



Maturing urban cycling: Comparing barriers and motivators to bicycle of cyclists and non-cyclists in Lisbon, Portugal

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ABSTRACT

Cities with low cycling maturity (LCM) are cities with a small cycling modal share and little cycling infrastructure. Despite the increasing public interest in cycling as travel mode, LCM cities are still prevalent in the western world, and few research has been developed on which are the barriers and what lead people to bicycle in this type of cities, that still are changing. This research explores the motivators and deterrents to bicycle in Lisbon (Portugal), a city with a cycling modal share below 1%, and compares the perceived barriers to cycling between cyclists and non-cyclists, as well as the triggers and motivators to start cycling between the same groups.

Results from a survey (n = 1079) showed that both groups considered the issues related to the perception of safety, physical effort, the lack of a safe cycling network, and bicycle ownership as important barriers to take up cycling in Lisbon. We conclude that non-cyclists' perceived barriers are similar to the barriers cyclists had before they changed behavior. In contrast, the self-reported triggers that induced cyclists to take up cycling are not similar to the expectations that non-cyclists have of what would, or could, change their behavior. Nevertheless, the expected motivators stated by non-cyclists are consistent with their perceived barriers, which are more community-oriented and not so much related to personal interests or needs. We analyzed the triggers for cycling for different generations of cyclists, taking into consideration specific public policies and infrastructure investments that promote bicycling. Triggers vary over time, and they should also change as cities transition to higher cycling maturity levels.

This research and conclusions may support the design of policies in order to increase cycling levels in LCM cities by acknowledging the barriers and motivations of potential new cyclists and learn from current cyclists.

1. Introduction

The benefits of cycling – an active transportation mode – are well known for cities, including sustainability, equity, health, and life quality. Increasing active mobility behavior, such as cycling, could help to address increasing rates of obesity, benefit physical and mental health, and reduce serious health problems associated with lack of exercise and air quality (Garrard et al., 2012; Pérez et al., 2017; Sallis et al., 2004). However, changing the behavior of a population could be described as one of the challenges of our time.

Cities with low cycling development and maturity (LCM) - as opposed to bicycle-friendly cities like Copenhagen or Amsterdam - are cities with a low cycling modal share and little cycling infrastructure and facilities. This type of cities has been little addressed in

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research studies. These cities face difficult challenges in encouraging cycling: negligible cycling culture, little interest in collecting cycling data, the widespread perception that cycling is unsafe and not respected, and a car-oriented road design. The (lack of) conditions provided in this kind of cities contribute to the individual's decision of cycling or not, in a transitional way. Given that these cities do not have historical experience with cycling, there is a need to understand and better inform city planners and players of what strategic infrastructure investments should be made and programs to deploy in order to grow their cycling mode share and mature the cycling culture.

Understanding the key factors influencing bicycling is essential to develop effective cycling policies. Again, there is no evidence for such analysis in LCM cities. The literature has focused on the barriers to bicycling while looking less towards the factors that initially triggered people to shift to cycling. This suggests that barriers to cycling have opposing motivators and that acting on these motivators will eventually remove those barriers. In this paper, we show that this is not necessarily always the case.

This research presents a pseudo-longitudinal examination of how, at an aggregate level, perspectives of travelers may or may not change once cycling is adopted, throughout a city's cycling maturity evolution. This study explores the perceived barriers and the motivators to cycling and compares them between the Non-Cyclists and Cyclists. Lisbon (Portugal) is an LCM city and the addressed case study, that is experiencing a paradigm shift after important improvements in cycling network and facilities. The results and conclusions may support the design of policies and actions that public or advocacy organizations might focus to increase cycling levels in LCM cities, which are still very common in Europe and North America.

The paper is organized into five sections. The introduction presents the research framework, motivation, and objectives, a proposed cycling behavioral change conceptual model and a brief literature review on the barriers and motivators to bicycle. The methodology and the case study are then described, followed by the results. The discussion compares the results from Cyclists' and Non-cyclists' barriers and motivators to bicycle. The paper finishes with conclusions and future research directions.

1.1. Cycling behavioral change

The theoretical background of this study is rooted in the behavioral change literature, travel decision theories, theories of planned behavior and social learning (Ajzen, 1985; Bandura, 1977, 1971; Ben-Akiva and Lerman, 1985; Singleton, 2013), which set the underlying framework for qualitative and quantitative research.

The overall underlying assumption is that the factors that prevent people from cycling are caused by a combination of personal and external factors, which together constitute the perceived barriers to cycling and influence the expectations of potential regular cyclists. Some of these factors are subjective, and others are objective. Some of the objective factors – e.g., *distance* or *slope* – may be perceived differently among potential cyclists, and may present a strong or an irrelevant barrier to cycling. These vary over time and can potentially lead to a behavioral change towards adopting cycling. Another assumption is that the paradigm shift reflects the behavioral change, where perceived barriers are outweighed by perceived benefits (Kahneman and Tversky, 1979) and motivators and the ensuing expectations lead to real outcomes (effective results). The influence of personal or external factors on decisions to cycle more frequently may change over time, especially if the influence of acquired experience is also factored in.

For this study, we are interested in understanding the circumstances of change for the population of cyclists in the past, and the current attitudes of non-cyclists towards cycling. The challenge is to measure and model the key factors that lead to a change in travel behavior towards cycling, as well as to identify the perceived barriers towards, and expectations for, cycling. Modeling can help to unravel the underlying combination of causes that may be further extrapolated or transferred to other cycling environments, and thus support the planning and design of pro-cycling policies and actions.

1.2. Barriers and motivators towards bicycling

In cities with few regular cyclists, there is a large share of the population who chooses other modes for commuting, and among them it is possible to distinguish groups of potential cyclists (people who could be willing to bicycle regularly) and a group of non-cyclists who, for various reasons, are not able or willing to bicycle (Félix et al., 2017). There is a need to appropriately measure the relevant factors that determine whether people choose to cycle or not.

The literature explores several hypotheses relating to social and cultural background, attitude, travel behavior, safety perception, and habit. It is commonly agreed that active modes tend to be more influenced and conditioned by the physical and build environmental factors, which translate potentially into significant barriers and motivators for walking and cycling. For instance, the implementation and expansion of segregated cycling networks and facilities are interventions that have a high likelihood to successfully induce cycling (Dill and Carr, 2003; Pucher and Buehler, 2005; Santos et al., 2013), as tested before and after some interventions (Braun et al., 2016; Marqués et al., 2015). Nevertheless, it was found that changes in travel behavior can also be associated with a change in life circumstances rather than a change in the external environment (Chatterjee et al., 2013), such as health problems, the birth of a child, a change in employment, school or residence. Also, climate and weather (Winters et al., 2007), the built environment (Winters et al., 2010) and topography (Dill and Voros, 2007) are also perceived barriers that influence cycling choice. The relative impact of these barriers certainly varies from place to place, though in many situations, the lack of data hinders the possibility of making such an evaluation.

