International Journal of Production Management and Engineering

https://doi.org/10.4995/ijpme.2020.10834
Received: 2018-10-18 Accepted: 2020-01-04

Development of a biking index for measuring Mediterranean cities mobility

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Abstract: The European Union, its member states and local authorities have been working for long time on the design of solutions for future sustainable mobility. The promotion of a sustainable and affordable urban transport contemplates the bicycle as a mean of transport. The reasons for analysing the cycling mobility in urban areas, has its origin in the confrontation with motorized vehicles, as a sustainable response to the environment. In this context of sustainable mobility, the research team has studied the use of bicycles in Mediterranean cities, specifically in coastal tourist areas. The present work shows the development of a mobility index oriented to the bicycle, transport that competes with the private vehicle. By means of a survey methodology, the research group proceeded to collect field data and the subsequent analysis of them, for the development of a mobility index adapted to bicycle mobility, and with possibilities to adapt to urban environments.

Key words: urban mobility; sustainable mobility; bicycle in cities; biking index.

1. Introduction

Mobility is crucial for the socioeconomic growth of urban areas; its positive effects must be confronted with the negative effects that this growth of mobility has brought during the last 30 years. In this sense, the constant increase of motorization indices in cities and countries annul any argument that seeks to minimize their use (Goldman & Gorham, 2006; Holden, 2007). Likewise, the difficulty of parking in the urban area along with traffic congestion reduces the efficiency of private cars, equaling in this aspect to the public transport. In addition, the environmental costs (noise, pollution, etc.) of its use begin to affect the conscience of many drivers.

For this reason, the EU, its member states and local authorities have been working for some time on the design of solutions for future sustainable mobility (Akerman et al., 2000; Banister, 2008; EU Commision, 2013). The promotion of a sustainable and affordable urban transport contemplates the transport of the bicycle (DGPI, 2010; EU Commision, 2013). In this context of sustainable mobility, the research team has studied the use of bicycles in a Mediterranean city, both in the urban centre and in the touristic seaside area. The reasons for analysing

To cite this article: Ros-McDonnell, L., de-la-Fuente, M.V., Ros-McDonnell, D., Cardós, M. (2020). Development of a biking index for measuring Mediterranean cities mobility. *International Journal of Production Management and Engineering, 8*(1), 21-29. https://doi.org/10.4995/ijpme.2020.10834

the cycling mobility in urban areas, has its origin in the confrontation with motorized vehicles, as a sustainable response to the environment.

The needs of the roadways for motorized vehicles have been widely studied (e.g. Nijkamp et al., 1996), the vehicles that circulate through each street have been counted (e.g. Muñuzuri et al., 2000; Ros et al. 2018) , the waiting times at the traffic lights have been analysed, the width of the roadway is being worked on, speeds and other variables (Rodriguez & Alonzo, 2005), in such a way that it allows to evaluate the road network and act in the points where it is required, but this analysis of the road system does not take into account other forms of mobility such as the bicycle, as much as urban planners arrive to work with certain design parameters that work better or worse, without stopping to analyse in any case, the reasons of the users of bicycles to choose some streets or others, urban networks or others, affecting other urban mobility systems.

2. Cycling mobility in urban areas

There are many ways to consider urban mobility. In the majority of European countries, mobility discussions focus on promoting the shift from motorized to non-motorized vehicles for short trips or to promote walking or cycling as a healthy leisure activity (DGPI, 2010; EU Commission, 2013).

The bicycle is a flexible means of transport for urban and interurban trips, as well as other uses (sport, leisure, tourism). In addition, it does not pollute, it is silent, fast in small and medium distances, economical, easy to use and beneficial for health, economy and the improvement of environmental quality.

Therefore, the creation of a framework that allows the increase of cycling in its different aspects (sports, recreational, daily transport) making it more secure and properly combined with public transport systems, could ensure citizens mobility and accessibility easier (ECF, 2017).

No wonder and worldwide, more than 1000 million people use this method on their daily journeys, and around 30% of the European population uses it regularly, but 73% consider that the bicycle should enjoy preferential treatment in front of the automobile (Sanz, 1997; Miralles & Cebollada, 2003; Santos & Rivas, 2008; DGPI, 2010; GEOSP, 2017).

