boost

boosting starter cycling cities

Starter City Roadmap

“

...making cities more bicycle-friendly has become a priority in many regions worldwide that envision a post-carbon society...

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Introduction

1.1 The bicycle as an alternative to car-centric planning

Today, some of the major global societal challenges revolve around issues of environmental degradation and climate change, in line with worsening health conditions sprouting from growing levels of sedentarism. Automobile domination, previously the leading trend since the end of the Second World War, is inseparable from these concerns, with increased traffic congestion and pollution, moving in parallel with reduced urban liveability. Streets became dominated by motorized vehicles, side-lining the pedestrian while urban areas lost its human scale (Gössling et al., 2018). Within the urge to a move beyond car-dependent cities and societies, making cities more bicycle-friendly has become a priority in many regions worldwide that envision a post-carbon society, embracing the many benefits associated with this transport mode. The term bicycle-friendly city (or bike-friendly city) has become widespread, referring to a combination of efficient infrastructure, transportation policies and societal consensus in favour of this transport mode (Zayed, 2017).

Figure 1: Car-centric planning (source: https://www.flickr.com/photos/agenciasenado/23427565625/in/photostream/)

Nevertheless, while cycling has been experiencing increasing interest, when in comparison with other modes of transport the discrepancy in research and policy commitment is still noticeable (Gössling and Cohen, 2014; Heinen et al., 2010). As such, analysis and planning methods have not kept pace with demand (Kuzmyak et al., 2014), meaning that the exploration of the potential of the bicycle often remains dormant. In addition, as the turn to cycling is a transition from the well-established car-centric paradigm, any robust approach should rely on an understanding of the complex dynamics and factors at stake in the shift of behaviours, requiring interdisciplinary responses (Spotswood et al., 2015). These include contributions from the fields of environmental sciences, urban planning, and transport studies, but also engineering, computer science, geography, sociology, or even psychology and medicine. This means embracing the complexity of planning for cycling and recognizing that the involved factors are not only numerous, but also highly location and time specific.

To understand the challenges of planning for cycling, first it is necessary to understand that cities are not at the same level of cycling maturity. The most widespread typology of cities according to their level of cycling has been developed by the European consortium BYPAD (2008), creating three main categories according to the bicycle modal share in comparison with other modes of transport, that is, the share of commuting trips done by bicycle. “Starting cycling cities” are defined as those that have a cycling modal share below 10%; “Climber cycling cities” have a modal share between 10-20%; and “Champion cycling cities” have modal shares above 20%. Later, this typology was further developed by the European research project Presto, which defines the same three “cycling development levels” based on two indicators: cycling conditions (how safe, easy, convenient and attractive cycling is) and cycling modal share (Dufour, 2010) (Figure 2).

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...cities are not at the same level of cycling maturity...

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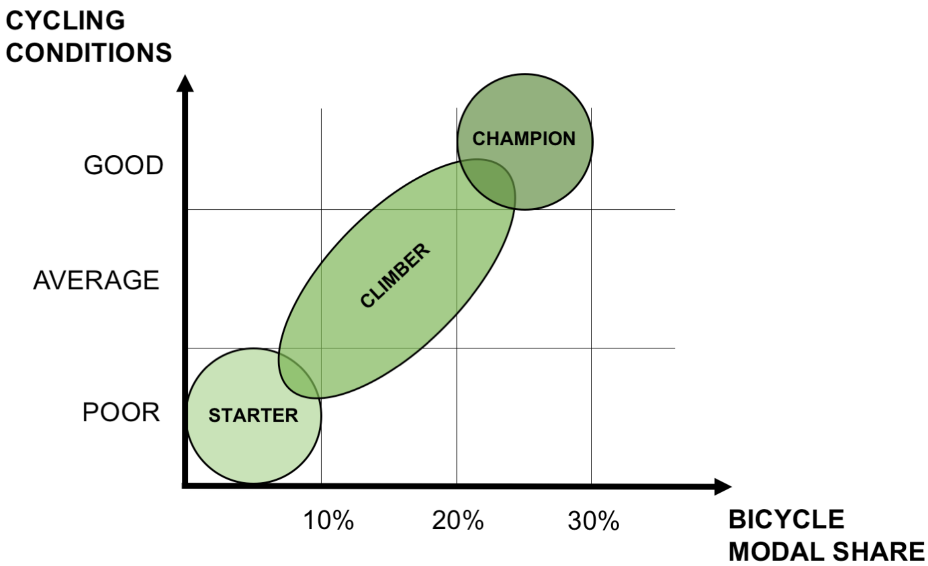

Figure 2: Typologies of cycling cities (adapted from Dufour, 2010)

Starter Cycling Cities, while encompassing numerous realities, all have in common a lack of cycling tradition and technical know-how to overcome cycling resistance (Silva et al., 2018a). Other modes of transport (especially the car) are dominant both at the level of practices and discussions on urban mobility, leading to political, social, and technical scepticism over a scenario of transition. These cities commonly have shown timid efforts towards cycling, often limiting actions to less effective measures, such as building leisure-oriented cycling infrastructure (in parks or waterfronts) or providing symbolic bike-sharing systems (Silva et al., 2018a). That is the case of virtually all Portuguese cities, which stand out for the low rating of walking and cycling friendliness and for the lack of detailed data on active modes (EC Directorate-general for Mobility and Transport, 2017).

Despite the residual cycling modal share and the lack of infrastructure and cycling culture, starter cities have an unexplored demand for bicycle commuting. To harvest its benefits, it is essential to create basic cycling conditions through infrastructure efforts that make cycling safe, possible, and respectable (Dufour, 2010), followed by education and dissemination actions that contribute towards increasing awareness and cycling normalization. So far, research has mainly concentrated on 'champion' and 'climber' cities, meaning that the problems and solutions for 'starters' tend to be approached from the lens of champion cities. Extended research and tools considering the specificities of starter cities is yet to be developed. However, taking advantage of the vast expanse of benefits that are associated with the bicycle (Figure 3) should not be limited to these more mature bicycle contexts.

HEALTH
BENEFITS

ENVIRONMENTAL
BENEFITS

ECONOMIC BENEFITS

SOCIAL BENEFITS

Figure 3: Benefits of the bicycle

> *To meet the 2050 EU targets for emissions, the transport sector will have to reduce its emissions by an estimated 60%.*

The positive externalities in what concerns the impact on the environment appear as one of the most studied benefits of cycling. The global transport sector is responsible for roughly 14% of the global CO2 emissions (IPCC, 2014) and 25% of all EU emissions (ECF, 2011a), and this is if considering solely the movement of people and goods. In urban areas the environmental burden of the transport system is, for the most part, associated with the use of private vehicles, i.e. automobiles. To meet the 2050 EU targets for emissions, the transport sector will have to reduce its emissions by an estimated 60%. The shift from motorized modes to the bicycle comes associated with less use of natural resources, reduced traffic congestion, pollution and noise levels, which can be particularly felt in central urban areas, where traffic pressure is usually higher (Garrard et al., 2012; Krizek, 2007; Rabl and de Nazelle, 2012). And although any shift away from car trips, for instance to public transport, can provide similar benefits, those induced by the bicycle are significantly more noticeable, as it is seen as the ultimate ‘zero carbon’ solution for personal transport (Chapman, 2007). These claims only relate to the ‘trip making’ part of the equation, as the life cycle of the transport chain, manufacturing, maintenance, infrastructure, and disposal must also be considered. Still, estimations point to each km covered by a bicycle producing just 7% of those emitted by cars (ECF, 2011b).

Health benefits are also strongly related to these environmental impacts (Götschi et al., 2016). The increase in physical activity rates severely reduces the risks of cardiorespiratory diseases and the incidence of obesity, diabetes and hypertension, both synonyms of a sedentary lifestyle (de Hartog et al., 2010; Götschi et al., 2016; Oja et al., 2011). Long term benefits can also be found on an improved cognitive function, reduced risk of depression (Garrard et al., 2012; Gatersleben and Haddad, 2010), and increased social engagement (Götschi et al., 2016). However, it is important to stress that most of these benefits are minimized if cycling for transport substitutes other forms of regular physical activity (Handy, S., Wee, B. v. & Kroesen, 2014). All these are directly related to economic benefits, as health expenditures are significantly lower (Fishman et al., 2011; Mulley et al., 2013).

And while by using a bicycle means being closer to car traffic, which means that crash risks and increased exposure to air pollution are inherent negative externalities, the wider benefits outweigh these risks (de Hartog et al., 2010; Heinen et al., 2010; Rabl and de Nazelle, 2012; Rojas-Rueda et al., 2013). It is defended that the optimal approach to maximize health rewards induced by increased cycling is to increase both its safety and convenience (Götschi et al., 2016). Safety can be achieved through the creation of segregated infrastructure and other road arrangements aiming at minimizing the speed differential between the bicycle and motorized vehicles (Broach et al., 2012; Heinen et al., 2010; Segadilha and Sanches, 2014). Convenience, on the other hand, lies on connecting the major trip generator nodes, while avoiding segregated stretches of dedicated bicycle infrastructure

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In less dense locations, the bicycle does still have an important role, expanding access to jobs and other travel opportunities by feeding public transport infrastructure where coverage is low.

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(Heinen et al., 2010; Hull and O'Holleran, 2014). These factors are key in the decision of switching the preferred transport mode to the bicycle. In less dense locations, the bicycle does still have an important role, expanding access to jobs and other travel opportunities by feeding public transport infrastructure where coverage is low (Handy, S., Wee, B. v. & Kroesen, 2014; Heinen et al., 2010).

Direct economic benefits, that can be directly quantified, are another key important factor (Ferreira et al., 2014; Fishman et al., 2011; Gössling et al., 2019a). Cyclists save money over transit or driving, particularly on fuel, tolls, and parking, meaning that they can spend more elsewhere, increasing their levels of satisfaction. Conversely, authorities save money on infrastructure costs, particularly due to less wear-and-tear on road and thus can invest it in other ways that can benefit the community (Gössling et al., 2019a; Handy et al., 2014). National economic balances are also improved, particularly in fuel importing countries, as foreign dependency on primary energy is reduced (Neun and Haubold, 2016a).

While some studies have documented a positive association between residential property values and proximity to bicycle facilities (Krizek and Johnson, 2006), these results might be skewed towards a preference toward recreational facilities, which tend to mimic the positive influence of proximity to green spaces. Still, in consolidated urban areas, there appears to be a positive contribution in housing prices from proximity to bike sharing systems (Pelechrinis et al., 2017a).

Urbanity can also be strengthened with the increased use of the bicycle. The considerable reduction of space requirements for the transport infrastructure (Buehler, 2012; Gössling et al., 2019a) can lead to increased space allocation for pedestrians, especially in the space constrained streets that compose much of the urban fabric of European cities. Bikeable neighbourhoods and cities are perceived more positively by tourists (Flusche, 2009), and as such, bicycle master plans are now part of several urban redevelopment strategies worldwide (Lowry et al., 2016), meaning that authorities are clearly aware of the added value of increased bicycle usage.

Important societal benefits come through an improved sense of community (Gatersleben and Appleton, 2007; Rissel et al., 2013) and increased freedom for children to use and explore the urban environment (Tight et al., 2011). Less congestion also means a more livelily urban environment, free

> *This focus on the bicycle extends not only from harvesting its positive externalities, but also towards a growing awareness of how city planning drifted away from the human scale.*

from overly saturated streets and roads (Fishman et al., 2011). The affordability of the bicycle embeds a key equitable component to the transport system (Pucher and Buehler, 2008), as more people can have access to identical mobility opportunities. Also, the bicycle can provide the needed social distancing that will be preferred by commuters, for health safety reasons, for the foreseeable future (Teixeira and Lopes, 2020). Finally, the provision of suitable bicycle infrastructure both in existing and in new developments can strengthen the development of compact, mixed-use and human scale urban settings (Pucher and Buehler, 2008), further reinforcing all the above stated benefits.

This focus on the bicycle extends not only from harvesting its positive externalities, but also towards a growing awareness of how city planning drifted away from the human scale. While this discussion has been gaining traction in the recent years, the core concept itself is, in fact, everything but new. In the early 1900's, and inspired by William Drummond of the Chicago School, the North American sociologist Clarence Arthur Perry coined the term "neighbourhood unit". In his 1929 paper, Perry defined a set of necessary conditions for its establishment: a population of 5000 to 6000 inhabitants, 800 to 1000 children on a primary school, and an area of roughly 65 hectares, defining an 800m square. Here, the school played a nuclear role, defining the arrangement of the surrounding residential spaces, community activities and local retail (Perry, 1929). This last one, located at the edges of the square, was destined to promote cooperation and association principles. Residents would then gather in front of the school or the playground for social or cultural purposes (Figure 4).

Additional recommendations stated the hierarchization of the road infrastructure, locating arterial streets along the perimeter of the unit and dedicate at least 10% of its land area to parks and open spaces. Applied at a large scale, he envisioned an urban model based on a series of interlinked neighbourhood units, connected by small functional commercial centres. This concept was then a strategy to protect the livelihood of small neighbourhoods, allowing access to the main destinations of families without the need to cross major traffic thoroughfares, that at the beginning of the 20th century threatened to split the main American cities. And while this approach was criticized for its strict focus on urban design aspects, lacking a sensitivity to racial, ethnic, and religious segregation (Alexander, 1965; Jacobs, 1961), it inspired the reconstruction of several European cities in the post-war period.

