The Growing Urban Accessibility: A Model to Measure the Car Sharing Effectiveness Based on Parking Distances

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Abstract. The spread and development of shared mobility makes it possible to offer users various forms of shared service that promote a sustainable approach. The choice of transport mode often depends on the distance travelled and the motivation for the journey. Among the conditions and variables that most influence the propensity to use a shared transport mode, the distance between the users' places of origin or destination and the parking areas covered plays an important role, especially in the case of station-based type. The common system that has become more and more widespread in Italy is car sharing, with its various forms (i.e. station-based, free-floating, electric vehicles) that allow the use of reserved parking spaces or shared with other circulating vehicles. In urban areas, people generally tend to walk the first and last mile or use micro-mobility, while for longer distances they tend to use private or shared motor vehicles. Starting from this premise, this thesis provides a methodology for evaluating the effectiveness of car sharing by measuring the probability of using it based on parking distance. The proposed model is based on the estimation of O/D matrices with associated distance levels and the calculation of a probability index derived from several distance combinations. This research lays the foundation for a deeper analysis, which includes model calibration for different common mobility solutions and the evaluation of user probability in relation to implemented common mobility systems in several case studies.

Keywords: Propensity to car sharing · Parking distance · O/D matrix · User perception

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1 Introduction

Urban and infrastructure planning have effects on the entire national system. Several strategies and actions are essential to optimize the use of transport networks, improving different aspects, such as urban logistics, public transport system and intermodality, urban spaces and interactions between different traffic components, all in the vision of sustainability [1–3]. The design and construction of new transport systems change the urban layout and spaces. This has a profound effect on the functional layout of the city by changing the accessibility, times and land uses.

The sustainable city development aims to reduce the use of private means by promoting both slow mobility and means-sharing strategies [4–7]. This type of mobility is often identified as a socio-economic phenomenon that correlates the supply and demand of transport [8]. This concept was developed from traditional to innovative system and it was described by the authors, by highlighting the increase of the use of sensors, digital platforms, the interactivity and community cooperation collaboration and finally by the flexibility of the service [9–11].

Four different parameters generally had described the mobility with private car such as accessibility, availability, continuity and versatility. The spread of integrated mobility has provided a good opportunity to redefine the city map and to consider a new mobility management. The widespread change in the preference for shared use of the medium at the expense of private medium use is associated with an increase in efficiency in resource consumption, emissions and social inclusion.

Among the negative externalities associated to the high levels of motorization rate and traffic congestion there are the oversaturation of road capacity and unreliability of travel times [12, 13]. According to [14], the implementation of shared mobility will make it possible to eliminate road congestion, reduce CO_2 emissions by about 30% and cut the need for public parking by 95%. Furthermore, it has been shown that shared mobility guarantees greater social justice by eliminating or reducing the problems associated with home schooling and home health facilities.

The future structure of this transport resource involves the implementation of the concept of mobility as a service (MaaS) and thus the creation of a platform that is optimally linked to the other modes of transport, with the choice of vehicle being essentially determined by the needs of the users [15–17].

The parameters that describe this utility include the definition of transport capacity and unused capacity. The former is considered as an estimate of the number of passengers transported per day/month/year. The second, however, which is largely related to the MaaS, correlates with a more general concept of the industrial sector and the examination of when a machine/vehicle produces less than it could. As a result, the fixed and general costs integrated into the unit cost of the product tend to carry more weight than if the machine could fill its remaining capacity. Residual capacity is typical for ridesharing such as carpooling and vanpooling, but also for some of the on-demand facility that offer the possibility to share the vehicle for the same itinerary. In the case of the bike, scooter and micromobility, there is only one seat used by those booking this transport mode, instead the remaining capacity is linked to the number of free seats on board. The choice is often linked to the measurement of distances: these concern both the distances to be covered during the journey (short, medium and long distance) and the distances to reach the car park from the starting point of the movement.

With regard to its development, the aim of this research is to describe a methodology to define the probability of using car sharing when the distance between the origin of the movement and the car park where the shared car can be collected is changed. In the second paragraph, attention was paid to the development of car sharing and its effects; in the third paragraph, the evaluation methodology based on a probability calculation was described; and finally, discussions were held on the potential of the methodology and future research developments.

2 The Development of Car-Sharing and its Implication

Car Sharing is an urban mobility service consisting in renting a car owned or owned by third parties so that users can use a vehicle on reservation for a limited period of time, paying for the use. Its development depends on the purpose of the move and on the infrastructure of the cities where it is implemented as described below.