This European development, promoted since the 70s and 80s, has been due to several factors:

- Agreement between the different political groups or leaving the bicycle outside political controversy, and promoting its use as a means of transport.
- Support to biking user groups, and stable and permanent participation with associations, companies and public administrations related to mobility in the city.
- Take advantage of the capital of technical knowledge and people who have been promoting favorable changes for sustainable mobility and the use of bicycles as a means of transport.
- Promotion of the process of changing infrastructures, the necessary services and of changing the culture and mobility habits of the population.
- Planning process of temporary actions, integrating the bicycle into the general mobility plans and the urban planning of the city.

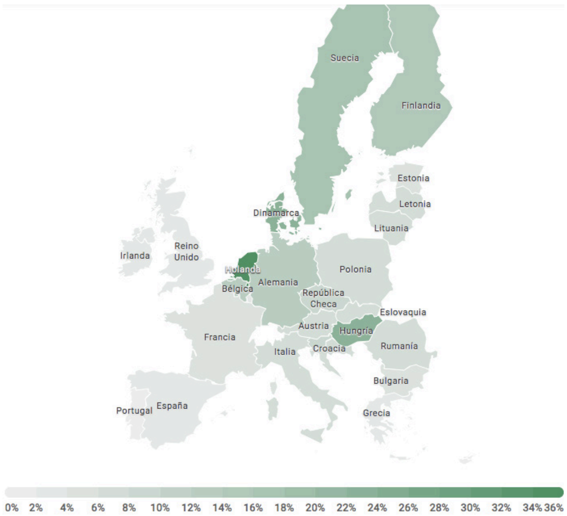

Figure 1. Use of the bicycle in Europe (Eurobarometer, 2014).

As a result of these actions, and according to Eurobarometer (2014), more and more Europeans are using the bicycle as a means of transport in everyday life, although the preferred transport continues to be the car. The European average of the use of bicycle in its daily mobility is 8%. But Spain has not yet reached those levels, its percentage is 3%. Far are countries like Holland, with 36%; Denmark, with 23%; Hungary, with 22%; Sweden, which meets 17%; Finland, 14%; and Belgium, 13%.

Besides that, according to the Barometro de la Bicicleta 2017 (GEOSP, 2017) made by the Spanish Network of Cities for the Bicycle, in Spain there has been an increase in its use and the intensity with which it is used with respect to previous years (2011 and 2014). The main results of this barometer (GEOSP, 2017) are:

- Half of Spanish population are bicycle users with some frequency, and 10% use it every day. A quarter of the users who work or study use the bike as a means of transport to go to their jobs or the study centers.
- The use given in large municipalities and small is different, since in large cities people use it more to go to work or to their study center, while in towns, especially in the smaller ones, its use is for short trips or sports.

There is still a long way to reach the European levels of daily bicycle use.

But what are the reasons why the bicycle is not used in Spain?

- The main reason, according to Barometer 2017, is because they do not want or do not need them. In this motive they fit some like: It does not have bicycle, it prefers to walk or the car, lack of time or, simply, that it does not like.
- Because they can not use the bike, either due to health problems, age, lack of physical shape or because the orography does not allow to use it.
- Due to lack of facilities: afraid, the municipality is not adapted for the use of the bicycle, that there is a lot of traffic, or it has no place to store it.

In Spain, the social potential of the bicycle is greater than imagined. Around 66% of the population is in favour of alternative mobility policies to those that have been granting hegemony to the automobile (Miralles & Cebollada, 2003; Santos & Rivas, 2008; GEOSP, 2017). The bicycle represents a more than valid means of transport to promote sustainable mobility and reduce the daily conflicts of urban traffic. Annually, the DGT publishes the report of the Annual Barometer of the Bicycle in Spain. These reports reflect an increase of 0.53% of cyclists per year, reflecting a positive image of cycling, both as a vehicle and as a healthy leisure offer, as well as the main advantages of its use and the reasons for its non-use in the city (GEOSP, 2017).

