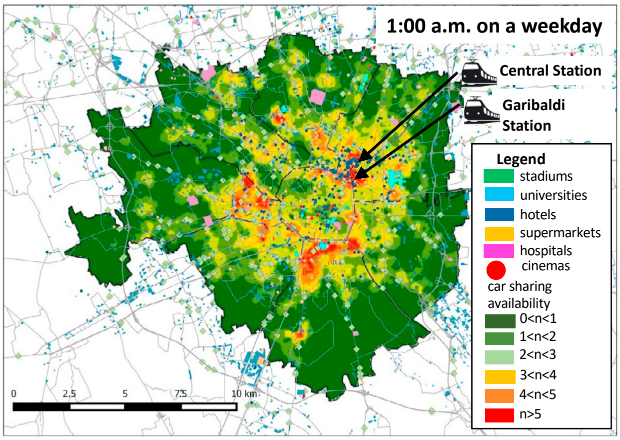


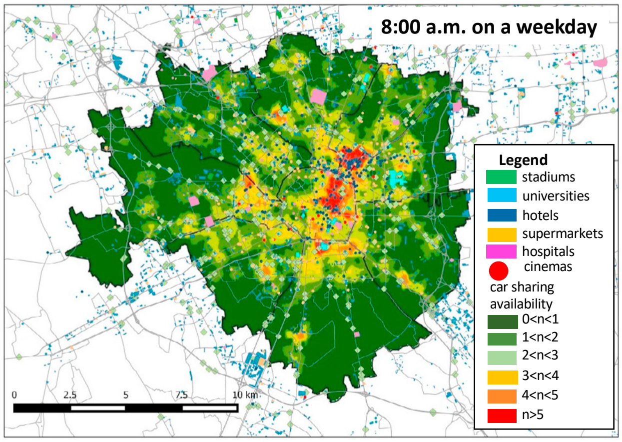
Fig. 2. Milan metropolitan area: indication of total daily flows (no freeways) (a) >24,000 and (b) >8000, fuel distributors and urban centers with population >30,000.

The information described above has been integrated with data on the use of cars in FFCS. The data collected by AMAT - Agenzia Mobilità Ambiente e Territorio regarding the hourly availability of car sharing vehicles on the municipal territory are clustered in three different scenarios: at 01:00 a.m., at 08:00 a.m. and at 5:00 p.m. on a weekday as illustrated in Figure 3. Three thematic maps have been created overlapping the information regarding the use of the service in terms of number of vehicles available on the territory and those described above (stadiums, universities, hospitals, etc.). Examining the map related to 1:00 a.m. (Figure 3a) it is possible to identify the areas affected by a greater number of cars sharing vehicles releases (e.g., universities, main rail station in the city, etc.). The second map (Figure 3b) concerns the time of 8:00 a.m.; it is evident that the greatest number of available cars has moved to the city center, while the area of Central railway station is always well supplied. Car sharing, therefore, plays a fundamental role in the integration with public transport and is used by commuters to reach their workplace or by occasional users to go shopping in the central areas of the city.

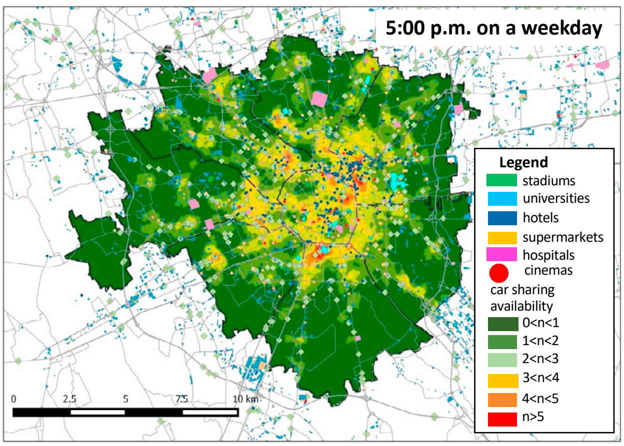
The last processing is at 5:00 p.m. (Figure 3c); this time is the period of the day in which users make the most use of the service; in fact, there are no areas with a high concentration of car sharing vehicles releases and the availability of the fleet is uniformly distributed over the city. However, it is evident in all three representations that the peripheral area of the city does not yet use this service: only a few points and certain routes are involved.



(a)



(b)



(c)

Fig. 3. Availability of car sharing vehicles at (a) 1:00 a.m., (b) 8:00 a.m., and (c) 5:00 p.m. on a weekday.

3. Analysis of users and different scenarios

An E-mobility infrastructure must be able to respond to different needs for the transport of people and goods. It is interesting to analyze the point of view of potential users and to analyze the different scenarios taking into account the infrastructure (slow or fast charging). Below is an analysis of the recharging needs of each user class.