2.1 The Benefits of Car Sharing Development

From an economic point of view, a Car-Sharing user does not have to bear the fixed costs that a car entails by refraining from buying and using a private car. These costs are additional to the purchase and insurance. In addition, there are costs defined as variables, such as maintenance, the purchase of winter tires and vehicle cleaning. It can be observed that costs are incurred not only when the car is moving, but also when it is stationary, i.e. when it is in a garage or in a public parking lot, very often for a fee. Moreover, it is necessary to take into account the costs that have the greatest influence on the ownership of a car, namely the cost of fuel, which is certainly not a small expense in the case of a petrol or diesel car.

Car sharing makes it possible to reduce these costs. In some cases, the km tariff is activated only after a certain number of kilometers has been exceeded, in other cases it is possible to choose a daily tariff. In general, in order to ensure the spread of joint mobility, companies agree with local administrations on the location of stands and relative areas (e.g. ticket offices). As far as time and space management is concerned, Car-Sharing customers can also easily gain access in areas with limited traffic volume that are inaccessible to private drivers. Moreover, the problem of parking costs does not exist, as cars can be parked in any parking space, including the blue stripes, provided that this is obviously in the area where it operates. However, reducing costs must also be understood in the sense of reducing environmental pollution. The continuous use and the consequent reduction in the number of vehicles in circulation leads to a drastic reduction in CO_2 emissions into the atmosphere [18–20].

Car sharing is a system that is often seen as an alternative to public transport (not flexible) and to the taxi (more expensive) than your own car. Apart from the economic aspect, users who want to use it take other aspects into account. The system is often judged on cleanliness (critical aspect, especially if a previous user has transported animals there), the presence of safety systems and the availability of essential accessories such as Bluetooth and the navigator.

2.2 Different Business Model of Car Sharing

Car Sharing, born in Switzerland on the initiative of some private individuals motivated by ecological ideals, then moved away from the original idea of timeshare to progressively arrive at an organization of the offer according to commercial and entrepreneurial criteria.

Four different emerging models are identified in:

- Free floating within an operating area;
- Free-floating with swimming pool stations;
- Return, based on the area of residence;
- Round trip, based on the pool station;
- Peer-to-peer and community schemes.

Currently, it is going through a phase of full development, especially in the countries of Northern Europe, where it has managed to consolidate an image of quality and reliability and the operators in the sector have reached a good level of professionalism. The favourable condition for this development lies mainly in the current rigidity of the vehicle market, which offers ample choice for those who want to buy a vehicle, but grant few alternatives, economic and functional, to those who use it occasionally. Car Sharing is aimed at the latter category of motorists: the choice opportunities guaranteed by the composition of the car fleet and the ability to move without incurring the inconvenience and fixed costs associated with owning the car represent a valid alternative to purchasing.

Paying attention to shared model and the type of vehicle power, it is possible to guarantee a reduction of environmental impacts in terms of CO_2. The specific configuration cannot be assimilated to traditional forms of car rental, which represent the ideal solution for long and protracted journeys over time. The vehicles that make up the Car Sharing fleet are in fact positioned on several parking areas, located near the residences or at the stops and public transport stations (in city centers they can be also made in garages, private spaces, condominium courtyards or directly on the street). The use of vehicles is reserved for members of the organization only and is allowed even for limited periods of one hour. The member can book and pick up the vehicle requested from the nearest parking area at any time of day or night. The return of the vehicle usually takes place in the departure parking area, but in the most advanced systems it is possible to leave the vehicle in a different equipped area.

The overall cost for the member is made up of a fixed cost and a variable cost linked to the use of this facility. The fixed cost includes a non-refundable entry fee, which the member pays one-time membership fees, a refundable deposit and a subscription fee to be paid annually or monthly to join the association. The variable cost, linked to the use of the vehicles, includes a mileage and an hourly quota, which can vary according to the vehicle class, the time of use and any additional resource requested (for example, the home delivery of the vehicle).

