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Title: ***How infrastructures can promote cycling in Mediterranean Cities: Lessons from Sevilla.***

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ABSTRACT

In this paper we analyze the experience of the development of a separated cycling infrastructure in Sevilla, during the period 2006 – 2011, as well as its consequences for the city mobility. The development in such a short period of time of a fully segregated cycling infrastructure has proven to be a valuable tool for the promotion of urban cycling in a city without previous tradition of everyday cycling like Sevilla. Besides segregation from motorized traffic, connectivity, continuity, visibility, uniformity and comfort have proven to be good criteria for the design of such infrastructure. All these criteria are aimed to make cycling not just safe, but also easy and comfortable for everybody. Our analysis suggest that the fast building of such kind of infrastructures will provide solid grounds for the development of everyday cycling, with a high cost effectiveness, even in cities without any previous tradition of urban cycling.

HIGHLIGHTS:

- ✓ Increase of urban cycling in Sevilla and other Spanish Cities.
- ✓ Segregated cycling infrastructure as a powerful tool to promote urban cycling
- ✓ Connectivity, homogeneity and quick building as key factors of success.

How infrastructures can promote cycling in Mediterranean Cities: Lessons from Sevilla.

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In this paper we analyze the experience of the development of a separated cycling infrastructure in Sevilla, during the period 2006 – 2011, as well as its consequences for the city mobility. The development in such a short period of time of a fully segregated cycling infrastructure has proven to be a valuable tool for the promotion of urban cycling in a city without previous tradition of everyday cycling like Sevilla. Besides segregation from motorized traffic, connectivity, continuity, visibility, uniformity and comfort have proven to be good criteria for the design of such infrastructure. All these criteria are aimed to make cycling not just safe, but also easy and comfortable for everybody. Our analysis suggest that the fast building of such kind of infrastructures will provide solid grounds for the development of everyday cycling, with a high cost effectiveness, even in cities without any previous tradition of urban cycling.

I.- INTRODUCTION

Growing public awareness about the negative impacts of car-based urban mobility on ecological issues (local pollution, global warming, scarcity of resources...), public health (obesity, cardiac diseases...), the economy (growing economic costs of traffic congestion and infrastructures), urban livability, and land use have pushed up for the search of urban mobility alternatives based on the promotion of walking, cycling and public transport all around the world. Bicycles may contribute to these policies as an independent mode of transport for trip distances up and around 5 km (ECMT, 2004), or for longer trips in combination with public transportation (Martens, 2004).

Promotion of cycling is usually made at the local level, and the impacts of these policies (as well as these policies themselves) vary from one country to another and from one city to another. Participation of cycling in modal split as high as 30% of all trips are common in many cities of central and northern Europe (Pucher and Buheler, 2008) and, in spite of its growing motorization (Hook and Replogle, 1996), in many cities of China (de Boom et al, 2001), Japan (Pucher et al., 2012) and other eastern Asian Countries. However, in most cities in the rest of the world, percentages of cycling in urban mobility are still very low, although efforts in order to amend this situation are ongoing in North America (Pucher et al., 2011), South America (Montezuma, 2005), Australia and other regions of the world (Pucher et al., 2010; Pucher et al, 2012; Pucher and Buehler, 2012).

Urban cycling in Mediterranean Countries has only reached meaningful levels in a few number of cities in France and the north and center of Italy, with some tradition of cycling. Most Italian, Greek, Spanish, former Yugoslavian and Portuguese cities – not to mention cities of Magreb - did not seriously included cycling in their urban transportation plans until very recently, and with quite uneven success. Sevilla has probably been one of the most successful Mediterranean Cities to include cycling as an important part of its modal split in recent times (Marques, 2011; Morales, 2011, Marques et al., 2012). In just five years (from 2006 to 2011) cycling in the Municipality of Sevilla increased from negligible levels to more than 5% of the total number of trips (SIBUS, 2012; Marques et al., 2012). This change was closely related to the building of a cycling infrastructure, which also had a considerable impact on the landscape of the City, as well as on the mobility culture of the population. This cycling infrastructure mainly consists of a highly connected cycle network with presently includes 164 km of bi-directional segregated cycle-tracks (Ayuntamiento de Sevilla, 2013), and of a public bike sharing system with 2,650 bikes and 260 stations all around the City (Ayuntamiento de Sevilla, 2013b). These developments followed similar initiatives in other Spanish cities, such as Barcelona and San Sebastián, and contributed to the present wave of interest in urban cycling mobility in many other Spanish cities, such as Valencia, Vitoria or Zaragoza (ConBici, 2007; OCU, 2013).

We feel, however, that the success of Sevilla cannot be explained as the mere consequence of the financial investment made to create such infrastructure (which was comparatively quite modest), but rather as the result of the specific tailoring of the design and development of this infrastructure, in close connection with the specific urban and social structure of the city and pushed by a strong political will (Marques, 2011). Our contribution aims to describe and analyze this process (its methodology, planning and main achievements) not only in their engineering aspects, but also in their political, economical and social aspects. This analysis is based on the meta-analysis of the available sources, on an extensive fieldwork realized before and during the preparation of this article and on our personal experience as active participants in the whole process.

II.- METHODOLOGY, PLANNING AND DEVELOPMENT OF THE BIKE INFRASTRUCTURE

To begin with, let us properly place the process in its context. Sevilla has a population of approximately 700,000 habitants in the City and 1,500,000 in the whole Metropolitan Region, with a urban density of around 5,000 hab./km² in the City and 3,500 hab./km² in the Metropolitan Region. The per-capita gross domestic product is of 18,600 €/hab-year and the percent of car-free households is over 20% in the whole Metropolitan Region. The percent of university students is of over 15% in the city and 8% for the whole Metropolitan Area. Precipitations are very low, over 53 cm per year. There are no days with temperatures below 0 ºC but there are over 80 days per year with temperatures above 32 ºC, and the average maximum temperature is 29.9 ºC[1]. It is, therefore, a typical medium sized Mediterranean City with not very high income and a relatively high level of motorization. Climate and orography (which is very flat) favors cycling, except in summer, when temperatures become very high.

The development of the bike infrastructure in the city of Sevilla followed a methodology developed in three main planning documents. First of all is the Urban City Masterplan (Ayuntamiento de Sevilla, 2006) which was aimed to the general urban development of the City, and approved by the City Council in 2006. This document contained the concept of a segregated bike network as a part of the new city mobility system. In 2005 (Ayuntamiento de Sevilla, 2005) the municipality approved the Strategic Document for the Integration of the Bike in the Mobility System of Sevilla, which included a first approach to the design of the future bike network. And in 2007 (Ayuntamiento de Sevilla, 2007) the City Council approved the Bike Masterplan for the city. The main contents of these documents are shown in Table I.

[1] Data from *Instituto Nacional de Estadística* (Spain), *Instituto de Estadístico de Andalucía* y *Asociación Española de Meteorología.*

A previous survey made in 2006, before the cycle network was built, evaluated the potential number of everyday cyclists in 89.000 - more than 10% of city population - (Ayuntamiento de Sevilla, 2007). This survey did also show a high level of interest on the project among the population, providing a strong political support for its realization.

The development of the bike network between 2006 and 2010 is shown in Fig. 1. From the total length of 120 km at the end of 2010, 76 correspond to the basic network defined in the Bike Masterplan (Ayuntamiento de Sevilla, 2007). Most of the remaining 44 km correspond to the first enlargement of the network (see Table II; before 2006 there were some sparse and unconnected bike paths that were integrated either in the basic network or in its first enlargement). Further developments can be seen in (Ayuntamiento de Sevilla, 2013).

II.1.- *The cycle network*

The starting point for the design of the basic network (Ayuntamiento de Sevilla, 2005) was a “theoretical network” (Ayuntamiento de Sevilla, 2005, 2006) mainly based on the information collected during the elaboration of the City Masterplan. This theoretical network connected major trip attractors of the city, such as intermodal centers, main public service centers and main relational spaces (such as squares, commercial streets and green areas). This work was partially done during the elaboration of the City Masterplan, which included a parallel citizen participation process, where the local cyclist's union “A Contramano” participated actively. During the discussions, some specific trip attractors – such as university centers - were positively biased because of its previous cycling tradition. A first version of this theoretical network was included in the City Masterplan, as a part of its determinations for the city development.