The analysis of the relationship between the observed choice to cycle and the factors influencing this choice is a complex process. Parkin et al. (2007) recognize that other, less tangible factors play a role, such as the physical effort expended by the cyclist, self-image, perceived ability, and social norms. In Sydney, Daley and Rissel (2011) studied how the public image of cycling and cyclists can act as barriers or facilitators of cycling for both cyclists and non-cyclists. Other authors draw conclusions related to the perceived

barriers to cycling in The Netherlands (Engbers and Hendriksen, 2010), Brussels (De Geus et al., 2008) and Montreal (Damant-Sirois and El-Geneidy, 2015), although these are all places with a higher cycling maturity.

Various authors (Crawford et al., 2001; Gatersleben and Appleton, 2007; Lois et al., 2015; Shannon et al., 2006; van Bekkum et al., 2011) explored the personal and external barriers to cycling that take into consideration the Stages of Change, distinguished from Prochaska and DiClemente (1984). De Geus et al. (2008) assessed the perceived barriers and benefits of cycling among cyclists and non-cyclists and analyzed these two groups as different but homogeneous within themselves. In other research, with a similar approach, De Geus and colleagues (De Geus et al., 2019) found that the influence of individual and social factors can better distinguish Cyclists and Non-cyclists, than the environmental ones. In Poland, Biernat et al. (2018) used a national dataset to segment the population of cyclists and assessed the reasons why they bicycle (motivators), and rate the condition of infrastructure, safety and the availability of bicycle facilities at destinations (barriers). In Madrid, an LCM city, Muñoz et al. (2013) examined perceptions of different cycling factors and their influence on bicycle commuting between Cyclists and Non-cyclists, assuming that the perceptions with higher scores were motivators, and lower scores were barriers to cycling. They found that attitudes and other psychological variables play a less important role in cycling in a city where cycling is not common.

Based on a review of the literature, it is not uncommon for researchers to seek to understand the barriers to bicycling, addressing cyclists and non-cyclists as two different groups. However, the literature does not address the (less obvious) triggers that induce changes towards cycling separately from barriers to cycling. There is even less research in cities with low cycling development and maturity, which typically have a sizeable non-cyclist population, that includes the potential cyclists.

This research aims to:

- Understand the key motivators and deterrents to bicycle in an LCM city;
- Compare the perceived barriers to cycling between cyclists and non-cyclists; and
- Compare triggers and motivators to start cycling between cyclists and non-cyclists.

2. Methods

Generally applicable for any city, regardless of cycling maturity level, a survey was written to cover respondents' current mobility patterns; attitudes towards urban cycling; personality traits and willingness to change behavior; and finally, socio-demographics and housing. All questions were closed-ended.

2.1. Questions and methods

Participants were categorized as "Cyclists" and "Non-Cyclists," based on self-identified criteria, adopting the Stages of Change (Prochaska and DiClemente, 1984), and considering their mode of transportation, as follows:

- Cyclists: if the respondent answered "I travel by bike almost always"/"I sometimes bike" and chose Bicycle as travel mode;
- Non-Cyclists: if the respondent answered "I do not ride a bike but I am interested in doing it"/"I'm not interested and I will not be in the next few years" or did not choose Bicycle as travel mode.

Different lines of inquiry were addressed to each group. The survey asked Cyclists to recall their past experiences when they took up cycling, and Non-Cyclists to respond based on their current experience. Concerning attitudes, participants were asked to select the factors that influenced their behavior, from a list that contained about 40 suggested options (see Appendix), as follows:

- Non-Cyclists' barriers: reasons why they do not ride a bicycle more often or at all;
- Non-Cyclists' motivators: what could encourage them to bicycle;
- Cyclists' previous barriers: recalling the barriers they experienced before choosing to bicycle; and
- Cyclists' triggers: decisive factors that influenced their decision to ride a bike.

For Cyclists' triggers Non-Cyclists' barriers, participants were also asked to select up to five most important ones, and scale the relative importance of each barrier or trigger from 0 to 10, scoring the most important one with 10 points (totally important), and the remaining ones in relative to the most important one. For Non-Cyclists' motivators, participants were additionally asked to select up to three most important ones and ranked them in decreasing order of importance.

The presented lists of motivators/triggers were similar, except that some items in the Cyclists' list, such as "environmental concerns," or "degradation of public transit," were not included as options of motivators for Non-Cyclists, because these are mostly attitudes that are not easy to predict. Respondents could add other barriers or motivators.

The relevance given to each motivator or barrier was weighted for each factor by dividing the respective score by the sum of all the scores of each set of factors chosen as the most relevant ones. For instance, in a scenario that one would score 10 points in the most relevant factor, then 8 points on the second one, and 2 points on the third one, the most relevant factor would have a relative relevance of $10/(10 + 8 + 2)$, i.e. 0.5, the second would have a relative relevance of 0.4, and the third would have a relative relevance of 0.1. If someone selected only one factor, the relative relevance would be 1. In the cases that participants didn't score the importance of the chosen factors, the relevance was weighted by the number of selected factors (for: previous barriers, all; motivators, top 3), meaning that if someone selected only one factor, that one would be more relevant than one chosen within a set of

four.

A question about change of habits in the past year compared the propensity of someone to change any habit, such as quitting smoking, becoming vegetarian, learning a new art, or changing travel behavior (Shannon et al., 2006). The commuting distances between home location and frequent destinations, such as work or school, were computed with OSM Tools plugin for QGIS software.

2.2. Case study

Lisbon, Portugal, is an LCM city with about half a million inhabitants, and the case study for this research. Its cycling modal share was 0.2% in 2011, far below the EU average of 8%. Lisbon's hills may influence the low rates of cycling. Nevertheless, 54% of the streets are almost flat, and 75% of the streets are below a 5% grade, good enough for cycling. The city offers a highly fragmented bicycle network and a lack of places to safely store or lock a bike (Moura et al., 2017).

From 2007 to 2015, the municipality invested in a segregated cycling network that reached 60 km and installed 300 parking facilities. Some tentative bicycle promotion campaigns were made during this period. The number of cyclists has been visibly increasing in recent years and tripled to 0.6% in 2017. Since 2017, recent municipal improvements include the expansion and completion of a more comprehensive, connected, and commuting-oriented bicycle network, with 210 km of dedicated cycling infrastructure; and a bike-sharing system of 1400 bicycles (70% e-bikes). Although Lisbon's housing is not homogeneous, in some districts it may be difficult to store a bicycle at home. In the city center, buildings tend to be smaller, old, and with 3–5 floors without elevator. Furthermore, it is unusual to see bicycles parked outdoors at night due to the risk of theft, in contrast to cities with a higher bicycle modal share (Pucher and Buehler, 2008).

2.3. Dataset

An extensive survey of Lisbon's residents, workers, and frequent visitors was launched using an opportunistic sample approach following a stratified sample methodology at the district level, based on the number of electors. The survey was distributed on social media and in the press, under the title of "Survey on transportation patterns in Lisbon," and conducted in an online-only format. In districts with a low rate of response, flyers with the link were left in mailboxes and in local businesses. To target cyclists, we published the survey link in cycling advocacy groups' newsletters, and flyers were left on parked bicycles. The survey was online during January and February 2018 and collected 1457 responses.

2.4. Sample description

From a data sample of 1079 valid answers, 70.9% (765) of the participants were classified as Non-cyclists, while the remaining ones were classified as Cyclists.