Table 1. Modal share of bicycle, on total trips, in Spanish cities (GEOSP, 2107).

Sevilla	6%
Zaragoza	3%
Vitoria	2-3%
San Sebastian	2-3%
Sabadell	2%
Lerida	2%
Barcelona	1.33%
Madrid	0.3%
Granada	0.25%
Malaga	0.2%

Intermodality, as reflected in table 1, is a pending issue in most Spanish cities. Taking into account the bicycle in relation to other transport (bus, tram, subway, car, etc.) is a proof of the structural integration of the bicycle in urban planning and mobility.

3. Proposal of a biking index

The objective of this work is to study the citizens' mobility using means such as cycling in Mediterranean cities, considering:

- The importance of the mobility of citizens in their immediate surroundings.
- Obtain an index that could be used by local authorities.
- Help city planning by understanding the conditions of biking mobility compared to other cities or urban areas.
- Assist city planning by identifying useful aspects for biking mobility as well as future recommendations.

Next section will show a brief summary of existing bikeability indexes, as well as the work developed by the research team.

3.1. Measuring Bikeability: literature review

The development of bikeability indexes during the last decade has shown that cycling has received less attention than walking in the scientific literature.

Different cycling measures began in order to improving citizens health and public health aspects, but now its also focus is on neighborhoods and city planning and design. A growing body of research has explored how the built environment influences physical activity, with findings that people who live in more walkable neighbourhoods walk more, have lower rates of obesity and chronic disease, and travel less by car (Ewing et al., 2003 & 2006; Pucher & Dijkstra, 2003; Forsyth et al, 2007; Flowerdew et al., 2008; Dill, 2009; Frank et al., 2009).

The existing focus on walking is justifiable given that it is the most common form of leisure-time physical activity, with few barriers and no cost. However bicycle travel, being faster and more efficient while nearly as accessible and economical, is a more reasonable substitute for automobile travel when trip distances exceed 1 km (European Commission, 1999). In this sense, cycling is not only an underused transportation mode in developed countries. The utility of cycling for transportation has been recognized in model cities such as Copenhagen and Amsterdam, and but EU and American countries want to promote a shift to active transportation for trips of moderate distance, beyond distances suitable to walking.

Among the variety of indexes to measure active accessibility, Bike Score® stands out, developed by Winters et al. (2013, 2016), which combines environmental characteristics with between and within-city variability in cycling behavior, and based on the concepts of infrastructure, safety, topography and climatology. Its peculiarity resides in that it has been exclusively developed for North American cities, clearly different from European cities.

Krenn et al. (2015) propose a new bikeability index developed for mid-sized European cities and based on GIS, that seeks to measure the bicyclefriendliness, based on infrastructure, green areas and topography. For the calculation of this index they define 200m cell buffers, but it presents severe limitations in the update of the digital maps.

An international index, the Copenhagenize Index (2011), gives cities points for their efforts towards reestablishing the bicycle as a feasible, accepted and practical form of transport. The authors consider three parameters (streetscape, culture and ambition) that cover different factors of the city and the bicycle: infrastructures, facilities, traffic calmimg, safety, modal share, politics, urban planning, etc.

Developed since 2011, the Copenhagenize index aims to point out the most important bicycle-friendly cities. Although it only considers capital nations and cities with more than 600,000 inhabitants, not facilitating the calculation of the index to small cities.

It should not be forgotten indexes specifically designed for cities and regions. In this sense, it is important to note the study conducted by Har-tanto et al. (2017), in a Dutch city region, mea-suring bikeability in a TOD context, with the objective of consolidating and facilitating combined means of transport, especially bicycle-train, the most common combination of travel for work in the Netherlands.

In another study, Mesa & Barajas (2013) developed the Bikeability Index for Cali city in Mexico. This biking index is based on four factors (slope, environmental quality, quality of infrastructure and personal safety), and was used to evaluate connectivity between major zones that generate and attract cycling trips, in order to show that the potential impacts of proposed cycling investments are in areas with low bikeability.

Finally, to point out a recent Spanish study conducted for a Mediterranean city (Sanchez, 2016), but that only contemplates the infrastructure of the bike lane, and avoiding factors such as environment, traffic conditions, or personal safety.

