A PARKING MANAGEMENT SYSTEM FOR FEE-PARKING TRAFFIC ZONES: THE WIPARKING PROJECT

Stefano Carrese, Roma Tre University, Rome, 00139, Via Vito Volterra 62, Italy, carrese@uniroma3.it

Marialisa Nigro, Roma Tre University, Rome, 00139, Via Vito Volterra 62, Italy, mnigro@uniroma3.it

Antares Pennetta, Roma Tre University, Rome, 00139, Via Vito Volterra 62, Italy, a.pennetta@hotmail.it

ABSTRACT

The WiParking project (www.wiparkingroma.it) starts from the need of the Mobility Agency of Rome (Italy) to manage the parking of private vehicles inside the fee-parking traffic zones of the city, using available parking spaces inside car garages.
Objectives of the WiParking project are: to reduce the problem of parking supply in traffic zones with high parking demand, to reduce the congestion derived from vehicles searching for a free parking space, to induce private vehicles to park inside car garages, not far from their final destination in order to shift the “last mile” of the trip on public transport.
The paper shows a method to quantify the level and the distribution of the WiParking transport demand and to define the optimal fee considering both the needs of users and the needs of the car garage administrators. The findings of the paper demonstrate the financial feasibility of the project and suggest the application of the WiParking management system for other urban contexts with high private demand and low parking supply.

Keywords: Parking management, Urban Transport Policy, Parking demand model

1. INTRODUCTION

The management of parking spaces is a fundamental aspect of traffic management due to its correlation with land use, travel mode choice, traffic flow, community character, and so on (Jin and Guo, 2006, Carrese and Saracchi, 2009).

Different studies have been conducted related to this topic. Richardson and Merz (2010) describe the Parking Management of the city of Perth (Australia) as a way to "*promote a balanced transport system to gain access to central Perth, and to limit the growth of traffic congestion and deterioration of air quality in the central area"*.

Marshall *et al.* (2008) focus on the link between on-street parking demand and the pedestrian environment as a measure of the efficiency of land use. For the authors "*on-street parking is not purely a device to be used in the right environment; rather, it is a tool to help create that right environment"*.

Engel-Yan *et al.* (2007) show the relation between parking policies and parking supply, underlining that, in the real case study of the city of Toronto, the reduction of parking standards does not always lead to corresponding reductions in parking supply.

About the parking demand, Peng *et al.* (1996) investigate the effect of parking prices on mode choice.

Most studies focus on the application of advanced traveller information system (ATIS) and intelligent transport system (ITS) technologies on parking management (Beltran and Carrese, 2006): for example Jin and Guo (2006) describe the EZ M-parking system implemented in China, where each parking space is assigned a number including a check digit and motorists dial a single number to start or end parking service.

Caicedo *et al.* (2006) finds that an intelligent parking management system that tells a customer the exact locations of the available spaces is of great benefit both for patrons and operators.

Shaheen and Kemmerer (2008) report about the Rockridge field test (San Francisco Bay, California), notable for its integration of numerous smart parking technologies, including Internet reservations and billing, mobile phone and PDA communications.

Moreover next to the parking management of private vehicles, an extensive debate regards also the parking management of Heavy Good Vehicles (Carrese *et al.*, 2011).

The WiParking project (www.wiparkingroma.it) starts from the need of the Mobility Agency of Rome (Italy) to manage the parking of private vehicles inside the fee-parking traffic zones of the city, using available parking spaces inside car garages.

The solution is modern, because it adopts current technologies for the control of vehicles and for the transmission/reception of information in real time; it is flexible, because not bound to particular technologies and is therefore future-proof, modular and finally adaptable in time, since it provides different degrees of development.

In fact the project provides for two different stages of development:

1. pilot project in a real context;
2. application to customers.

The pilot project was launched July 29, 2010 following the preparation of the protocol agreement of the parties concerned (the mobility Agency of Rome and the Garage Managers Association, AGA) and it firstly addressed private parking areas, involving a group of 11 private garages.

The rate has been established in this first phase in €1 for each hour or fraction and €4 for 8 consecutive hours.

The reduced rate is applied from Monday to Saturday, excluding Sundays and night times until six in the morning, during which the usual prices of the garages are applied. The reservation of parking is possible via the website (www.wiparkingroma.it) available 24 hours a day.
To access to the service, users must have the Metrebus Card, that is a contact-less card usually adopted to access to the public transport services in the Rome urban area.
Objectives of the WiParking project are to:

- reduce the problem of parking supply in traffic zones with high parking demand;
- reduce the congestion derived from vehicles searching for a free parking space;
- induce private vehicles to park inside car garages, not far from their final destination in order to shift the “last mile” of the trip on public transport.

In order to answer to the objectives of the WiParking project, the main goals of the paper are to:

1. quantify the level and the distribution of the WiParking transport demand;
2. define the optimal fee considering both the need of WiParking users and the need of the car garage administrators.

The adopted methodology is based on the development of behavioural models that make use of random utility theory in order to estimate the WiParking transport demand due to private commuters; instead the WiParking transport demand for leisure trips has been estimated using descriptive aggregate models. In order to calibrate and validate both types of models data collected with an SP survey of 200 potential users of the WiParking system has been conducted.
The rest of the paper is organized as follows: section 2 describes the adopted methodology; in section 3 the case study of Rome is presented with the main results of the SP survey; section 4 reports the demand models formulation, their calibration and the estimated demand values; section 5 reports a cost-benefit analysis in order to compute the optimal fee of the service and finally section 6 summarizes the main conclusions.