Table 1 shows significant differences between the groups of Non-cyclists (NC) and Cyclists (C). Among Cyclists, a higher percentage were male, as expected in low cycling countries (Garrard et al., 2008). Also, they were younger than Non-Cyclists and had lower levels of higher education (although only marginally). The Non-Cyclists participants were more likely to commute to work or school 5-days/week compared to Cyclists. The two groups showed similar self-assessed income status. In both groups, 41% of the participants' households had children, while Cyclists seem to have more children under the age of 11 living with them, which was unexpected as families with children are usually correlated with higher use of a private car (Santos et al., 2013).

There was a higher percentage of Cyclists living in Lisbon City, compared to Non-Cyclists, where residents have access to more bicycle infrastructure and facilities within the city limits than in the outer Metro area. The commuting distance was not statistically different between the two groups, but the proportion of trips below 5 km was higher for Cyclists. Although the access to a car was very similar in both groups, the access to a bicycle was very different, with Cyclists with higher bicycle availability, as expected (Heinen et al., 2010). Both groups presented a high rate of car ownership and the ability to drive, contrary to the results from a project that conducts a similar analysis for seven European cities (Raser, 2018). Both groups had similar rates of habit changes during the previous year; notably, eating habits accounted for 21% for C and 23% for NC, sport practicing for 15% for C and 19% for NC, and transportation mode change for 19% for C and 13% for NC. Pearson's chi-squared test does not exclude the hypothesis of both groups being different regarding habits changes, suggesting that these persons do not have a different propensity to change habits, generically in their life.

We denote a higher education level of the participants when compare to the overall population, which might be related to the dissemination strategy of the online and press diffusion and the online survey approach itself.

3. Results

Besides identifying the main barriers to bicycle, we requested the respondents to quantify the relevance of each barrier relative to the most relevant selected barrier. The relevance of each barrier is shown in brackets along with the results and it corresponds to the mean of the relative relevance (weighted scores), on a scale of 0 (irrelevant) to 100 (the most relevant). After presenting our results for barriers, the survey outcomes for motivators and triggers are presented, following the same approach.

Table 1
Demographic and socio-economics of Non-Cyclists and Cyclists.

	Non-Cyclists n = 765		Cyclists n = 313		Total n = 1079		Pearson's χ^2 test
	n	%	n	%	n	%	p-value
Gender							
Male	332	43	225	72	557	52	.000
Female	432	56	87	28	519	48	
Other	2		1		3		
Age							
16–20	18	2	7	2	25	2	.024
21–30	150	19	64	20	214	20	
31–40	242	32	131	42	373	35	
41–50	219	29	70	22	289	27	
51–60	105	14	33	11	138	13	
+60	32	4	8	3	40	3	
Education							
Less than Secondary	6	1	6	2	12	1	.026
Secondary	68	10	44	15	112	11	
Higher	691	89	263	83	955	88	
Commuting distance*							
≤1 km (0.6 mi)	43	6	25	8	68	7	.121
1–5 km (3.1 mi)	249	37	123	42	372	39	
5–10 km (6.2 mi)	191	29	85	29	276	29	
10–15 km (9.3 mi)	71	11	30	10	101	10	
+15 km	113	17	32	11	145	15	
Home location							
Lisbon City	446	65	219	73	665	67	.014
Lisbon Metro Area	319	35	94	27	414	33	
Days/Week to workplace or school**							
0 to 4	103	15	60	22	163	17	.022
5 to 7	567	85	215	78	782	83	
Self-assessment of income status							
Live without difficulties	266	39	120	40	386	39	.846
Live with moderate ease	369	53	160	53	529	53	
Live with difficulties	57	8	22	7	79	8	
Children at household							
≤10 years old	142	24	80	31	222	27	.004
> 10 years old	96	17	22	9	118	14	
No	342	59	151	60	493	59	
Bicycle ownership at household							
Yes	384	50	281	90	666	62	.000
No	381	50	32	10	413	38	
Car ownership at household							
Yes	602	79	248	79	851	79	.916
No	163	21	65	21	228	21	
Driving license and ability to drive							
Yes	591	86	264	88	855	87	.417
No	174	14	49	12	224	13	
Changed habits during the last year							
Yes	434	57	181	58	616	57	.806
No	331	43	132	42	463	43	

Notes: *From 962 valid cases, when the corresponding distance could be computed. **From 945 cases that were not unemployed or retired; in both groups, it represents 88% of the sample. Chi-square test with Yates correction for minimal values.

3.1. Barriers to cycling

3.1.1. Non-cyclists

The most relevant barriers for Non-Cyclists were: not feeling comfortable with the idea of cycling with traffic (relevance = 100); the perception of the commute being too far or that biking takes more time (87 and 40, respectively); the perception that motorists don't respect cyclists (59); that the city is too hilly (57); or unwillingness to arrive to a destination sweaty (56). Not owning a bicycle (57) is also perceived as one of the main barriers, as well as the lack of a safe route (54) and an inadequate cycling network for the most frequent trips (52). Having to take children to school (40) and lacking room to store a bicycle at home (37) are also perceived barriers to cycling, though less frequently chosen (below the 75th percentile). The lack of showers at destinations was one of the most chosen factors (above P75) but given a low relevance (25).