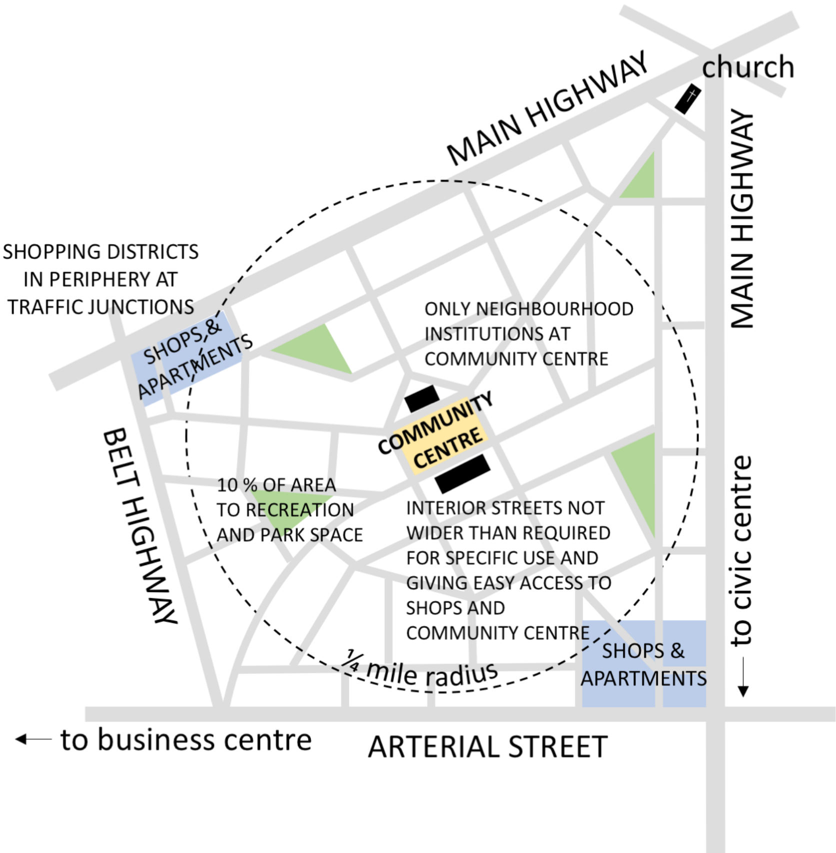

Figure 4: Perry's representation of a neighbourhood unit (adapted from Perry, 1929)

> *...most of the 20th century was characterized by car centric urban policies, selling the car as the object of freedom and economic prosperity...*

Still, these ideals did not endure for long and most of the 20th century was characterized by car centric urban policies, selling the car as the object of freedom and economic prosperity (Gössling et al., 2019a; Urry, 2004). Monofunctional urban areas, especially in the suburbs, became the predominant form of urban development, steering away from the human scale of cities that characterized the pre-car period. The car, thus, became omnipresent in the urban space. The finite street space became progressively dominated by motorized vehicles, which required significantly more space than the pedestrian. Sidewalks became increasingly narrower and often seen as accessory, and pedestrian crossings were understood by traffic engineers as a threat to optimal traffic efficiency. Given the exponential increase in speed, urban areas could extend beyond the reaches of acceptable walking and cycling trips.

However, the recognition of the perverse consequences of this path reinforced the need to rethink the role of the neighbourhood. In her book "The Death and Life of Great American Cities" Jane Jacobs (1961) challenged the existing modern development mindset. Mixed used and diverse urban environments were argued as key to increase opportunities for social interaction, along sidewalks and public spaces, encouraging a sense of connection with the urban environment. In European cities, where older urban fabrics still retained part of these attributes, attempts focused, initially, to restrict car usage, such as reducing parking availability, introducing congestion charges and car-free superblocks (Börjesson et al., 2012; Prud'homme and Bocarejo, 2005; Rueda, 2019).

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The concept of human scale cities is a natural evolution of this trend, as it dives deep into the relationship between the configuration of the urban fabric, the density and diversity of activities and housing, and the physical and functional organization of the transport network. The "15-minute city" concept attempts to mimic the major premises of Perry's neighbourhood unit. This notion of "chrono urbanism" rides on the premise that quality of life is inversely related to the amount of time spent on transportation (Moreno et al., 2021). Therefore, it encourages an arrangement of urban functions to fulfil all basic needs (jobs, commerce, healthcare, education, and entertainment) within 15 minutes of home (Figure 5). Similar examples can be found in the 15-minute walkable neighbourhood (Weng et al., 2019) and the 20 minute city (Da Silva et al., 2020), that expands accessibility to include public transport. They all have in common the idea of bringing activities closer to people, epitomizing the human scale of cities prior to age of the car. The Paris mayor Anne Hidalgo, supported by the Sorbonne scholar Carlos Moreno, is one of the strongest defendants, within the political community, of this form of urban development.

Figure 5: Schematic representation of the 15-minute city

The promotion of human scale cities has a series of common key objectives. It defends the creation of urban areas that are more equitable, as one does not need to own a car, more eco-friendly, as less (polluting) vehicles are required, and livelier, as less space for vehicles on the streets are need and, hence, they become more populated by pedestrians. This alternative lifestyle that represents the antithesis of car dependency will lead, almost unconsciously, to important time savings that could be directed towards physically and mentally enhancing activities (Moreno et al., 2021). Benefits extend beyond the social and environmental realms, as the promotion of social cohesion in these human scale cities also increases the overall attractiveness of their urban environment, which can increase property values but also tourism levels and employment opportunities (Leyden, 2003; Song and Knaap, 2004).

While human scale cities combine multiple urban development strategies, ensuring adequate mobility is one of its key premises. In this regard, relying solely on the pedestrian mode can limit the potential of a set of interconnected urban centralities, that in larger urban areas will be, necessarily, further apart than the optimal 15-minute trip. The bicycle is seen as the ideal vehicle for short to medium length trips (Fishman, 2016), satisfying the majority of urbanites needs for daily mobility without a significant time penalty (Ellison and Greaves, 2011) and extending the functional area of 15-minute cities based solely on active mobility. For even longer distances, the bicycle can also be used as a complement public transport, with the adoption of first and/or last-mile solutions.

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1.2 Roadmap for starter cycling cities

These themes highlight the role of the bicycle as a catalyst to create major changes in the planning paradigm of starter cities. As it can act as an entry point into a more sustainable and healthier urban environment, providing the needed support to the planning process becomes paramount. This is the purpose of project BooST. Contrary to the principles applied to champion cities, such as evaluating available cycling infrastructure, current travel behaviours and/or satisfaction of cyclists, any strategy applicable to starter cities firstly must assess both their potential, constraints, and available resources to increase cycling as a relevant transport mode for everyday travel. Beyond the development of new technical knowledge, this project was also designed to promote its dissemination among planning practitioners, aiming to provide crucial support to the development process of new cycling strategies.

Considering this, the project BooST provides a roadmap which, as a whole, contextualizes the bicycle and its benefits in the greater human scale paradigm. Simultaneously, it directly responds to the particular needs of the starter context, with clear and relevant information to forward the debate between the different participating entities. Three tools were developed to integrate this roadmap (Figure 6), focusing on three distinct challenges.

Figure 6: The three tools of the BooST roadmap

The first tool attempts to answer the question on how to quantify the benefits of increased bicycle use. This is, indeed, a crucial question on the decision-making process and can facilitate the debate between planners, politicians, and the general society. The 'Economic Value for Cycling' (EVC) is aimed at measuring the direct monetary benefits, at different scales, of an increase in bicycle use. This tool seeks to open the path for actual interventions by clarifying the advantages of adopting the bicycle as a transport mode.

As urban territories are highly heterogeneous, so is their potential for bicycle usage. Thus, certain territories might h ave greater ease at harnessing the benefits of cycling, which can act as a promotion strategy for other areas, with less cycling propensity. Comprehending how this potential is distributed in space is paramount to optimizing its use. The 'Gross Potential for Cycling' (GPC) does this through a detailed territorial characterization of the potential for bicycle use.

Once the potential for cycling is established, it is crucial to evolve from theory to practice. This requires a strong and comprehensive cycling mobility plan, capable of harnessing the existing potential and overcoming existing barriers to the bicycle. Having decided on where to intervene, the question rests on how to do it. The range of available options, whether in physical or immaterial actions, often overwhelms decision makers. The optimization of the efficiency of bicycle promotion strategies, exploring the links between possible measures and actions is made possible with a second tool, the “Cycling Measures Selector” (CMS).

Given its intention to provide meaningful guidance to the planning process, the contribution of the BooST project did not exhaust on the sole development of these three tools. Five events were hosted by project BooST with fifty-eight participants from fourteen Portuguese municipalities. These workshops were followed by two additional events that counted with the participation of four members of the Portuguese research community and ten bicycle activists, this time aiming at a broader discussion of the main attributes of the tools, their limitations, and possible contributions to influence the bicycle planning paradigm in the country. In these workshops important insights were given on the validity of the results and different moments of discussions targeted the necessity of punctual improvements.

This journey culminates in this roadmap, that serves not only as a vehicle of dissemination of the Project Boost’s main findings but also as a guiding document for all the relevant content available on the project’s website (https://boost.up.pt/en/) and how can interested parties take advantage of it.

> “**...the project BooST provides a roadmap which, as a whole, contextualizes the bicycle and its benefits in the greater human scale paradigm.**”

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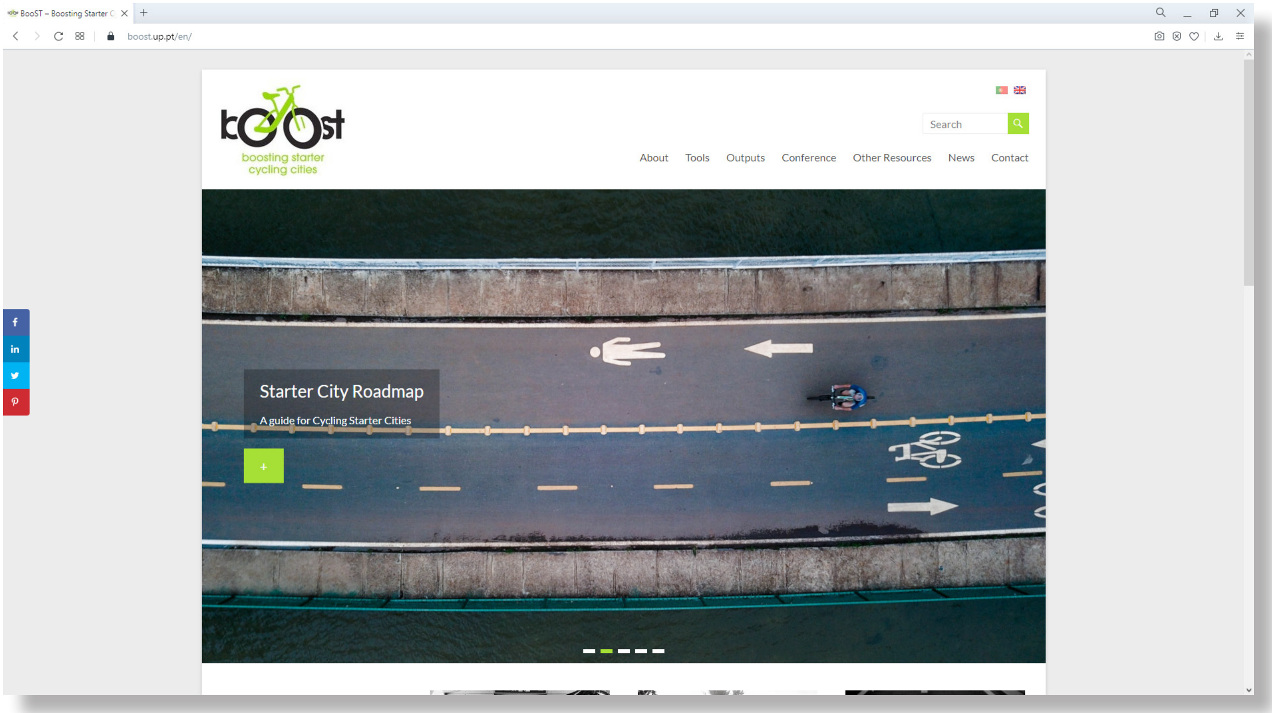


Figure 7: Landing webpage of the Boost project

1.3 Structure of the Roadmap and how to use it

This document doubles then as an instruction manual for the three tools of the BooST project, each described in an individual chapter that follow a similar structure. The first section of each of the following three chapters details the evidence that guided the development of the corresponding tools and that can be consulted if additional information is needed. The second section describes the tool itself, guiding users on how to use it. Its structure differs according to the tool being presented. For the case of web-based tools, as is the case with the Economic Value for Cycling and the Cycling Measures Selector, this guidance is materialized through step-by-step visual cues. In the case of the Gross Potential for Cycling, instructions are presented on how interested stakeholders can apply the designed workflow in their daily practice. The final section explores the feedback of the hosted workshops and the results from the application of the tools to Portuguese municipalities, when applicable.

2
Measuring the benefits: The Economic Value for Cycling

2.1 Context: Why plan for Cycling?

The bicycle, in addition to an object or asset, is also a means of transport, associated with important benefits, namely in health and financial terms. It has also an important role in urban mobility, as it is considered the fastest transport mode for trips up to 5km, which constitute most of urban travel (Ferreira et al., 2020; Vale, 2017).

Despite the proven benefits, investments in cycling are not always considered a priority (Krizec, 2007), meaning that it is important to be able to translate in economic terms the impact of these benefits to guide decision-making in mobility management and the promotion of cycling. To determine the economic value of cycling (EVC) it is necessary to go beyond the assessment simplification of the direct benefits, based on indicators such as revenue, sales and rental or jobs generated.

Empirical evidence highlights the need to develop quantitative and qualitative research to quantify the positive effects of bicycle use, in order to draw a more accurate picture of the economic benefits of cycling (Neun and Haubold, 2016b), that includes:

ENVIRONMENTAL AND CLIMATE IMPACTS

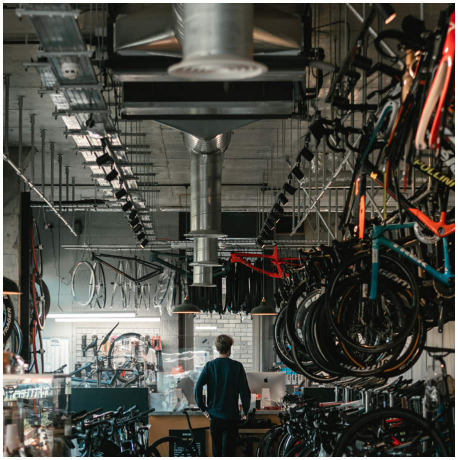
Includes the savings of CO2 emissions; the reduction of air pollution; the reduction of noise pollution and environmental assets (Blondel et al., 2011; Fishman et al., 2014; Médard de Chardon, 2016; Zheng et al., 2019). For energy and resources, fuel savings and resource savings in vehicle production and infrastructure construction should be accounted (Maibach et al., 2008

Encompasses the results of reduced mortality due to physical activity; the effects of road traffic accidents, air pollution and carbon emissions; and the mental health benefits and reduced absenteeism from work (Deenihan and Caulfield, 2014; Geus and Hendriksen, 2015; Mueller et al., 2018; Otero and Nieuwenhuijsen, 2018; Rojas-Rueda et al., 2011; Rutter et al., 2013; WHO, 2011);

HEALTH BENEFITS

ECONOMIC ACTIVITIES

Includes the value generated by the bicycle industry (number and value of bicycles produced and jobs associated); sales and repairs (sales volume; value of accessories and equipment and repairs sales) (Blondiau et al., 2016; Blondiau and Van Zeebroeck, 2014); up to bicycle tourism (Deenihan and Caulfield, 2015; Piket et al., 2013; Weston et al., 2012) and the impact of cycling on the local economy (local shops, restaurants and cafes) (Blondiau et al., 2016).