2. METHODOLOGY

The estimation of the WiParking demand is the main objective of the study (Fig.1): it is composed of two components:

1. a component related to the private commuters demand (systematic demand);
2. a component related to the leisure trips (non-systematic demand).

The first component has been derived from the calibration of two different behavioural models that make use of random utility theory: they are both MultiNomial Logit models (MNL): one model considers a fixed fee, while the second model considers a variable fee in order to understand the elasticity of the demand.
The specific selection of MNL derives from the structure itself of the model, which can be well adapted to represent the choice context of a decision-maker with respect to the use of the WiParking system.

The utility function defined for each alternative *j* of the choice context described by MNL (Ben Akiva and Lerman, 1985) is generally expressed as a function $V_j(X_{kj})$ of attributes X_{kj} relative to the alternative and the decision-maker, as:

$$V_j=\sum_k \beta_k X_{kj} \quad (1)$$

Each attribute X_{kj} is multiplied by a coefficient β_k, so giving a certain weight to each term inside the utility function. Once all the attributes to be inserted inside the utility functions have been defined, the calibration of the model gives rise to the values of the coefficients β_k.
The calibration of random utility models can be conducted through the maximum likelihood approach, where the likelihood function $L(\beta)$ can be defined as the product of the probabilities of choosing the actual user's choice:

$$L(\beta) = \prod_i p_i[j(i)] \quad (2)$$

$$\beta^*=\mathrm{argmax}\ L(\beta) \quad (3)$$

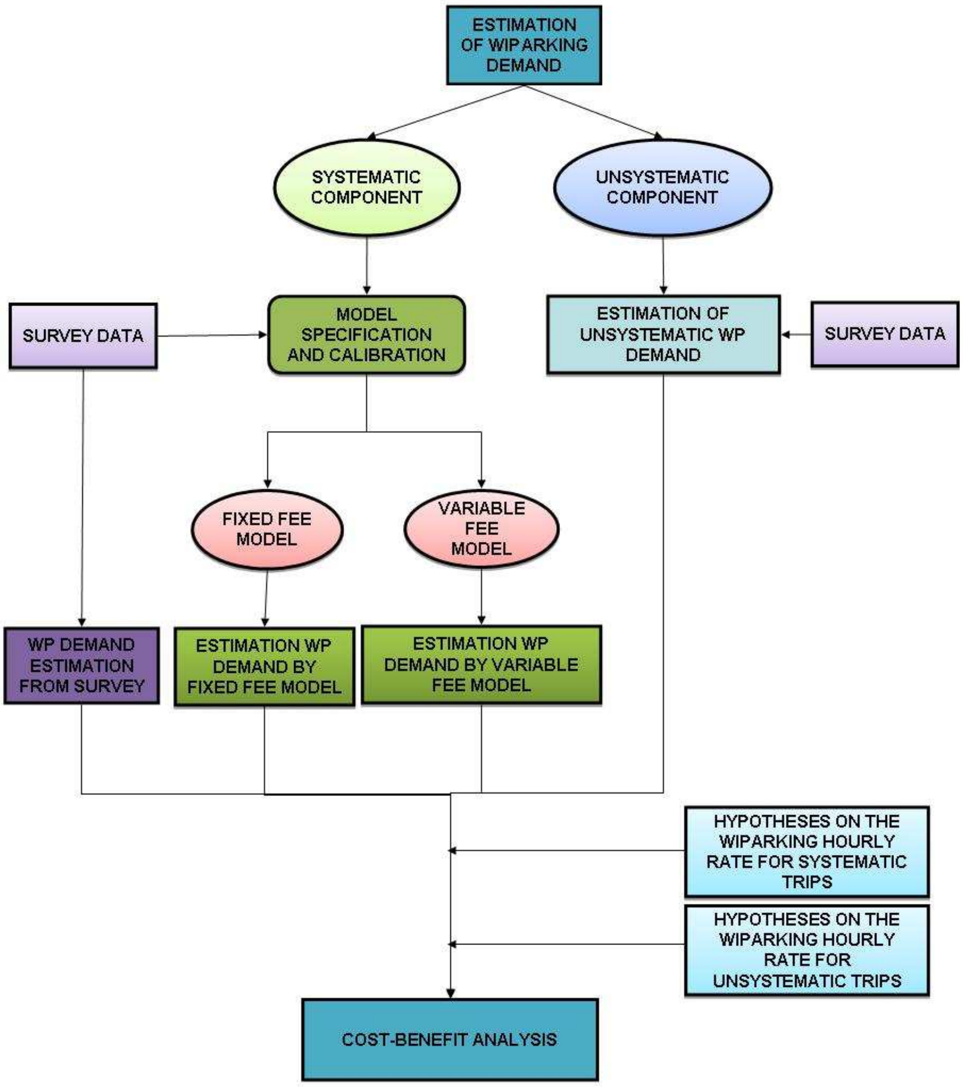

Figure 1 – Structure of the adopted model of the study

In order to better define the attributes inside the utility functions and to collect data for the calibration and validation of the MNL models, the first step has been to perform a survey of stated preferences (SP) on 200 potential users of the WiParking service.

About the second component, *i.e.* estimating the WiParking demand derived by the leisure trips, a descriptive aggregate approach has been followed extending the results of the previous survey to the whole population.