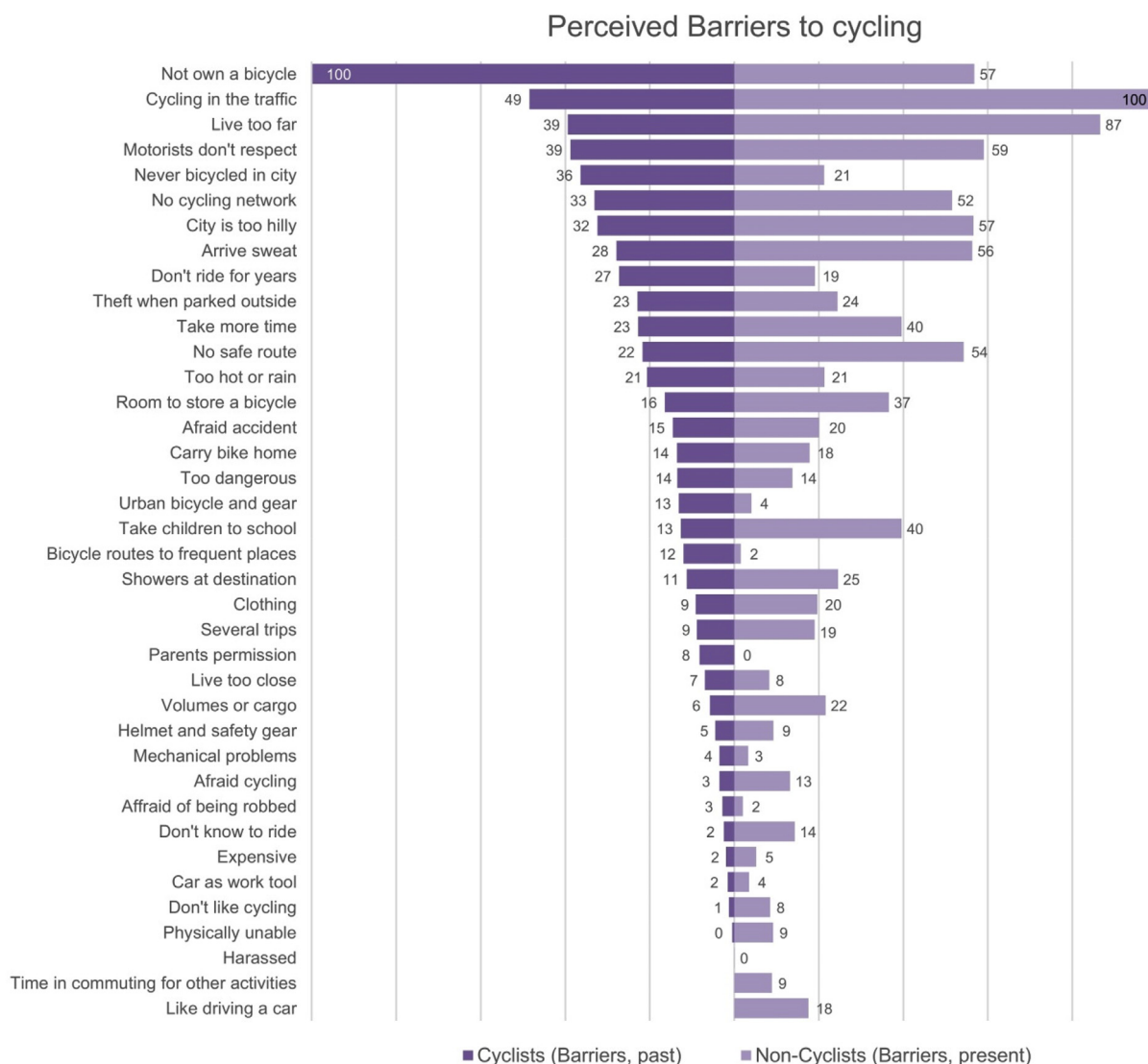


Fig. 1. Comparison of the barriers to cycling between Cyclists and Non-Cyclists ranked according to the relevance of Cyclists' barriers.

3.1.2. Cyclists

The most relevant and chosen perceived barriers identified by Cyclists, before they take up cycling, were: not owning a bicycle (relevance = 100); being afraid of cycling with traffic (49); fear of motorists' behavior and lack of respect for cyclists (39); having never bicycled in an urban environment (36); the lack of a cycling network (33) and the perception that the city is too hilly (32). Although less frequently selected (below P75), living too far from work or school was also perceived as a relevant barrier (39). The perception of not having a safe route was one of the most frequently elected barriers (above P75) but assigned a lower relevance (22).

3.1.3. Cyclists and non-cyclists comparison

Despite some differences, Fig. 1 illustrates a close similarity in the ranking and relevance between the Cyclists' previous and the Non-Cyclists' current perceived barriers. We found a high and significant correlation, concerning rank and magnitude of the factors' relevance between both groups (Spearman's rho = 0.810, p-value < 0.001).

3.2. Motivators and triggers to cycling

3.2.1. Non-cyclists

For Non-Cyclists, the most relevant and chosen factors that would encourage cycling are: the expansion of the cycling network (relevance = 100); moving closer to work, school or home (86); owning an electric-bicycle (60); better and easier bicycles on public transit (43); having room to store a bike at home (42); and the existence of a bike-sharing system (34). Other factors considered

Perceived Motivators for cycling

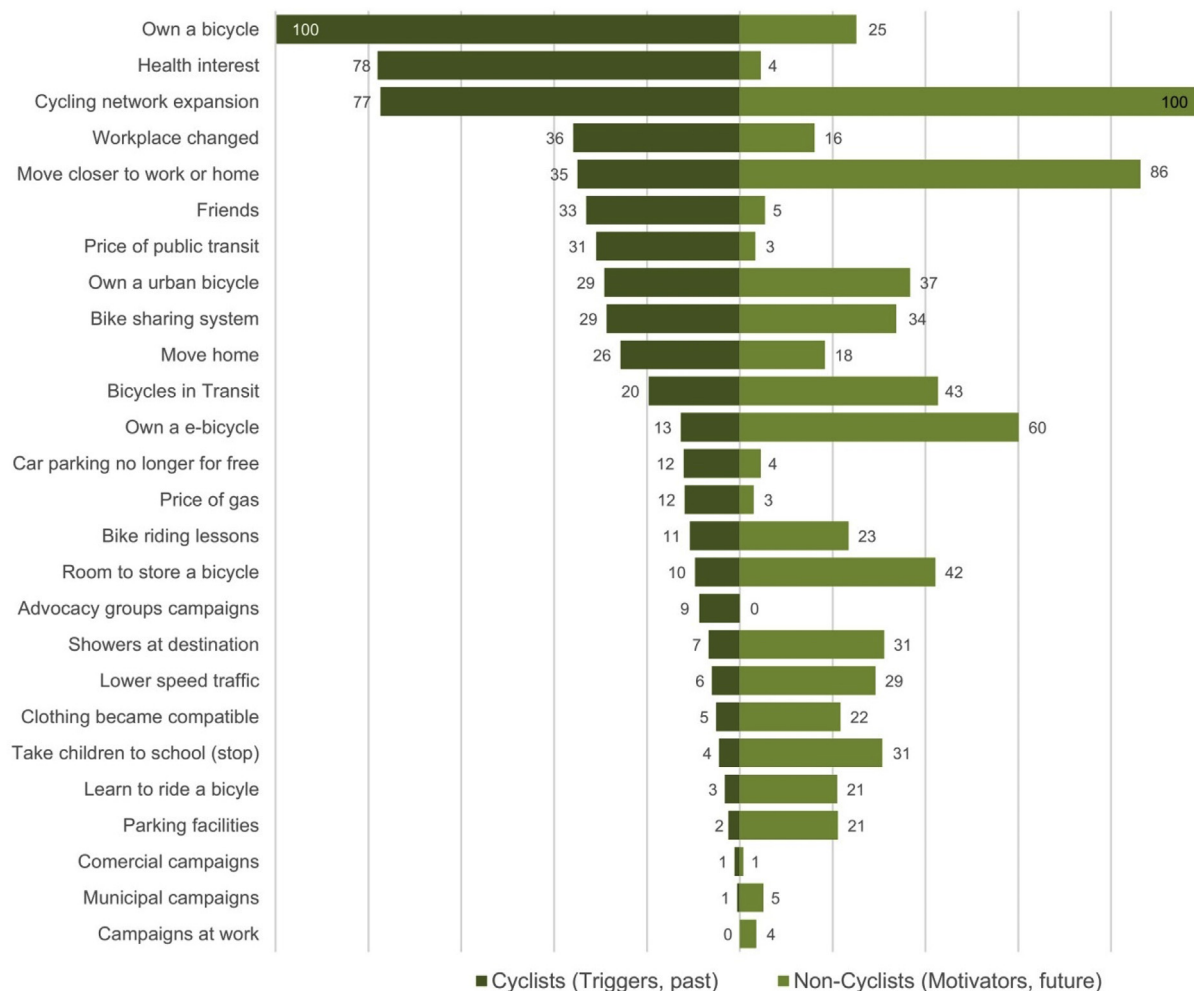


Fig. 2. Comparison of the triggers and motivators for cycling between Cyclists and Non-Cyclists ranked according to the relevance of Cyclists' triggers.

relevant include owning a bike suitable for urban trips (37); the availability of showers at the destination (31); and not having to take children to school (31), although these fell below the 75th percentile of choices. The availability of parking facilities (21); employer-based incentives for biking such as financial or paid time off (29); and tax incentives for purchasing a bicycle (15) are among the most frequently chosen although the corresponding relevance is low.