The next step (Ayuntamiento de Sevilla, 2005, 2007) was adjusting this theoretical network by optimizing the distance to the specific trip attractors (educational centers, markets...) along the network, and taking into account the space constraints and opportunities in the different streets. This adjustment was made in a qualitative way, on the basis of extensive fieldworks and discussions, and resulted to a first detailed proposal for the bike network. This proposal also included proposals for bike paths typologies along the network (Ayuntamiento de Sevilla, 2005). It is worth noting that the aforementioned space constraints and opportunities usually favor the location of bike-paths along main streets and avenues. This location is also favored by the analysis of the main trip attractors, which were also located along such roads. On the other hand, it is desirable to locate bike paths along main streets in order to provide visibility to the network (see below). Therefore, it can be concluded that, as a “rule of thumb”, bike paths should be located along main streets and avenues. Finally, after some final fine adjustments, more than 200 trip attractors were identified at a distance below 300 m from the cycle network (Ayuntamiento de Sevilla, 2006b).

The main characteristics of the resulting network (Ayuntamiento de Sevilla, 2005, 2006, 2007), which are confirmed by our fieldwork, are:

- Continuity and connectivity: the network is designed with the aim of connecting, through a continuum of bike paths, the main trip-attractors and the main residential areas of the city.
- Cohesion and homogeneity: the design of the bike paths is very similar throughout all the network, so that cyclists can easily follow it. This is achieved by using an uniformly colored (green) pavement throughout all the network, as well as a uniform morphology which will be described below.
- Directness and visibility: as we have already mentioned, the network follows the main streets of the city. Therefore it is quite visible. Moreover, as a general rule, detours and multiple street crossings were avoided.
- Comfort: The whole network should be comfortable for everyday cycling, with parking

facilities and uniform pavement, without unexpected steps at intersections, etc...
- Quick building: The whole basic network (76 km) was built in less than two years, along 2006 and 2007.

Of course, not all these criteria are original. Many of them – such as connectivity, cohesion or directness - can be found in many manuals and are commonplace for many bike planning departments around the world (CROW, 2007; Danish Cycling Embassy, 2012; German Federal Ministry of Transport, 2010). Continuity, connectivity and cohesion are important because everyday cyclist's needs for transportation are similar to those of the rest of the citizens. Moreover, they need to move easily from one point to another in the city without leaving the cycle network except – perhaps – at the beginning and the end of their trips. Directness is important because bicycles are human powered vehicles, and it can not be expected that cyclist make big detours in their trips. Detour factors higher than 1.2 or 1.3 are considered excessive by dutch manual for cycling infrastructure (CROW, 2007). Visibility and homogeneity, as well as comfort, are important on its own, but they are even more important in cities without a previous everyday cycling tradition, because potential cyclists will only be persuaded to cycle if the cycling infrastructure is visible and comfortable, and can be easily interpreted. Finally, building quickly the infrastructure is very helpful in cities without a previous cycling infrastructure, because what is useful and attractive for potential bicyclists is the whole network, not just one or two isolated and unconnected bike paths.

Regarding the constructive criteria for the bike paths, the planning determinations (Ayuntamiento de Sevilla, 2007) and our fieldwork show that most bike-paths follow these criteria:

- Segregation: The whole cycle network is segregated from the motorized traffic.
- Bi-directionality: Most bike paths are bi-directionals, with a width of 2.5 m
- Uniform pavement and signposting: Bituminous pavement painted in green color, with clear and uniform signposting, including specific traffic lights
- Located between the motorized traffic zone (carriageway or parking lane) and the pedestrian area, following one of these criteria:
  - At the same level of the sidewalk, with a different pavement in color and texture[2] or
  - At the same level of the carriageway, but separated from it by bollards or other discontinuous physical barrier.
  - In case a parking lane persisted in the street, the bike path is usually built at the same level of the sidewalk.
- Intersections parallel to crosswalks, but separated from them.
- Built mainly over previous parking lanes.

Once again they are well known concepts. Which may be is not so usual is the systematic application of these concepts, in order to ensure the aforementioned homogeneity of the network (Ayuntamiento de Sevilla, 2007), as well as the political decision of building up the whole network in such very short period of time. The 100% of the network was segregated from motorized traffic, and almost all bike paths are bi-directional, with the aforementioned characteristics. Segregation of motorized traffic, as well as continuity, are considered an essential characteristic of the network (Ayuntamiento de Sevilla, 2006, 2007), which was designed not to fulfill the needs of present cyclists, but to be attractive to potential bicyclists. Bi-directionality might be controversial, because in many cities with long cycling tradition, like Amsterdam or Copenhagen, bike paths are usually mono-directional. It is beyond the scope of this paper to develop a complete discussion about the advantages and disadvantages of both designs. Bi-directional bike paths were preferred mainly because they might save space (a mono-directional cycle path must be at least 1,50 m width,

2 These design characteristics became afterwards enforced by law by the Regional Government (Junta de Andalucía) for any bike path built along pedestrian areas or sidewalks.

whereas a bi-directional cycle path must be 2,5 m width; Ayuntamiento de Sevilla, 2006, 2007; CROW, 2007). Moreover, in a city with low cycling tradition, it is expected that mono-directional bike paths were used at first as bi-directional ones (as actually happened in Sevilla with the few previously existing mono-directional bike paths), which will create conflicts once bicycle traffic increased. Location of the bike-paths at the same level of the sidewalk has been controversial because of conflicts with pedestrians (Malpica, 2010). However, when a parking lane persisted in the street (the most common case), this design provides an easy access to the parked cars from the sidewalk. Most bike paths were built on previous parking lanes (A Contramano, 2009). This design implies the loss of either parking places or traffic lanes (when the parking lane moves to the center of the road). This loss of parking places and/or traffic lanes was also controversial (Malpica, 2010), but helped to reduce car traffic. Fig. 2 shows a photograph of a typical bike-path on a busy street at the center of the city. This photograph illustrates the main characteristics of the design, as well as the previous configuration of the street.

In the following years, the cycle network continued its expansion, with the same criteria and the same constructive characteristics (see Fig. 1), until it reached the present length of 164 km (including recreational and pedestrian-shared paths) which makes a 12% of the total road length in the city (Ayuntamiento de Sevilla, 2013 and personal communication). Nowadays, it makes a homogeneous and continuous network connecting the most important trip attractors and residential areas through the main streets and avenues, with a typical cell size of about 500 m. It is determined than new urban developments should be connected to this network by new bike-paths, built following the same criteria of design (Ayuntamiento de Sevilla, 2006,2007). It is also determined that the network should be completed by other complementary actuations, such as parking infrastructure, at a smaller scale inside residential and industrial areas (Ayuntamiento de Sevilla, 2007), although this last determination is followed very unevenly in practice. In any case, it can be safely said that cycling from one point to another in the city can be done nowadays following the cycle network in a quite safe and comfortable way (Ride the city, 2013).

II.2.- *The historical center*

As many Mediterranean Cities, Sevilla has a big historical center, of about 4 square km, with very narrow streets and a very old street map. In the case of Sevilla this street map comes basically (except a few modern developments) from the XIII century, when the city was the capital o a small muslim kingdom in Southern Spain. More than 56,000 people live in this area, and many of the most important relational spaces and commercial streets are located on it. Both, the City Masterplan (Ayuntamiento de Sevilla, 2006) and the Bike Masterplan (Ayuntamiento de Sevilla, 2007) determined that inside this area there should be strong traffic restrictions and priority for pedestrians and bicyclists. Therefore, as can be seen in Fig. 1, there were no planned bike paths inside the historical center, and bike promotion mainly relies on traffic calming policies (Ayuntamiento de Sevilla, 2007)

These determinations, however, have been followed in a quite loose way by the different Local Governments, so that there is not presently any real enforcement to follow them. However, there are many narrow streets in the historical center which make their job for speed limitation, providing some traffic calming and creating many areas with some kind of effective priority for pedestrians and bicyclists. Therefore, in practice, and without too many specific policies to promote cycling, the historical center is still well suited for bicycle traffic, and a lot of people can be seen cycling everyday on it.

II.3.- *The public bike sharing system.*

The public bike sharing system of Sevilla (*Sevici:* http://www.sevici.es/) is an important part of the cycling infrastructure, carrying a high percentage from the total bicycle daily trips (see Section III). It was introduced in a relatively late step of planning (Ayuntamiento de Sevilla, 2007), but the success was immediate, reaching a maximum of 59,455 associates in December 2009 (Ayuntamiento de Sevilla, 2012), two years and four months after the system started. At such time, the system became almost saturated (Castillo-Manzano and Sanchez-Braza, 2013), with peaks of more than 10 uses per bike and per day. Presently, the system has 2,650 bikes and 260 stations, and is stabilized with a number of associates around 50.000 and between 6 an 7 uses per bike in a typical business day (Ayuntamiento de Sevilla, 2013b).

