Improving bicycle mobility in urban areas through ITS technologies: the SaveMyBike project

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Abstract. This paper describes some ITS solutions and rewarding policies to increase the use of sustainable transport means in urban areas. Firstly, existing policies are described, and the advantages of rewarding systems are presented. Afterwards, the ITS technologies application to monitor mobility modes is described. In this context, the paper presents the SaveMyBike prototypical project and its solutions. SaveMyBike is an anti-theft monitoring system, based on RFID technologies and made of three modules. The first module creates secure urban areas through installed alarms where owners can leave their bike safely. The second module uses fixed RFID gates to monitor journeys and detect stolen bikes. The third module uses portable RFID readers that, during the parking and street control, read in-bike tags, detecting: the stolen bikes, and origins/destinations of bicycle trips. The system is based on rewarding policies, to incentivize people to use their private bikes and public transport modes.

Keywords: sustainable mobility; rewarding; citizen behavior; bike; ITS; anti-theft system; peer-to-peer bike-sharing.

1 Introduction

Private car mobility registers a high accident rate: in 2014 it was responsible for over 25,000 fatalities in the EU-28, while 3,400 fatalities occurred in Italy in the same year [1]. In addition, in 2014 in the EU-28, around 70% of the overall CO2 emissions from transport were generated by road mode; in Italy this percentage was even higher: around 83% [1]. Moreover, in urban areas they occur 38% of the overall fatalities from road transport, and 23% of the overall CO2 emissions [2]. As a result, a modal shift of at least a part of passenger transport in urban areas, from private car to sustainable transport systems is desirable.

"Sustainable mobility", that is disconnecting mobility from its harmful effects, is the element around which gravitates the EU transport policy [2]. The Communication n. 433 [3] lists several strategies to increase sustainable mobility in urban areas. Among these, systems of payment for the use of roads (e.g. Pricing) or systems for rewarding for good practice (e.g. Mobility credits) allow to act on the mobility behav-

ior. However, currently only a few rewarding policies have been put in practice; moreover they act on occasional basis.

In this field, the project SaveMyBike, funded by the Tuscany region, has been developed in order to improve the bike mobility in urban areas. The project regards the development of an ICT platform capable of: monitoring systematically bicycle trips inside the city, creating secure areas for bike parking, tracking stolen bicycles, rewarding people who perform the majority of their trips by bike.

In this paper, firstly an overview on existing transport demand management policies, with a focus on accessibility restrictions and on rewarding policies, is exposed. After, the main characteristics of the project SaveMyBike are described. Conclusions follow.

2 Transport demand management policies

2.1 Classical accessibility restriction policies

A study made for DG TREN by the Italian ISIS - Institute of Studies for the Integration of Systems [4] in December 2010 analyzes various systems of restriction accessibility in 417 different European cities. The two policies of restriction used in most cases are the Access Restriction Scheme (ARS) and the Low Emission Zone (LEZ). ARS can broadly be classified into four types:

1) Point based (e.g. restriction to cross a bridge or to enter a small section of city)

2) Cordon based: a restriction is applied for crossing a cordon, and may vary with time of day, direction of travel, vehicle type and location on the cordon. There could be several cordons in the same urban area with different rules or prices. This scheme is the typical form of road pricing; the main advantage is the flexibility in eventual variation by time of day and vehicle type.

3) Area license based pricing: a restriction is applied for driving within an area during a period of time; restrictions may vary with time and vehicle type. In alternative to a restriction, the access to a given area may be charged. The main field of application of this restriction policy is the inner core of cities. Restrictions may vary with time and vehicle type. An application of this policy is the London Congestion Charge.

4) Distance or time based: it is essentially a pricing restriction based upon the distance or time a vehicle travels along a congested route or in a specified area, and may vary with time, vehicle type and location.

2.2 Rewarding demand management policies

In Europe in a few cases alternative systems to the current simple accessibility limitation policies, such as pricing, have been introduced. Three different levels of complexity, in the management of transport demand for modal split, have been studied.

The first level ranges from a simple reward, for those who use public transports or shared means, to a system of penalties, for those who carry out certain modes of transport, to a real credits market managed by the public administration, similar to the 'Carbon credits' market in relation to emissions.

The second level of complexity regards a system which uses the internal GPS traces of the black boxes installed in cars, whose installation incentive is due to the dis-

counts made by several insurance companies. In this system, incentives gained in the usage of public transport can be exchanged, creating a sort of incentives "market". In a similar way, the Mobility Credits can be exchanged among drivers with a negative balance of credits to buy extra-credits from other credit-positive drivers. The only limitation is that the total amount of credits must remain the same avoiding the distribution of "new credits", which will be not coherent with the purpose of reducing carbon footprint.