3.2.2. Cyclists

The triggers that participants identified as the most relevant for their behavior change were environmental concerns (100); knowing that the bicycle would be faster than the other modes of transportation (78); owning a bicycle (69); a concern with physical fitness (65); the relative affordability of cycling compared to other transportation options (57); an interest in personal health (54); and the expansion of the cycling network (53). Other factors that were assessed less relevant but were still among the most frequently chosen were the degradation of public transit service (29); interest in conveying a political message (29); the influence of friends (23), and the participation in Critical Mass (9) - a monthly activist bicycle ride in the city. Although these factors were not the most influential ones, they are among the most frequently chosen, so their impact was relevant in some way. These Cyclists gave almost no relevance to bicycle parking facilities and commercial, municipal, and work campaigns.

3.2.3. Cyclists and non-cyclists comparison

Fig. 2 shows Cyclists' triggers and Non-Cyclists' motivators to bicycle, but only the ones that are comparable – not including attitudes that are not easy to predict, as referred to in the methodology. To be comparable, the relevance was re-scaled and indexed, based on the comparable factor with the maximum relevance. For instance, “owning a bike” was not the most relevant trigger (69),

but for making this comparison, it was re-scaled to the maximum value (100).

From Fig. 2 we found that there is no similarity between the triggers that led people to bicycle and the expectations (motivators) non-cyclists have regarding what could make them change to bicycle. The relevant triggers for cycling are not considered relevant motivators for Non-Cyclists, and *vice-versa*, except for the cycling infrastructure expansion. Spearman correlation tests revealed a low, but not statistically significant, correlation of the factors rank and relevance between both groups (Spearman's $\rho = 0.310$, p -value = 0.130).

4. Discussion

4.1. Barriers and motivators to bicycle

Non-Cyclists' barriers to cycling are related to a perception that riding a bicycle with traffic is not safe, that the city is too hilly, distances are not close and require too much effort. Not owning a bicycle and the lack of a safe and suitable cycling network are also key barriers perceived by Non-Cyclists. These results are consistent with previous findings for low cycling maturity contexts (Gatersleben and Appleton, 2007; Iwińska et al., 2018; Muñoz et al., 2013). Non-Cyclists' motivators to bicycle more, or at all, are mostly related to the existence of infrastructure and facilities. For example, major motivators include access to, a more extensive cycling network; a bike-sharing system; the ability to, and ease of, taking a bicycle on public transit; having a place to store a bike at home; or owning an e-bicycle - probably to overcome the hills and distances as perceived by this group. The expected motivators are consistent with the perceived barriers stated by Non-Cyclists, which are more community-oriented (e.g., related with facilities and infrastructure improvements), and not so much related to personal interests or needs (e.g., health, fitness, or environmental concerns).

The barriers before cycling reported by Cyclists are similar to those stated by the Non-Cyclists. Environmental concerns lead the list of factors that triggered Cyclists to start bicycling, along with interest in personal health and concern with physical fitness. The affordability of cycling was also identified as a trigger. These results are consistent with previous findings (Muñoz et al., 2013). Owning a bicycle and the cycling network expansion were also relevant triggers. Availability of bicycle storage at home is an important motivator to start cycling for Non-Cyclists, which is very relevant in Lisbon considering the housing characteristics, although current cyclists did not identify it as a relevant trigger.

Cyclists consider that owning a bicycle made the difference towards changing behavior to bicycling. Nevertheless, the Non-Cyclists did not identify bicycle ownership as a relevant motivator. There are two plausible explanations for this: an underrated appreciation of the importance of owning a bicycle and how this availability can be a motivator for behavior change; and, as a bike-sharing system was recently available in Lisbon at the time the survey was launched, Non-Cyclists may have the perception that they can easily access a bicycle service, and complementary latent factors emerge, referring the bicycle ownership as not so relevant. The time effect analysis reinforces this idea, as will be discussed in section 4.2.

From the correlation tests, we conclude that there is a general similarity between the perceived barriers respondents had or have, although there is not a similarity between the triggers that led people to bicycle and the motivators of Non-Cyclists, regarding what could persuade them to a behavioral change towards bicycling. Fisher's r -to- z transformation confirms that there is a higher and statistically relevant correlation (p -value = 0.003) between the rank and relevance of barriers of Cyclists and Non-Cyclists than between the equivalent rank and relevance of motivators. The discussion of this observed discrepancy is compelling and relevant. It is not clear whether Non-Cyclists were realistic about what they thought would make them start cycling, particularly when the barriers are much correlated between Cyclists and Non-Cyclists, in contrast to the motivators and triggers. Also, Non-Cyclists may better perceive the barriers and worse perceive the benefits to bicycling than Cyclists (De Geus et al., 2019). Non-Cyclists' self-assessment about what would make them shift to cycling may be faulty (Morwitz, 1997). A caveat should be made regarding the limitations of asking someone about their perceived behavior in the past. People may rationalize post-hoc their past (and current) behavior, putting forward reasons that make sense now but were not the actual causes of their behavior when they actually changed. The socially desirable stated answers may also contribute to a higher bias, in particular regarding the "environmental concerns" that outstand on Cyclists' triggers. By forcing the choice of the most important items and then, in a second phase, to assess their relevance, we can understand that some items that are even socially desirable – most frequently chosen – were no longer the most relevant.

There is a clear disparity in the relevance of health improvement as a factor that made respondents shift to cycling between groups (Fig. 2). According to data collected, Cyclists attribute a high relevance, while Non-Cyclists consider it almost irrelevant, which suggest different perspectives as to how each group regards or is aware of the health benefits of physical activity through cycling.

As referred by Götschi et al. (2016), safety risks cause a smaller, negative impact on public health, such as for air pollution increased exposure, when compared to the benefits of increased physical activity (Oja et al., 2011). However, to what extent health benefits serve as a motivator for day-to-day cycling is not well understood (Götschi et al., 2016). The authors claim also that "*the promise of health benefits (...) is unlikely to sway potential cyclists who currently perceive safety risks as too high a barrier*". Our results corroborate with this hypothesis, in the sense that only a small percentage of Non-Cyclists identify health interest as a motivator, with a relative minor relevance, while indicating cycling network expansion (safety-related) as a major motivator to bicycle.