Once estimated the total WiParking demand and its distribution, different hypotheses on the WiParking hourly rate have been proposed both for the systematic trips and for the non-systematic ones, that varies according to the destination area of the user and then on the location of the private garage. These hypotheses have been set in order to ensure the financial viability of the project, taking into account the response of the users to the fare.

3. THE CASE STUDY OF ROME

The metropolitan area of Rome is characterized by a population of 3 million with 1.1 million employees, contributing to about 552,000 trips in the morning peak hour.

The city can be divided into three macro-areas: the first one between the City Centre and the “rail ring”, an half circle created by the union of five metropolitan rail lines; the second one between the “rail ring” and the GRA (“Grande Raccordo Anulare”) a circular freeway of approximately 68 km of length. Finally the third area can be considered the area outside the GRA.

Inside the GRA, the average population density is not high (about 70 persons/ha) and a similar measure is obtained in terms of the average employee density (about 75 employees/ha). Outside the GRA, in a very large area (about 90,000 ha) the density decreases to very low values of 6 persons/ha and 1.5 employees/ha even if the population of this external area is larger than half a million. In terms of employees, about half of the total are distributed in the peripheral districts, also situated outside of the GRA.

Since 2008, different studies have been conducted with the assistance of EU commission in order to develop a fee based parking management system for the city of Rome; these studies defined a set of indices able to measure the functional condition of the zones of the city for different activity scenarios.

Some of these indices basically evaluate the parking demand during the night due to the local residents, as the parking demand in the transition phase between the day and the night, as the parking demand due to the leisure trips.

Starting from the evaluation of these indices, the fee parking zones have been defined as the most critical traffic zones, *i.e.* where at least two indices reported potential problems.

Actually there are 26 traffic zones of Rome with a fee based parking system: the parking slots on street have an hourly fare of 1.2€/h or 1€/h (in particular the fare of 1.2€/h is applied inside the controlled traffic area). Some reduced fees are provided in case of short-term parking (15 minutes with a fee of 0.2€), or in case of 8 consecutive hours of parking (4€) or for monthly parking (monthly subscription of 70€). Instead the parking is free nearby hospitals, only for three hours; police cars or emergency vehicles, electric cars and residents do not to have to pay.

The payment can be made by parking machines, cash or by ATM, with the prepaid card "Taki Time", through prepaid coupons to be placed on the dashboard of the car.

The current total demand from the global metropolitan area of Rome to the 26 fee-parking based traffic zones is about 70,000 vehicles in the morning peak hour (about the 19% of the total peak hour car demand): 11,000 of these trips are internal to the 26 traffic zones, while about 7,000 trips are generated outside the boundaries of the municipality.

The main generation points are located outside the GRA and include the areas of "Castelli Romani", the area of Guidonia (in the North-East along the Tiburtina road axis) and the municipality of Fiumicino; the main attraction points are located in the outer zones of the 26 fee-parking zones.

Actually the fee-parking system of Rome is close to the capacity: despite the increment of Park&Ride areas near the main transit stations, despite the location of new parking areas in specific attraction points with differentiated charging modes in order to promote the rolling use of the parking spaces, the time spent to find a slot is going to increase.

3.1. SP SURVEY

In this study, an SP survey (Cascetta, 2009) has been carried out on a sample of 200 users, relating to:

1. systematic trips (home-work/study trips, private commuters);
2. non-systematic trips (leisure trips).

A simple random sampling method has been adopted to make as uniform as possible the sample in terms of age: 30% of the sample is 18- 25 years old (mainly students), 31% 25 - 35 years old, 39% 35 - 65 years old (divided into 13% between 35 and 45 years old, 15% between 45 and 55 years old and 11% between 55 and 65 years old). The survey has been conducted through the Internet (e-mail and web page), face to face and at destination in central zones of Rome, where fee parking areas are located.

Residents in the 26 traffic zones or users with a disability pass have been excluded by the survey, as they are not potential users of the Wiparking service (they already have a special pass for parking for free).

Data on mobility habits have been acquired, especially on the needs for parking, on the propensity to use the WiParking service, on the variability of this propensity for different ranges of the WiParking fee and finally on the possibility to link the WiParking service to the transit service.

About the systematic trips, the main findings are the following:

1. 60% of the sample reaches fee-parking areas of Rome by car;
2. 80% of them goes regularly to these areas, while the remaining 20% only 1 or 2 times a week;
3. most of the users make their systematic trips with city-Car (for example, Fiat Cinquecento, Fiat Panda, Opel Agila, *etc*) and compact cars (Fiat Punto, Volkswagen Polo, Ford Fiesta, Renault Clio, *etc*);

4. the largest number of systematic trips is concentrated between 6:00 am and 10:00 am, usually with a parking time from 5 to 8 hours a day;
5. 80% finds very difficult to park even if tolled ("blue lines": fee parking spaces);
6. the distribution of origin-destination travel times shows an average value of around 45 minutes for home-work trips, while the parking time ranges mainly from 10 to 30 minutes (depending on the destination area) with an average value of 17 minutes;
7. the preferred way of booking for an Intelligent Parking System is by website or mobile phone, while the preferred payment method is directly on site;
8. 22% of users already have the metrebus card.

Once the WiParking scenario was explained to the interviewees, as expected from the pilot-project, 75% of the sample would choose it; the reasons why the remaining 25% would not choose the WiParking are:
1. 50% have the possibility to park for free near the place of work/study, so resulting in 12.5% of the sample not interested in the Wiparking service;
2. 21% do not want to pay for parking and prefer to find a free parking space (if the destination zone has a share of fee and not-fee parking slots), although it could involve a higher time for searching;
3. 21% finds the WiParking cost too high especially for a long parking stay;
4. 8% doesn't find any affordability respect to the usual fee parking spaces.