Considers the benefits related to congestion reduction and savings in road infrastructure construction and maintenance (Neun and Haubold, 2016b; Raje and Saffrey, 2008); connectivity and accessibility improvements, and the possible savings in public transport (Bullock et al., 2017; Haubold, 2014).

MOBILITY

URBAN SPACES

Contains savings associated with the space that needs to be dedicated to the bicycle and the improved urban design making cities more accessible to all (Bullock et al., 2017; Neun and Haubold, 2016b); and impacts on the property value of housing (El-geneidy et al., 2016; Pelechrinis et al., 2017b)

Although there is still no recognized monetary valuation of cycling on issues such as quality of life; social equity; gender equality; or children's well-being, it is fundamental to assess the social impact of bicycle use (ECF and WCA, 2015; Prati, 2017; Shaheen et al., 2010).

SOCIAL IMPACTS

Figure 8: Measurable economic benefits of the bicycle

The EVC assessment and methodological challenges

As mentioned before, despite the proven benefits, investments in cycling mobility are not always considered a priority, especially in contexts where the rate of bicycle use in commuting is residual, as is the case of Portuguese cities, with an average modal share of 0.5%. All these benefits (which include economic, cultural, social, environmental dimensions, among others) can be translated into a monetary framework (Gössling et al., 2019b).

However, from a methodological point of view, this assessment is not so simple, and the attribution of economic value to cycling continues to face methodological challenges, namely lack of consistent data, an inexistent standardized approach and a complexity associated with monetizing the full extension of the benefits associated with cycling (Ferreira et al., 2020).

Figure 9: The Economic Value for Cycling

> "...the attribution of economic value to cycling continues to face methodological challenges, namely lack of consistent data, an inexistent standardized approach and a complexity associated with monetizing the full extension of the benefits associated with cycling..."

...the range of benefits associated with cycling includes indirect effects and social impacts, such as well-being and quality of life, effects on health, congestion, and accidents, etc., for which there is still no recognized monetary assessment.

Methodological challenges

One of the issues raised in the literature about the economic value of cycling is related to the lack of information about bicycle use in transport statistics, and the fact that the existing data is generally dated (Weston et al., 2012). For the ECF, the counts of the population who use the bicycle regularly are 'ad hoc' and usually linked to specific infrastructure projects, and most of the time there is no monitoring, which makes it impossible to assess and analyse its evolution (European Cyclists' Federation, 2017). Also, different geographic levels generate different datasets, and can vary from individual counts, to aggregated information for a specific area. Thus, national averages differ from city averages making comparisons between cities, regions and countries impracticable, as the exact figures vary due to local conditions and used methodologies (Krizec, 2007; Steenberghen et al., 2017).

Another challenge is related to the simplification of the assessment of the direct benefits of cycling. As mentioned, the range of benefits associated with cycling includes indirect effects and social impacts, such as well-being and quality of life, effects on health, congestion, and accidents, etc., for which there is still no recognized monetary assessment. This could lead to cycling being considered less viable compared to other modes of transport (Blondiau and Van Zeebroeck, 2014; Krizec, 2007; Raje and Saffrey, 2008). This issue is closely linked to the methods and units used to calculate different benefits, since cycling benefits are usually measured only when a modal shift occurs. That is, health and other benefits are only considered if the users switch to other forms of transport. However, the absence of these benefits is not assessed and taken into account in mobility and transport solutions (Raje and Saffrey, 2008).

A second issue concerns the methodologies, such as Cost-Benefit Analysis (CBA), which are widely used in the evaluation of transport projects, to compare the effects of certain policies or projects, attributing a monetary value to the positive and negative impacts, which result in a cost or benefit to society (Gössling et al., 2019b; Krizec, 2007). These analyses include criteria such as travel time, operating costs of vehicles, accidents / collisions, noise, air pollution and climate change. However, these basic requirements of a CBA do not represent all the externalities of transport, which reveals the limitations of this methodology as a decision-making tool. Here, we focus on the subjective choice and lack of public participation over the items to be included, the possibility of reductionist analyses that only value economic aspects, and the allocation of monetary values, for which there may be no market values, such as perceptions of security, discomfort or immeasurable aspects as are the effects of injury or death (Gössling et al., 2019b; Gössling and S. Choi, 2015). One exception is the Copenhagen CBA, in which the methodology was redefined based on environmental economics to comprise the various externalities linked to the car and bicycle. Important parameters were included such as vehicle operating costs, time costs, accident costs, pollution and externalities, recreational value, health benefits, safety, and discomfort; and concepts such as contingent assessment, hedonic price index, travel cost assessment, avoided social costs, health costs, and shadow prices. The extension of the analysed parameters allowed to evaluate the impact of cycling not only as an alternative to the car but also because of the different dimensions that generate a certain financial impact (Gössling and S. Choi, 2015).

In this work, as well as in others that followed (Blondiau and Van Zeebroeck, 2014; Bullock et al., 2017; Macmillan et al., 2014; Sustrans, 2019) the impact of cycling was measured not only as an alternative to the car that generates a certain financial impact, but also because it incorporates different social dimensions (Ferreira et al., 2020).

In view of the above, and in order for the cycling potential to be recognized, it is necessary to develop holistic models that incorporate cross-sectional effects and an interaction between this means of transport and the society (Ferreira et al., 2020). These models are essential to inform the decision-making process on mobility and, therefore, the evaluation of cycling impacts should include both the direct benefits for the user, such as health, and the indirect benefits for society, as is the case with externalities such as consumption, energy consumption, among other factors.

2.2 Tool description

The EVC tool aims to provide an analysis of the impacts of higher bicycle use in the economy, estimated at the local level, through its environmental, energy and health impacts. In this Roadmap the EVC tool at the local scale is presented in detail. The methodology, assumptions and results described in this section can be adapted and recalculated by the user according to the available data and the tool's application objectives. As with the other tools developed by BooST, the EVC is available on the BooST website (https://boost.up.pt/en/veb), through the main menu and through the slider section of the project's Home page (Figure 10). A video explanation can also be found though the outputs option on the top bar (https://boost.up.pt/en/videos/).

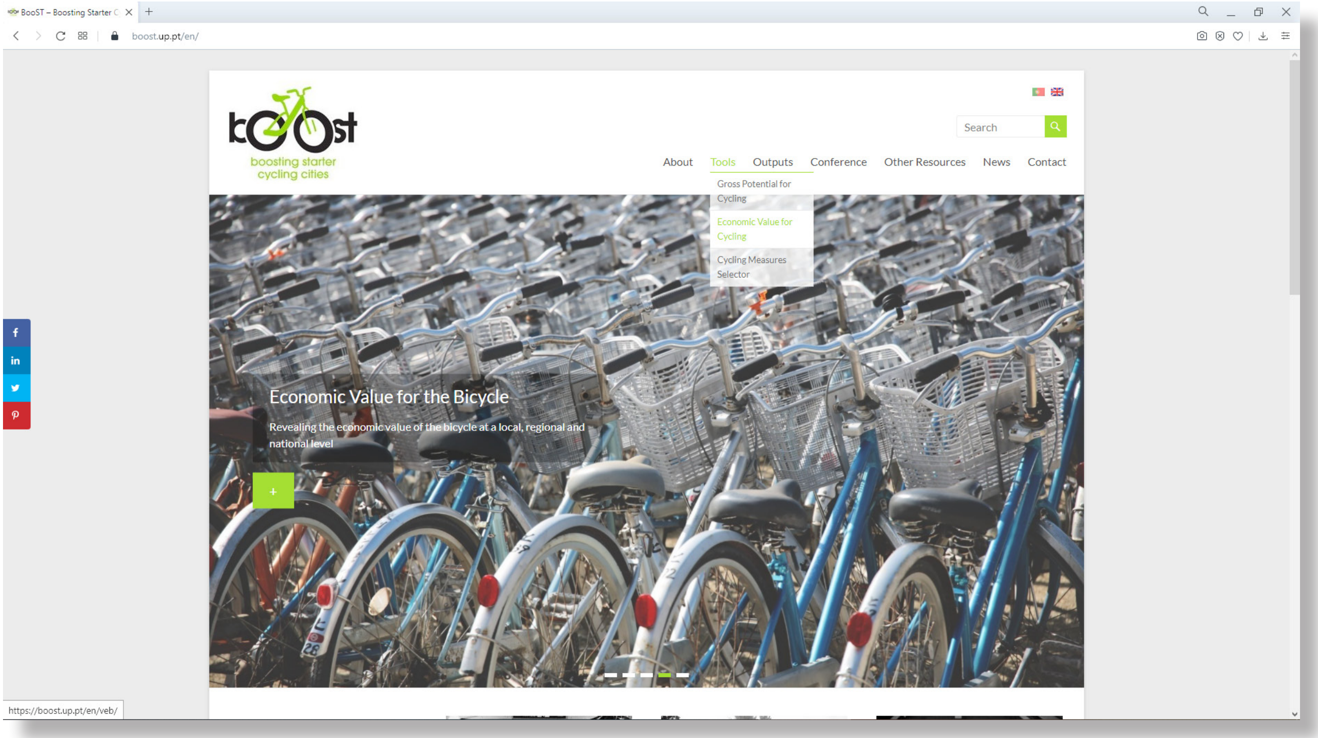


Figure 10: Location of the EVC in the BooST webpage

At the local scale the EVC tool provides a quantification of the impacts of cycling, providing to municipalities and other stakeholders access to comparable indicators based on the local modal distribution and the scenarios they intend to assume. This quantification of cycling impacts incorporates two dimensions. The analysis of environmental and energy impacts, which includes CO2 emissions, fuel consumption and air quality costs. And a second dimension, related to the health benefits associated with the increase of cycling.

As the objective was to enable the application of the tool to all municipalities, statistical data from the 2011 Census were used to extract the base information for 308 Portuguese municipalities:

- Km travelled by municipality (average time at average speed);
- Current modal split - (2011 Census data with spatial disaggregation by municipality of residence and resident population by main transport mode and by the length of commute).

Environmental and energy impacts

This process is explained on the 'methodology' option on the top bar of the EVC page. The first step to assess the environmental and energy impacts included the calculation of CO2 emissions, fuel consumption and air quality costs for all Portuguese municipalities. To obtain these values, the following general indicators were calculated:

Indicators	Description
Population by main transport mode	Resident population by main transport mode and according to the journey length from place of residence to place of work or study
Vehicle occupancy rate	Passengers per vehicle
Travel by transport mode	Pop. Resident / Occupancy Rate
Modal split	Pop. Resident by transport mode / Total Pop. Resident
Average speed of different transport modes	km per hour travelled
Average travel time by transport mode	Commuting time
Average distance travelled	Average time for the average speed by means of transport (Km / h)
Average consumption	litre per km travelled
Number of litres compared to the kilometres travelled	distribution of the average distance per fuel per average fuel consumption

Table 1: Indicators for environmental and energy impacts assessment

CO2 emissions costs: To calculate the CO2 emissions costs associated with the travel pattern in Portuguese municipalities, the following methodology and conversion factors[1] were adopted:

1° Step	2° Step	3° Step	4° Step	
Fuel consumption in relation to the kilometers traveled by individual motorized transport/year	Fuel in tons	Convert to tons of oil equivalent (toe)	Calculate the CO2eq. emissions	**Cost of CO2 emissions per trip (€ / tonne CO2)**
Type of fuel Average consumption (l/100km) Distance (km) Consumption (l)	Conversion factor (1000l/t) N° tons (t)	Conversion factor (toe/t) N° of tons of oil equivalent (toe)	Conversion factor (kg CO2/toe) CO2 eq. emitted (kg CO2eq.)	

Table 2: Conversion factors

[1] IMTT. (2016). Plano de Monitorização - U-Bike.

Fuel consumption costs: For the calculation of the costs of fuel consumption, the price of fuel[2] (€/l) was multiplied by the number of litres consumed in relation to the kilometres travelled in order to obtain the value of fuel consumption in € per trip, which was later multiplied by trips per means of transport.

Air quality costs: Regarding the costs of air pollution, the price of air pollution[3] (€/1000 pkm) was multiplied by the average distance travelled per trip and, subsequently, by travel by means of transport.

To assess potential savings, a pre-established growth scenario in bicycle use was adopted and applied to each municipality. The results of each indicator are presented by municipality and sorted in a municipal ranking, where it is possible to verify their position regarding the assessed impacts. They can be assessed through the municipality ranking tab at the top bar of the EVC page (Figure 11).