This is one possible explanation for the difference in the relevance of cycling for health improvement. Complementarily, we could argue that, in general, the interest in improving one's health would follow a medical prescription or advice from a relative or friend, besides our own decision. This decision, mostly related to a need, would require some personal effort, both physical and mental, and self-discipline, at least in the transition stage. Therefore, it is not expectable that someone would begin improving her health through cycling if they do not need it, just because they are (or became) aware of the related benefits of physical activity. If someone has that

need and interest, cycling is an easy, economical and pleasurable solution, although there are many other alternatives to achieve the same goal.

Transportation policymakers and public health officials should consider these findings when designing policies and campaigns to pave the way for higher cycling rates. The segments of the population that do not need to improve their health might not be receptive to such a message, alone.

It is important to monitor and compare the perceived motivators and triggers over time and, more importantly, between different time periods of cycling infrastructure and facilities development, and other public policies of cycling promotion. It would also be interesting to compare the Cyclists' triggers from a period of no cycling infrastructures and facilities at all (nor any plan for that), with Non-Cyclists' motivators, after the implementation of a cycling network and bike-sharing system, to assess the suggestion effect.

Sometime in the past, both groups were "non-cyclists", and shared similar perceived barriers. However, only one of the groups actually changed their behavior, becoming a "cyclist", and can, therefore, identify what triggered them to make this change. The group that remained as "non-cyclist" has assumptions, perceptions, expectations, and ideas about cycling that are related to their perceived barriers. Their expectations are different from the reality experienced by cyclists.

4.2. Time effect

The Non-Cyclists' perceived barriers and motivators were captured at the point in time that respondents were taking the survey. In contrast, we ask Cyclists to identify the barriers and motivators that caused them to start cycling at some point in the past, which was not the same for all the Cyclists respondents. Their individual barriers and triggers were probably different, due to age, life circumstances, peer influence, as well as external factors (Chatterjee et al., 2013).

The city of Lisbon went through a period of investment in infrastructure, facilities, and public policy initiatives for bicycle transportation. We can better identify these external factors that may have influenced cycling at the time, but the individual ones are not as easy to comprehend. We analyzed the triggers for cycling over three different time periods, before the year of the survey (i.e., 2018):

- More than five years (i.e., before 2012), $n = 96$;
- Between five years and one year (i.e., 2013–2016), $n = 130$; and
- Less than one year (i.e., 2017–2018), $n = 87$.

From Fig. 3 we may detect some differences between the triggers that led people to bicycle in different periods. With respect to municipal policies, the relevance of the cycling network was higher in recent years, and the bike-sharing system also became very relevant, as expected, when it was rolled out in 2017–2018. On the other hand, owning a bicycle was a more relevant trigger in the past, and the need for an own bicycle was probably replaced by the bicycle availability a public scheme offers.

Investment in infrastructure has a greater likelihood of inducing cycling (Dill and Carr, 2003; Pucher and Buehler, 2005; Santos et al., 2013), but it is not clear whether people started cycling due to changes in the built environment, or due to other latent factors. Specifically, a self-selection variable should not be overlooked (Krizek et al., 2009; Pinjari et al., 2009). In addition, there is evidence that increases in bicycle use after the implementation of bike-sharing programs are sometimes confused by concomitant improvements in bicycling facilities (Pucher et al., 2010), which may be the case in Lisbon as from 2017.

Many respondents who started cycling from 2013 to 2016, coincident with the financial crisis in Portugal, reported that the relative affordability of cycling was a driving factor, as well as the rising price of transit and gas.

Visiting another city where it was common for people to ride a bicycle was relevant until a certain time, which may correspond to the fact that, in recent years, it is more common to see people riding bikes in Lisbon. Critical Mass events played a role but became irrelevant as a trigger after 2012, suggesting that promotion campaigns can become ineffective and should be replaced with timely new campaigns.

If triggers change over time and within different contexts, we may question if the perceived barriers would also be different over time. We found that the Cyclists' barriers before cycling were similar over the three periods. The only exception was bicycle ownership and lack of cycling network, which became more relevant in 2017–2018 when major bicycle infrastructure and facilities became more widely available in Lisbon. In LCM cities, there is an expectation that people will start cycling without or with few infrastructure and facilities. With time and implementation of policies that support cycling, the factors that lead people to bicycle also change. What triggered people to become the first generation of cyclists is not the same as what triggered subsequent generations of cyclists, as shown in Fig. 3.

Dividing cyclists into groups rather than analyzing them as a whole population has proven to give better, more nuanced results (Damant-Sirois and El-Geneidy, 2015; Kroesen and Handy, 2014). In an LCM city, more non-cyclists and potential cyclists are expected; whereas in a high cycling maturity city, more cyclists are expected. In an evolutionary context, as cities evolve from Starters to Climbers and then to Champions, using the European Union Presto program terms (European Union's Intelligent Energy, 2010), their cycling maturity also increases, and different approaches are needed to urge more people to start cycling or to maintain levels of cycling.

Using the Stages of Change to understand better what could shift people from the "Contemplation" or "Preparation" stages towards "Action," could provide a useful tool for creating targeted policies that are more efficient at fostering a change in behavior towards cycling. Barriers and motivators to change to bicycle might differ among non-cyclists, depending on which Stage they are, and should be explored in future work. Although the group of people who do not currently cycle at all is unlikely to take up cycling, at