Regarding the geographical dispersion of car sharing organizations, there is not a uniform distribution in Europe, according to [21, 22]. In Eastern Europe, the lowest number of car sharing organizations was detected (8%), the services are on average the younger ones and also the freer buoyancy systems of the round-trip systems are active there. Northern and Southern Europe have an almost equal share in the total number of car sharing organizations, respectively 15% and 18%. However, there are many differences for the average age of organizations and the car the category of sharing to which they belong most. The organizations in Southern Europe are among the youngest and are mostly aimed at a free-floating system with an operating area compared to organizations in other parts of Europe. In Northern Europe, peer-to-peer fill car sharing has a strong position.

The shared mobility provides for adequate planning or a review of its implementation in order to promote total accessibility, for the purpose of accessibility which can be both physical and cognitive [23, 24]. In addition, the implementation of car sharing in urban and it cannot support the strategies of the public system in order to guarantee an optimal use of resources for the creation of overall present and future value in local communities, mitigating the economic-social and environmental impacts.

2.3 Italian Car Sharing and Statistical Values

In accordance with [25, 26] in 2018 there were one million and 860 thousand subscribers to car sharing services in Italy, of which 90% subscribed to free-floating. From a geographical point of view, a prevalence of the north over the center-south is confirmed, where almost 60% of the entire Italian sharing mobility offer is available, for a total of 271 Italian municipalities with at least one system accessible to 2018.If on the one hand the fleet of shared vehicles present on Italian roads slows down, mainly due to the exit from the market of some free-floating bike-sharing that arrived only a year ago, on the other the movements continue in a trend of positive growth. The common national user is male with 66% of members and on average in the age group between 30 and 39 years.

The user of electric Carsharing is younger, of which 2 out of 3 users are between 18 and 29 years old. Rentals that are on average shorter in terms of km travelled for free-floating (6.8 km/rental) than station-based (30.8 km/rental), but for both types of service, more on weekdays that is from Monday to Friday (66% and 78% of the total respectively). On a national level, the kilometers travelled by carpooling total 88.9 million in 2018. The free-floating sector, with 80 million km, doubled those travelled in 2015, while the station-based sector total a plus 12 in 2018% compared to the previous year, for an absolute value slightly lower than the maximum recorded in 2016. In Italy in 2018, 7.4% of those who move share their car with their study or work colleagues.

Car sharing is widespread above all in urban areas: 10.8% of people up to 34 years of age have used it in municipalities in the centers of metropolitan areas (against 1.5% of the national total); among the major users of car sharing students (11.9%) and employees (11.1%). Among the reasons that induce citizens to choose car sharing over their own car there is ease of parking, while the benefit compared to public transport is given by flexibility. Therefore, it is possible to affirm that the success of car sharing is not registered as uniform at national and European level. This criticality can be addressed by investigating user characteristics and infrastructure and parking through surveys and interviews. The variables that influence its implementation are manifold and this work highlights how the distance between origin and destination and origin and stall where picking up the vehicle can sometimes be fundamental in travel choices.

3 Methodology

The methodology presented in this study in based on a structured procedure to evaluate the probability of using a shared mobility service based on the infrastructural characteristics related to the service itself. In particular, in applying the proposed methodological framework it is possible to assess the potential use resulting from the implementation of a station-based car sharing service in an urban area, by relating the location of parking spaces (reserved and not) and points of origins and destinations of daily trips. The overall procedure consists of three steps and is summarized in Fig. 1.

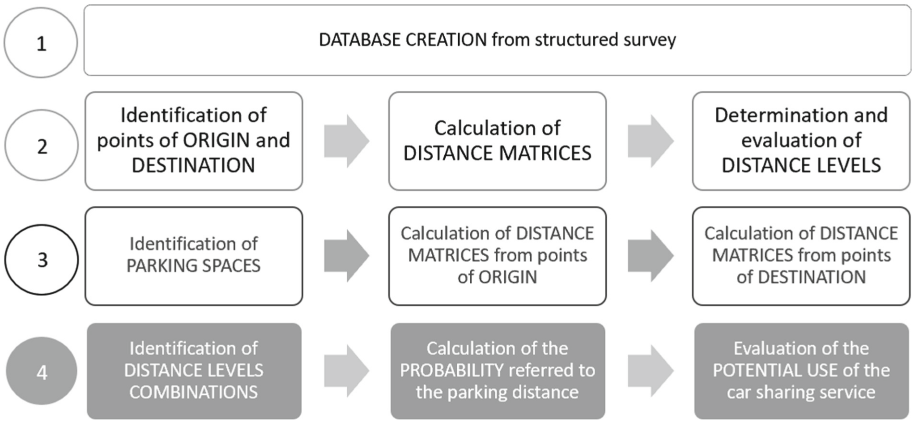

Fig. 1. Methodological framework (own setup)

3.1 Structured Survey for Database Creation

The acquisition of data relating to the transport demand has been acquired for years through surveys and the administration of online and paper questionnaires. Through these methods it is possible not only to collect socio-economic data but also the users' attitudes related to mobility and citizens preferences [27–31].