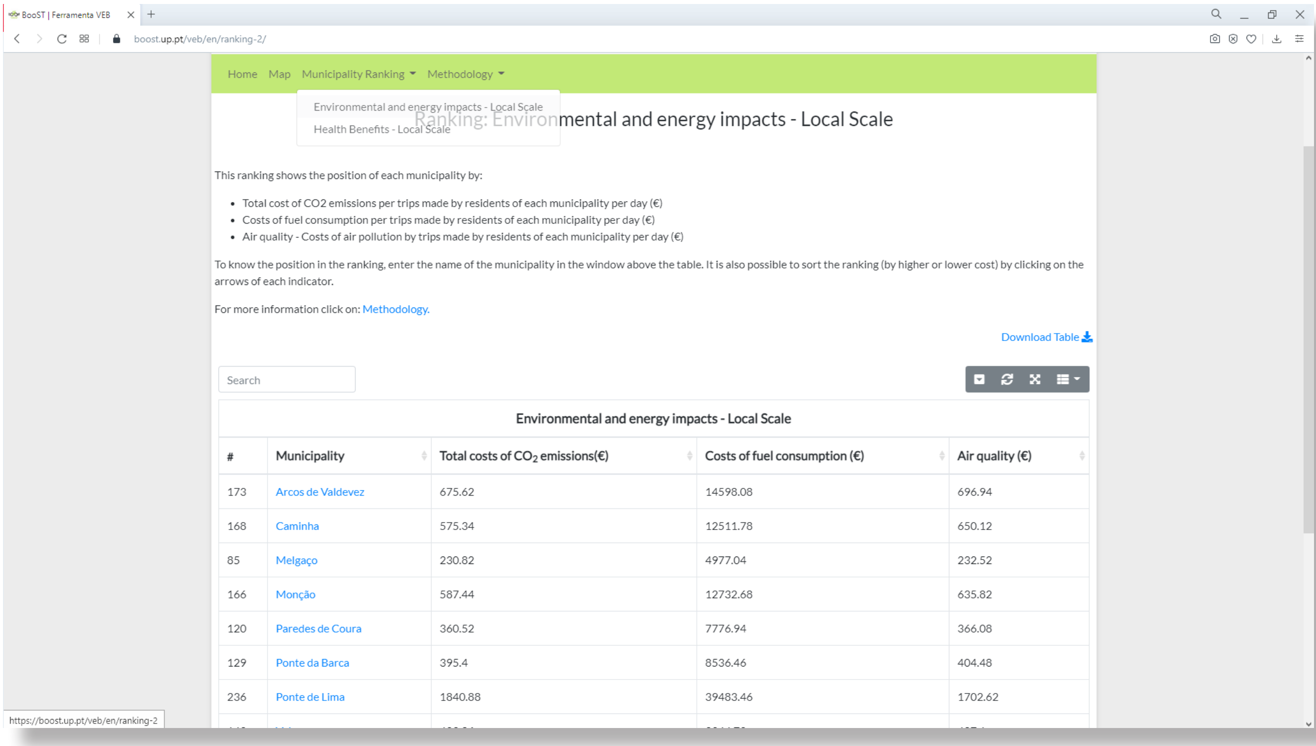


Figure 11: Ranking of Local Scale Environmental and Energy Impacts on the EVC page

[2] https://www.maisgasolina.com/ consultado em 8/11/19

[3] CE_Delft_4215_External_Costs_of_Transport_in_Europe_def

In the second step to assess the potential for decarbonization and energy savings of each Portuguese municipality a pre-established scenario of growth in bicycle use was applied. Thus, following the scenario established by the ITDP, of an increase of 0.2 percentage points per year (representing a 2.02% increase of cycling modal share in 10 years), the number of future trips and the average fuel consumption was estimated. For this scenario, it was assumed that the increase of bicycle use represents a replacement of 20% of walking, 30% of individual motorized transport (car and motorcycle) and 50% in of public transport (bus and metro) trips.

From here, the number of trips by means of transport were recalculated and the respective of CO2 emissions; fuel consumption and air quality costs, which allows to understand the savings caused by the increase of cycling between modal distribution of the 2011 Census and ITDP scenario. Users can quickly select between the 2011 census scenario and the ITDP one to identify shifts over modal shares of each transport mode (Figure 12).

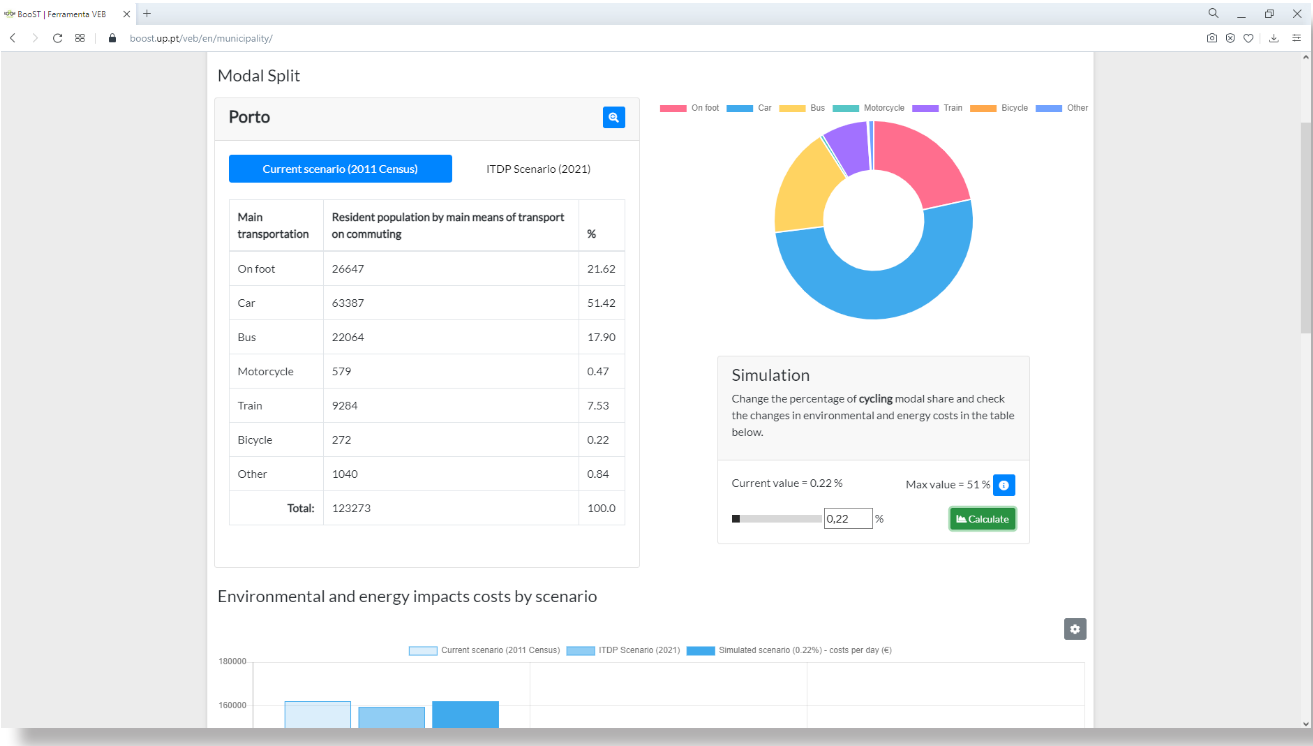


Figure 12: Example of the results by scenario in the EVC webpage

The third step, to promote interaction with the tool and enable a deeper study of the environmental and energy impacts of mobility patterns, is the scenario simulation. The VEB tool allows the user to enter, over on the simulation section of the page (located on the right), an intended bicycle modal share and compare the savings associated with a change in mobility patterns. Results appear on the bottom section of the page, detailing for each new simulation the full range of environmental and energy impacts (Figure 13).

Figure 13: EVC simulation in the BooST webpage

Health Benefits

For the calculation of health benefits of cycling the HEAT tool[4] was used. It produces an estimate of the annual benefit (per cyclist; per trip; and total annual benefit) due to reduced mortality because of increased cycling. This tool is based on the following premise: If a certain amount of people regularly walk or cycle, what is the economic value of the health benefits resulting from the reduction in mortality caused by their physical activity? In addition, it is also possible to calculate the health effects caused by a reduction in road accidents and air pollution, and the inherent impacts on carbon emissions.

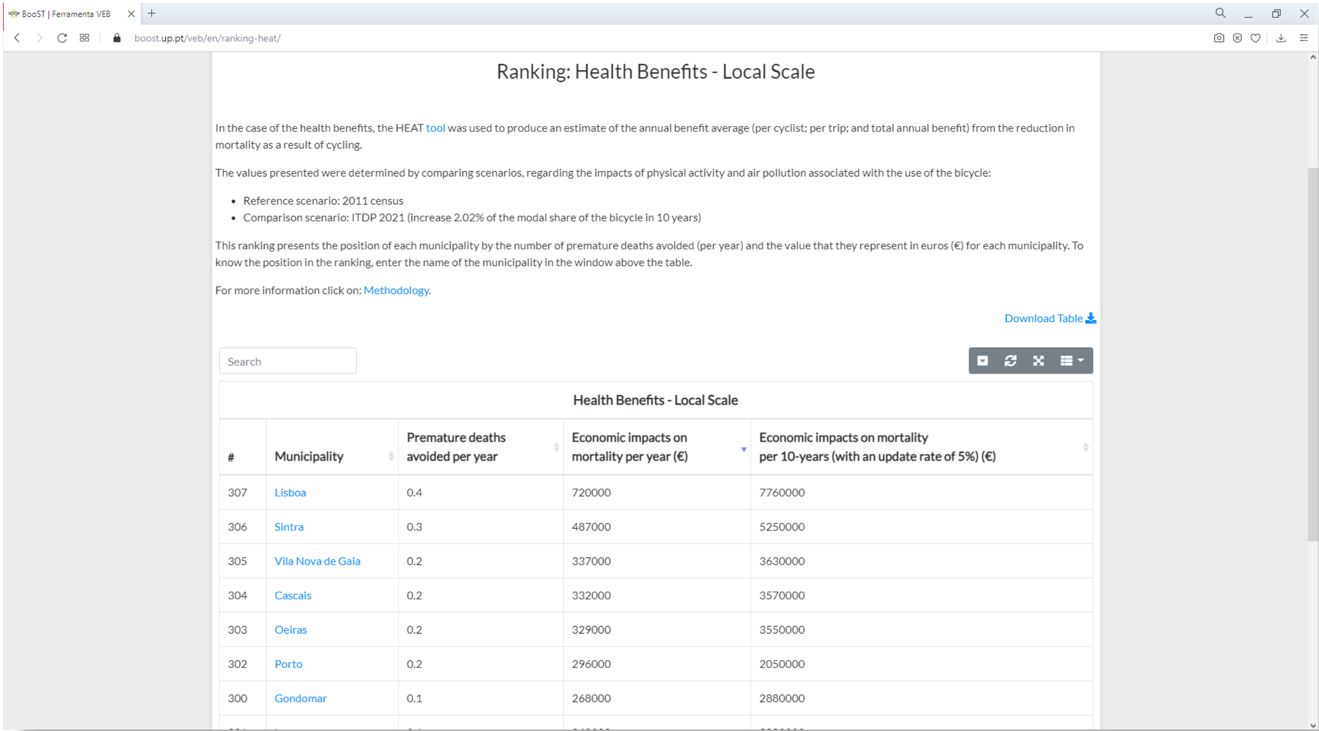
The available evaluation models include the evaluation of changes over time, comparisons of "before and after" situations, or comparisons between scenarios. The impacts of physical activity and air pollution were measured by comparing two scenarios. Following the same criteria used in the calculation of the environmental and energy impacts, the 2011 Census was used as a reference case and the ITDP scenario was used as a comparison. With this analysis, it was possible to obtain results on the increase in cycling time, premature deaths avoided and the economic impacts on mortality. The following table summarizes the information to be entered in the HEAT tool for the type of evaluation selected.

Scenarios	"reference case" VS "comparison case"
Time Scale	year of the reference case year of comparison case how long the data should be calculated
Data for the reference case VS comparison case	population cycling modal share total volume of trips per day: sum of trips for all modes of transport distance travelled by bicycle
Take-up time	number of years until the maximum volume of active travel is reached
Other adjustments	proportion of new bicycle trips proportion of bicycle trips made for transport VS recreational proportion of bicycle trips "in traffic"
Other parameters	mortality rate value of a statistical life average bicycle speed PM 2.5 concentrations

Table 3: Information for HEAT tool

[4] https://www.heatwalkingcycling.org/#homepage

In the case of health benefits, the results for each municipality and their position in the municipal ranking are also presented. They are accessible via the ‘municipality ranking tab’ of the EVC webpage (Figure 14). The simulation of different scenarios can be done directly in the HEAT tool, following the steps describing the methodology available on the EVC webpage (https://boost.up.pt/veb/en/heatmethodology/).



#	Municipality	Premature deaths avoided per year	Economic impacts on mortality per year (€)	Economic impacts on mortality per 10-years (with an update rate of 5%) (€)
307	Lisboa	0.4	720000	7760000
306	Sintra	0.3	487000	5250000
305	Vila Nova de Gaia	0.2	337000	3630000
304	Cascais	0.2	332000	3570000
303	Oeiras	0.2	329000	3550000
302	Porto	0.2	296000	2050000
300	Gondomar	0.1	268000	2880000

Figure 14: EVC Health Benefits in the BooST webpage

Visual representation

Finally, the results of the baseline mobility pattern costs for all environmental indicator are available represented under a visual representation by selecting the municipality though the map option available on the EVC webpage (Figure 15). From the appearing pop-up users can access the scenario building tool for the environmental and energy impacts.

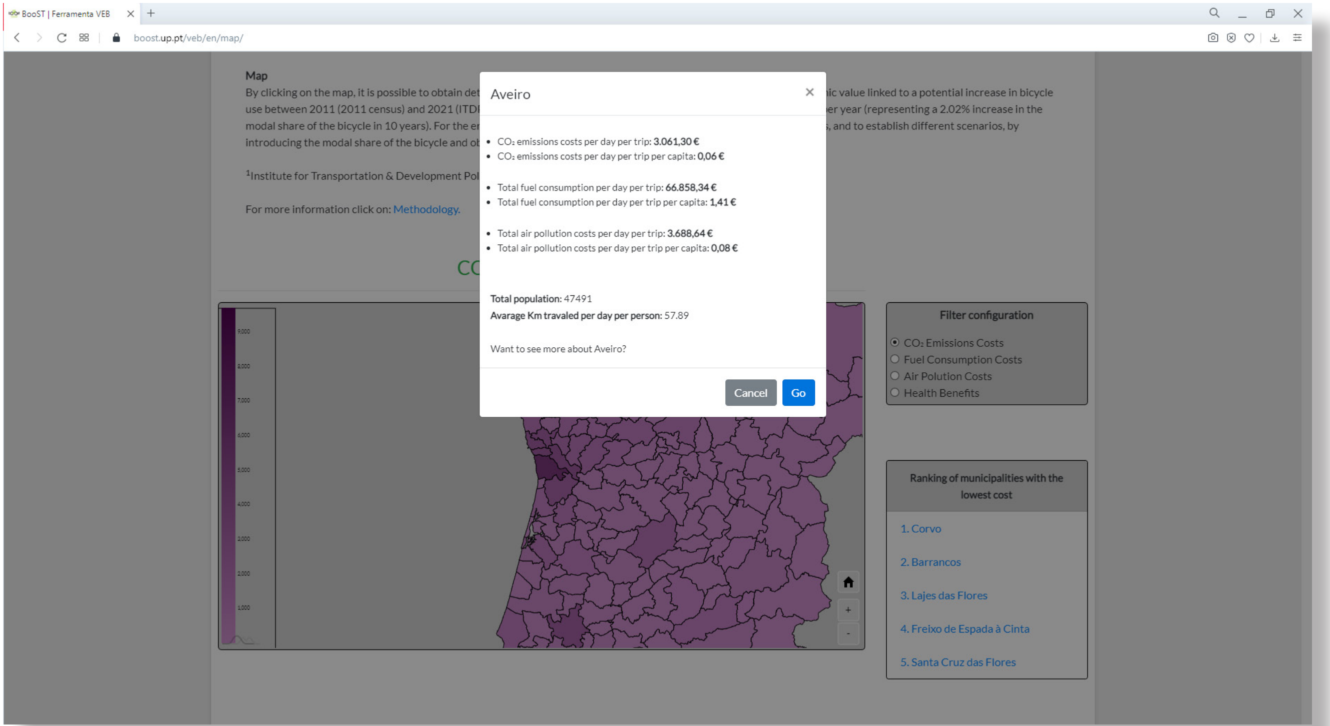


Figure 15: Example of the results by municipality in the EVC webpage

2.3 Using the EVC in planning

One of the goals of the BooST project was to empower local policy makers with data and arguments against the general sceptical attitudes towards cycling, and the capacitation of municipal technicians to promote cycling mobility through strategies adjusted to the reality of each municipality. With this in mind, the EVC tool was developed to allow the simulation of more demanding or more conservative alternative scenarios per municipality and to quantify the associated financial benefits. This methodology and results have multiple potential uses. They will be able to justify the social, economic, and environmental benefits of promoting cycling, quantifying the annual savings, a fundamental fact to support applications for European or National funds, and also support alternative public policy options. Knowing that within the scope of the Recovery and Resilience Plan (PRR) and the PT2030, the theme of sustainable mobility will gain prominence, namely due to the impact it may have on the agenda of the European Ecological Pact, and with new funding opportunities to which municipalities can apply to.