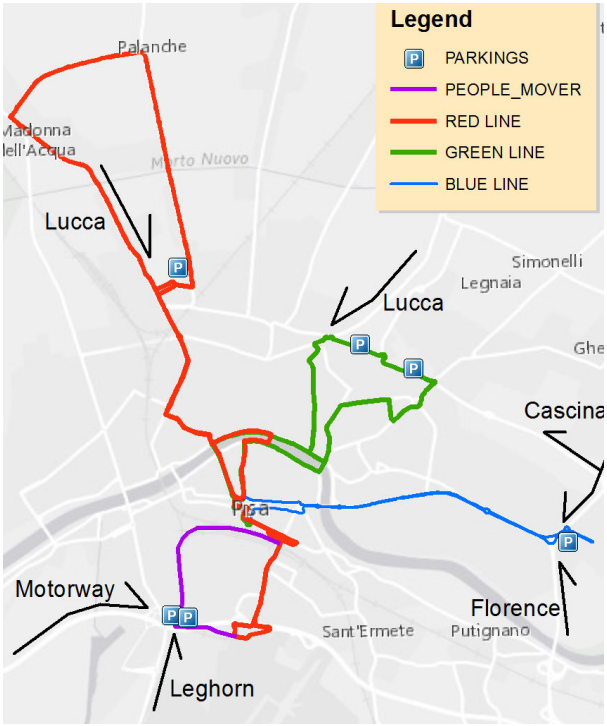

Fig. 1. The general Pisa municipality rewarding project (source: own research).

The third level of complexity regards a system, called "Mobility Credits Model", which allows to create a behavioral context where travelers and transport operators can experience the effects of changing attitudes and choices in mobility within a range of possible implementations, from a "pedagogic tool" to a "mandatory demand management scheme". The mechanism of this context is to set a quantitative target of Sustainable Environmental Footprint (SEF), for example an allowable threshold for each type of externality (e.g. energy consumption or CO2 production), to make the approach path to the target measurable (e.g. how much CO2 is not produced on account of a different mobility behavior) and to apply a driving force (incentive or obligation) from the current status to the target.

For the second rewarding system, it is complex and expensive to have car GPS data (to buy from insurance) and to solve legal problem linked to the penalty system while the third system is always too much at theoretical state. Then, we project to

apply the first rewarding system, with a real application in Pisa. The project is illustrated in Fig. 1.

The Pisa project tries to decrease the commuters entering in the city every day applying a rewarding system to those leaving their car in the cordon parkings and taking sustainable transport means to enter the city. In cordon parkings are located bike-sharing station and bike-lanes, and are crossed by high frequency bus lines that bring directly to the city-center. Regarding bike users, there is always a bottleneck disabling the application of rewarding policies: i.e., the inexistence of a systematic daily monitoring system. From this evaluation, it starts the SaveMyBike system.

3 The SaveMyBike system

As demonstrated from the TEMS-The EPOMM Modal Split Tool, there are several cities where bike mobility is very low: several EU cities such as Bilbao, Brno, Paris, Warszawa, London, Madrid, Budapest, Stockholm, Geneva, Nice and Porto reported a bike use between 0 and 3%. This trend is mainly due to local habits and to the high theft rate. Italian cities in particular suffer from high cars density.

The SaveMyBike system aims at breaking the economic circle created around the private car replacing it with a remuneration system based on the cycle usage. Moreover, SaveMyBike aims at decreasing the operating costs of bike-sharing systems, currently too high also for medium-little cities: in Pisa a system with 18 bike-sharing stations costs every year about 200.000€ with annual operating costs for each bike of about 1.000€; in Mexico City bike sharing systems costs are even higher, equal to 2.594$ [5]).

SaveMyBike therefore creates an urban service, for the first time, also for occasional city users like tourists but also asking citizens an annual fee subscription and giving, in exchange, an antitheft, monitoring, recovering and rewarding system.

Recent researches show that bike theft is up 25 percent in many cities and that up to a million bikes get lifted annually, without considering those not reported. The average stolen bicycles and their parts sum up to about 300 million Euro per year. Notice that there are two types of bike thieves. In many cases, they are occasional thieves, but some others are professionals who steal large amounts of bikes, using effective lock-breaking tools, and resell them in other cities or countries.