3.1. Residents

The goal is to allow an electric vehicle to perform the functions of principal vehicle (first car) for most users. Consider that 95% of daily trips is less than the autonomy of an electric vehicle; it follows that for "routine" trips the need for recharging can be met when returning to one's home, if one has a parking space or box, it is possible to recharge during the night using low power (slow charging station). In areas where there is a high number of homes with parking spaces/boxes, an integration is necessary through the realization of slow or fast infrastructures depending on the population density and attractiveness of the area. The user with a private car park/box will carry out the main recharging at home: (i) standard recharging (at the private parking); (ii) occasional recharging along the trip (for journeys occasionally exceeding the daily average/vehicle autonomy); e.g., trips more then 250 km where in this case the fast recharging available in the area is used. Instead, the user without a private car park/box will recharge: (i) at an area near the residential home (shared standard recharging); (ii) two/four times a week using different type of charging station (slow and/or fast).

3.2. Commuters

Commuters are mainly moving for work and study reasons. Two types can be distinguished:

a) within 50 km
   - daily recharge: standard recharge at private car park/box
   - occasional recharge: fast recharging at the Park and Ride and/or at a recharging point at a petrol station

b) over 50 km
   - daily recharge: standard recharge at private car park/box
   - daily recharge: standard recharge at the Park and Ride or company parking (workplace)
   - occasional recharge: fast recharge at petrol station

3.3. Fleet

This category of potential users of electric vehicle charging infrastructure includes corporate and public entity fleets and taxi. International and national experiences indicate that for taxies, a network of fast rechargers would be desirable, able to refuel vehicles in a time of 5-10 minutes in a city area (1-2 times per day). For utilities (phone, energy, gas, water) it should be noted that some companies have already considered the possibility of converting their fleet with electric vehicles and of having their own fast charging network. However, a possible issue for utilities is that they are allowing staff to take their service cars home; in this way there is a need to have a recharging network to maintain efficiency and operation of vehicles h24 (the users always cannot charge the EVs at home). A possible solution for these users' category is a fast-recharging station petrol stations area.

3.4. Car Sharing Free Floating

Data from the Milan experience, indicate that free-floating car sharing is certainly the business model that best meets the demand for local mobility. Local authorities may also have an interest in including among their environmental and traffic policies incentives for shared vehicles and vehicles with alternative fuels. In this way, electric free floating is therefore considered as a potential business model. The implementation of a public infrastructure of charging stations could make free floating electric car sharing more like endothermic. Usage data from existing endothermic free-floating fleets indicate that this is possible. The average mileage per use is very low, about 6 km. Each vehicle is used about 3 to 5 times a day, for a total average daily distance of about 30 km. Since the average current autonomy of electric vehicles is about 100 km in winter and 150 km in summer, it is assumed that with a fast recharge every 2 - 3 days (3 fast recharge per week) there is an optimization of the refuel.

3.5. Business User

Electric mobility has already been chosen by several business users (e.g., DHL, GLS, Heineken Italia, Coca-Cola) for the advantages it brings, such as access to Limited Traffic Zones. The challenge is to make a daily trip without the need for recharging. In fact, the main characteristic of business users is to have a high daily mileage, from 100 km to 400 km. It is essential that on the one hand the vehicle have a high autonomy and on the other hand they meet several fast-charging stations per day (e.g., at petrol stations).

3.6. Occasional Users/Tourism and LPT

The category "Occasional Users/Tourism" needs to have quick recharges at petrol stations with using payment without contracts or registrations.

Local Public Transport (LPT) is a category that includes: 6 m, 7.5 m and 12 m buses in several cities. These vehicles recharge at dedicated fast-charging stations located at a bus terminal, depot, or bus stop.