2.4 Results

The Economic Value for Cycling at the local scale was calculated for all 308 Portuguese municipalities, and it is expected that the municipalities with the largest resident population will be at the top of the list with regard to mobility costs. However, it is also on those municipalities where an increase in bicycle use will translate into greater economic savings. The analysis of the results allows the understanding of the environmental and energy impacts caused by the travel behaviour of the population. Where the overall distance travelled by car is greater greater savings are expected when in comparison with more populated municipalities. For the health benefits, it is necessary to consider not only the population, but also the distances covered by bicycle that influence the time spent cycling and, consequently, the increase in physical activity with an impact on health. It is important to mention that although the daily savings may be considered low, the economic environmental and energy impacts at national level reach 105 million euros per day and 26 million euros per year. On a national scale, the health benefits of a 2.02% increase of cycling modal share can reach the value of 140 million euros in 10 years. As mentioned, the Municipal Ranking with information on all municipalities is available on the VEB page of the BooST project.

> *...the most participants considered the results as being comprehensive, credible and with an appropriate territorial scale, allowing comparisons between scenarios and providing new ways to measure the impact of cycling.*

2.5 Evaluation of the tool

To evaluate the potential of the EVC and its impact on the decision-making process, a series of workshops were devised to test its soundness, user-friendliness, and utility. A session was organized with planning practitioners from twelve Portuguese municipalities. All groups were asked to evaluate the tool through a survey with predetermined statements ranked in a five-point Likert scale, from ‘Strongly disagree’ to ‘Strongly agree’. This session was followed with two additional ones, which gathered 4 academics and 10 bicycle activists, respectively.

In the workshops about the EVC tool the participants appreciation was, for the most part, very positive. The results presented in this document focus solely on the responses from practitioners. When detailing the evaluation of these results, regarding the soundness of the tool, the survey results reveals that the most participants considered the results as being comprehensive, credible and with an appropriate territorial scale, allowing comparisons between scenarios and providing new ways to measure the impact of cycling. Within the evaluation of user friendliness, most participants argued that the EVC allows an easy comparison of results among different generated scenarios, while displaying them in a clear manner. Activists and academics shared the same opinion. Suggestions for improving the tool focused on a clearer distinction between external costs/ benefits (those that do not directly affect the user) and internal costs (those that the user considers in their decisions because it directly affects him/ her), and between national and local accounting. Additional comments mentioned the inclusion of more indicators for the analysis of cycling benefits, namely those that imply budget reductions in relation to the necessary investments (infrastructure costs, congestion, etc), but also the possibility to create scenarios with different parameterizations of the modal distribution, adapted to the reality of each municipality. In the case of metropolitan areas, participants demonstrated the need to present more updated results based on the available statistics for these municipalities (INE, 2018).

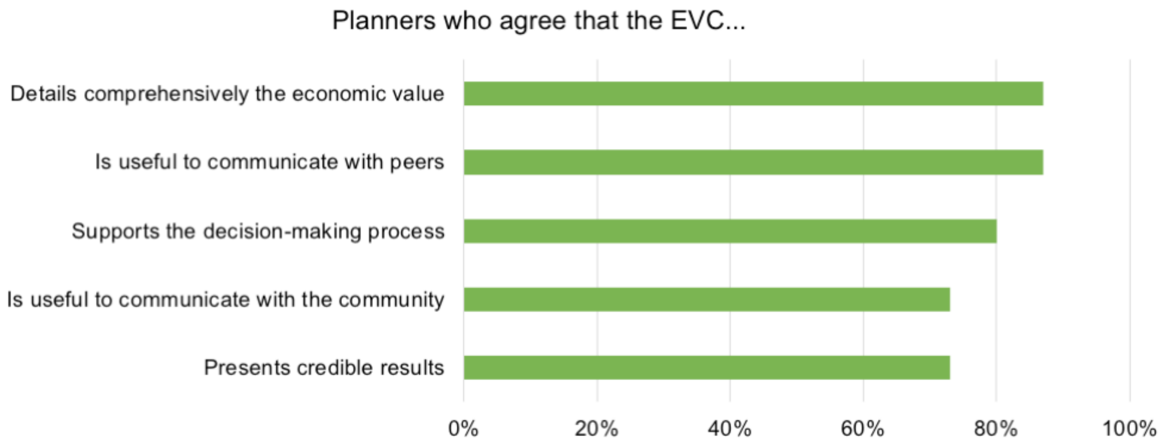


Figure 16: Summary of planners' evaluation of the EVC

Regarding the utility of the tool, most of the practitioners and activists agreed that it facilitates communication and consensus around the cycling and that it can contribute to the decision-making process and to guide public policies to promote this means of transport.

In the case of academics, there was a consensus on how the tool can facilitate the quantification of the economic value of cycling, as well as to broaden communication on the topic. However, there seems to be some disagreement regarding the utility of the tool to guide public policies or to overcome local authorities resistance about the cycling mobility potential.

Overall, the analysis of the workshops reinforced the perception of the recognition of the benefits of the bicycle, but also the difficulties in quantifying these impacts. By showing the savings that can be obtained, the EVC confirms the importance of making this type of tools available for work and communication, both with decision makers and with the community, for a greater acceptance and investment in cycling.

3
Unveiling the cycling potential:
The Gross Potential for Cycling

3.1 Context: What influences bicycle use?

To determine the hidden potential of the territory to foster bicycle use, i.e., its gross potential for cycling, the key is to go beyond the most relevant aspects such as population density or the distribution of existing infrastructure. Over the last decades research has extensively studied the most relevant factors that influence the decision to use the bicycle to satisfy commuting needs. A complex assortment of factors is involved (Figure 17), grouped into different sets according to the disciplinary background, theoretical framework, methodological approach, and purpose of research. Five main groups can be highlighted: sociodemographic factors; the built environment; cycling facilities; natural environment; and perceptions and attitudes (psychosocial factors) (Heinen et al., 2010; Kuzmyak et al., 2014).

SOCIO DEMOGRAPHIC FACTORS

age

Many studies state that the use of the bicycle, especially for commuting purposes, tends to be more frequent among the younger sectors of the population (Dill and McNeil, 2013; Goldsmith, 1992; Litman et al., 2018; Pnina, 2005), often justified with the physical effort that is perceived as a barrier by the elderly (Heinen et al., 2010). This also indicates that starter cities should prioritize cycling promotion efforts in areas with higher proportions of young people, such as schools and universities (Marqués et al., 2015). However, when studies focus on more mature cycling contexts, where the use of the bicycle is deeply embedded with societal values, the age of cyclists becomes a less relevant factor (Geus et al., 2008; Heinen et al., 2010; Parkin et al., 2008; Stinson and Bhat, 2004).

gender

Women's lower participation in cycling is a consistent pattern in the literature (Dill and Carr, 2003; Gatersleben and Appleton, 2007; Parkin et al., 2008; Savan et al., 2017), especially in territories with reduced expression of this transport mode. Similarly to the previous sociodemographic factor, as cycling becomes more common no significant gender differences are found, as studies in the Netherlands and Denmark demonstrate (Heinen, et al., 2010). Beyond the impact of the stage of cycling maturity, some argue that gender differences in cycling are inseparable from similar differences in society, relating to the threats (actual and perceived) that women experience in public space and to the counter-processes of women's emancipation (Baker, 2009; Prati, 2018; Shearlaw, 2017).

educational level

The link between cycling and education diverges, since some studies have found a positive connection between higher levels of education and cycling (Geus et al., 2008; Pnina, 2005; TfL, 2010), while other did not found any significant relation (Dill and McNeil, 2012; Handy et al., 2010). As a result, the influence of this factor is inconclusive, and as such should not be a part of the definition of cycling potential.

income

The literature is also inconsistent on the relation between cycling and income, which proves to be particularly sensitive to the sociocultural context. In fact, while some studies have found a positive association between bicycle commuting and lower incomes (Dill and Carr, 2003; Litman et al., 2018; Plaut, 2005), others found the opposite (Parkin et al., 2008; TfL, 2010), while a third branch failed to identify any relation (Dill and McNeil, 2013; Goldsmith, 1992; Handy et al., 2010; Stinson and Bhat, 2004).

home ownership

Some authors have found a negative association between home ownership and cycling to work, although this is mostly due to the association with the income variable (Plaut, 2005; Pucher et al., 2010). As such, the influence of home ownership is also inconclusive.

car ownership

Contrary to income or education, there is consistent evidence pointing to the influence of car ownership. The comfort and safety attributes of the private vehicle have, in fact, a strong influence on mode choice decisions, and as such this mobility alternative has a negative effect of cycling levels (Buehler, R. & Pucher, 2011; Heinen et al., 2010; Hoedl et al., 2010; Litman et al., 2018; Parkin et al., 2008; Plaut, 2005; Stinson and Bhat, 2004).

ethnicity

Travel behaviour also tends to vary according to race and ethnic origin, particularly in diverse cities, such as London, where white residents are more likely to cycle than those from ethnic minority groups (Parkin et al., 2008; Plaut, 2005; Rietveld and Daniel, 2004; TfL, 2012). This tends to express a city's cycling development, particularly in its early stages, as a niche (Marije de Boer and Caprotti, 2017). However, for the sake of inclusion, ethnic divisions should not be a defining factor in the definition of a transport strategy.

occupation/ employment status

In line with the evaluation of the age profile of cyclists, students are seen as a favourable target population (Baltes, 1996; Dill and Carr, 2003; Gatersleben and Appleton, 2007; Heinen et al., 2010; Litman et al., 2018; Marqués et al., 2015; Whalen et al., 2013), while the presence of a university has been considered the most significant environmental factor in cities with higher levels of bicycling commuting (Goldsmith, 1992). However, there is a gap in research analysing the links between other occupations/ employment status and cycling. While it could be expected that being employed increases the possibility to use the bicycle, as the need for mobility is greater, strong ethical issues can be raised if the division employed/ unemployed is used.

BUILT ENVIRONMENT

traffic conditions

One of the key limiting barriers to perceive cycling as a suitable mobility alternative lies on the coexistence with motorized traffic, specifically along fast moving vehicles. As such, low or slow traffic roads are positively associated with higher cycling frequency (Broach et al., 2012; Delso et al., 2018; Heinen et al., 2010; Ma, L. & Dill, 2015; Mertens et al., 2017; Segadilha and Sanches, 2014). Also, in places where traffic calming measures are adopted (such as home zones, road narrowing and artificial dead ends) as cyclists become less exposed to the speed differential with cars perceived safety and comfort levels naturally increase (Mertens et al., 2017; Pucher and Buehler, 2009; Titze et al., 2010).

road design and conditions

Beyond the coexistence of bicycles and motorized traffic, the physical condition of the infrastructure is another key built environment factor. Poorly maintained roads and streets tend to be avoided as they are not only deemed uncomfortable but also can lead to unnecessary swings, which can increase the risk of accidents (Parkin et al., 2008; Segadilha and Sanches, 2014). Intersection control, such as stop signs and traffic lights, can be inconvenient to cyclists, especially for more experienced ones, as stopping and accelerating requires increased physical effort and time (Heinen et al., 2010; Segadilha and Sanches, 2014). The presence of roundabouts has also a negative effect on bicycle users as they induce additional crossing with the paths of motorized vehicles (Segadilha and Sanches, 2014) and blind spots can also increase the risk of accidents. The configuration of car parking also affect cyclists, who particularly fear parallel parking due to the possibility of colliding with unexpectedly opened car doors (Segadilha and Sanches, 2014).

land use

High functional separation and low density are a defining feature of car mobility environments, as opposed to cycling and walking environments, which thrive in areas with high density and diversity of uses (Bertolini, 2017). Denser urban areas favour higher cycling levels as the greater agglomeration of different activities tends to reduce distances (Baltes, 1996; Fraser and Lock, 2010; Heesch et al., 2015; Heinen et al., 2010; Litman, 2010; Ma, L. & Dill, 2015; Parkin et al., 2008; Stinson and Bhat, 2004). This positive outcome is applicable to both residential and employment densities (Kuzmyak et al., 2014). Simultaneously, the car becomes less attractive due to increased driving time and parking difficulty (Parkin et al., 2008). On the downside, higher densities can also mean greater traffic congestion on streets and lesser road space available for cyclists, (Goldsmith, 1992), requiring extra efforts from authorities to allow the coexistence of different transport modes.