In literature many authors show preparatory or a posteriori analyses to the implementation of car sharing services, obtained through surveys. In accordance with [32, 33] it is possible to outline the characteristics of the most frequent car sharing users through descriptive statistics of the survey on the Internet and qualitative analyses of the results of the focus groups (both verified with respect to the previous literature) and from this emerges a behaviour of social activists, environmental protectors, innovators, economists or practical travellers. Therefore, car sharing companies and their partners could presumably increase their membership by targeting individuals and others with certain demographic characteristics.

The survey approach is also useful in order to evaluate the best choice of type of service to be implemented. According to [34] the survey data allow to compare the user groups and the usage patterns of a self-floating and station-based car sharing service, both operating in the city of Basel, Switzerland. These results suggest that the schemes actually attract different groups of users and are also used differently, changing the city size, from small towns to megacities. According to [35] making a comparison with the taxi service and obtaining as a result that car sharing tends to thrive in environments where the large population has experience with driving and car ownership. Analysis of the Shanghai-based survey showed that those interested in car sharing were younger, more likely to be educated, had longer journeys and owned fewer cars than those without interest in car sharing.

3.2 O/D Matrices and Distance Levels

The second step is primarily based on the identification of the main points of origin and destination of journeys. The motivations connected to a single trip can derive from different reasons: e.g. it is possible to consider regular movements from places of residence to the workplace and to the school or occasional ones as leisure trips. Depending of the motivation, the users' needs linked to the transport system change in terms of travel time reliability, flexibility of departure or arrival times, need for a private vehicle, etc. These factors are also strongly influenced by the context of analysis and by the transport supply present in the considered study area. Therefore, the previous phase described as the database creation, through a structured survey, constitute a fundamental support for identifying the points of origin and destination. Table 1 shows some examples of O/D points classified into different categories (i.e. residential; transport; public services; health; education; leisure; tourism) according to the list of Points of Interest (POIs) provided by HERE Navteq (2020).

Table 1. Subset of categories for the identification of points of origin and destination (Source: HERE Navteq, 2020)

Category	Point of O/D
Residential	Residence or domicile
Transport	Airport; taxi station; bus station; metro station; railway station; port; car rental; park & ride; sharing mobility parking area; open parking area; garage station
Public services	Post office; bank; insurance; police station; government office
Health	Hospital/policlinic; medical center; pharmacy
Education	School; college; university; library
Leisure	Gym; cinema; pub; disco; supermarket/shopping area; green area; historical monuments; museum; restaurant; theatre
Tourism	Hotels and B&B; tourist office; ATM; cash point; tourist attractions

After the identification of the points of origin and destination and their categorization, it is necessary to evaluate the distances between them. The calculation of these distances can be carried out considering different approaches. The most immediate is represented by the identification of the O/D distance as the crow flies between origins and destinations. However, when the orography of the terrain is particularly variable it is possible that this simplifying hypothesis could lead to too excessive approximations. Thus, in this case it is better to consider the real road-distance instead of the Euclidean one. Often, this distance is made to coincide with the shortest path. All the way, in congested urban contexts it may be useful to take into account travel times as well as only distances, as it may happen that longer routes have shorter travel times.

Then, once this identification is complete, it is possible to define the O/D matrices, in terms of distances or travel times. Afterwards, it is necessary to evaluate the values of these matrices, in order to immediately understand which movements can be subject to the use of a vehicle and which ones will certainly be accomplished by walking, given the short distance. In this regard, in the case of the considered shared mobility service, i.e. car-sharing, five distance levels are identified on the basis of an increasing range of distances, as reported in the following Table 2.