Public bike sharing systems evolved from the early free use “white bikes” of Amsterdam to the present third generation of modern automatic systems (de Maio, 2009). The bike sharing system *Sevici* is one of such third generation systems, conceived as an “individual public transport system” (Midgley, 2011) providing 24 hours almost door to door transportation every day of the week. Accordingly, the system has a high density of stations, similar to those of bus stops (average distance between stations is less than 300 m). The system is designed to have some level of auto-regulation, so that there is few need of re-arranging bikes between stations, which is favored by the flat orography. It is also designed with the aim of favoring connections with the traditional public transportation system: at least one bike sharing station is aways located near any public transportation node (Ayuntamiento de Sevilla, 2007). As complementary actions, the Municipality promote agreements between the main public institutions and *Sevici*, in order to promote the registration of their members, a fact which contributed to the early system saturation, specifically regarding the University (Castillo-Manzano and Sanchez-Braza, 2012), which reacted creating its own (long term) bicycle sharing system (SIBUS, 2011; Castillo-Manzano and Sanchez-Braza, 2012)

At this point, it may be worth to say a few words about the role of smart public bike sharing systems in the mobility planning of modern cities. There is presently a big burst of smart bike sharing systems all around de world (Bike Sharing World Map, 2013). In Spain, many cities like Barcelona, Valencia, Zaragoza or Sevilla also have successfully implemented such infrastructure. Spain was, in fact, the European countries with more automatic bike sharing systems installed: 147 at the beginning of 2011 (Anaya and Castro, 2011). However, their success has been quite uneven. A few number of big systems installed in very populated cities which simultaneously developed other cycle infrastructure (Barcelona, Sevilla, Valencia and Zaragoza) have been quite successful. However, there also are a big number of systems with few bikes and/or a low density of stations, installed in cities without any other cycling infrastructure, which have been very unsuccessful (Anaya and Castro, 2011). It seems, therefore, that a high density of stations as well as some previous cycling infrastructure are necessary for the success of a smart bike sharing system (Midgley, 2011). These considerations reinforce the consideration of bike sharing systems as a new kind of public transportation (Midgley, 2011). They also suggest that bike sharing systems should be considered as a complementary infrastructure, useful once other infrastructures, such as cycle networks and/or traffic calming, have been implemented. The experience of Sevilla fully confirms this hypothesis.

II.4.- *Parking, intermodality and other complementary infrastructure*

Parking is a very important part of cycling infrastructure (CROW, 2007). The Bike Masterplan (Ayuntamiento de Sevilla, 2007) included determinations about the location and design of bike parkings – up to 5,728 parking places at the end of 2010 (Muñoz, 2010) - along the cycle network, with emphasis in the main nodes of public transport, as well as the main trip attractors, such as schools, workplaces, commercial areas, public transport nodes, parks, etc. This infrastructure is very used, and our fieldwork shows that nowadays this parking infrastructure is almost saturated, mainly in central areas.

Providing indoor parking infrastructure at origin and destination (CROW, 2007), as well as in the main nodes of public transport (Martens, 2004, CROW, 2007) is also very important in order to attract potential bicyclists. The Bike Masterplan included some initiatives in order to promote indoor parking facilities inside residential and public buildings, schools, companies and shops, etc, which have had an uneven success. Probably, the most relevant initiative came from the University, which has built closed parking areas with automatic card access near its schools and administrative buildings (see Section V). Another interesting initiative came from the Metropolitan Public Transport Authority (*Consorcio de Transporte Metropoliatano del Área de Sevilla*), which provided closed parking facilities and a manual system of public bikes inside the main metropolitan bus station (see Section V). Nevertheless, parking facilities in public transport stations, residential buildings, public buildings, companies and shops, etc... are still far from those currently available in countries with a longer tradition of urban cycling (Martens, 2004, CROW, 2007; Danish Cycling Embassy, 2012).

II.5.- *Stakeholders engagement and participation.*

To develop public works during two years along 76 km on the streets of any city can not be done without controversy. Therefore, if stakeholders engagement and participation is an essential part of any social or political process by its own, in the present case it is even more important. Public participation began during the elaboration of the City Masterplan, and continued with the design and implementation of the basic cycle network and the public bike sharing system, thanks to the creation of a Civic Committee (Spanish: *Comisión Cívica de la Bicicleta*). This Civic Committee participated in the design of the cycling infrastructure, and closely followed its implementation.

The Committee met almost each fortnight at the Town Hall during the busiest time of the works, and regularly at any time during the whole design and development period. Representatives of the local cycling union, pedestrians, skaters (which are allowed to ride on the bike paths), bike shops and bike rentals, as well as consultants and other professionals linked to active mobility participated in the committee, which was open to all of them without restrictions. Network and bike path designs, as well as the public bike sharing system main characteristics were discussed in the Committee. These discussions helped to a better design of the infrastructure and played an important role for the communication between the Municipality and the Citizenship. The Committee actively participates in the design of the complementary promotion programs, which included bike demonstrations, participation in events such as the car-free day, ciclo-vías, and initiatives such as “bike to work”, bike to school”, “bike for health”...

II.6.- *Management and costs*

As it was already mentioned, the basic cycle network (76 km) was built in just two years. It was sub-divided into 8 independent but connected “itineraries”, which were built-up simultaneously. These independent “itineraries” had the sole functionality of allowing for a faster realization of the public works. This was the first phase of construction of the network, followed by other developments which are shown in Table II, altogether with their monetary costs, which can be estimated around 0.27 million euros per km. All these developments were managed from a new *ad-hoc* department of the City Municipality, the Bike Office (Spanish: *Oficina de la Bicicleta*)[3], and disseminated through a specific web page: http://www.sevilla.org/sevillaenbici/. This Bike Office was in charge of the redaction of the projects and the supervision of the public works. It was also in charge of the development of the Bike Masterplan in its different aspects, including the supervision of the public bike sharing system. Further developments of the cycle network reached the figure of 164 km, with an overall maintenance cost between 250,000 and 350,000 euros per year

3 After 2011 the Bike Office disappeared as a specific department of the Municipality.

(Ayuntamiento de Sevilla, 2013 and personal communication).

It is illustrative to compare the aforementioned costs with other capital costs incurred by the city transportation system in the same period. The first line of the metropolitan subway (18 km) became operational in November 2009, with a final cost for the civil works of around 35.2 million euros per km. This mode carried around 53.000 daily trips in November 2011. The 21.5 km of suburban city highways presently in construction have a budget of 30.8 million euros per km, with an expected average traffic of 50.000 vehicles per day (Junta de Andalucía, personal communications). Although these capital costs are not directly comparable with the capital costs for the cycle network, because they respond to very different demands, the above figures illustrate the high cost effectiveness of the cycle network, which presently carries more than 72.000 trips per day (see next Section).

The public bike sharing systems is operated as a public private partnership: The City Municipality provides the company (JC Decaux) with advertising space on street furniture in exchange for the company providing and operating the bicycle sharing system. This model also operates in many other cities, such as Rome, Paris, Zaragoza or Valencia (Midgley, 2011), and has the obvious advantage of no cost for the City (except for the opportunity costs associated to the advertising spaces lent to the private company). Registration fees and tariffs follow the same schema as in the aforementioned cities (Midgley, 2012), with the particularity of a 24 hours operation. Although the costs of the system is not assumed by the City Municipality, an estimation of the operation cost per trip may be illustrative of the intrinsic cost effectiveness of the system. Our estimations give some figure around one euro per trip, which is in agreement with other estimations for similar systems (Midgley, 2012). This figure is similar to the operation costs of the city urban buses: 1.34 euros per trip in 2012 (TUSSAM, 2013). This cost is much higher for the single subway line in operation: 3.84 euros per trip in 2012 (Junta de Andalucía, personal communication). These data show the intrinsic high cost effectiveness of the public bike system.

III.- IMPACT ON CITY MOBILITY

III.1.- *Evolution of bicycle trips*

Data about the evolution of bicycle trips mainly come from the successive counts made along the cycle network in September 2006[4], July 2007, May 2008, November 2010, and November 2011 (Ayuntamiento de Sevilla 2006c, 2007b, 2008, 2010; SIBUS, 2012). They show a steady increase in the number of cyclist on each point of observation. Since these counts not always included the same number of observation points, we use the evolution of average number of cyclist per observation point (or *average bike traffic intensity*) as a first rough measure for the evolution of the bike use in Sevilla. These data are shown in the first row of Table III.