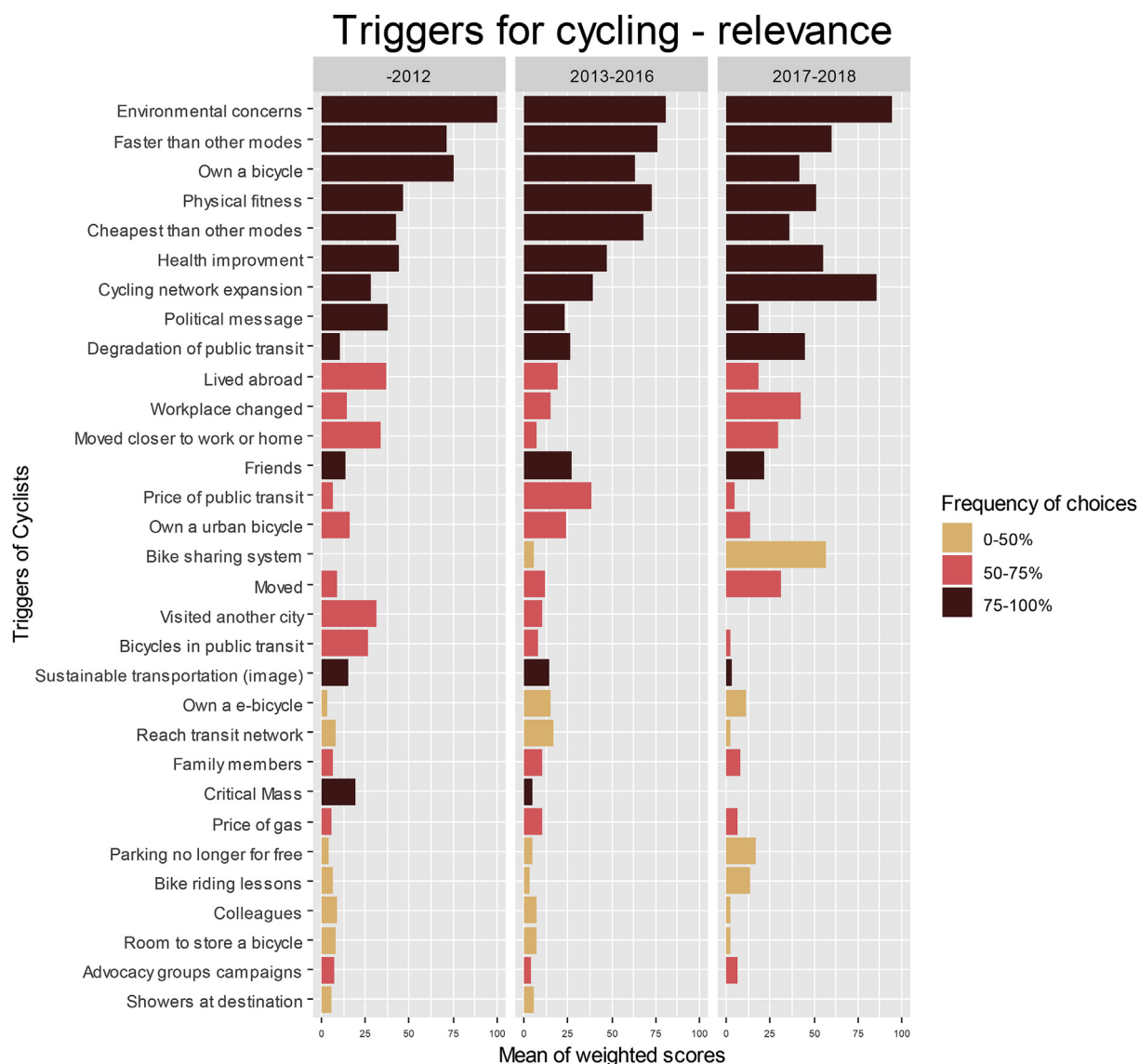


Fig. 3. The relevance of Cyclists' triggers by time period, ordered by the general relevance of Cyclists' triggers. The different colors grade the frequency of choices by percentiles. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

least in the short term, cycling promotion campaigns should not disregard them.

5. Conclusions

This study explored the perceived barriers to and the motivators for cycling, and how they change over time, in the context of an LCM city (Lisbon).

The factors related to the perception of safety, effort, the lack of a cycling network, and bicycle ownership were considered relevant barriers for both groups of Cyclists and Non-Cyclists. The Non-Cyclists' motivators to bicycle are related to infrastructure, and bicycle availability and ownership. Consistently, those factors were pointed as relevant motivators by Non-Cyclists (with a particular emphasis on e-bike availability) and as relevant triggers to bicycle by Cyclists in this LCM city, although not on the top of the most relevant ones. Personal concerns and interests are more relevant triggers for Cyclists.

Although there is a general similarity between the perceived barriers between Non-Cyclists and Cyclists, we conclude that there is not a similarity between the triggers that led Cyclists to bicycle and the expectations the Non-cyclists have regarding of what could make them switch to cycling. Nevertheless, the motivators of Non-Cyclists are related to their barriers.

We also conclude that the motivators for cycling vary over time, and it is expected that they also change as cities transition along

cycling maturity levels. In an LCM city, there is an expectation that people will start cycling with none or little infrastructure and few facilities. With time and implementation of policies that support increased cycling, the factors that lead people to bicycle also change. What triggered people to become the “first generation” of cyclists is not the same as what triggered subsequent generations of cyclists.

The evolution of cycling maturity of cities is a continuous process from an LCM until an HCM. However, this continuum of evolution occurs also within each of these levels of cycling maturity. For instance, the results from our time effect analyses suggest that the first generation taking-up cycling had different requirements for cycling when compared with the most recent generation that, while having access to better cycling conditions, expressed different concerns to change behavior towards cycling. For example, peer pressure, advocacy for cycling (e.g., the critical mass in Lisbon) or personal experiences (e.g., having lived in or visited a more cycling-mature city) exerted much more influence on the behavioral change before than nowadays. Interestingly, individual concerns (for instance, environmental, health, physical and political) are constant triggers to shift to cycling, over time. As such, we would argue that these should be triggers to target with specific policy measures, on a continuous basis (as they are constant concerns for everyone), but complementary policy measures are needed to match the remaining motivators highlighted by Non-Cyclists.

The relationship between the observed choice to bicycle and the factors influencing this choice is a complex process. However, overcoming perceived barriers to cycle may not be enough to make the modal shift, as we learn from Cyclists. Individuals make deliberated choices, but also life circumstances and contextual changes play an important role in behavioral change. For example, breaking a leg or having a new bike lane in one's home street can strongly influence behavior. What happens, in reality, is not necessarily related to the expectations people have to start bicycling.

This research explores some of these questions, but further research should explore additional findings. Evidence from our research suggests that it is possible to identify and characterize different sub-groups of the large group of potential cyclists, and their particular barriers and motivators. Moreover, triggers of Cyclists and barriers of Non-Cyclists should be different in cities with different cycling maturity levels. For each group, it is crucial to understand their barriers and motivators to shift to cycling, to better identify strategies to overcome those barriers and learn from current cyclists. In the context of changing cycling maturity, policies and interventions outlined and directed toward people who are willing to cycle (or cycle more often) should be a priority when attempting to increase cycling modal shares.

Our research contributes to the understanding of cycling behavior change, and to the identification of the barriers to cycling and the understanding of triggers that led people to cycle in a low cycling maturity city. Additionally, it is a contribution to the planning and definition of local policies and actions (hard and soft measures) that can potentially foster a modal shift to cycling in cities with low rates of cycling. We denoted a concern with individuals' health improvement that plays an important role in the decision to adopt cycling. The methodology proposed here to understand and compare the barriers and motivators to bicycle, is transferable to other contexts, regardless of their cycling maturity level. From the results, practitioners should look at the barriers and motivators in the fields of urban planning and engineering with a strong focus on the built environment and built interventions, regulation, and programs.

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Appendix

List of barriers to bicycle (Non-Cyclists)

What are the reasons that you do not ride your bike more often?

Select, from the following list, the ones that apply to you.

BICYCLE

- I do not have a bike in Lisbon
- I have not biked for several years
- I do not know how to ride a bike
- I have never ridden a bicycle in the city
- I'm afraid to ride a bike
- I do not like bicycling

I am physically unable to ride a bike
 It is expensive to have a bike and its equipment
 My bike is not suited for riding in the city; I do not have a lock or lights
 It is not practical to manage a helmet, lock or other safety gear
 I am concerned about having to deal with potential mechanical problems

SECURITY AND EQUIPMENT

I do not feel comfortable with the idea of cycling in the traffic
 There is not a safe route between my home and workplace
 There aren't enough bike lanes, bike paths or low traffic streets that suit my commute
 I consider it too dangerous to ride a bicycle, in general
 I'm afraid of having an accident
 I am concerned that motorists do not respect cyclists
 I'm afraid that someone will steal my bike when it's parked outside
 I'm afraid I'll be robbed on the street if I'm on my bike
 I am afraid of being harassed on the street if I am on my bicycle

PERSONAL CIRCLES

My parents or family will not let me ride my bike in the city

RESIDENCE AND WORK

I do not have room to have a bike at home
 I do not have a simple way to carry the bike home
 I live too far from my workplace/school for cycling to be a good option
 I live too close to my workplace/school for cycling to be a good option
 I'm worried about getting to work sweaty
 My work clothes are not compatible with cycling
 There is no shower or dressing room at my workplace/school

ROUTINES

I have to make several trips a day
 I have to take children to school
 I need to carry cargo or large things regularly
 I use the car for work (e.g. courier, taxi driver, etc.)
 I use my commute time for other activities incompatible with cycling, such as reading, talking on the phone, working, etc.