Varying the hourly cost of WiParking, the share of the sample that would use it changes from the starting 75% for a fee of €1 (for each hour) to 35% for a fee of €2 and finally to 8% for a fee of €3.
It also appears that the sample would appreciate a monthly cost of 75-100 euros.
About the possibility to link the WiParking service to the transit service:
1. 71% of users would continue to use Wiparking up to a walking distance between the workplace and the garage of 500 meters;
2. 27% of users would continue to use Wiparking over a walking distance of 500 meters, only if there is an efficient public transport service;
3. only the 2% of users declares that they would use WiParking only if the garage is strictly closed to the place of work/study.

Regarding the non-systematic trips, the main findings are the following:
1. 88% of the sample travels for reasons other than work/study to zones of Rome where the parking is tolled;
2. the most attractive zones are found to be the Historical Centre and other tourist and business districts (Trastevere, , Prati, Testaccio, Ostiense and Eur);
3. the frequency of non-systematic trips is generally equal to 1-2 times a week (41%), usually in the afternoon (14:00 pm to 20:00 pm, 39%) and in the evening (after 20:00 pm, 46%);
4. 78% of the sample would choose the WiParking for this type of trips and the reasons why the remaining 22% would not choose the WiParking are:

   a. 30% does not want to pay for parking and prefers to find a free parking space (if the destination zone has a share of fee and not-fee parking slots), although it could involve a higher time for searching;
   b. 24% considers this type of trips too much sporadic for the WiParking service;
   c. 20% doesn't find any affordability respect to the usual fee parking spaces;
   d. 10% moves on Sunday or after 20:00 pm, when the parking spaces are usually available and for free.
5. The percentage of 78% would be reduced respectively to 45% and 6% if the hourly rate changes respectively to 2 and 3 euros for hour;
6. 57% of users would use this service on an average of 2-3 hours at a time;
7. In this case, as for the systematic trips, the booking procedure preferred by most of the interviewees is by website or by mobile phone, and the preferred method of payment is directly on site.

4. WIPARKING DEMAND MODELS

The Wiparking demand is composed by two components: a first one related to the private commuters demand and a second component related to the leisure trips.
The first component has been derived from the calibration of two different logit models using the maximum likelihood approach: one model considers the current fixed fee, as in the pilot project, and the second one considers a variable fee in order to derive the elasticity of the demand.
The two logit models are binomial logit models, considering the two choice alternatives: Yes to the WiParking service, No to the WiParking service (Fig.2).

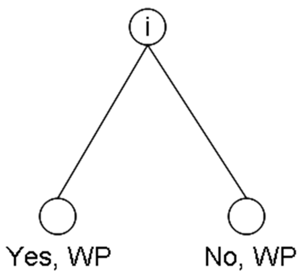

Figure 2 – Binomial Logit Model for the WiParking choice

In the case of fixed fee, in particular considering the fee of the pilot project (€1/h), the binomial logit model assumes the following expressions for the two systematic utilities (1):

$V_{YES\text{-}WP} = \beta_{Tpark} LnT_{park}$ (3)
$V_{NO\text{-}WP} = \beta_{park\_free} Park\_Free + \beta_{card} Card + CSA$ (4)

where
T_{park} = the time spent to find a parking space;
Park_Free = dummy variable representing the possibility to park free near the place of work/study or not;
Card = dummy variable representing the availability of the Metrebus Card;

CSA = the remaining utility that the previous attributes cannot describe.

In the case of variable fee, the binomial logit model assumes the following expressions for the two systematic utilities:

$V_{YES\text{-}WP} = \beta_{Tpark}LnTpark + \beta_{parkingTime}ParkingTime + \beta_{fee}Fee$ (5)
$V_{NO\text{-}WP} = \beta_{park\_free}Park\_Free + CSA$ (6)

where
T_{park} = the time spent to find a parking space;
ParkingTime = the time during which the car is left parked;
Fee = the fee of the parking space
Park_Free = dummy variable representing the possibility to park free near the place of work/study or not;
CSA = the remaining utility that the previous attributes cannot describe.

The attribute Tpark is inserted in both the models as a logarithmic function: in fact this type of function represent the correct response of the users to the increment of the attribute value, as results from the sample (Fig.3)