There is, however, a strong seasonality in the use of the bike, which can be clearly observed in the public bike sharing system statistics (Ayuntamiento de Sevilla, 2012). These statistics show a strong valley in August, between two strong peaks around May and October - November. Therefore, in order to have a better picture of the evolution of the bike traffic intensity, it is convenient to adjust the aforementioned crude data to the same month of each year. These adjusted data are shown in the second row of Table III, where the data of 2006, 2007 and 2008 are adjusted to November of each year by using the simple formula $Y = (P/Q)\cdot X$, where Y is the adjusted traffic intensity, X is the crude traffic intensity, and P/Q is the ratio between the average number of public bike rentals in a sunny business day of November 2011, and in a similar average day of the considered month of this year. 2011 is taken as a reference because in this year the total number of associates to the public bike sharing system was very stable (around 50,000).

[4] This count was made before the cycle network was done, and it may be seen as the starting point of the process.

Consecutive counts of cyclist on similar points along the cycle network can give a good picture of the evolution of the number of bicycle trips in the city, but does not give any indication on the absolute number of such trips. For this purpose we need some reliable data about the absolute number of trips, to be used as an starting point for the evaluation. Fortunately, the city bike sharing system provides records of the daily number of rentals of public bikes (Ayuntamiento de Sevilla, 2012, 2013b). In the 2011 count (SIBUS, 2012) the number of public bikes were counted at each observation point, and the percentage of such bikes over the total (28.77%) evaluated. Knowing this data, as well as the total number of trips made in public bikes during these days – 20,877 in average (Ayuntamiento de Sevilla, 2012) – the total number of bicycle trips can be estimated after a linear extrapolation. The final result was 72,565 trips in a typical business day of November 2011 (SIBUS, 2012). This figure matches quite well the number of potential everyday cyclists predicted by the Bike Masterplan (Ayuntamiento de Sevilla, 2007), which was 89.000. The total number of bicycle trips in 2011 can be estimated by using the same procedure, that is by dividing the total number of public bike rentals in 2011 by the measured percentage of use of public bikes (0.2877).

Starting from these results, it is possible to make an estimate of the number of bicycle trips in a typical business day (or in each year) along the period 2006-2009. This estimate is made by assuming that the absolute number of bicycle trips is proportional to the adjusted traffic intensity shown in Table III. The datum for the remaining year, 2010, is obtained by a spline interpolation. The results of such estimate are shown in Fig. 3. It shows an almost linear increase between 2006 and 2009, which was smoothened between 2009 and 2011. Other estimates can be found in the 2007 mobility poll, which give an estimate of 41,744 bicycle trips in November 2007 (CTMAS, 2007; cited in SIBUS, 2012), a 50% higher than our estimate; and in (Ayuntamiento de Sevilla, 2010) which gives an estimate of 52,800 bicycle trips in November 2009, a 11% lower than our estimate. These discrepancies can be expected from the very different methodologies used for the estimates. Therefore, the results in Fig. 3 for years different from 2011 must be taken as a rough, although consistent, estimation. In any case, whatever the correct estimates are, they show a high increase in urban cycling in parallel to the development of the cycle network, which had a strong impact on city mobility

III.2.- *Modal split*

Participation of bicycle trips in the modal split was evaluated in the last metropolitan mobility poll, made on November 2007 (CTMAS, 2007). From these data, and from the evolution of the trips made on the different modes of transport in the period 2007-2011, the modal split in 2009 and in 2011 was evaluated in (Ayuntamiento de Sevilla, 2010) and in (SIBUS, 2012), respectively. The results of these evaluations are shown in Table IV for all mechanical modes. If pedestrian trips are included in the analysis, the available estimates show an increase of bicycle trips from 3.2% in 2007 to 5.6% in 2011 (CTMAS, 2007, SIBUS, 2012). In order to properly interpret these results, it must be taken into account that the results for 2007 correspond to a period where the basic cycle network was almost finished and partially in operation (see Table II). The percentage of bicycle trips before the cycle network was built, was much less for sure, between 1% or 2%, as can be deduced from Fig. 3. Table III shows a 4% increase in the participation of public transport and a -11% fall in the participation of private cars in the City modal split (this is, however, non true for the metropolitan region, which show the opposite trend). This substantial decline of private car trips (-11%) can be partially motivated by the economical crisis, apart from specific traffic policies. The combined result of all these factors seem to have been a net transfer of trips from private cars to public transport and bicycle. However, without the described active policies for promoting bicycling, this last transfer would have not been possible, as the experience of the metropolitan region - where cycling remained stationary - shows.

The results of Fig. 3 and Table III show an impressive increase in cycling mobility. Which was the origin of the new bicycle trips? The available data (Ayuntamiento de Sevilla, 2010; SIBUS, 2012) show that new bicycle trips came from previous pedestrian trips 26-28%, public transport 37-40% and private motor vehicles 37-32%. However, the results of Table IV show that when all other transfers are taken into account, the result is a net increase in bicycle and public transport trips, and a net decrease in car trips. Regarding gender distribution, the different counts show an increase in female participation, from a 25% in 2006 (Ayuntamiento de Sevilla, 2006) to a 32% in 2011 (SIBUS, 2012). These figures are similar to other cities with similar percentages of bicycle trips (Garrard et al., 2012), and still far from cities with a longer tradition of everyday cycling, like Amsterdam or Copenhagen (Garrard et al., 2012).

IV.- OTHER IMPACTS

IV.1.- *Bicycle traffic safety*

One of the most important targets of any policy of bicycle promotion is to reduce the number and the seriousness of bicycle accidents. In order to evaluate the impact of the analyzed policies on traffic safety, we used the data coming from the Spanish Traffic Authority (*Dirección General de Tráfico, DGT).* The DGT develops since 1993 a very complete data base of all accidents happened in Spain, with indication of the place of the accident, involved vehicles, injuries and material damages, etc. Table V (SIBUS, 2013) shows the absolute number of bicycle accidents recorded in the city of Sevilla in the period 2002-2010, as well as the number of accidents per 100,000 bicycle trips (the estimates of Fig.3 are used for the annual number of trips). The Table shows an increase in the absolute number of accidents after 2006 (i.e. after the first cycle tracks became operative), probably as a consequence of the increase in the number of bicycle trips. However, as is shown in the column for the number of accidents per 100,000 trips, this relation is non-linear, in agreement with previous results (Jacobsen, 2003; Elvik, 2009). In fact, a dramatic reduction of about a 50% in the number of accidents per trip is observed after 2006, when the cycle network began to operate (since the number of accidents before 2006 is quite similar, and the number of trips should not be higher, we can assume that the number of accidents per trip before 2006 was similar or higher than in 2006). The dramatic step between 2006 and 2007 can be attributed to a reduction of risk associated to the presence of the cycle network. The presence of the network seem to have changed the way of cycling in the City towards a much safer schema.

The last column of Table V shows the number of cyclist killed or seriously injured (KSI) each year as a consequence of a traffic accident. In the period 2002-2005, a 10% of the cyclists involved in an accident were KSI, whereas in the period 2007-2010 this percent was a 6,3%. These data suggest that the cycle network also contributed to make cycling accidents less serious in average. More research will be necessary, however, before to reach a definite conclusion on this issue.

Let us now examine if there have been substantial changes in the typology of bicycle accidents as a consequence of the presence or not of the cycle network. Table VI shows the vehicles involved in bicycle traffic accidents. Between 2002 and 2005, 94% of all accidents were collisions with motor vehicles, whereas between 2007 and 2010, 78% of all accidents were consequence of such kind of collisions. Therefore, in both periods, most accidents were collisions with motor vehicles, which is also true for accidents with KSI cyclists. Therefore, although the presence of the cycle network reduced the percentage of accidents due to collisions with motor vehicles, this kind of accident still is, by far, the dominant one, and the most dangerous.

In summary, the available data show that the cycle network reduced the risk of cycling by a factor of two, and that collisions with motor vehicles are, by far, the dominant kind of accidents. Taking into account that all cycle paths are fully segregated from motorized traffic, our analysis implies that most accidents occur at the remaining friction points with ordinary traffic: intersections and streets without cycle paths. Therefore, traffic calming strategies, such as reduced speed or pedestrians and cyclists priority areas, appear as the next step towards safer cycling.