OTHER

I think the city is too hilly
 I think it will take longer to reach my destination
 I do not know how to cycle to the places I usually go
 It's too hot in summer or it rains a lot in winter to ride a bike
 I like to drive a motor vehicle

Other:

List of barriers to bicycle (Cyclists)

What were the barriers you had before choosing to bicycle for commuting, X years ago?
 Try to remember the worries, fears, or image you had before you started biking.
 Select, from the following list, the ones that apply to you.

BICYCLE

I did not have a bicycle in Lisbon
 I had not biked for several years
 I didn't know how to ride a bike

I had never biked in the city
 I was afraid to ride a bike
 I did not like to ride a bike
 I was physically unable to ride a bicycle
 I considered it too expensive to have a bicycle and equipment
 I didn't have a bicycle adapted for the city, and/or I don't have a lock or lights
 It seemed too impractical to manage a helmet, lock or other safety gear
 I was worried about having to deal with potential mechanical problems

SECURITY AND EQUIPMENT

I was not comfortable with the idea of cycling in traffic
 I worried there weren't enough bike lanes, bike paths or low traffic streets that suit my commute
 There wasn't a safe route for my commuting
 I considered it too dangerous riding a bicycle, in general
 I was afraid of an accident
 I worried that motorists would not respect cyclists
 I was afraid that my bike would be stolen when parked outside
 I was afraid of being assaulted on the street if I were on a bicycle
 I was afraid of being harassed on the street if I were on a bicycle

PERSONAL CIRCLES

My parents or family would not let me ride my bike in the city

RESIDENCE AND WORK

I didn't have room to store a bike at home
 There was no simple way to carry the bike home
 I lived too far from my workplace/school for cycling to be a good option
 I lived too close to my workplace/school for cycling to be a good option
 I was worried about getting to work sweaty
 I worried that my work clothes would not be compatible with bicycling
 There was no shower or dressing room at my workplace/school

ROUTINES

Had to make several trips a day
 I had to take children to school
 I needed to carry heavy or bulky items regularly
 I used a vehicle for my work, as a work tool (e.g. courier, taxi driver, plumber, etc.)

OTHER

The city seemed too hilly
 I thought it would take me longer to reach my destination
 I worried about not knowing how to cycle to the places that I usually go
 I was worried that it would be too hot in summer or it would rain too much in the winter to be able to ride a bicycle

Other:

I do not remember.
 None. For me to use the bike was always something natural.

List of motivators to bicycle (Non-Cyclists)

What could make you ride a bike more often?
 Select the items that apply to you.

BICYCLE

If I had a bicycle
 If I had a bike suitable for urban trips
 If I had an electric bicycle
 If I learned to ride a bicycle
 If I took biking lessons for urban cycling
 If I was accompanied during my first cycling trips

RESIDENCE AND WORK

If I change my place of residence
 If I moved workplace/school location
 If I had room to store a bike at home
 If my work clothes became compatible with cycling
 If I had showers or a dressing room available at my workplace/school

INFRASTRUCTURE, EQUIPMENT, AND SECURITY

Expansion of the cycling network, such as bike paths, bike lanes & sharrows
 Improvement of the existing cycling network (safety and quality)
 More bike racks and secure of protected bike parking
 The existence of a bike sharing system
 General reduction of speed of car traffic
 If the public transportation system easily accommodated bicycles

PERSONAL CIRCLES

If my friends/family/colleagues regularly rode bicycles

CAMPAIGNS

Bicycle promotion campaigns carried out by my employer/school
 Bicycle promotion campaigns carried out by the Municipality or City Districts
 Bicycle promotion campaigns carried out by Associations, Collectivities or other Non-profit Organizations
 Bicycle promotion campaigns carried out by commercial entities
 Discounts or similar incentives in shops if arriving by bike

COST

The rise in the price of gas
 The rise in the price of public transport
 If parking at my workplace/school was no longer free or became too expensive
 If there were tax incentives for purchasing a bicycle
 If there were employer-based incentives for bicycle adoption (financial or paid time off)

PERSONAL

If my financial situation changed
 If I became physically able to ride more or at all
 If riding a bicycle became necessary for my health
 If I did not need to regularly transport children to daycare/school and/or another place

Other:

Nothing

List of triggers to bicycle (Cyclists)

For this question, recall the time before you started bicycling, X years ago.
What made you start biking?

Recall if there was any decisive factor that influenced your decision.
Select, from the following list, all the factors that apply to you.

BICYCLE

I acquired a bicycle
I acquired a bicycle adapted to urban cycling
I acquired an electric bicycle
I learned to ride a bike
I took bike riding lessons in an urban setting, and/or have biked in the city with experienced cyclists

RESIDENCE AND WORK

I moved
I moved to a closer work/study/living place
I changed my workplace/school
My residence now has room to store a bicycle
My work clothes became compatible with cycling
A shower or dressing room became available at my workplace/school
I bicycle was/is part of my job (e.g. bike courier)

OTHER CITIES

I lived in another city where it was common for people to ride a bicycle
I visited another city where it was common for people to ride a bicycle

INFRASTRUCTURE, EQUIPMENT, AND SECURITY

Expansion of the cycling network
Increased the number of bicycle parking facilities
The existence of a bicycle sharing system
Traffic began to circulate at a lower speed

INTERESTS

I had an interest in improving my physical fitness
I had an interest in improving my health
I was concerned about the environment
I wanted to convey a political message
I wanted to convey to those around me that I use sustainable transportation
I perceived riding a bike as fashionable

PERSONAL CIRCLES

Influence of family members
Influence of friends
Influence of colleagues

EVENTS, CAMPAIGNS, AND MEDIA

Participation in events such as Critical Mass
Participation in event or competition such as Bike to Work Day
Bicycle promotion campaigns carried out by my employer/school
Bicycle promotion campaigns carried out by the Municipality or City
Bicycle promotion campaigns carried out by Associations, Collectives or other Non-profit Organizations
Bicycle promotion campaigns carried out by commercial entities
Advertising
Cycling magazines
Newspaper articles, blogs or magazines
Strava, MapMyRide or similar applications

PRICES OR PUBLIC TRANSPORTATION

Parking at my place of work/study was no longer for free or became expensive
 The rise in the price of gas
 The rise in the price of public transport
 Get faster to the transit network
 The transit system started to allow the transport of bicycles
 Degradation of public transport systems
 The bicycle was the cheapest way compared to other modes of transport

PERSONAL

I stopped having to take children to school
 I knew a bicycle was going to be the fastest when compared to other transportation options
 I got without a car

Other:

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