As a summary of the literature review made for this work, note that most authors who have studied this topic have developed their indexes based on the two groups of variables next described. Some factors will encourage bicycle ridership: safer bicycle routes, better lighting, etc., while some factors were identified as obstacles to cycling: inclement weather, reduced bicycle security, crime, fear about personal safety and lack of bicycle lanes (Botma, 1995; Hydén et al., 1998; Bulkeley & Betsill, 2005; Jensen, 2007; Marqués et al., 2015; Vale et al., 2016; Winters et al., 2016; Gutierrez et al., 2017; Hartanto et al., 2017).

The proposal of a new index for Mediterranean cities, is carried out because most existing indexes obviate the size and characteristics of the city, focusing on the possibility of moving around the city between traffic but do not contemplate studying small cities, and as Lowry et al. (2012) propose, this new index wants to assess existing infrastructures, identify the problematic sections, inform against the high non-connectivity level of the bicycle network, and how to enhance biking mobility, and not only for leisure and sports.

3.2. Defining a biking index in a Mediterranean city

The present work shows the development of a mobility index oriented to the bicycle, transport that competes with the private vehicle, especially for mediterranean cities, coastal and flat cities, with a strong tourist component throughout the year due to its good weather, and with compact urban centers and narrow streets.

According to the study of Krambeck (2006), and by means of a survey methodology, the research group proceeded to collect field data and the subsequent analysis of them, for the development of an index adapted to bicycle mobility, also for urban centres and tourist areas.

The biking index is based on several variables: type of bike lane, lane cleaning, parking, illumination and signals, obstacles, lane layout, danger and accidents, etc.; includying the number of users (cyclists) and the lane's lenght.

The combination of these variables (qualitative and quantitative) allows the calculation of an index that will reflect the status of bicycle mobility, firstly in tourist areas (environment initially studied), but later extended to biking mobility in the city center.

Figure 2. Bike lane developed along La Manga area (marked as red line).

3.2.1. Research methodology

In a first phase, based on the work of Krambeck (2006), the research team designed a questionnaire in order to collect all the peculiarities of the bicycle lane and its use in order to reflect all the information related to the mobility of cyclists in the mediterranean city,differentiating the tourist area from the urban area.

Likewise, the two areas selected for the present study were clearly delimited (Figure 2 and 3). In the tourist area the bike lane was divided into 38 equidistant segments (of 500 m), but in the urban area the bike lane network was divided in 58 segments of 100-300 m of length, due to the irregular lane layout in the city centre. These divisions of the bike lane in segments will facilitate the data collection.

In a second phase, the research team conducted the surveys for the data collection, during two different periods:

- June-July: for the tourist area, because of there is enough population in this area to study the infrastructure under analysis, the cycle path and its use by cyclists.
- March-May: for the urban area, according to labor periods and also on Easter holidays.

Information was collected from two random statistical samples (one for each area under study and its segments), taking data from each segment in the morning and afternoon, and distinguishing between right and left lanes (if possible).

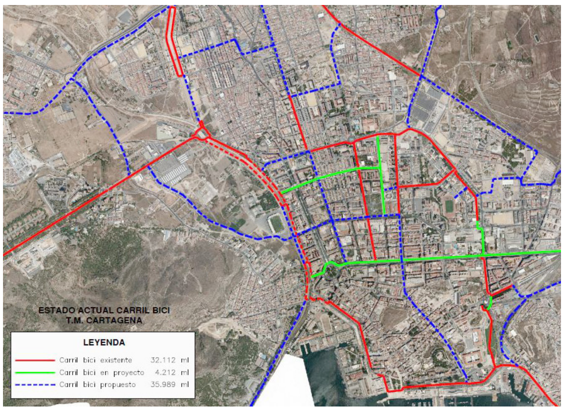

Figure 3. Bike network developed in urban area of Cartagena. Existing lane is marked as red line. Proyected lane is marked as green line. Proposed lane is marked as blue line.

In a third phase, the collected data were analysed, and the analysis of the defined variables allowed the development of the biking index (see tables 2 and 3).