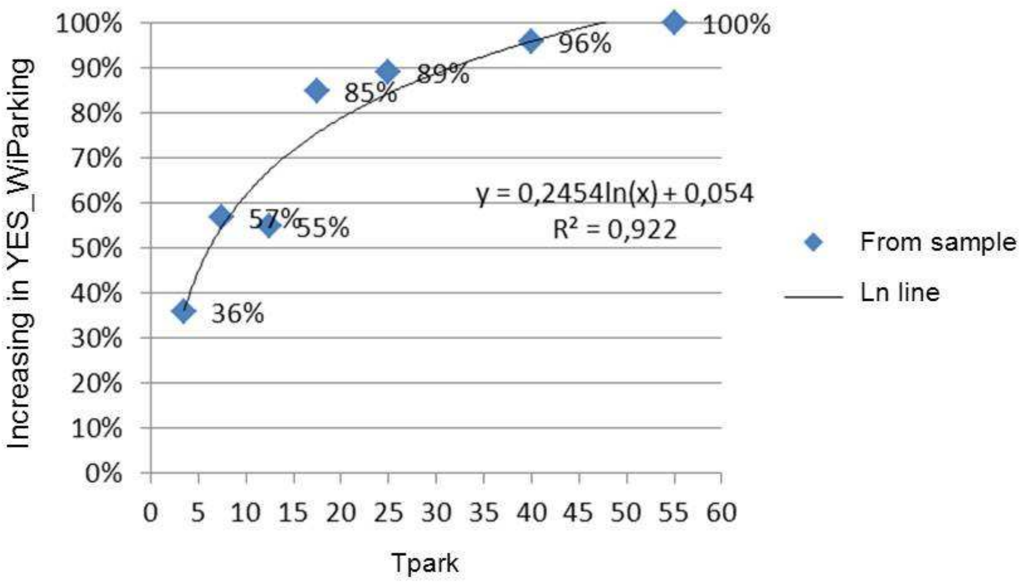

Figure 3 – Response of the users to the increment of the Tpark value (results of the survey)

The calibration of the coefficients have been done with the maximum likelihood approach, maximizing the likelihood function L(β) in (3).

Regarding the second component of the demand, related to the non-systematic trips, the results of the survey have been extended to the whole population, following the hypothesis reported in the next paragraph.

4.1. WIPARKING DEMAND MODELS RESULTS

The results of the calibration of the two logit demand models for the systematic trips (fixed fee model and variable fee model) are reported in Table 1, while the validation tests in Table 2, showing a better results for the variable fee model (higher ρ^2 value).

From the application of the two binomial logit models, the derived WiParking demand can be estimated (Table III): the systematic demand for the hourly cost of €1/h is very similar in the cases of fixed fee and of variable fee, while the demand deriving from simple extending the percentage obtained from the surveys to the whole population results to be the highest one.

For an hourly cost of €2/h, the lower value of demand is obtained with the variable fee model with respect to the survey, while for an hourly cost of €3/h it is exactly the other way round.

Table I – Results of the calibration of the two demand models

Model	Coefficient values					
	β_{Tpark}	β_{park_free}	β_{card}	$\beta_{parkingTime}$	β_{fee}	CSA
Fixed fee	0.371555	0.431455	-0.66622	-	-	-0.4489
Variable fee	0.397650	0.278196	-	-0.1763	-0.9785	-1.8760

Table II – Validation tests of the two demand models

Model	ρ^2	ρ^2 corrected	LogL(β*)	LogL(0)	likelihood ratio LR(0)
Fixed fee	0.41	0.36	-43.2286	-73.4736	60.49
Variable fee	0.68	0.65	-71.1914	-220.421	298.45

Table III – WiParking Demand values derived from the two logit models

	WiParking Demand [veic/h]		
	Fixed Fee	Variable fee	extension of the sample to the whole population
1€/h	41.600	41.300	49.900
1.5€/h		34.700	
2€/h		22.000	23.300
2.5€/h		13.600	
3€/h		7.700	5.300

Further analyses have been conducted in order to define the sensitivity of the WiParking demand to the different parameters/attributes.

In particular, the following Figure 4 represents the decreasing WiParking demand level for different variations of the fare (from €1 to €1.5, from €1.5 to €2 etc.). The different curves are related to different values of the time spent to find a parking space (Tpark); they are obtained by computing the probabilities of choosing the WiParking system (adopting the calibrated variable fee behavioral model), fixing an average value for the time during which the car is left parked (ParkingTime) of 6 hours (quite common for the case of commuter trips).

The decrease of users choosing the WiParking System can range between approximately 10% (increasing the fee from €1 to €1.5 with a time spent to find a parking space of 45min) and 30% (increasing of the fee from €2.5 to €3 with a time spent to find a parking space of 5min); these two results correspond to the following two cases:

1. the first case to a small increase of the fare (€0.50) with a low starting fare (€1) and a high Tpark (45 min), in such a condition the user can easily accepts the increase of the fare;
2. the second case to a small increase of the fare (€0.50), but with a high starting fare (€2.5) and a low Tpark (5 min), in such a condition the user clearly prefers to not use the WiParking system.

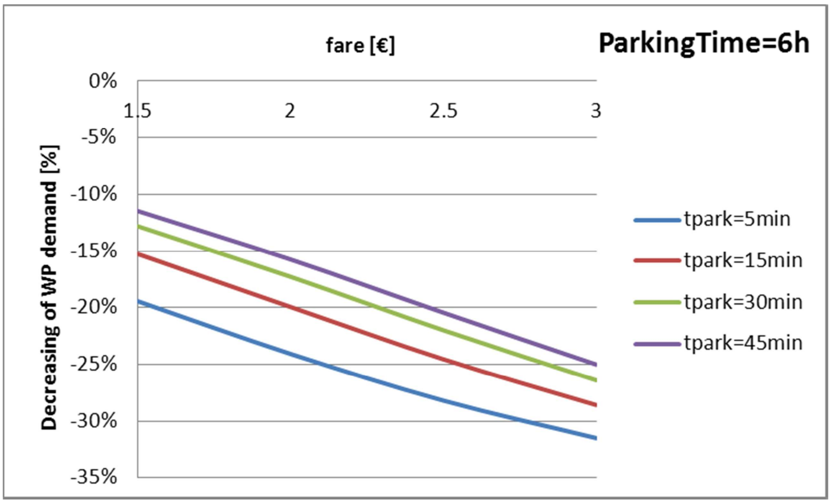

Figure 4 – Sensitivity analysis

For each curve (*i.e.* fixing the Tpark) the variation range between the maximum and the minimum points along the y-axis remains around values of 10 percentage points: in particular, this variation increases until a Tpark of 15 minutes, while after 15 minutes it seems to remain constant. This is an interesting result, because it means that over a certain value of the time to find a parking space (Tpark), the user has approximately the same behavior varying the rate and the model is able to reproduce that behavior.