Table 2. Distance levels determination for O/D matrices

Level	O/D distance [m]	Walking	Micromobility	Bike	Car/Bus
1	$D_{o/d} < 500$	++	+	+	− −
2	$500 < D_{o/d} < 1000$	+	++	++	±
3	$1000 < D_{o/d} < 2000$	±	+	++	+
4	$2000 < D_{o/d} < 4000$	−	±	±	++
5	$D_{o/d} > 4000$	− −	−	±	++

The values relating to the O/D distances (in meters) shown in the table above, specifically refer to the car sharing service provided in an urban area. It would be possible to hypothetically associate these levels with other specific shared transport modes (e.g. bike sharing; scooter sharing, etc.), by recalibrating the values of these distances. Indeed, relying on these levels, it is possible to categorize each element of the distance matrices: in the case of distances less than 500 m, it is probable that the trips will be made by walking (see "++" in Table 2), therefore these connections will not be considered in the subsequent analysis; distances between 500 m and 1 km still fall within the walking range or even better by using bike or micromobility; while for greater distances a bike or motorized vehicle (i.e. car or bus) is almost certainly necessary.

3.3 Distance Matrices from Car Parks and Distance Levels

In the third step, a similar calculation of the distance matrices must be done considering, instead, the location of the car parks with respect to the points of origin and destination, identified in the previous step. The considered quantities are represented by the schematization of distances in Fig. 2. The respective distances between origin and car parking $D_{o/p}$ and between destination and car parking $D_{p/d}$ are assumed to be covered by walking (dashed line sections), while the distance between the two parking lots will be traveled by the car sharing vehicle (double continuous line section).

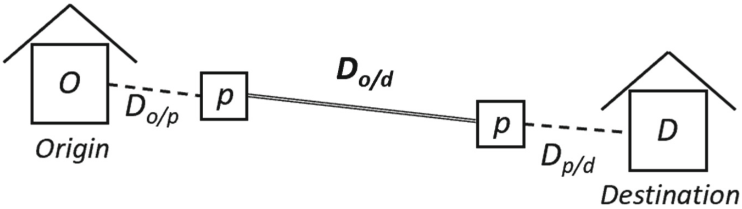

Fig. 2. Schematization of car parking distances (own setup)

In this case, the distance levels L_i (for origin-parking distance) and L_j (for parking-destination distance), with i, j = 1, 2, 3, are related to walking distances.

The identified levels are three, as shown in Table 3: the first occurs when the distances from the parking area are less than 500 m, which is an absolutely compatible with the pedestrian mode; the second one is and intermediate level, whit a distance between 500 and 1000 m, so it is still possible walking but it starts to get onerous; and finally the third level for distances greater than one kilometer, for which it will no longer be convenient walking to reach the parking lot and use the shared car.

Table 3. Distance levels determination for distance matrices from car parks

Level	$D_{o/p}$, $D_{p/d}$ distance [m]	Walking
L_1	$D_{o/p} < 500$ V $D_{p/d} < 500$	+
L_2	$500 < D_{o/p} < 1000$ V $500 < D_{p/d} < 1000$	±
L_3	$D_{o/p} > 1000$ V $D_{p/d} > 1000$	−

Through the evaluation of the distances, it is possible to trace the need to place other parking stalls or reallocate existing ones in order to induce the users to use it minimizing the distances that link the presence of each stall at the various points of origin and destination. This hypothesis starts from the idea that each user starts to experience discomfort in moving on foot for a distance greater than 500 m.

3.4 Distance Levels Combinations and Probability Estimation

In the last step, the probabilities associated with the potential use of car sharing are determined, based on the simultaneous distance between the car park and the points of origin and destination, respectively. Different combinations of distance levels are considered both for the total distance of the trip $D_{o/d}$ and for the partial distances of origin and destination with respect to the parking $D_{o/p}$ and $D_{p/d}$, as resumed in Table 4:

Table 4. Probabilities of potential use of station-based car sharing

Hyp.	Parking distance [m]	Total travel distance [m]	Probability P_{ij}
1	–	$D_{o/d} < 500$	Not considered
2	$D_{o/p} < 500$ and $D_{d/p} < 500$	$500 < D_{o/d} < 1000$	Medium
	$D_{o/p} < 500$ and $500 < D_{d/p} < 1000$	$500 < D_{o/d} < 1000$	Low
	$500 < D_{o/p} < 1000$ and $D_{d/p} < 500$	$500 < D_{o/d} < 1000$	Low
	$500 < D_{o/p} < 1000$ and $500 < D_{d/p} < 1000$	$500 < D_{o/d} < 1000$	Very low
	$D_{o/p} < 500$ and $D_{d/p} > 1000$	$500 < D_{o/d} < 1000$	Null
	$D_{o/p} > 1000$ and $D_{d/p} < 500$	$500 < D_{o/d} < 1000$	Null
	$500 < D_{o/p} < 1000$ and $D_{d/p} > 1000$	$500 < D_{o/d} < 1000$	Null
	$D_{o/p} > 1000$ and $500 < D_{d/p} < 1000$	$500 < D_{o/d} < 1000$	Null
	$D_{o/p} > 1000$ and $D_{d/p} > 1000$	$500 < D_{o/d} < 1000$	Null
3	$D_{o/p} < 500$ and $D_{d/p} < 500$	$D_{o/d} > 1000$	Very high
	$D_{o/p} < 500$ and $500 < D_{d/p} < 1000$	$D_{o/d} > 1000$	High
	$500 < D_{o/p} < 1000$ and $D_{d/p} < 500$	$D_{o/d} > 1000$	High
	$500 < D_{o/p} < 1000$ and $500 < D_{d/p} < 1000$	$D_{o/d} > 1000$	Medium
	$D_{o/p} < 500$ and $D_{d/p} > 1000$	$D_{o/d} > 1000$	Null
	$D_{o/p} > 1000$ and $D_{d/p} < 500$	$D_{o/d} > 1000$	Null
	$500 < D_{o/p} < 1000$ and $D_{d/p} > 1000$	$D_{o/d} > 1000$	Null
	$D_{o/p} > 1000$ and $500 < D_{d/p} < 1000$	$D_{o/d} > 1000$	Null
	$D_{o/p} > 1000$ and $D_{d/p} > 1000$	$D_{o/d} > 1000$	Null

By crossing the data of the distance matrices calculated in the second and in the third steps, it is possible to estimate the associated probability matrices P_{csO} and P_{csD} referred to each area of origin O and destination D. From these probabilities, it is possible to evaluate P_{ij}, that estimates the potential use of the station-based car sharing, related to each O/D pair, depending on the infrastructural characteristics deriving from the location of the parking areas (Eq. 1):

$$P_{csO} * P_{csD} = P_{ij} \tag{1}$$

Specifically, three different hypotheses have been identified. The first refers to trips less than 500 m and for which a probability of using car sharing is assumed to be zero since the distance can be made by walking. On the other hand, the second and the third hypothesis refer respectively to trips between 500 m and 1 km and more than 1 km. In these cases, it is plausible to think about the use of a motorized vehicle, and obviously, at equal distance from the car park, the probabilities of using car sharing are higher in the case of the third hypothesis. Finally, for distances to the parking areas higher than one kilometre, it is difficult to think of a potential use of car sharing and, therefore, the associated probability is zero.

Figure 3 shows a schematization of an O/D pair and the possible combinations by considering the total number n of parking lots associated to the point of origin and the total number m of parking lots associated to the point of destination.

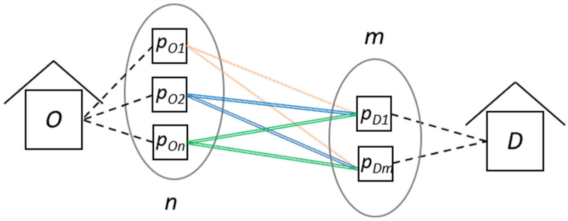

Fig. 3. Schematization of probability combinations (own setup)

Accordingly, the probability P_{cs} associated to the potential use of car sharing to move from the origin O to the destination D depends both on the distance $D_{o/d}$ between them and also on the presence of car parks and more specifically on the distances $D_{o/p}$ and $D_{p/d}$ that these car parks have with respect to the departure and arrival point of the trip. Therefore, this probability P_{cs} can be estimated through the following equation (Eq. 2):

$$P_{cs} = \sum\nolimits_{i=1;j=1}^{3} n_{Li(r,f,p)} * m_{Lj(r,f,p)} * P_{ij(r,f,p)} \tag{2}$$

where:

- n_{Li} is the number of car parks with a variable distance L_i from the point of origin, depending on the value assumed by subscript i in accordance with the levels identified in Table 3;
- m_{Lj} is the number of car parks with a variable distance L_j from the point of destination, depending on the value assumed by subscript j in accordance with the levels identified in Table 3;
- P_{ij} is the probability of using the car sharing service associated with the single combination ij of car parks, in accordance with the probability combinations identified in Table 4;
- the three subscripts r, f, p refer to the type of parking. Specifically, r stands for "reserved"; f stands for "free" and p stands for "paid". The associated probability is variable depending on the considered type of parking, in fact reserved car parks will have a greater weight in terms of probability because these are parking areas specifically dedicated to the car sharing service.