IV.2.- *Health, and environmental impacts*

Cycling is an inherently healthy activity whose benefits for public health usually outweigh their risks (de Hartog et al., 2010; Pucher et al., 2010). In (SIBUS, 2012) the Health Economic Assessment Tool (HEAT) for walking and cycling (WHO, 2011) was used for the estimation of the health benefits of the recent increase of cycling in Sevilla. With the percentages of substitution reported in Section III.2 and an estimate of the average distance for bicycle trips of 5.1 km (SIBUS, 2012), this analysis provides an estimate of 24.17 deaths avoided per year as a result of the increase of physical activity (SIBUS, 2012). This result is in qualitative agreement with the available estimations for other Spanish cities in the same period (Rojas-Rueda et al., 2011, 2012).

Savings in greenhouse emissions were also estimated (SIBUS, 2012) using the methodology recently developed by the European Cycling Federation (ECF, 2011), and the aforementioned percentages of substitution and average distance for bicycle trips. The result is an overall saving of 8,633.9 tons of CO_2 equivalent, corresponding to a fuel savings of 27,151 oil barrels (SIBUS, 2012). These fuel savings imply monetary savings associated to the reduction in fuel imports of around 2 million euros per year (SIBUS, 2012).

But probably the most important environmental impact was the change in the city landscape. The presence of a crowded continuous, and uniform network of cycle paths along the city changed the city landscape in a irreversible way. More research will be necessary on this topic in order to make a more precise evaluation of this impact, but it is clear that the impact of the cycle network in the city landscape has been enormous.

IV.3.- *Social impacts*

As a consequence of the increase in utilitarian cycling, cyclist evolved from a minority group to a emergent group, increasingly accepted and integrated in the city (Malpica, 2010). Regarding the impact of the cycle network itself, opinion polls show a sustained support from the population (Marques, 2011), who consider it necessary for the safety of cyclists (Ayuntamiento de Sevilla, 2007, Marques, 2011). However, some controversy arose about the elimination of thousands of parking places, as well as on the loss of space for pedestrians (Malpica, 2010, Marques, 2011). Loss of car parking places due to the construction of the cycle network can be evaluated around 8,000 places (Ayuntamiento de Sevilla, personal communication), which makes this controversy unavoidable. On the other hand, in spite of the fact that most bike paths were built on previous spaces in the carriageway (A Contramano, 2009; see also Fig. 2), the building of many bike paths at the same level as the sidewalks created the perception that most space for bike paths was taken from pedestrian aras. And, in spite of the fact that the increase in city cycling had not a big impact on the safety of pedestrians (see Table V), controversy about pedestrian loss of safety due to the presence of bicyclist near the sidewalks has been constant since 2006 (Malpica, 2010). More research on this issue will be necessary, but it is clear that a more unified approach to active mobility (pedestrians and bicyclists) would help to avoid these conflicts in the future.

The big increase in city cycling also had a clear impact on the local economy. Although more research is necessary to quantitatively evaluate this impact, it was apparent that many local industries, such as bike shops, retails, rentals and workshops, flourished surfing on this new wave of cycling. Tourism also take advantage of the city cycle network and the public bike sharing system, which changed the external image of the city (Lonely Planet, 2012; Reuters, 2012).

V.- SOME GOOD PRACTICES

In this section we will describe some new practices that were developed in parallel to the Bike Masterplan and helped to its success. These good practices could also help to further developments of the bike system of the city

V.1.- *University of Sevilla*

University of Sevilla groups around 70.000 people, including students, professors and administrative staff, which makes around a 10% of the total population of the city. Therefore the mobility policy of the University has a big impact on the city mobility. The University buildings are not concentrated in a single campus, but spread out along the city, many of them in the central areas, which is a quite common situation in many Mediterranean Cities.

Far before the cycle network was built (by the end of the 90's), the University was developing some initiatives aimed to promote cycling. Most important of them was providing parking facilities at all its buildings, including closed parking areas with restricted access, similar to those which are common in the main train stations in Denmark, Germany and the Netherlands (Martens, 2004; CROW, 2007). In 2011 there were closed parking areas at each university building, with 1,618 parking places, as well as 771 free bike parking places near the university buildings (SIBUS, 2011). When the public bike sharing system was operative, the University developed a program to promote the affiliation of its members to this system. The program was so successful that in November 2009, 30% of the total associates of the public bike system came from the University, which contributed to the the saturation of the system (Castillo-Manzano, 2012). The University reacted creating its own long term bike-lending system with 400 units (SIBUS, 2011), which are planned to increase in the near future. A research group and a web page – http://bicicletas.us.es – was created in order to disseminate all these initiatives. The combination of all these policies led to a participation between 11% and 14% of bicycle trips in the modal split of trips to and from the university buildings (Chávez de Diego, 2009; SIBUS, 2011), which more than doubled the participation of the bike in the city modal split (see Fig. 3).

V.2.- *Bus+Bici.*

Although intermodality with public transport was an important part of the the Bike Masterplan (Ayuntamiento de Sevilla, 2007), this determination was followed in a very uneven way, so that presently there is almost no specific infrastructure on the main bus, metro and train stations, except a few outdoor parkings and some public bike sharing system stations near the public transport stations. An exception is the suburban buses main station “Plaza de Armas”, where indoor bike parking facilities and a manual public bike-lending system are offered for free to all users of the station. The bike-lending system had, in October 2010, 172 bikes which are lent for a whole day maximum, after the signature of a short contract. The system is mainly intended to commuters, and operates everyday from Monday to Friday, from 7:30 to 24:00 hours. Bikes had an average rotation rate of about 1.5 uses per day, which gives an estimate of around 3-4 trips per bike and per day. Estimated cost per trip is around 0.75 euros, including capital and operation costs. Demand is very high, with a 65% of lends during the first two and a half hours of operation each day (CTMAS, 2010 and personal communications).

The aforementioned initiatives, developed in parallel to those of the Municipality, offer good examples of collaboration between different administrations in order to promote utilitarian cycling. Although they can be considered as exceptions in the present city context, they could pioneer future initiatives aimed to overcome some of the present bottlenecks for bike promotion (see next Section).

VI.- DISCUSSION AND CONCLUSIONS

“A simple and fundamental principle of economics is that consumption increases as goods become more attractive to the consumer. If transportation is viewed as consumable goods, then transportation infrastructure will partly determine its attractiveness to the potential user” (Pfleiderer and Dietrich, 1995). This effect of infrastructure-induced traffic is usually seen as a “negative” effect, due to the associated increase in air pollution, fuel consumption, traffic congestion, etc. However, this concept can be also applied to bicycle traffic: bicycle traffic infrastructure can make cycling attractive or even “irresistible” (Pucher and Buehler, 2008) and those “negative” consequences can be shifted to “positive” ones: reduced pollution, less fuel consumption, less traffic congestion, and so on... We feel that the experience of Sevilla is a good example of how this effect may work in a medium-sized Mediterranean City with no previous culture of utilitarian cycling.

Although it is not necessarily the only effective model, the infrastructure model of Sevilla has some characteristics that, in our opinion, helped to its success. The main idea behind the model was to make cycling not just safe, but also easy and comfortable for everybody. The philosophy was that making cycling easy and comfortable also will make it safe (Jacobsen, 2002, Pucher, 2010). And indeed our analysis confirms this expectation (see Table V and its discussion). A key issue to be taken into account regarding the aforementioned philosophy is that the infrastructure must be designed to fulfill the needs of everybody, not just the needs of “present” bicyclist, which was a minority group in 2006 (Malpica, 2010). In order to make cycling easy and comfortable for everybody, the infrastructure has to be segregated (from motorized traffic), coherent, continuous (i.e. without interruptions), visible, uniform and easy of recognize and interpret. In the case of Sevilla, it was a green strip flowing uniformly along the city, connecting without discontinuities the most important residential areas and trip attractors.

A last consideration regarding the micro-design of the infrastructure: Mono-directional cycle ways may not be very appropriate at the first steps of a cycling infrastructure, because in conditions of still low bicycle traffic they will very probably be used as bi-directional, which will later cause conflicts. The choice in Sevilla was to begin with a network of bi-directional cycle paths with the perspective of, once bicycle traffic will make them too narrow, transform each bi-directional cycle path into two Copenhagen-style mono-directional cycle paths, by simply building up a parallel cycle path on the other side of the street. This procedure has the advantage of saving space in the street at the moment of the construction of the infrastructure, which is often a key political issue.