Unfortunately, most of the proposed countermeasures result almost ineffective as the consequence of the current unavailability of unique and irremovable (in a few words, completely reliable) identification systems. Public officers cannot demonstrate that a bike has been stolen in almost all cases. Besides, removing a bike from the street is fast and easy, even when locking tools impede the movement. Some producers (see for instance [6]) propose a complete set of locking belts that can be used to fasten wheels, handles and other parts. An appropriate key is then needed to release the bike, but still thieves can remove the whole bike and work on it later.

However, in the last years, due to the gravity and the growing frequency of bicycles thefts, different systems to prevent them have been proposed over time. In Italy, for example, a public register has been created in 2007, while in the UK a register of stolen bicycles already existed. It consists of a system of software applications, often web-based, and hardware tools that try to help owners to signal the theft, identify the

stolen bike and verify if those available on the market have been previously looted elsewhere. It is noteworthy that tracking devices are not an anti-theft solution. Because no bike lock can offer total protection, tracking devices offer a last-resort, post-theft recovery support.

Referring to all the above mentioned aspects, some approaches to bike security can be identified, each with its own strengths and weaknesses:

- Metallic plates: these, reporting unique numbers, can be fixed or welded onto the frame. Similar solutions have been adopted since many years in Switzerland and Denmark. Recently, in some Italian cities plates, among them Pisa, have been tested to the aim, but results have been rather poor mainly due to the fact that removal is all but difficult.
- Adhesive plates: similarly, some cities in northern Italy have adopted adhesive plates. However, these can be easily removed.
- QR codes: this is a solution that has been tested mostly in northern Europe. Codes can be punched onto the metallic parts of the bicycle, but removal, covering or hiding is almost easy.
- GPS-GPRS and Bluetooth systems: these are advanced and costly solutions (an interesting program using GPS tools has been proposed by both the Taiwan University and the Copenhagen municipality) that allow the identification and also the tracking of the bicycle within a given area (Bluetooth) or almost without restrictions (GPS). Unfortunately, they are heavily affected by the short life of batteries and by the easiness with which the emitting sources can be removed from the frame. Besides, the cost of the anti-theft system is often burdensome.

Finally, the main aims of the SaveMyBike project are:

- Encourage citizens to use bicycles through a rewarding system and a bike insurance. Currently, there are still no examples of rewarding systems for citizens based on bike's usage. Moreover, Zurich insurance company would guarantee the theft insurance for the bikes using SaveMyBike system (end user = citizen).
- Create an efficient anti-theft system (end user = citizen).
- Monitor cyclists trips (and their origin and destination) to implement an effective decision support system to plan bike mobility (end user = municipalities) without obligate them to use an App for smartphone [7].
- Monitor bike stolen trends and locations to prevent future ones (end user = police).
- Develop a peer to peer bike-sharing system which is managed by the citizens themselves who, also, could receive a revenue. Therefore, users can rent or borrow bikes hourly or daily from the other citizens, providing therefore also a revenue for private bike owners. Although it is very popular, peer-to-peer bike sharing has not yet applied to real urban center for the absence of a proper technology [8].

The SaveMyBike approach is meant to deal with all the previously mentioned issues and, in detail, it is intended to provide an anti-theft monitoring system based on the well-known RFID technology and built mainly upon three different modules.

- The first module is intended to create secure urban areas with installed alarms, where owners can leave their bike safely. In case of theft an alarm is sent to the management system, to the owner and to all the registered members of the Save-MyBike network: this works as a fully cooperative control, delineating the Save-MyBike system as a Cooperative-ITS platform (see Fig. 2) [9]. Besides, the creation of well delimited secure areas constitutes a particularly strong feature of the whole project, because it provides the town administrators a valuable mean to avoid the annoying "wild parking". Actually, users often park their bicycles almost everywhere. While parking is properly regulated both for cars and motorbikes, nothing has been conceived yet for bicycles. This is why the secured areas may come useful. Moreover, while it is certain that covering with RFID signals the entire metropolitan areas would be rather impossible (or at least extremely expensive even for small towns), the dedicated areas represent truly economic, closed and controlled parking areas for bicycles. A well-thought rewarding mechanism is suitable/necessary to stimulate the citizens to use such areas, in order to make the implementation effective in a reasonable time.