Regarding the distribution of the estimated demand, in the case of logit model with fixed fee, the attributes inside the utility function are: the time spent to find a parking space Tpark, a dummy variable representing the possibility to park for free near the place of work/study, a dummy variable representing the availability of the Metrebus Card.

For the application of the model to the 26 zones and therefore for the estimation of the WiParking demand due to commuters trips in each of the 26 zones, the values of these attributes at the level of single zone have to be defined.

Regarding the time to find a parking space, it was studied by analyzing the results of the sample in the different zones; where possible a trend of the time to find a parking space has been identified, where not (due to insufficient data), an average parking time has been assumed, following a criterion of similarity with respect to other known zones. For example, in Fig.5 a distribution of the attribute Tpark has been obtained for one of the 26 zones ("Eur").

Regarding the other two dummy attributes, also on the basis of the results obtained by the survey, a share of 49% has been adopted as the number of users who have the ability to park for free near the workplace; finally, considering the transit modal shift in Rome (30%) and the number of Metrebus Card (about 100,000) respect to the number of trips with the public transport (about 200,000 in the peak hour inside Rome), a share of 15% has been considered as potential owner of the Metrebus card.

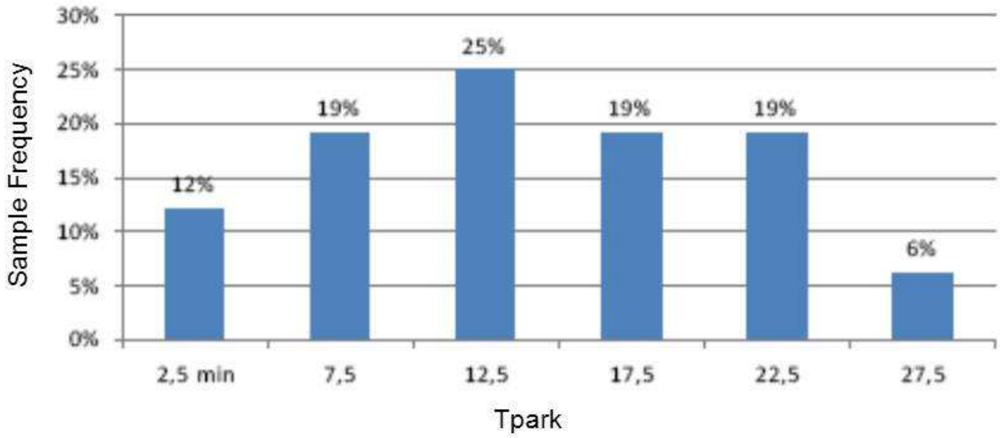

Figure 5 – Tpark distribution values for the “Eur” zone

For the second logit model, *i.e.* the model with variable fee, other attributes appear such as the time during which the car is left parked and the fee of the parking space: while the fee has been tested for different values, regarding the time during which the car is left parked, the percentages reported by the survey has been considered in the model application. In particular:

- 20% of the potential Wiparking users stopping in on average 2 hours a day;
- 15% of the potential Wiparking users stopping in on average 4 hours a day;
- 25% of the potential Wiparking users stopping in on average 6 hours a day;
- 30% of the potential Wiparking users stopping in on average 8 hours a day;
- 10% of the potential Wiparking users stopping in on average 10 hours a day.

In the application of the two logit demand models, the values of the attribute Tpark, found as previously reported, have been halved to take into account the differences between the future scenario (WiParking) and the current one, where in the latter parking times are definitely higher due to the lack of parking supply.

The most attractive WiParking zones derived by the application of the fixed fee model are: Eur, Nomentano, Tuscolano and Appio Latino (Figure 6).
The same distribution is obtained with the variable fee model (Figure 7) and low differences are reported passing from the hourly fare of €1/h to €3/h.

About the second component, related to the non-systematic trips, the results of the survey have been extended to the whole population.
The basic hypotheses defined for this extension are:

- only the population between 14 and 75 years old has been considered (2.140.082 inhabitants at 2011);
- 2 users for each car (average loading rate);
- 50% of generated users;
- 65% goes to the fee-parking traffic zones of Rome;
- 88% reaches the fee-parking traffic zones with the car (current modal shift of non-systematic trips, derived from the survey).