Another key issue in order to help to the success of the infrastructure was quick building. Cities have “horror vacuum”, and unused infrastructures will be almost immediately used for other unexpected purposes. This effect is even more present in compact cities, like Mediterranean ones, where there are a high demand of space in the streets. On the other hand, what is useful is the whole infrastructure, not just a small part of it. Therefore if the infrastructure is built fearfully and slowly, very probably we will see how other activities, such as terraces or motorbike parking, flourish on the bike-paths, making them useless for cycling. However, if the whole infrastructure is fully operational few months after the civil works began, most probably many people will realize its usefulness and will use it soon.

Monetary costs is a factor that may act against quick building. However, as we already see in Section II.6, these costs are rather modest wit regard to other costs of the transportation system of any modern city, such as highways or subways. Investment in cycling infrastructure has big returns in terms of less capital and maintenance costs per trip. Moreover, smart public bike sharing systems imply similar or less operation costs that conventional public transport, provided they are properly integrated in the city cycling infrastructure (see Section II.6). Infrastructure for urban cycling also has big returns in terms of improved public health, improved traffic safety, reduced greenhouse gases emissions and reduced fuel imports (see Sections III and IV).

There are also social and political costs, although benefits – for instance for public health (see Section IV.2) – largely exceed them. As it was already pointed out in Section II.1, building the cycle network of Sevilla was controversial in some aspects (Malpica, 2010; Marques 2011). Integration and social acceptance of the cyclists in the city mobility system is not an easy process (Malpica, 2010), in spite of the high level of acceptance of the cycle network itself reflected in the opinion polls (Marques, 2011). Regarding these social aspects, we are probably faced to a much slower process, that will probably take much more time than building the infrastructure. Probably, only once this process will end the Town will achieve levels of cycling comparable to those of some Northern European Cities. However, it is undeniable that building the infrastructure played a crucial role as the starting point of this process.

Closely related to this process of social acceptance is a key aspect of the development of the cycling infrastructure: parking. Like any other vehicle, bicycles need of parking infrastructure. Developing indoor parking facilities at the origin (residences) and at the destination of bicycle trips (educational centers, workplaces, shops...) is an essential part of this infrastructure (CROW, 2007, Pucher and Buehler 2008). These parking facilities, however, need for its effective development of the collaboration of many people and institutions, which will be only possible in an environment of public acceptance of bicycling as a part of "normal" everyday mobility. In spite of some interesting good practices (see Section V), this kind of infrastructure is far from being fully developed in Sevilla.

Also closely related with the social acceptance of cycling as a part of everyday city mobility is the integration of bicyclists in the city traffic, beyond the cycle network. This integration, which has much to deal with traffic calming policies, is also far from being fully developed in Sevilla. Same thing happens with intermodal connections between bike and public transport, which in spite of some good practices (see Section V.2), are still far from the achievements of other cities in northern and central Europe (Martens, 2004). Moreover, the experience of Sevilla is still an isolated experience, with no similar experiences in other neighboring cities, nor even in its own Metropolitan Area. The Regional Government of Andalucía is now reacting to this situation by the elaboration of a regional bike masterplan, which will include as a central issue intermodality between bicycles and public transportation (Junta de Andalucía, 2013).

In summary, the experience of Sevilla during the period 2006-2010 shows that the fast development of a segregated cycling infrastructure can be a powerful first step towards the integration of bicycling as an important part of urban mobility, also in cities with no previous culture of everyday cycling. Making cycling not just safe, but also easy and comfortable for everybody is a very appropriate guiding philosophy for the design of such infrastructure. But, of course, this first step should be followed by other measures aimed to the social and structural integration of cycling, including traffic calming in central and residential areas, indoor parking areas et the origin and destination of bicycle trips, intermodal facilities, promotion campaigns, etc.

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REFERENCES:

(A Contramano, 2009) A Contramano *¿Quitó el carril-bici espacio al peatón? Informe sobre el trazado de la vía ciclista sobre la Ronda Histórica de Sevilla* http://www.acontramano.org/index.php?option=com_joomdoc&task=document.download&path=acontramano%2Fsevilla%2Fiquito-el-carril-bici-espacio-al-peaton&Itemid=62 (accessed 07/25/2013).

(Anaya and Castro, 2011) Anaya, E. and Castro A. (2011) Balance General de la Bicicleta Pública en España (Power Point presentation) *3as Jornadas de la Bicicleta Pública*, Santander (Spain) http://www.bicicletapublica.org/pdf3/1-EsterAnaya-AlbertoCastro.pdf (accessed 07/26/2013).

(Ayuntamiento de Sevilla, 2005) Ayuntamiento de Sevilla (2005) *Bases y Estrategias para la integración de la bicicleta en la Movilidad Urbana de Sevilla* (2005) Sevilla. (2005) Gerencia de Urbanismo, Ayuntamiento de Sevilla.

(Ayuntamiento de Sevilla, 2006) Ayuntamiento de Sevilla (2006) *Plan General de Ordenación Urbana (Plan de Sevilla)* http://www.sevilla.org/plandesevilla/adef/contenido.html (accessed 07/26/2013).

(Ayuntamiento de Sevilla, 2006b) Ayuntamiento de Sevilla (2006) *Vías ciclistas de Sevilla, dotaciones, equipamientos y espacios libres.* (2006) Gerencia de Urbanismo, Ayuntamiento de Sevilla.

(Ayuntamiento de Sevilla, 2006c) Ayuntamiento de Sevilla (2006) *Desplazamientos en Bicicleta, conteos en 24 puntos de observación* (2006) Gerencia de Urbanismo, Ayuntamiento de Sevilla..

(Ayuntamiento de Sevilla, 2007) Ayuntamiento de Sevilla (2007) *Plan de la Bicicleta de Sevilla 2007-2010*. Sevilla http://www.sevilla.org/sevillaenbici/plandirector/PlanBiciSevilla.html (accessed 07/26/2013).

(Ayuntamiento de Sevilla, 2007b) Ayuntamiento de Sevilla (2007) *Cuantificacion de bicicletas en los itinerarios de la nueva red de vias ciclistas de Sevilla. Julio 2007.* (2007) Gerencia de Urbanismo, Ayuntamiento de Sevilla.

(Ayuntamiento de Sevilla, 2008) Ayuntamiento de Sevilla (2008) D*esplazamientos en bicicleta en la red de vias ciclistas de sevilla. Conteo en 42 puntos de observación. Mayo 2008.*(2008) Gerencia de Urbanismo, Ayuntamiento de Sevilla.

(Ayuntamiento de Sevilla, 2010) Ayuntamiento de Sevilla (2010) *Estudio sobre el uso de la bicicleta en la ciudad de Sevilla (noviembre de 2009).* (2010) Gerencia de Urbanismo, Ayuntamiento de Sevilla.

(Ayuntamiento de Sevilla, 2012) Ayuntamiento de Sevilla (2012) *Evaluación Sevici año*

2011.http://www.sevilla.org/sevillaenbici/contenidos/1-enbici/SEVICI-Balance2011.pdf (accessed 07/28/2013)

(Ayuntamiento de Sevilla, 2013) Ayuntamiento de Sevilla (2013) *Tipología de las Vías Ciclistas* (2013) http://www.sevilla.org/sevillaenbici/Pdf/tipologia_vias_ciclistas.pdf (accessed 07/28/2013).

(Ayuntamiento de Sevilla, 2013b) Ayuntamiento de Sevilla (2013) *Evaluación Sevici año 2012* (2013) http://www.sevilla.org/sevillaenbici/contenidos/1-enbici/SEVICI-Balance2012.pdf (accessed 07/27/2013).

(Bike Sharing World Map, 2013) The Bike Sharing World Map: https://maps.google.com/maps/ms?ie=UTF8&oe=UTF8&msa=0&msid=214135271590990954041.00043d80f9456b3416ced (accessed 07/28/2013)

(de Boom et al, 2001) de Boom, A. Walker, R and Goldup R. (2001) Shanghai: The greatest cycling city in the world? *World Transport Policy & Practice*, 7, 53-59.

(Castillo-Manzano and Sanchez-Braza, 2013) Castillo-Manzano, J.I. and Sanchez-Braza A. Managing a smart bicycle system when demand outstrips supply: the case of the university community in Seville *Transportation*, 40, 459–477.