4 Discussion and Conclusions

The analyzes carried out in the context of this work show that car sharing is an innovative mobility service that guarantees performance comparable to that of a private car in terms of reliability, comfort and flexibility. The car-sharing formula is particularly advantageous for users who occasionally use the car for their journeys and who can count on more convenient transport alternatives at the same time. The economic benefits for those who give up possession of the car to join the car sharing scheme are considerable, as it is possible to use the car when needed without having to bear the fixed costs associated with its ownership.

It distribution is entrusted to both companies and local administrations. Among the main features of car sharing that qualify the offer and satisfy the needs of users that are not met by other mobility systems are two in particular, namely the possibility of using the vehicles for limited periods and distances at any time of day and the ease of its access. At present, the efforts of undertakings are directed towards achieving and maintaining a high level of efficiency, productivity and quality of service:

- to increase market share;
- to spread on a wider geographical scale, keeping at the same time a dense network of stations in the area;
- to modernize the dispensing process with the introduction of new solutions technology;
- to orientate the service to customer needs and expectations;
- to establish partnership relationships with other operators in the transport sector in order to offer its customers integrated facilities with an excellent relationship quality price.

Although the operators of the sector agree that the strategies for the development of new shared mode should leverage the market, there is no doubt that the introduction of political measures to support the start-up process and relative dissemination is of utmost importance. Furthermore, in order to implement an effective shared transport system that reflects the demand it is fundamental a thorough knowledge of the study area and the characteristics of the potential users. In this sense, the urban planning must be integrated at all mobility levels, paying particular attention not only to the possibility of implementing shared transport utilities within a city, but also outlining the infrastructures and spaces dedicated to (e.g. the parking locations in the case of station-based car sharing). Moreover, it must consider the community as a decision support, using specific tools and procedures (i.e. debates or questionnaires or interviews) to acquire data of preference. In fact, it allows to highlight the benefits and critical issues related to the context in which its is implemented.

The last decade has been characterized by the maximum diffusion of the use of car sharing with its different business models, offering an ad-hoc utility in accordance to the type of user (e.g. tourist, worker, student, etc.). Therefore, as previously highlighted, during its development (i.e. planning and implementation) by companies, it is necessary to establish active collaboration with the community (democratic participation).

The current transport supply is very wide, with the diffusion of various shared transport modes. In Italy, the car sharing is not evenly spread within the national territory and this often derives from the usability of a service that is not well tailored to the transport demand. Even in some of these cases, the car sharing facility threatens to cease in the short term.

Several parameters tend to influence the definition of transport in charge of sharing. In particular, the planning and location of reserved parking areas for the users represent a pillar of the car sharing system. The possibility of having a determined parking space, with an optimal location respect to the points of departure and arrival of the trip, implies two important consequences: from a strictly individual point of view, it allows to save time and from an overall point of view, the average travelled mileage and the impact of air emissions are reduced. For this reason, the identification of parking areas must be the result of an in-depth analysis of the city territory, which takes into consideration socio-economic and transport indicators with reference to the inhabitants' transport mobility behaviour.

Generally, the parking areas of the car sharing can contain a variable number of stalls between 2 and 5, depending on the number of potential users, and in accordance with the objective of integrated mobility, they are located in correspondence of intermodal exchange nodes or attracting poles (e.g. shopping centers). The methodology presented in this work considers as the main variable the distance between the points of origin and destination linked to daily trips in urban areas and the location of car parking, in order to evaluate the potential use of car sharing. The research brings forward interesting evidence from both a methodological and operational point of view, by defining an estimation method of the effectiveness of car sharing, that can be also applied as a planning support tool.

The diffusion of a well-modulated utility based on the characteristics of the user offers direct benefits in terms of better accessibility in the cities where the it is implemented, as well as other benefits from an environmental, social and economic point of view. In this respect, this thesis lays the groundwork for further research, based on the development of a composite estimation methodology, focusing on the combination with other specific variables (i.e. the type of parking and the type of power supply of the vehicle; the existing traffic supply in the study area; variables characterizing the user and his willingness to pay), in order to evaluate the probability of users in relation to implemented shared mobility systems in several case studies.

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