SPECIFIC CYCLING CONDITIONS

dedicated infrastructure

Perhaps one of the most studied aspects, multiple studies show a positive correlation with the presence of dedicated infrastructure. One group of the literature found positive outcomes from any type of infrastructure, from segregated to shared typologies (Dill and Carr, 2003; Fraser and Lock, 2010; Garrard et al., 2012; Mertens et al., 2017). Others, using safety from traffic as justification, justify that only protected infrastructure or off-street paths have a positive impact (Broach et al., 2012; Dill and McNeil, 2013). Still, it is important to note that any sort of infrastructure will only lead to the necessary shift if combined with other policies and physical interventions (Parkin et al., 2008). This combination explains the success of the Netherlands, Denmark, and Germany in becoming world leaders in bicycle use, who combined the provision of separate cycling facilities along heavily travelled roads and at intersections with traffic calming of most residential neighbourhoods (Pucher and Buehler, 2009).

continuity and connectivity of infrastructure

Besides its presence, all cycling infrastructure should be designed with continuity and connectivity in mind (Heesch et al., 2015; Heinen et al., 2010; Mertens et al., 2017; Segadilha and Sanches, 2014). Connectivity measures are important to evaluate how efficiently a network connects destinations, with smaller blocks reducing the average extension of trips (Cantell, 2012; Dill, 2004; Handy, S., Butler, K. and Paterson, 2003; Tresidder, 2005). If a certain path turns into an excessive deviation from the shortest route, cyclists will tend to avoid it (Segadilha and Sanches, 2014).

Beyond infrastructure connecting the different urban locations, the presence of (safe) parking facilities, showers, changing facilities and lockers at the workplace were considered important by bicycle commuters (Goldsmith, 1992; Heinen et al., 2010; Stinson and Bhat, 2004). The possibility of integration with public transport is also very relevant, as the integration in “first mile” or “last mile” solutions, through bicycle parking at major stations or bike sharing systems naturally increase its coverage area (Kager et al., 2016; Pucher and Buehler, 2009; Rietveld and Daniel, 2004). This simultaneously reduces the necessary investment for the establishment of a comprehensive public transport system in less dense urban sections.

other facilities

NATURAL ENVIRONMENT

landscape

slope

weather

Large shares of open space, parks and waterfronts along cycling corridors offer pleasant viewscapes that tend to encourage bicycle commuting (Cervero et al., 2019). This explains why the first steps of cycling strategies in many cities consisted mostly of leisure-focused infrastructure.

Irregular topography has a negative impact on bike commuting, with an inverse relation between hilliness and the suitability of cycling (Parkin et al., 2008). However, the adoption of electric bicycles or even technological urban design solutions can help to minimize this negative influence, with a clear example being the city of Trondheim, Norway, with a bicycle modal share of 9% (Lunke et al., 2018).

Despite the seasonality that is inherent to weather patterns, adverse conditions (heavy rain and snowfall, extreme low and high temperatures, and especially wind) have a relatively strong negative impact on cycling (Flynn et al., 2012; Parkin et al., 2008; Zhao et al., 2018). However, this can be minimized if the destinations provide suitable supporting facilities, such as locker rooms and showers.

ATTITUDES AND PERCEPTIONS

perceived benefits

Health and environmental benefits stand at the top of the list on the definition of a pro-bicycle mindset (Gatersleben and Appleton, 2007; Heinen et al., 2010). The recognition of the comparative advantage of bicycle over other modes, particularly with the car, is also key. These can concern savings in travel time, effort and driving cost (fuel, parking fees and tolls), reinforced in case of financial incentives to cycling. Also, positive perceptions towards increased safety and independence (Geus et al., 2008; Handy et al., 2014; Heinen et al., 2010) often associate bicycle use with higher levels of happiness and emotional well-being (Zhu and Fan, 2018).

Under the opposite perspective are the perception of barriers, whether external, such as safety or the weather, or related to the self, with examples such as lack of skills, time, motivation or interest or health problems (de Souza et al., 2014; Fernández-Heredia et al., 2014; Geus et al., 2008; Muñoz et al., 2016). In addition, individual lifestyles and necessities in daily travel needs, such as transporting children, running errands or shopping, can also have negative implications on the decision to cycle (Dickinson, Kingham, Copsey, & Hougie, 2003; Muñoz et al., 2016).

perceived barriers/ disadvantages

social acceptance and constraints

The influence of social networks, as those established within the workplace or by friends and family (Geus et al., 2008), and the presence (or absence) of a wider bicycle culture also have an impact. The perception of cycling as socially acceptable positively influences people´s choice, further reinforcing the community norm (Aldred and Jungnickel, 2014; Handy et al., 2014; Litman et al., 2018; Pooley et al., 2011). A negative social environment towards cycling tends to influence bicycle commuting more than a pro-bicycling environment. This can include factors such as supervisor´s disapproval of bicycle commuting, negative attitudes of co-workers and the need to dress professionally (Handy et al., 2010). In contrast, positive influences of employers towards cycling can range between residual effects (Handy & Xing, 2011) to measurable impacts (Dickinson et al., 2003; Geus et al., 2008).

physical activity habits

Being physically active (Heinen et al., 2010) and often using a bicycle for non-work trip purposes (Muñoz et al., 2016; Stinson and Bhat, 2004) are also associated with a higher probability of bicycle commuting.

perception of confidence and past experience

Many have shown that those with a high level of confidence in their own ability are more likely to cycle (Geus et al., 2008; Heinen et al., 2010; Hoedl et al., 2010; Marqués et al., 2015; Titze et al., 2010). This can result from life-long experience, particularly if there is a track record of frequent bicycle usage since early ages, such as using the bicycle to commute to school (Dill and McNeil, 2013).

Figure 17: Factors influencing bicycle use

3.2 Tool Description

The Gross Potential for Cycling (GPC)[5] aims to provide to planning practitioners, especially at the municipality level, a new tool to identify the territorial hotspots for the placement of new infrastructure and the implementation of cycling promotion measures to jumpstart bicycle use. A description of how to use the tool is available on the project website (https://boost.up.pt/en/roadmap/gpc/). A video explanation can also be found though the outputs option on the top bar (https://boost.up.pt/en/videos/).

[5] The Gross Potential for Cycling (GPC), built on the intersection between Planning Support Systems and starter cities, was developed from previous work on the evaluation of cycling potential (Silva et al., 2018b) and on existing fundamental research on the factors influencing bicycle use.

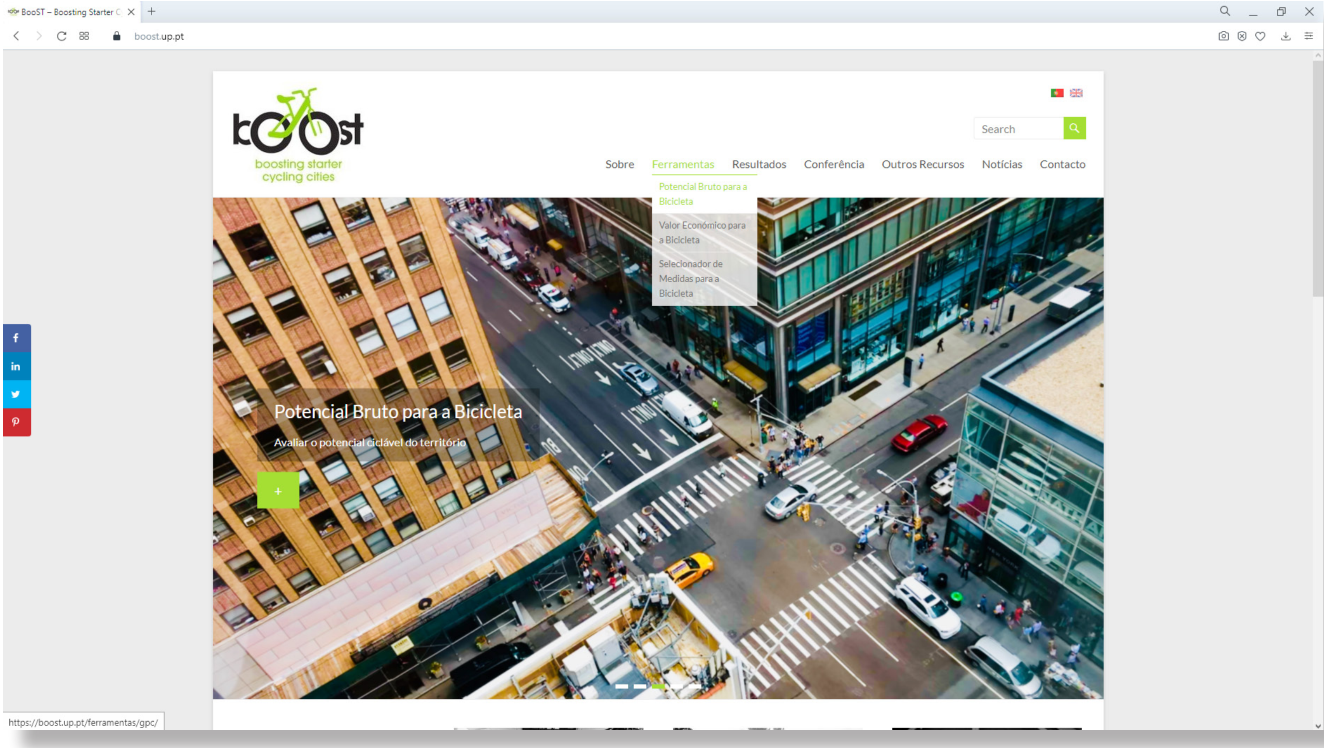


Figure 18: Location of the GPC on the Boost website

The Gross Potential for Cycling employs a two-dimensional approach. The first (Target Population) evaluates, through socioeconomic factors, the predisposition of prospective bicycle users. The second (Target Areas) assesses the physical conditions of the territory, from a set of geographical and built environment factors. Since the characteristics of the infrastructure vary throughout the territory, the GPC incorporates a set of circulation/ traffic conditions – comprising topography, road hierarchy, car parking pressure, average congestion, number of car accidents and current cycling infrastructure. These are then used to calibrate cycling and driving speeds to create a better representation of real-world conditions (Figure 19).

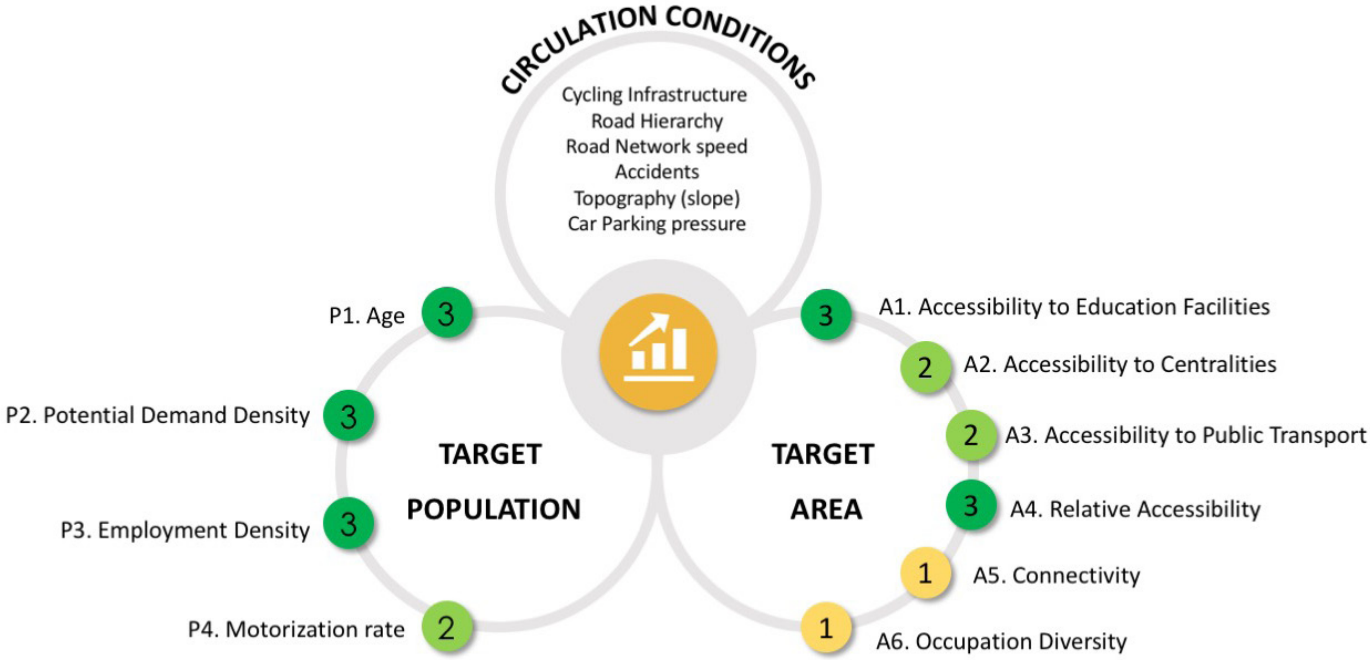


Figure 19: GPC Structure

Target-population

The dimension of target-population is built by assessing four sociodemographic indicators: age; potential demand density; employment density; and motorization rate.

Age (P1) identifies the location of the age groups more prone to cycle. As most of the evidence shows that bicycle commuting tends to be more frequent among younger ages, students and younger adults should be seen as the major target-group to promote the shift of travel behaviour. As a result, this indicator favours the areas with a higher incidence of population between the ages of 15 and 29;

Potential demand density (P2) measures the concentration of prospective users, using travelled distance as a proxy, seen as having a direct negative impact on cycling. An 8km threshold was used to filter those who perform trips that can switch to cycling. As the Portuguese Census database provides average trip durations instead of length, this 8km threshold considers all pedestrian trips, all bus trips below 30 min, and all trips below 15min on the remaining modes. Territorial performance is calculated via a standard deviation data classification method;

Employment Density (P3) focuses the density analysis on a destination perspective, identifying the hotspots of job opportunities. The rating system is similar to the previous indicator;

Motorization rate (P4) is based on the premise that car ownership has a negative effect on cycling levels. This variable is built from census data, based on the question on the main mode of transport used for commuting trips, with these results used in comparison with the national average. As all car trips are addressed in this indicator, the risk of collinearity with indicator P2, which filters those based on trip duration and combines it with other transport modes, is minimized;

Target-areas

The second dimension of the GPC comprises six indicators: accessibility to education facilities; accessibility to centralities; accessibility to public transport; relative accessibility (between the bicycle and the car); connectivity; and occupation diversity.