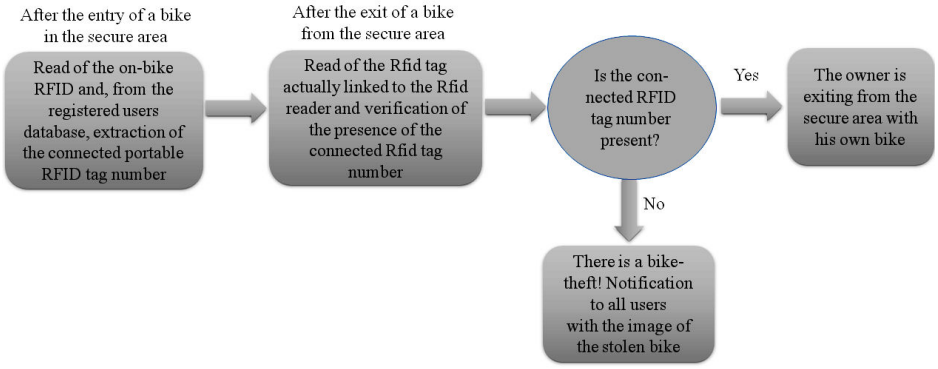

Fig. 2. A chart flow describing the first module (source: own research).

- The second module, aimed at the identification and tracking of bicycles, uses fixed RFID gates to monitor daily journeys and to detect stolen bikes. This module is built upon the newest UHF passive RFID technology, that has grown enough in the last years to grant the capability of identifying the bicycles when they are within the protected areas. The reading range goes up to some meters and this allows to effectively cover the closed and secured zones. RFID gates cover an entire road section, as bicycles could be identified until a distance greater than 20 metres. Fixed readers will be also available in different locations within the metropolitan areas, to track and trace bicycles while they are moving on the roads. These readers provide a valuable tool both to determine the zones were bicycles have been stolen and to analyse the most/less used paths in the bike-sharing programs. The passive tags will be built and installed using a specific technology, therefore they are immovable and protected from damaging and manumissions. In the ideal situation, when a bicycle producer inserts the tag within the bike body, a visible and charac-

teristic marking should be applied on the metallic structure of the bike itself, for example, by a punching process. Obviously, removing the marking is possible (for instance, by abrasion), but in this case the metallic surface of the bicycle will be visibly damaged, signaling immediately that it is a possible bike suspected of theft. Fixed or portable RFID readers can be then used to verify the current state of the vehicle. Even if the passive tag has been somehow damaged, removed or tampered, the marking or the missing-marking can be used as further significant signals.
Finally, the system is capable of recognizing which bikes leaving the secure urban area in the following way. During the registration, the system users provide not only the bicycle data but also a photo of the bike itself. This photo allows an unique identification of the bike in case of theft.

- The third module uses portable RFID readers. Such instruments will be given to each policeman or parking enforcement officer, allowing them to read the "in-bike" tags and to detect stolen bicycles. Since the RFID tags will be hidden and immovable, the system can be used to rapidly verify the state of any "suspected" bicycle, as explained within the last point. Furthermore, it allows the system to control those areas where fixed readers cannot be installed.

To resume, the SaveMyBike system uses, for the first time, immovable sensors in the bike and it is based on a rewarding system elaborated on the routes monitored and on the travelled kilometers. Moreover, each citizen can leave their bike in the nearest secure area, where other users can take it, simply booking the service by means of the smartphone. As a result, SaveMybike will allow the implementation of the first real peer-to peer bike-sharing linked to a rewarding system. In addition, SaveMybike will enable several travel demand policies, basing: on incentives to switch from private car to bike mode, or on rewarding policies for citizens who use bus, bike or car-sharing modes, or electric cars, in performing their trips. In Fig. 3 it is possible to see a summary of the problems of the users and their solutions offered from the system.

Finally, this project will encourage the development of bike-sharing systems also in small and medium cities due to the low-cost of the system, that can be totally amortized from the annual registration fee in about 2-3 years, and it will provide citizens a central role in the development of bike-sharing solutions [10].

The SaveMyBike system related privacy concerns will also be addressed. Actually, tracking data at individual level will be visible only to the single user (i.e. each user is capable to access only his own data), while only aggregated data will be available to public administrators which are therefore able to efficiently implement the rewarding policies.

In Fig. 4, the results of the cost-revenues analysis are represented, regarding Pisa scenario, including the bike-sharing capital and the actual operating costs. The analysis takes into account revenues coming from annual citizen fees (about 5 euros), the company subscribed to the rewarding system that give discount based on the credit points collected, from occasional users of the bike-sharing systems/tourists, from insurance companies (for example Zurich one will subscribe a contract with the service company manager to make an insurance against theft at 15euro/3years for each bike, from publicity. The costs are divided in capital costs for the first year and in operating costs for each year based on the number of users. The analysis shows that, comprising the bike-sharing operating costs, for the first three years there is a nega-

tive balance between revenues and costs, mainly due to the initial investments, while, after the third year, the balance becomes positive, therefore it is possible to break in a few years the private car economic hegemony.