(Chávez de Diego, 2009) Chávez de Diego, M.J., González-Herrera, A. Navas-Jiménez, A. and Revuelta-Marchena, M.P. (2009) *Estudio de movilidad en los Campus Universitarios de Reina Mercedes y Ramón y Cajal* (2007) Universidad de Sevilla http://bicicletas.us.es/wp-content/uploads/2010/10/INFORME-ESTUDIO-MOVILIDAD-US.pdf (accessed 07/28/2013)

(ConBici, 2007) ConBici (2007) *Estudio comparado de la situación de la bicicleta como medio de transporte en 30 municipios españoles* (2007) ConBici http://www.conbici.org/joomla/ciudades/estudiocompleto30ciudades.pdf (accessed 07/28/2013)

(CROW, 2007) CROW (2007) *Design manual for bicycle traffic* (2007) CROW. The Netherlands.

(CTMAS, 2007) Consorcio de Transporte Metropolitano del Área de Sevilla (2007) *Encuesta Domiciliaria de Movilidad 2007*. A short summary has been published in *Billete Único*, (2008), 20, 6-10. http://www.consorciotransportes-sevilla.com/comunicaciones/billeteunico/pdf/numero20.pdf (accessed 07/28/2013).

(CTMAS, 2010) Consorcio de Transporte Metropolitano del Área de Sevilla (2010) *Bus+Bici: Encuesta a usuarios 2010*. http://www.consorciotransportes-sevilla.com/proyectos/busbici/pdf/encuesta_busbici_2010.pdf (accessed 07/28/2013).

(Danish Cycling Embassy, 2012) Danish Cycling Embassy (2012) *Collection of Cycle Concepts 2012*. http://www.cycling-embassy.dk/2012/05/10/cycle-concepts2012/ (accessed 07/28/2013)

(ECF, 2011) European Cyclists' Federation (2011) *Cycle more often 2 cool down the planet! Quantifying CO2 savings of Cycling* http://www.ecf.com/wp-content/uploads/ECF_CO2_WEB.pdf (accessed 05/07/2012)

(ECMT, 2004) European Conference of Ministers of Transport (2004) *National policies to promote cycling*. ISBN 92-821-2325-1.

(Elvik, 2009) Elvik, R. (2009) The non-linearity of risk and the promotion of environmentally sustainable transport *Accident Analysis & Prevention*, 41, 849–855.

(Garrard et al., 2012) Garrard, J., Handy, S. and Dill, J. (2012) Women and Cycling *City Cycling* eds J. Pucher and R. Buehler, pp 209-234. MIT Press, Cambridge MA.

(German Federal Ministry of Transport, 2010) German Federal Ministry of Transport, Building and Urban Development (2010) *Cycling Expertise: Bicycle Use Trends in Germany* http://www.nationaler-radverkehrsplan.de/en/transferstelle/downloads/cye-a-01.pdf (accessed 07/24/2013)

(de Hartog et al., 2010) de Hartog, J.J. Boogaard, H. Nijland, H. and Hoek, G. (2010) Do the Health Benefits of Cycling Outweigh the Risks? *Environmental Health Perspectives*, 118, 1109-1116.

(Hook and Replogle, 1996) Hook, W. and Replogle, M. (1996) Motorization and non-motorized transport in Asia: Transport system evolution in China, Japan and Indonesia *Land Use Policy*, 13, 69–84.

(Jacobsen, 2003) Jacobsen P.L. (2003) Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention*, 9, 205–209.

(Junta de Andalucía, 2013) Junta de Andalucía (2013) Plan Andaluz de la Bicicleta (Avance) http://www.juntadeandalucia.es/fomentoyvivienda/portal-web/web/areas/transportes/plan_bici/texto/d461cdc3-87f6-11e2-a061-11e1170c2905 (accessed 07/28/2013).

(Lonely Planet, 2012) Lonely Planet (2012) *Seville Goes Green* http://www.lonelyplanet.com/spain/seville/travel-tips-and-articles/76948 (accessed 07/25/2013)

(de Maio, 2009) de Maio, P. (2009) Bike-sharing: History, Impacts, Models of Provision, and Future *J. of Public Transportation*, 12, 41-56.

(Malpica, 2010) Malpica, P. (2010) Los ciclistas en Sevilla como nuevo grupo urbano emergente *X Congreso Español de Sociología*. 2010 Pamplona (Navarra, Spain) http://www.fes-web.org/uploads/files/modules/congress/10/grupos-trabajo/ponencias/506.pdf (accessed 07/25/2013)

(Martens, 2004) Martens, K. (2004) The bicycle as a feedering mode: experiences from three European countries *Transportation Research Part D*, 9, 281–294 .

(Marques, 2011) Marques, R. (2011) Sevilla: una experiencia exitosa de promoción de la movilidad en bicicleta en el Sur de Europa. *Hábitat y Sociedad*, 3, 107-130. <www.habitatysociedad.us.es>.

(Marques et al., 2012) Marques, R. Hernandez-Herrador, V. Calvo-Salazar, M. Garcia Cebrian, J.A. *Sevilla: a successful experience of promotion of urban cycling in the south of Europe* Power Point presentation at Velo-City Global, 2012. Vancouver http://www.ecf.com/wp-content/uploads/Hernandes-V_-et-al-Sevilla-A-Successful-Experience-of-Promotion-of-Urban-Cycling.pdf (accessed 07/25/2013).

(Midgley, 2011) Midgley P. *Bicycle-sharing schemes: Enhancing sustainable mobility in urban areas* United Nations, Dept. of Economic and Social Affairs. Background Paper No. 8. CSD19/2011/BP8 http://www.un.org/esa/dsd/resources/res_pdfs/csd-19/Background-Paper8-P.Midgley-Bicycle.pdf (Accesed 07/27/2013)

(Montezuma, 2005) Montezuma, R. (2005). The transformation of Bogota, Colombia, 1995–2000: Investing in citizenship and urban mobility. *Global Urban Dev.* 1, 1–10.

(Morales, 2011) Morales, L. (2011) La movilidad ciclista como factor de sostenibilidad: breve análisis de su emergencia en la ciudad de Sevilla. *Hábitat y sociedad*, 2, 109-130. <www.habitatysociedad.us.es>.

(Muñoz, 2010) Muñoz, J.D. El modelo de infraestructura ciclista de Sevilla (Elementos para una nueva movilidad en bicicleta, Power Point presentation) *8º Congreso Ibérico la Bicicleta y la Ciudad*, Sevilla (Spain) http://www.acontramano.org/congreso/Presentaciones_Congreso.zip (accessed 07/28/2013).

(OCU, 2013) Organización de Consumidores y Usuarios (2013) *Estudio de las condiciones de circulación ciclista en 11 ciudades españolas*. A summary will be published in *OCU Compra Maestra*, 384, <http://www.ocu.org/publicaciones/ocu-compra-maestra>, to appear.

(Pfleiderer and Dietrich, 1995) Pfleiderer, R.H.H. and Dietrich M. (1995) New roads generate new traffic *World Transport Policy & Practice*, 1, 29-31.

(Pucher and Buehler, 2008) Pucher, J and Buehler, R (2008) Making Cycling Irresistible: Lessons from the Netherlands, Denmark, and Germany ” Transport Reviews, 28 (2008) 495-528.

(Pucher et al., 2010) Pucher, J. Dill, J. and Handy, S. (2010) Infrastructure, programs, and policies to increase bicycling: An international review *Preventive Medicine*, 50, S106–S125.

(Pucher et al., 2011) Pucher J., Buehler R. and Seinen M. (2011) Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. *Transportation Research Part A*, 45, 451–475.

(Pucher and Buehler, 2012) Pucher, J. and Buehler, R. (2012) Big City Cycling in Europe, North America and Australia *City Cycling* eds J. Pucher and R. Buehler, pp 287-318. MIT Press, Cambridge MA.

(Pucher et al., 2012) Pucher, J. Lanversin, E. Suzuki, T. and Whitelegg, J. (2012) Cycling in Megacities: London, Paris, New York and Tokyo *City Cycling* eds J. Pucher and R. Buehler, pp 319-345. MIT Press, Cambridge MA.

(Reuters, 2012) Reuters (2012) *Top 10 cycling destinations* (2012) http://www.reuters.com/article/2012/05/11/uk-travel-picks-cycling-idUSLNE84A01Q20120511 (accessed 07/25/2013).

(Ride the city, 2013) Ride the city Sevilla http://es.ridethecity.com/sevilla# (accessed 07/28/2013).

(Rojas-Rueda et al., 2011) Rojas-Rueda, D. de Nazelle, A. Tainio, M. and Nieuwenhuijsen, M.J. (2011) The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *British Medical Journal*, 343, d4521 .

(Rojas-Rueda et al., 2012) Rojas-Rueda, D. de Nazelle, A. Teixidó, O. and Nieuwenhuijsen, M.J. (2012) Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study *Environment International*, 49, 100–109.