Accessibility to education facilities (A1) integrates the importance of these facilities as trip generator nodes, with the added benefit of being mainly used by the younger sectors of the population that, as seen previously, have a higher propensity for bicycle use. Accessibility is measured through cycling travel isochrones to elementary and secondary schools and higher education facilities;

Accessibility to transport interfaces (A3) uses a similar approach, this time evaluating the proximity to high-capacity public transport facilities, namely rail, metro, and major bus stations. It is based on the premise that the bicycle can be used to extend the coverage of public transport;

Accessibility to centralities (A2) is grounded on the identified benefits of denser urban areas. In this indicator, accessibility is measured to two categories of poles of urban activity: main and secondary centralities. The main centrality is located at the city council building and is intended to represent the attractor nature that this type of facility generates over the surrounding urban area. Secondary centralities are defined based on relevant concentrations of population and/ or employment are represent locations with a significant concentration of daily activities;

Relative accessibility (A4) identifies the areas where the bicycle is more competitive than the car, comparing the average distance reachable by both modes in five minutes' travel time from each census tract centroid. Here, the time spent for parking, based on existing parking pressure on each street, was incorporated as a penalty for the car's catchment area. Bicycle parking provision was not addressed, as the impact of its parking procedures on global travel time is residual;

Connectivity (A5) relates to how efficiently a road network connects destinations and to the importance of minimizing commuting trip lengths. The GPC measure for this indicator is the average block size, with the adopted reference values inspired by the guidelines and good practices of urban design.

Occupation Diversity (A6) targets the spatial distribution of services and facilities and the variety of functions within an area. The index considers the diversity of nine types of activities at a 500 meter-radius buffer, selected by their high frequency of use in the Portuguese context: primary education institutions; secondary education institutions; restaurants; supermarkets and food shops; other shopping; pharmacies; health centres; services of public interest (banks, post office, public and administrative services); and leisure/ culture (theatres, showrooms, museums, libraries);

In order to meet its goal of identifying the most suitable locations for the introduction of bicycle promotion strategies, the exploration of the spatial diversity that characterizes urban areas is a key aspect of the Gross Potential for Cycling. The use of GIS software for the necessary calculations embeds the necessary spatial dimension. In the Portuguese context, the census tract was adopted as it is the smallest unit of territorial assessment for which information to feed the GPC indicators is available.

The individual indicators are presented on a scale from 1 (lowest potential) to 5 (highest potential). In a final step, these individual indicators are combined into an aggregated score, through weighing factors based on the relevance and representativeness of each indicator in the literature. Table summarizes the scoring criteria for each of the five classes of cycling potential. This table is also available on the Boost project's website section of the GPC.

Potential		5	4	3	2	1
P1		[15 – 29] > A	[10 – 14] + [30 – 39] > A	[40 – 44] > A	[45 – 19] > A	[<10] + [>50] ≥ A
P2		$D \geq \bar{x} + \sigma$	$\bar{x} + \sigma > D \geq \bar{x} + \frac{1}{2}\sigma$	$\bar{x} + \frac{1}{2}\sigma > D \geq \bar{x} - \frac{1}{2}\sigma$	$\bar{x} + \frac{1}{2}\sigma > D \geq \bar{x} - \sigma$	$D < \bar{x} - \sigma$
P3		$D \geq \bar{x} + \sigma$	$\bar{x} + \sigma > D \geq \bar{x} + \frac{1}{2}\sigma$	$\bar{x} + \frac{1}{2}\sigma > D \geq \bar{x} - \frac{1}{2}\sigma$	$\bar{x} + \frac{1}{2}\sigma > D \geq \bar{x} - \sigma$	$D < \bar{x} - \sigma$
P4		≤ 110	111 -220	221 - 330	331 - 440	≥ 441
A1	**Basic**	< 5 min	5–10 min	10–15 min	15–20 min	> 20min
	Secondary	< 5 min	5–10 min	10–15 min	15–25 min	> 25 min
	Higher	< 10 min	10–15 min	15–20 min	20–30 min	> 30 min
A2	**Primary**	< 10 min	10–15 min	15–20 min	20–30 min	> 30 min
	Secondary	< 5 min	5–7,5 min	7,5–10 min	10–15 min	> 15 min
A3		< 2,5 min	2,5-5 min	5-7,5 min	7,5-10 min	> 10 min
A4		Bike > Car	Bike ϵ [75%-100%] Car	Bike ϵ [50%-75%[Car	Bike ϵ [25%-50%[Car	Bike < 25% Car
A5		< 8.000 m^2	8.000-20.000 m^2	20.000-80.000 m^2	80.000-200.000 m^2	> 200.000 m^2
A6		9 types of activities	8-7 types of activities	6-4 types of activities	3-1 types of activities	0 types of activities

Table 4: GPC's indicators scoring criteria

As seen in Figure 19, not all indicators are weighted equally. The five considered most relevant in empirical studies (Age; Potential Demand Density; Employment Density; Accessibility to Education Facilities; and Relative Accessibility) are associated with a weight value of 3, and hence have greater influence on the combined GPC score. On the opposite end of the scale, the indicators of Connectivity and Occupation Diversity, feature a weight value of 1, representing less relevant features to the definition of cycling potential. The final GPC score for each census tract is calculated from the weighted average of the set of indicators, according to the following formula.

$$GPC = \frac{\sum_i s_i \times w_i}{\sum_i w_i}$$

Where:

s = score for indicator i

w = weight of indicator i

In addition to the visual representation of cycling potential, a municipality-wide average (MA) is calculated, for the GPC and its indicators, this time using a population weighted average of the values of the individual census tracts scores.

$$MA = \frac{\sum_j s_j \times p_j}{\sum_j p_j}$$

Where:

s = score for census tract j

p = population of census tract j

The Gross Potential for Cycling was applied in the BooST project to twenty-one Portuguese municipalities, in response to an online nationwide call for participation. The next figure describes the example for the municipality of Porto and all results for these municipalities are available on the project's website.

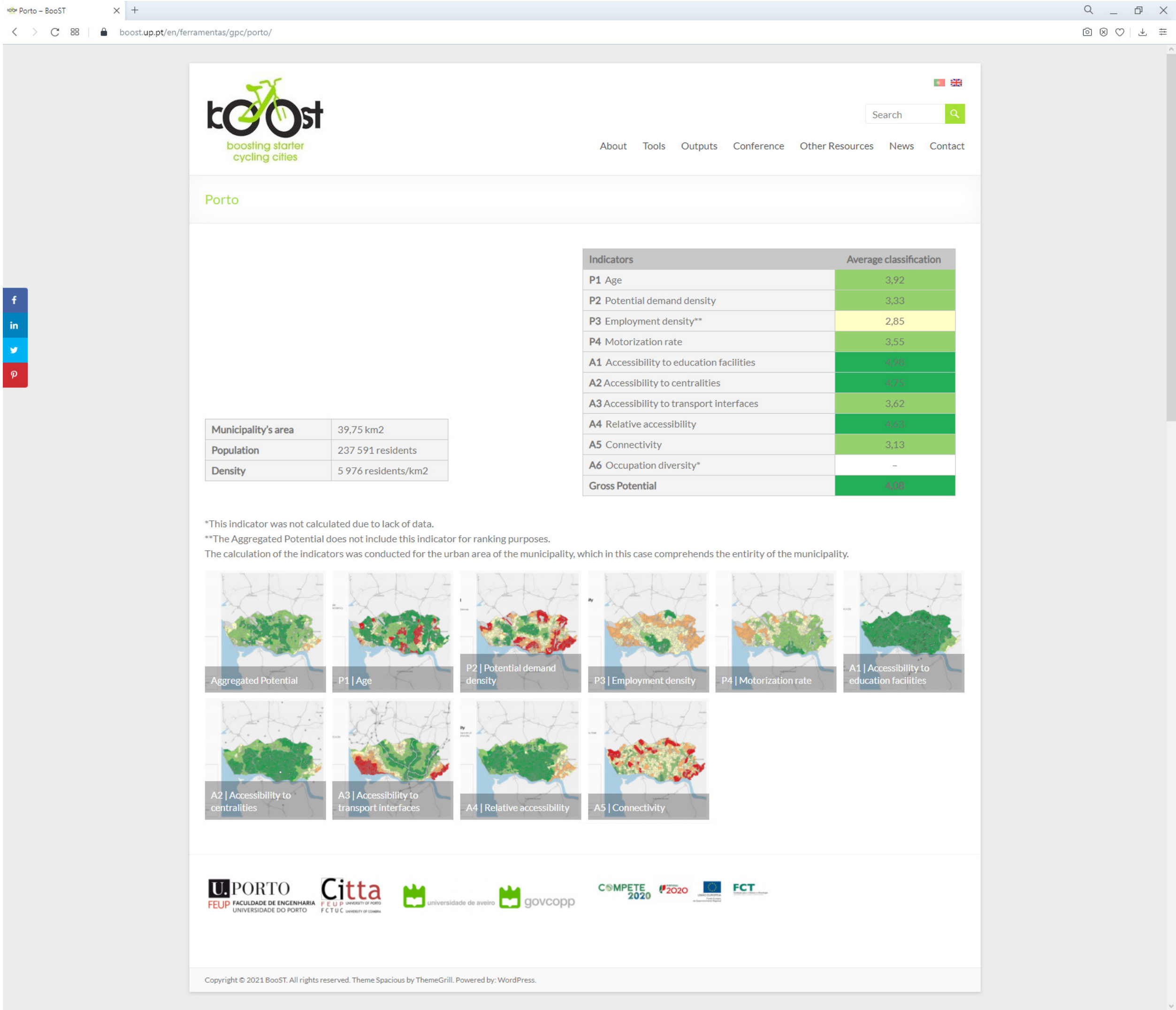


Figure 20: GPC results for the municipality of Porto

3.3 Some results: The National ranking of cycling potential

Within the assessed municipalities in this project, different typologies were included, ranging from rural and lower density areas to consolidated metropolitan areas. Beyond testing the suitability of the GPC on different urban contexts, this exercise allowed the creation of a national ranking of cycling potential (Table 5). It is important to refer that, given the unavailability of data for indicators A6 (occupation diversity) and P3 (employment density) for all municipalities, the GPC scores used for this national ranking only consider information on the remaining eight indicators. This ranking is also available on the webpage of the tool.

Rank	Municipality	GPC Score	Population density (residents/ km²)
1	Porto	4,08	Very High (5 976)
2	Tavira*	3,91	Low (43)
3	Beja*	3,78	Low (31)
4	Lisboa	3,78	Very High (6 448)
5	Portimão	3,69	Medium (305)
6	Amadora	3,69	Very high (7 367)
7	Matosinhos	3,59	Very high (2 811)
8	Vila Nova de Gaia	3,57	High (1 794)
9	Trofa	3,55	High (542)
10	Gondomar	3,53	High (1 274)
11	Odivelas	3,51	Very high (5 484)
12	Valongo	3,50	High (1 249)
13	Maia	3,48	High (1 627)
14	Loures	3,42	Very high (1 211)
15	Oeiras	3,40	Very high (3 751)
16	Fundão	3,32	Low (41)
17	Santa Maria da Feira	3,18	High (645)
18	Machico	3,14	Medium (319)
19	Marco de Canaveses	3,09	Medium (264)
20	Condeixa-a-Nova	2,93	Medium (123)
21	Chamusca	2,70	Very low (13)

* Only the central city was evaluated

Table 5: GPC National Ranking based only on the 21 participating municipalities

Some urban areas naturally present higher cycling potential than others, whether from the nature of its population, its urban structure or both. Looking at the table it becomes clear that different urban contexts are capable of enabling higher cycling potentials, from low density (ex: Tavira), medium sized cites (ex: Portimão) to cities in metropolitan areas (ex: Porto). This a These, however, are only average values for each municipality, meaning that within each there will always be areas within a particular territory with higher potential than other. This is a key conclusion of this process, as it demonstrates that all cities, regardless of its urban context or density, do indeed possess some potential for bicycle use. Figure 21 presents the visual GPC results for the studied cities validates such premise.

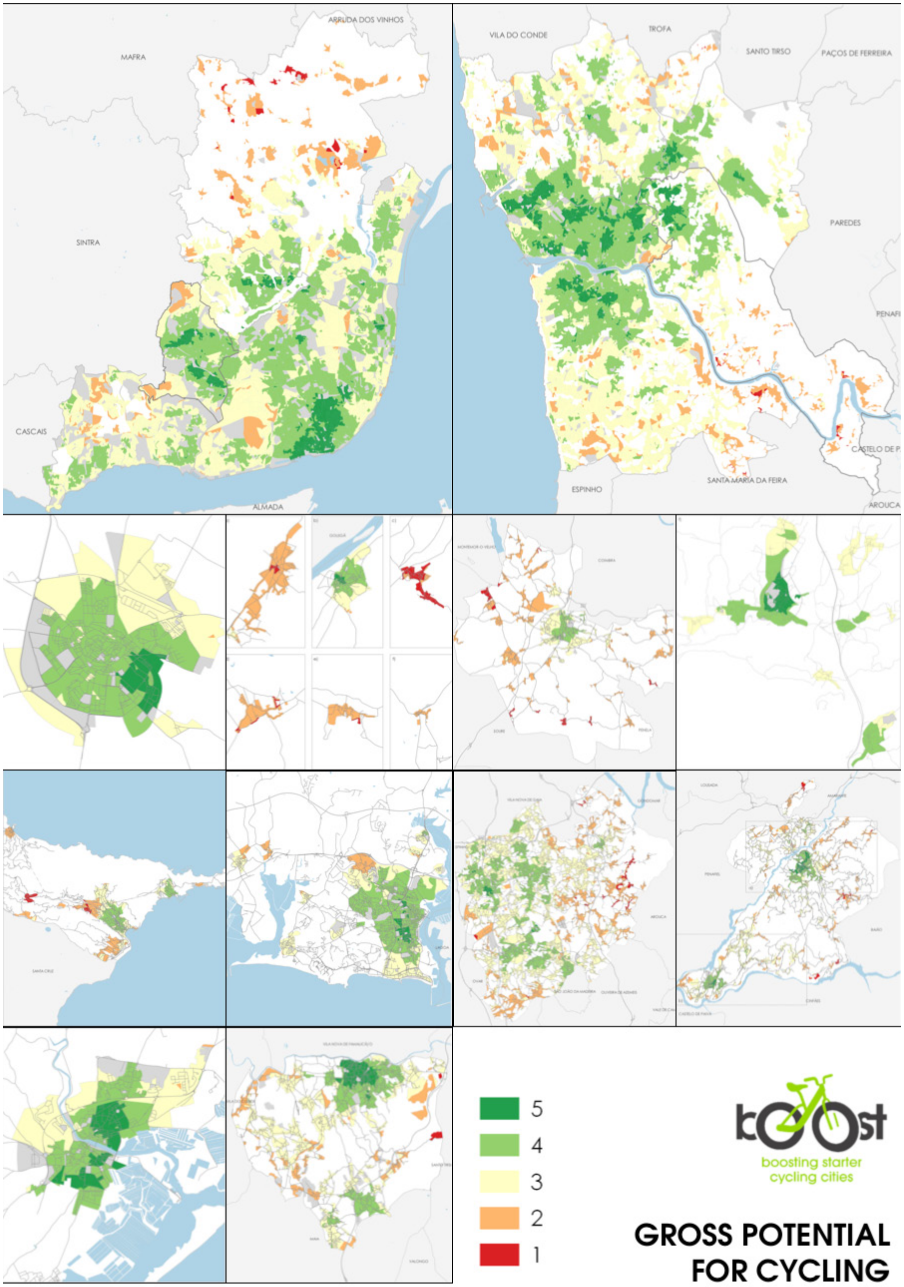


Figure 21: Gross Potential for Cycling results for all 21 evaluated municipalities (metropolitan municipalities are combined at the top)