In these tables the research team show the collected data (parameters of the bike lane network and the number of cyclists on it) and the biking index for a selection of segments of the two areas studied.

3.2.2. Analysis of results

As remarked in the previous section, the research team has considered a set of variables (type of bike lane, parking, illumination and signals, obstacles, lane layout, accidents, etc.) for the biking index calculation. The set of variables was grouped into six parameters to characterized the bike lane network:

- Parameter 1: characteristics of the segment for mobility (conflicts with other modes of transport, bike lane conditions, maintenance).
- Parameter 2: mobility and urban road crossing (type of bike lane, quality of crossing points).
- Parameter 3: obstructions in mobility segments (congestion due to use, temporary or permanent obstructions).
- Parameter 4: safety in mobility (bike lane safety, theft and crime, security against other modes of transport).
- Parameter 5: Signaling and lighting of the bike lane.
- Parameter 6: connection and distribution (use of the lane to reach the destination, parking, other facilities).

The research team shows a first approximation of the biking index (BI) for Mediterranean cities, the authors have considered that all the parameters have the same weight in the calculation of the index, which also includes as calculation factors the number of cyclists that use the lane segment and the length of the segment studied.

$$BI = \alpha P + \beta C + \gamma L$$

were:

- P: average of the parameters of the segment
- C: number of cyclists in the segment
- L: length of the studied segment.
- α, β, γ: coefficients associated with the variables

The value obtained for each of the segments of the bike lane varies from 1 to 5, indicating this value the level of use and state of the infrastructure. The results obtained are shown in tables 2 and 3, for each segment of the studied areas studied.

Table 2. Collected data along the segments of the tourist area. Results for the biking index.

	A-4	A-5	A-12	A-16	A-19	A-20	37	48	A-53	A-65	A-71
Parameter 1	3	5	3	4	3	5	2	4	2	1	4
Parameter 2	2	1	1	1	1	1	3	3	1	1	3
Parameter 3	5	5	3	4	5	5	5	5	3	4	5
Parameter 4	2	4	3	3	4	5	3	4	1	2	5
Parameter 5	2	3	3	3	3	3	3	4	2	2	2
Parameter 6	3	3	3	3	4	4	5	4	3	2	5
N° cyclists	1	2	1	3	3	0	4	5	1	2	5
Biking Index	2.7	3.6	3	3.3	3.6	3.9	3.4	4.9	2.3	2.4	4.3

Table 3. Collected data along the segments of the urban area. Results for the biking index.

	3	5	9	15	25	26	32	41	48	54	57
Parameter 1	4	4	4	5	3	4	3	5	5	5	5
Parameter 2	4	3	3	4	4	3	2	4	4	4	4
Parameter 3	3	3	3	4	3	3	2	4	3	4	3
Parameter 4	4	4	4	4	3	4	3	4	4	5	4
Parameter 5	5	3	4	4	2	2	3	3	3	3	4
Parameter 6	4	2	3	2	2	4	1	3	2	2	26
N° cyclists	3	3	6	15	6	6	7	12	3	5	4
Biking Index	1.96	3.21	3.62	4.04	3.46	2.86	2.68	4.24	4.25	4.36	3.67

Finally, the BI value has been calculated for each area of the city, obtaining the following biking index values:

Urban Area: BI= 3.54

Tourist Area: BI= 3.14

The calculated biking index for each segment determines its status and its use, as we can see in tables 2 and 3, most sections have a biking index value between 2 and 4, which shows the deteriorated aspect, the lack of maintenance and repairing, and the misuse of the bike path (Figures 4 to 7). Only in few sections, where the lane is unfolded (L/ R), segregated from the road and well signposted, the value of the index exceeds 4.

These results are very important for the responsible manager of the bike lane network. This information will entail different actions (as explained in next section) from the local administration, which has been recently warned, in order to improve the cycle path for daily use in the city and the next tourist season.