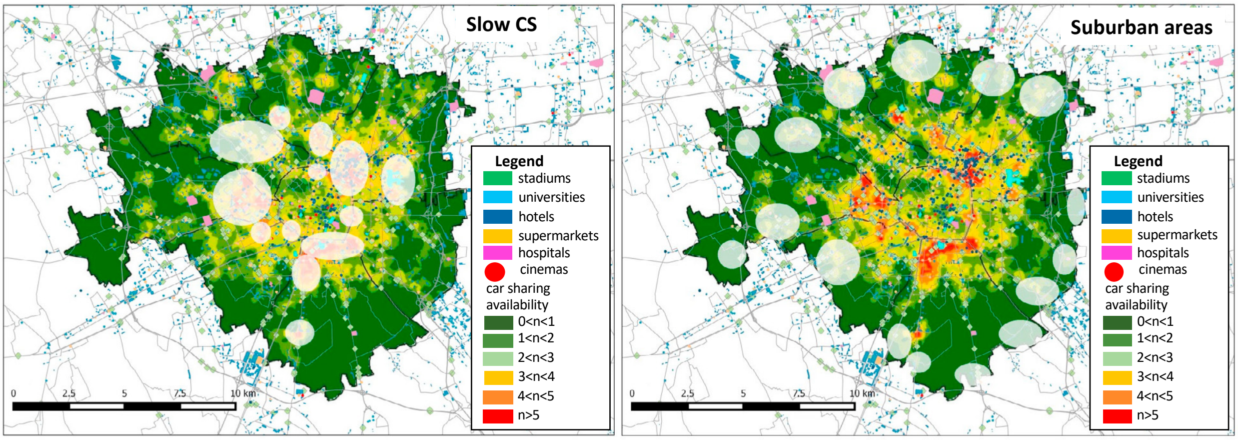
4. Discussion of Results

Table 1 summarizes the different charging modes (slow and fast) for each type of user described in previous section. Taking the regional guidelines as a reference point and considering the analyses carried out, it is possible to identify the areas where locate the different types of Charging Stations (CSs) in cities and suburban area in order to satisfy the recharging needs of the current Free-Floating Car Sharing. In this way, it is considered on the one hand the transport demand (e.g., traffic flow, point of interests) and on the other hand the transport supply.

Table 1. Charging modes for different types of users.

	Private CS	Area near the residential home	Occasional Fast CS	Fast CS	Slow CS in Park and Ride or company parking
Residents with private car park/box	X		X		
Residents without private car park/box		X		X	
Commuters within 50 km			X		
Commuters over 50 km			X		X
Taxi Service				X	
FFCS Service				X	
Delivery Service				X	
Occasional users				X	
Local Public Transport (LPT)				X	

Considering the assumptions illustrated in Table 1, it is possible to define the place in which to install the charging stations adopting the low power (slow charger). Figure 4 shows the different places in city and in suburban area where it is necessary to install the Charging Stations.



(a) (c)

Fig. 4. Assumed areas for installation of Slow Charging Stations (CSs): (a) in cities and (c) suburban areas.

Figure 5 represents the road links with high traffic flow. In this way, it is possible to install the fast-charging station where the time of recharge is about 15-30 minutes. The possible places are represented by railway stations and short-stay attraction points (e.g., public offices, shopping centers, etc.).

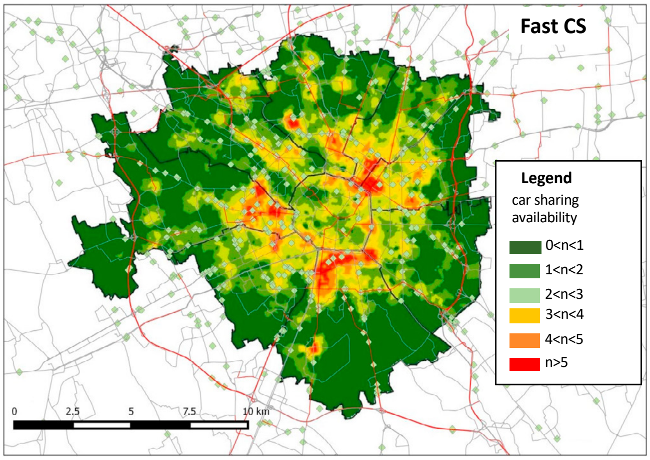


Fig. 5. Assumed road links for installation of Fast Charging Stations (CSs) in cities and suburban areas.

5. Conclusions

The aim of this study is to analyze the benefits of Free-Floating Car Sharing (FFCS) combined with the benefits of Electric Mobility in an Italian metropolitan city like Milan. The work represents a useful decision support tool for the planning and design of e-mobility in cities. The case study analyzed can be used as a starting point and could be extended to other contexts.

Analyzing the current FFCS in the city, the following average data of a vehicle use are:

- average distance 7 km for each use of vehicle
- about 4 daily uses of the same vehicle;
- average daily distance of a vehicle about 28 km.

Considering these average values, the feasibility of using an Electric Vehicle (EV) instead of one with endothermic engine is possible because the average autonomy of an EV is about 130 km. With this assumption, the need would be to recharge the vehicle every 2 or 3 days (about 3 recharges per week using the slow charging station).

Taking into account the location criteria established by the regional guidelines and the studies produced by AMAT related to the release of FFCS, a first level analysis is carried out for the location of the infrastructure where to place charging stations (slow and fast), implementing the specific maps using GIS software.

The study allows to support the decision-making process to encourage and promote electric mobility in the city of Milan and in the suburban areas. The possible develop of this work is to perform detailed analysis and evaluation on the technical feasibility to build charging stations in order to satisfy the several needs of different stakeholders: users, public authorities, municipalities, private and public companies, etc.

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