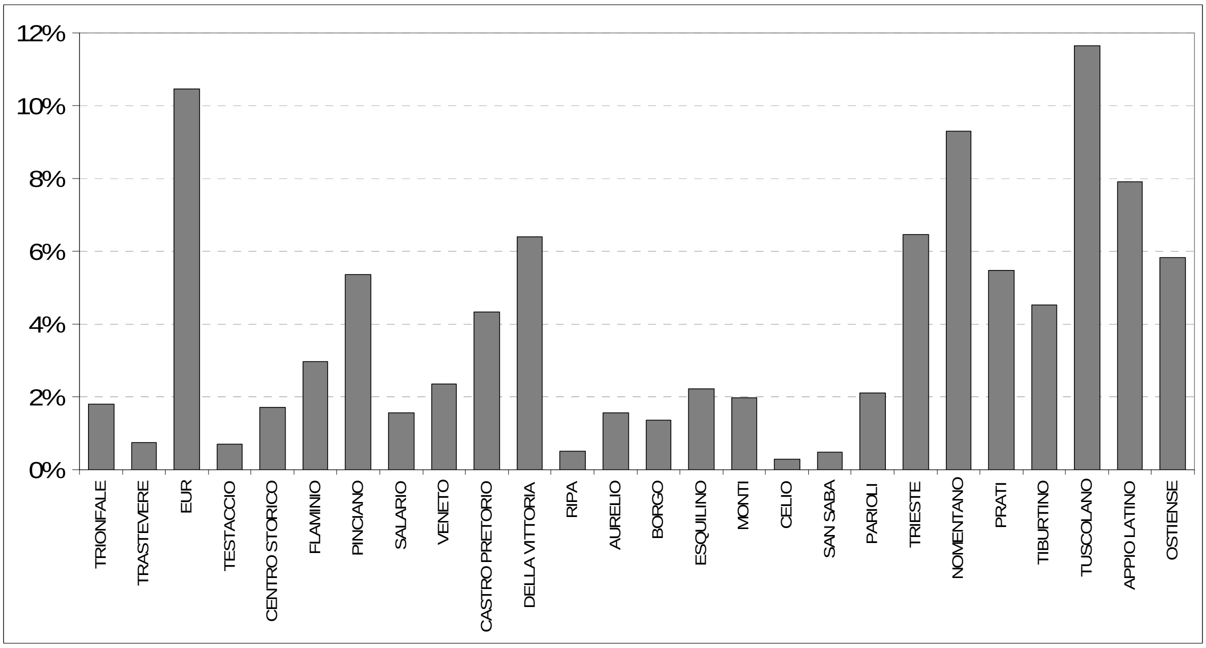

Figure 6 – Distribution of the WiParking demand computed with the fixed fee model between the 26 fee-parking traffic zones of Rome

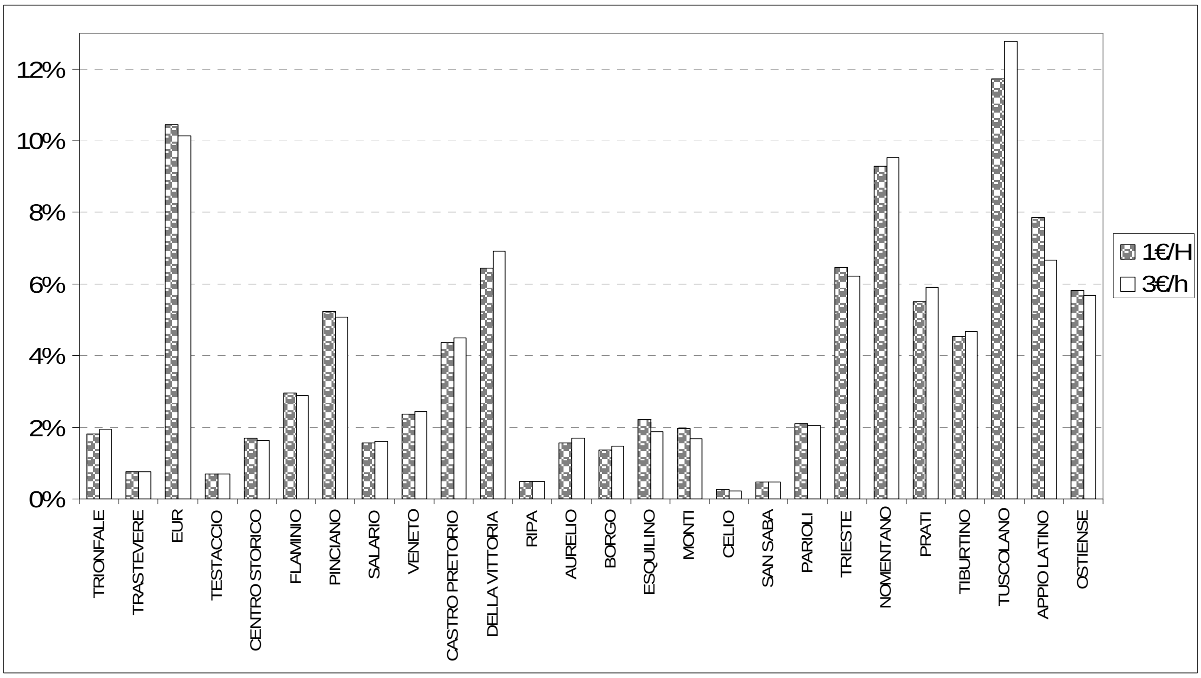

Figure 7 – Distribution of the WiParking demand computed with the variable fee model for the hourly rate of €1/h and €3/h between the 26 fee-parking traffic zones of Rome

The previous hypotheses allows the estimation of the total daily non-systematic WiParking demand, that is subsequently distributed between the different time slots, using the hourly distribution obtained by the sample (15% from 8:00 am to 14:00 pm, 39% from 14:00 pm to 20:00 pm, 46% after 20:00 pm).
So, the resulting WiParking demand for the non-systematic trips is reported in Table IV.
Also the WiParking demand for non-systematic trips can be distributed between the 26 zones and it has been done accordingly to the activity level of each zone.