Figure 4. Example of deteriorated bike lane, and lack of maintenance (tourist area)

Figure 5. Example of permanent obstacles in the bike lane (tourist area)

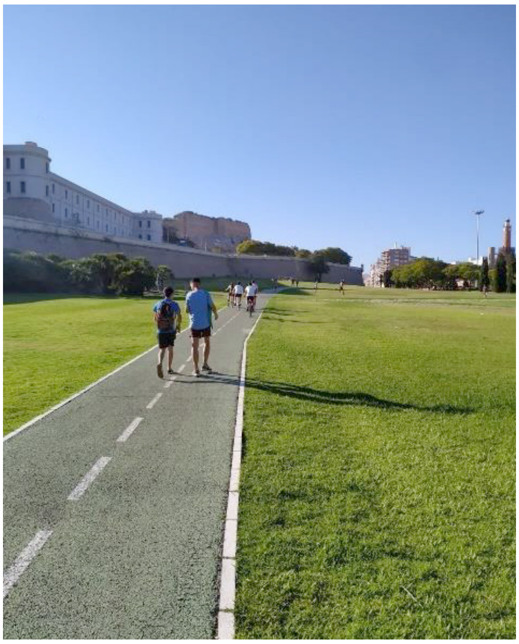

Figure 6. Example of conflicts with pedestrians (urban area)

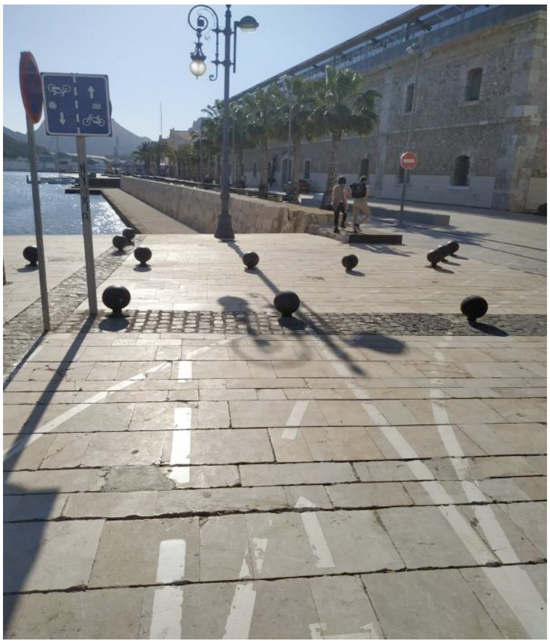

Figure 7. Example of permanent obstacles and bad signals in the bike lane (urban area)

4. Conclusions

A great number of Spanish cities, (DGPI, 2010, GEOSP, 2017) deal with the bicycle issue with great sensitivity, adapting its cyclist lane network around the urban core and within it, which enable a comfortable and functional circulation, choosing the bike as a vehicle to move. A key to this good functioning is the cyclist network master planning (mobility studies, user surveys), achieving a branched network, with connected segments, and reducing the isolated lanes to zero.

The proposal of a new index for Mediterranean cities, is carried out because most existing indexes are defined for big cities and focused on the possibility of cyclying betwwen daily traffic congestion. This new index wants to assess existing infrastructures, identify the problematic sections, inform against the high non-connectivity level of the bicycle network, and how to enhance biking mobility, and not only for leisure and sports.

The analysis of the studied network (infrastructure in La Manga del Mar Menor and the urban área of Cartagena) allows to identify the disparity of situations found along the bicycle lane (existence or not of cycle path, different types of them, etc.) together with an overpopulation of the geographical area in the spring and summer seasons, during the realization of the survey.

The following results and conclusions found after the visual analysis and data collection were considered:

- Need for connection of the different stretches of bike lanes,
- Uniformity of the different types of bike lanes,
- Need for investments to maintain the bike lane (high level of deterioration in a large number of areas).

If the local and/or regional administrations decide to bet on the use of the bicycle and its connection with urban buses and commuter trains, the above-mentioned needs could improve and increase bicycle mobility in the municipality, and establishing the connection of the different urban centers with the beach area.

This biking index will allow local authorities to take realistic decisions about:

- Safer and more adequate infrastructures in cities and neighbourhoods,
- Promote safety and education for bike riders and other citizens,
- Importance of intermodality, facilitating the use of bicycles together with other means of transport,
- Prevention of robberies and aggressions against cyclists.

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