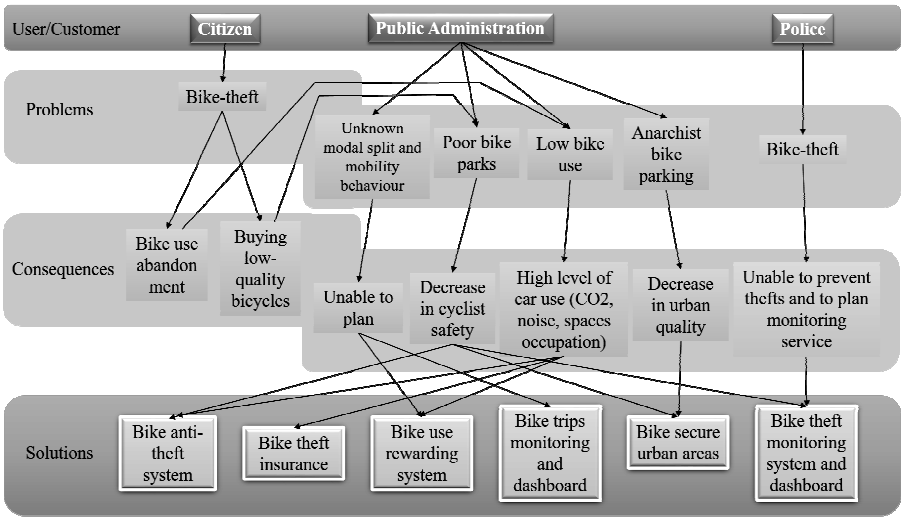

Fig. 3. Users' problems and their solutions offered from the SaveMyBike system (source: own research).

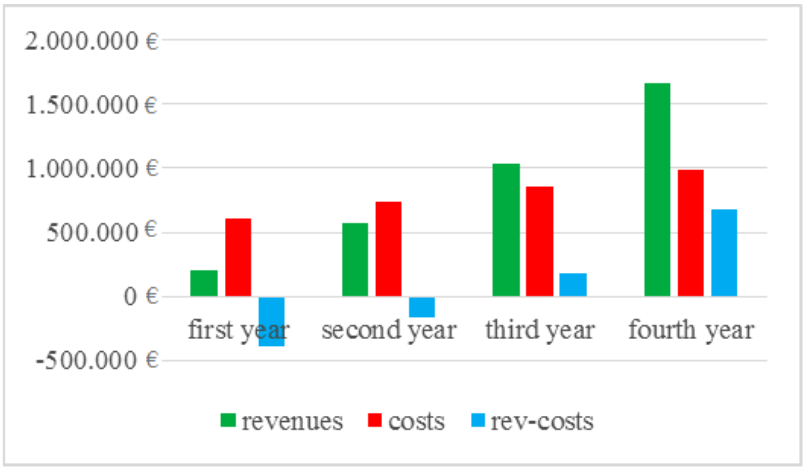

Fig. 4. The results of the cost-revenues analysis applied to Pisa scenario (source: own research).

4 Conclusions

Currently, urban areas register a high transport accident rate; moreover urban mobility is responsible for a relevant quota of pollutant emissions and fuel consumption.

As a result, a shift of at least a part of urban transport, from private car to greener means of transport, is desirable. While the usage of public transport is not negligible, specially by commuters, the bicycle is still used, as a transport mean, by only 0 – 3% of citizens in Europe, and this occurs both in big and medium sized cities. The reduced use of bicycle is due to mainly two reasons. Firstly, the high rate of bike thefts in Europe discourages citizens from bike mobility. Secondly, a "green" mentality among citizens is still lacking, while private car still occupies a central role in the overall urban economy.

The project SaveMyBike has been developed in order to encourage bicycle mobility in urban areas. As a result, the project has the following main targets.

Firstly, the project aims at discouraging the bikes theft, through the usage of RFID tags and detectors. The project therefore proposes the development of "secure areas" where bicycles could be parked safely: if a bike is stolen, an alarm signal, directed to the bike owner and to the police, is activated. Moreover, mobile RFID detectors provided to policemen and parking enforcement officers, allow, in case of theft, the recovery of bicycles. Furthermore, a bike insurance is however offered to citizens.

Secondly, the project proposes rewarding policies to encourage bike mobility in urban areas. In order to detect the actual kilometers travelled by bike users, a monitoring system, through fixed gates placed in the roads, is proposed: this however helps also in recovering the stolen bike.

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