(SIBUS, 2011) Sistema Integral de la Bicicleta de la Universidad de Sevilla (2011) *La bicicleta en la Universidad de Sevilla (curso 2010–2011)* https://www.dropbox.com/s/vrqi35pdsuo73nu/SIBUS%20informe%202010-2011.pdf?dl=1 (accessed 07/25/2013).

(SIBUS, 2012) Sistema Integral de la Bicicleta de la Universidad de Sevilla (2012) *Estudio sobre el uso de la bicicleta en Sevilla*, *2011* (2012) http://bicicletas.us.es/Sevilla2011.pdf (accessed 07/28/2013).

(SIBUS, 2013) Sistema Integral de la Bicicleta de la Universidad de Sevilla (2013) *Efecto del carril-bici sobre la accidentabilidad ciclista en Sevilla* http://bicicletas.us.es/?p=4215#more-4215 (accessed 07/28/2013).

(TUSSAM, 2013) Transportes Urbanos de Sevilla S.A.M. (2013) *Memoria annual 2012*. http://www.tussam.es/fileadmin/uploads/pdf/Memorias/MEMORIA_2012/TUSSAM_-_MEMORIA_ANUAL_2012_web_BAJA.pdf (accessed 07/28/2013).

(WHO, 2011) World Health Organization, Regional Office for Europe (2011) *Health economic assessment tools (HEAT) for walking and for cycling*. http://www.heatwalkingcycling.org/ (accessed 5/07/2012).

FIGURES AND TABLES

City masterplan	Strategies for bike integration	Bike masterplan
- Introduces the concept of a bike-network in the City - Defines the “theoretical network” of bike paths - Establishes segregation from motorized traffic	- Makes a proposal for a basic network of bike-paths - Makes a first proposal about the execution period of the works (less than 4 years) - Makes a proposal of parking program - Makes a first detailed proposal of bike-path typologies along the network.	- Develops a research on the potential of cycling - Defines the basic network (76 km) - Defines the basic constructive criteria for the bike-paths. - Defines the strategy for the historical center - Analyzes intermodality with public transportation - Defines the bike parking policy - Defines the main criteria for the public bike sharing system - Defines other policies to promote cycling - Creates a Bicycle Planing Department - Makes a proposals of bicycle traffic regulation

Table I: Content of the main strategic planning documents. Source: Compiled by authors.

Figure 1: Evolution of the cycle network between 2006 and 2010. Solid lines show the basic network (76 km), while dashed lines show the complementary network - up to 120 km. Source: Compied by authors from data of (Ayuntamiento de Sevilla, 2007) and (Muñoz, 2010). Further developments of the network can be found in (Ayuntamiento de Sevilla, 2013).

Figure 2: Before (left) and after (right) illustration of a typical bike path design. Source: (A Contramano, 2009)

Period	Action	Budget
2004-2006	Elaboraton of the projects for basic the cycle network	
Aug. 2006 – Dec. 2007	Public works for the basic cycle network (76 km)	18 Million €
July – Nov. 2008	Elaboration of the projects for the complementary cycle network	
June 2009 – June 2010	Public works for the complementary cycle network (up to 120 km)	12 Million €
Oct. 2009 - Feb. 2010	Elaboration of a project for the improvement of the cycle network at some conflictive points	
Sept. 2010 – June 2011	Public works for the improvement of the cycle network	2 Million €

Table II: Chronology and budget of the different phases of the development of the cycle network from 2006 to 2011. Source: (Muñoz, 2010)

Year	2006	2007	2008	2009	2011
Crude	330	532	1057	1587	1935
Adjusted	348	735	1054	1587	1935

Table III: Average traffic intensity for the different counts of cyclists from 2006 to 2011. Crude row correspond to actual counts. Adjusted row show the data adjusted to the month of November of each year. Source: Compiled by authors from data of (Ayuntamiento de Sevilla 2006c, 2007b, 2008, 2010, 2012) and (SIBUS, 2012).

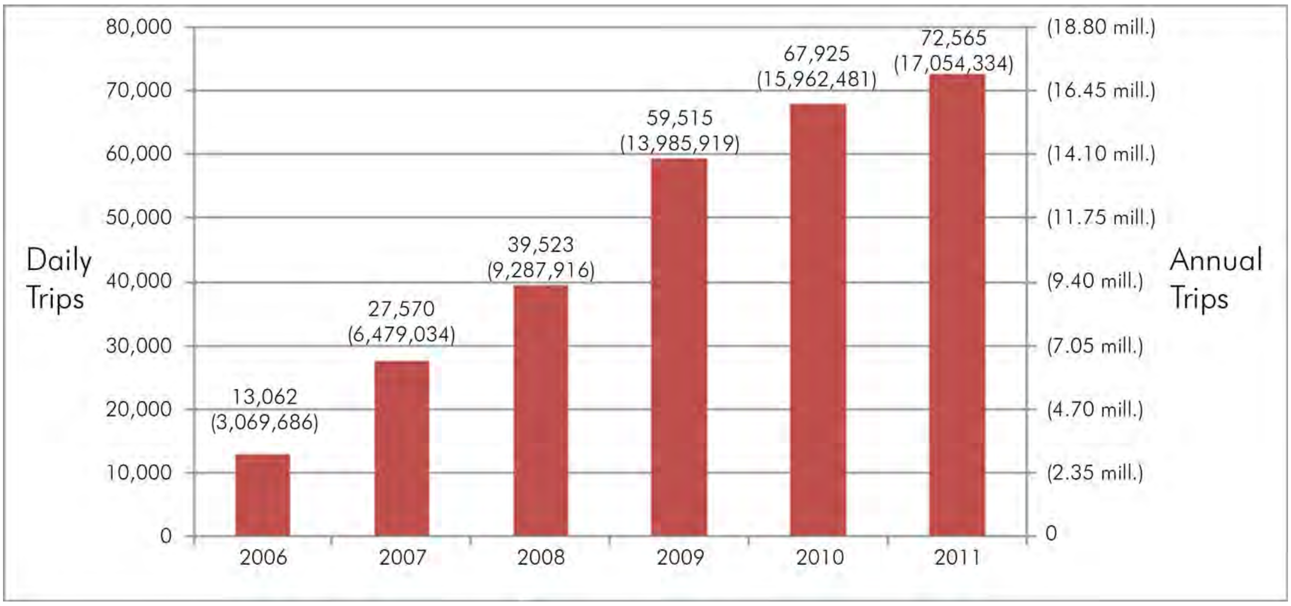

Figure 3: Estimations for the total number of bicycle trips in a typical business day of November, and for the total number of bicycle trips per year. Source: Compiled by authors from data of (Ayuntamiento de Sevilla 2006c, 2007b, 2008, 2010) and (SIBUS, 2012).

Mode	November 2007	November 2009	November 2011
Bicycle	**5.0%**	**6,6%**	**8.9%**
Public transportation	30.7%	32.5%	34.8%
Motorbike	7.1%	8.1%	8.0%
Car	57.1%	52.8%	48.3%

Table IV: Evolution of the modal split of mechanical trips in the city of Sevilla in a typical business day. Regarding trips by foot, see the text. Sources: (CTMAS, 2007), (Ayuntamiento de Sevilla, 2010), and (SIBUS, 2012).

Year	Total number of accidents	Accidents per each 100,000 trips	Killed or seriously injured (KSI) cyclists
2002	53	--	8
2003	59	--	7
2004	57	--	5
2005	42	--	1
2006	56	1.824	4
2007	56	0.846	3
2008	86	0.926	10
2009	146	1.004	11
2010	138	0.865	3

Table V: Total number of bicycle accidents and number of bicycle accidents per each 100,000 bicycle trips from 2002 to 2010. Last column shows the total number of KSI cyclists (serious injuries are defined as those resulting in a person being detained in hospital as an in-patient for more than 24 hours). Source: Compiled by authors (SIBUS, 2013) from data of *Dirección General de Tráfico* (Spain).

Year	Motorized vehicle	Bicycle	Pedestrian	No vehicle
2002	50	0	2	1
2003	58	0	1	0
2004	54	0	0	3
2005	36	0	1	5
2006	44	0	7	5
2007	41	0	2	13
2008	68	3	4	8
2009	116	6	9	8
2010	106	4	12	10

Table VI: Typology of bicycle accidents from 2002 to 2010. Accidents are classified as collisions with motorized vehicles, bicycles, pedestrians, and other accidents with no other vehicles involved. Source: Compiled by authors from data of *Dirección General de Tráfico* (Spain).