Table IV – WiParking Demand values for non-systematic trips

	WiParking Demand [number of trips]		
	€1/h	€2/h	€3/h
from 8:00 am to 14:00 pm	17.700	10.000	1.400
from 14:00 pm to 20:00 pm	46.000	26.000	3.500
After 20:00 pm	54.300	30.600	4.200
Total	118.000	66.600	9.100

5. OPTIMAL FEE ESTIMATION

5.1. METHODOLOGY AND ASSUMPTIONS

The optimal fee estimation consists in the maximization of the Net Present Value (NPV) of a cost-benefit analysis subject to different constraints.
The first constraint is the hourly fare, where it can change in the set {1€;1.5€;2€} for the systematic trips and in the set {1€;1.5€;2€;2.5€} for the non-systematic ones. Higher fares have been removed by the optimization procedure as unlikely accepted by the users. The second constraint is the time horizon of the cost-benefit analysis, that has been fixed to 4 years to take into account the upgrading of technologies. Finally the third constraint is the discount rate fixed to 8%, that is usually an acceptable value to evaluate investments in the transport sector.
So, the procedure has to maximize the NPV, varying the hourly fare for the different 26 zones of Rome.
About the investment costs, they have been computed as the sum of the costs for the technologies (computers, readers, metrebus card), for assistance and construction of the system and finally of the costs for advertising.
The investment costs, also the management costs have been considered for each year of the service.
Regarding the benefits, at this first level only the revenue coming from the parking fee has been considered.
The benefits are a function of the WiParking demand and the WiParking demand can be computed using the calibrated behavioral logit model with variable fee.

Also the costs are a function of the Wiparking demand, being the costs of metrebus card (more demand, more card), of computers and readers (more demand, more garages involved, more equipment required).

5.2. RESULTS AND IMPLICATIONS

The fare condition derived by the optimization process has been here reported, as the values of the final NPV and the IRR (Internal Rate of Return, *i.e.* the value of the discount rate that makes the NPV equal to zero).
Regarding the 26 zones of Rome with fee-parking spaces, 4 have a fee of €2/h (Eur, Tuscolano, Appio Latino, Nomentano), 6 have a fee of €1.5/h (Prati, Ostiense, Trieste, Tiburtino, Pinciano, Della Vittoria), while the remaining ones a fee of €1/h.
About the non-systematic trips, the hourly fare can increase until €2.5/h, in particular for the two zones of the Historical Centre and Trastevere.

The NPV of €22,000 ensures the financial viability of the project: the value is sufficiently high, considering that the time horizon of the cost-benefit analysis is of only 4 years. Moreover in the benefits computation, the following further benefits are not included:

1. the reduction of the time to find a free parking space;
2. less congestion from vehicles searching for a parking space;
3. less pollutant emissions;
4. logistics optimization for both the users of the service and the private operator.

If included, they will further increase the NPV.
The Internal Rate of Return (IRR), maintaining the fare condition derived from the optimization, results equal to 18.5%. NPV and IRR give the same indication in the judgment on the convenience of a project, in the sense that the condition NPV>0 (€22,000 in our case) with a given value of the discount rate "r" (8%), corresponds with the condition IRR>r.

A last consideration about this first application of the optimization procedure in the cost-benefit analysis is that the behavioral logit model adopted for the computation of the WiParking demand does not take into account other types of parking payment apart from the hourly rate. In reality, subscription forms may be defined to further facilitate the use of the service (especially for systematic trips).

6. CONCLUSION

The WiParking project (www.wiparkingroma.it) originates from the need of the Mobility Agency of Rome (Italy) to manage the parking of private vehicles inside fee-parking traffic zones of the city, using available parking spaces inside car garages.
The paper demonstrates a method to quantify the level and the distribution of the WiParking transport demand and to define the optimal fee considering both the need of WiParking users and the need of the car garage administrators.
The WiParking demand is composed of two components: the first one related to private commuters demand and a second one related to the leisure trips.

The first component has been derived from the calibration of two different logit models, using the maximum likelihood approach, based on the results of a survey conducted on 200 potential users of WiParking: one model considers the current fixed fee and the second one considers a variable fee in order to derive the elasticity of the demand.
The second model results are more robust in describing the effective choices of the users and it depends on the time spent to find a parking space, on the time during which the car is parked, on the hourly fare and on the possibility to park for free near the place of work/study.
The second component is related to the non-systematic trips, the results of the survey have been extended to the whole population.

Different pricing assumptions have been proposed as a function of the parking attractiveness of the zones, in order to find the optimal fee scenario considering both the need of WiParking users and the need of the car garage administrators.
The findings of the paper demonstrate the financial feasibility of the project and suggest the application of the WiParking management system for urban contexts with high private demand and low parking supply.
Finally, regarding the future development of the project, the first step will be to introduce the capacity of car garages inside the models. Moreover the optimal location of car garages could be defined in order to promote the shift to the transit system for the "last mile" of the trip. In fact, the private car garages, located just outside the fee-parking destination zones and located close to the metro stations, can be adopted as park & ride areas in which the user leaves her/his car and then complete the "last mile" to the destination using public transport.
To find out if the user could appreciate the WiParking linked to public transport, five cases have been analyzed by the authors of this paper comparing the journey times by only car and those with car plus WiParking plus the last mile with public transport and first results have shown a reduction of travel times of up to 54%.
This is a first step demonstrating the attractiveness of the WiParking system to increase the transit modal share; especially in a city like Rome, where both the metro network and the areas of particular urban relevance (and so with possible fee-parking) are extending in the next years, the WiParking can be inserted as one of the instruments for the development of a sustainable urban mobility.

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