3.4 Using the GPC to support cycling strategies

The Portuguese National Strategy for Cycling Mobility (ENMAC) aims to reinforce the use of the bicycle in the country and achieve a 7.5% modal share, increasing to 10% if considering urban mobility alone, in the year of 2030. To achieve so, it comprises a financial package to implement 10 000km of new cycling infrastructure. Attempting such a radical change in less than a decade requires strategic planning. Municipality technicians, for the most part, are equipped with a certain level of tacit knowledge that enables them to take the initial steps in the definition of a new cycling network. For example, the need to serve main education facilities is often within the priorities of most municipalities. However, given the multiplicity of factors that can influence bicycle use, the success of such strategies depends on a tighter fit with the territorial feature and the needs of its population. The Gross Potential for Cycling's ability to synthesize those same drivers of bicycle use into a series of visual cues is of the upmost importance to the planning process.

The Gross Potential for Cycling's ability to synthesize those same drivers of bicycle use into a series of visual cues is of the upmost importance to the planning process.

Its results can be integrated within the planning process under different perspectives. For municipalities with an existing cycling infrastructure plan, the results of the GPC can be used, on one hand, for its validation, solely by inspecting the coverage of the identified hotspots of cycling potential (i.e., those with a GPC score of 5). This process can also be used to identify punctual corrections, either by the deviation of proposed links to serve high potential cycling areas or by the introduction of new links to unserved priority locations. Neighbouring municipalities can also use the outputs of this tool to align strategies and thus foster the use of the bicycle in intermunicipal trips. This exercise was indeed tested in this project with the application of the GPC to the core municipalities of Porto and Lisbon metropolitan areas.

It is important to note that the results of the GPC are not provided in a per-street basis, as its goal was to provide guidance on a strategic level. This means that these results should be used to identify key areas for the introduction of not only new infrastructure but also different immaterial actions, within the realm of education and information initiatives. For municipalities already in the path towards a climber status, the results of the GPC can be used to identify priority areas for network densification or even the enactment of compatible mobility management actions that work towards favouring the bicycle.

In summary, the capacitation of municipality technicians to apply in their workflow the tools developed by the BooST project aims for the use of its results towards the development of new strategies or the improvement of existing ones.

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For municipalities already in the path towards a climber status, the results of the GPC can be used to identify priority areas for network densification or even the enactment of compatible mobility management actions that work towards favouring the bicycle.

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3.5 Evaluation of the tool

This section focuses on the reactions to the use of the GPC by planning practitioners at the developed workshops. Three sessions were organized with planning practitioners of thirteen Portuguese municipalities. Here, practitioners were presented with the results from the GPC for their own municipality and worked as a team to gauge the suitability of the results to assist in planning for the bicycle. All groups were asked to evaluate the tool through a survey with predetermined statements ranked in a five-point Likert scale, from 'Strongly disagree' to 'Strongly agree' (more information in Silva et al., 2021). The survey focused on the evaluation of this tool's user friendliness, soundness and utility. Similarly to the method used in the EVC, two additional workshops were hosted with academics and bicycle activists. The results presented in this section will be focused on the evaluation of practitioners.

Overall, planners recognize the added value of the GPC, with the vast majority of statements presenting an agreement rate of 70% or higher. Figure 22 presents some of the main outcomes of this evaluation process. Regarding its user friendliness, even though some participants questioned the capacity for reaching a decision solely on the evaluation of a territory's cycling potential, the communicative value of the results, and its clarity and ability to promote the creation of new ideas were successfully validated.

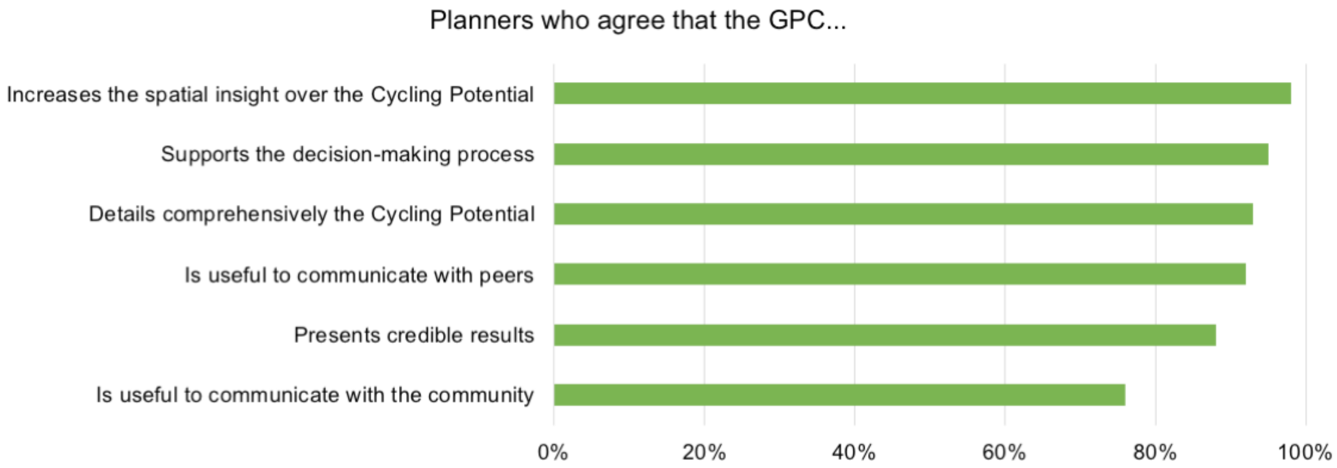

Figure 22: Summary of planners' evaluation of the GPC

Regarding the evaluation of the GPC's soundness the almost entire set of participants agree that it provides a novel spatial insight on cycling potential, quickly identifying the best and worst performing areas. Bicycle activists reinforced this aspect as being crucial to defeat an installed inertia within the planning community who often show concerns with insufficient or inadequate information. In this regard, some participants expressed the desire of seeing results on a smaller geographical scale, namely on a street-by-street basis. This justifies some disagreements over the evaluation of the adequacy of the indicators and the level of detail of the results. However, it appears to have had little influence on the positive perception of the GPC's comprehensiveness and the credibility of its results. Given the vast amount of information that is provided by this tool, as a result of the spatial nature of the results, participants were also questioned on the level of surprise produced by under or overperforming areas. More practitioners were surprised by areas having better performance than the opposite, it remains unclear if these results

Overall, planners recognize the added value of the GPC, with the vast majority of statements presenting an agreement rate of 70% or higher.

signal a certain skepticism of practitioners towards cycling potential or an excess of optimism embedded within the calculation process. Academics and activists, for the most part, shared a positive option on the soundness of this tool.

The relative importance of the ten indicators was also put to test, to gauge practitioners' perspectives on the main factors influencing cycling mobility. The three main accessibility indicators (schools, public transport, and centralities) were the highest ranked features. Generally, planning practitioners tend to take area-based indicators in higher esteem, revealing a preference for the physical aspects of the territory, as opposed to the specificities of the population. Although not measured by these results, the indicator 'Potential Demand Density' generated additional curiosity, for its deviation from more "common" population density evaluations. Overall, the results show some level of deviation with the adopted weighting system, although, by design, it can be adapted in response to the municipality's strategic vision.

On its possible utility to the overall decision-making process, most participants showed great excitement on sharing the acquired knowledge, which reinforces even further the GPC's soundness. The results demonstrate that the GPC facilitates reaching a consensus, under different perspectives and with minor differences between them. The communicative value of the GPC, namely for the visual nature of its outputs, was also understood by academics and activists as one of its key utility features. Only on the evaluation of its utility towards communicating with the wider community some, albeit minor, diverging opinions were formed. Overall, some territorial preconceptions might have interfered in this section of the questionnaire, as more participants agreed on using this newly acquired knowledge in their daily practice, than on demonstrating confidence in the cycling potential of their territory.

Beyond the scope of the overall result of the decision-making process, these sessions also aimed at the evaluation of the GPC's utility to specific aspects of the process. Agreeing views were generalized in aspects such as the capacity to support both the debate, the implementation of solutions and the development of strategies. This was no surprise, as it goes in line with the previously evaluated capacity to ease communication with participants and promote the comprehension of their ideas on cycling mobility. These attributes were also agreed upon by activists and practitioners, pointing the discussion over the small-scale detail of infrastructure, that should appear naturally from these results.

The presence of the disaggregated indicators was valued in greater extent than the aggregated GPC score, which is associated with a more abstract nature. This is in line with practitioners wishes for direct interpretations of territorial performance to guide the drafting of strategies and solutions. These differences became less noticeable when assessing the opinion of academics and activists.

Overall, the key usability, soundness and utility aspects were validating by the targeted beneficiaries of this tool. As such, it is believed that it will certainly provide an undeniable contribution towards the development of more efficient bicycle promotion strategies, reducing the gap between the peloton and the cycling city sprinters.

3.6 Other Tools

The evaluation of the cycling potential of a particular urban area is not novel. In fact, over the last years, several tools focused on the evaluation of the overall urban cycling environment have filled the research panorama, such as:

- 'The Copenhagenize Index' (Colville-Andersen, 2018) or the 'Index of City Readiness for Cycling' (Zayed, 2017), aiming at a swift evaluation of different urban areas;
- 'Propensity to Cycle Tool' from the British context (Lovelace et al., 2017) and the 'Analysis of Cycling Potential' in the city of London (TfL, 2017), focused on spatial and socioeconomic analyses;
- 'Bicycle Safety Index Rating' and the 'Bicycle Compatibility Index' (Schwartz et al., 1999), using micro-scale indicators to assessment the propensity of a particular street;
- Systematic approaches to evaluate the levels of traffic for cycling (Mekuria et al., 2012); and numerous bikeability indexes (Hoedl et al., 2010; Winters et al., 2016).

4
Structuring cycling promotion: The Cycling Measures Selector

4.1 Context: How to design efficient strategies?

Any efficient cycling strategy must address the complexities of appealing to the community's interest, i.e., its target beneficiaries. Simultaneously, it has to balance variable levels of resources, innovation, time availability, physical abilities and cognitive skills (Gössling et al., 2018).

In turn, this demands specific knowledge on strategic planning for the bicycle, which, particularly in the case of Starter Cycling Cities, can involve changing the current planning preconceptions. Some cities are still using a 'predict and provide approach', which focuses on providing more (road) infrastructure to fulfil travel needs. However, this has resulted in the allocation of an ever-increasing amount of space to the private vehicle, with its set of issues in terms of sustainability, social equality, and quality of life. To counteract this, a new approach of 'predict and prevent', or Mobility Management, emerged, focused on reducing the need to travel (Silva, 2008).

Figure 23: Multimodal urban environment

Promoting cycling depends on the efficient application of a comprehensive strategy. It needs to consider the different elements and stakeholders that can help to improve the visibility of the bicycle, and which ones can create barriers to it. Considering this, the European Platform of Mobility Management (EPOMM) defined the concept of Mobility Management. This approach seeks to modify travel behaviour, by appealing to the use of sustainable transports and reduce the attractiveness of the private vehicle (Banister, 2008; Bond and Steiner, 2006; May, 2016). To do so, it combines several mobility measures in a single strategy. In cycling, this could include physical infrastructure, financial incentives, information and education programs and land-use policies (Steg and Vlek, 2007).

Nonetheless, it is necessary to strike a balance between the applied measures, either to avoid contradictions or to create synergic relationships between them (Givoni et al., 2013; Litman, 2003). To this end, measures have been categorized in the following manner (Bamberg et al., 2011; Banister, 2008; Bond and Steiner, 2006; May, 2016):

- **Push and Pull**, the former referring to the way they reduce the attractiveness of the car, pushing it away, and the latter to the enhancement of the attractiveness of alternative modes, pulling on the community to want to use them.

- **Soft and Hard**, with the latter referring mostly to physical measures, encouraging the creation or maintenance of infrastructure and the management of public transport services. This category also includes physical and financial deterrents to car use. Parallelly, Soft measures use information and dissemination techniques and financial incentives to appeal to the voluntary change in behaviours.

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Promoting cycling depends on the efficient application of a comprehensive strategy.

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Figure 24: Examples of push and pull measures

Soft measures are often used to enhance the effectiveness of Hard measures. This combination of different categories of measures for the purposes of enhancing the final result is referred to as 'packaging'. It is based on the assumption that policy measures never 'work' in isolation (Givoni, 2014). When compared to the use of single measures, packaging produces better results in terms of increasing the attractiveness of alternative modes of transport (Banister and Marshall, 2000; Eriksson et al., 2010). Studies suggest three ways to combine measures in packages (Givoni, 2014):

- **Precondition relations**, where the successful functionality of one measure remains wholly contingent upon the prior successful implementation of another.

- **Contradictory relations**, where the conflicting presence of two or more policy measures has a detrimental effect on the functional capacity of both.

- **Synergetic relations**, where the functional capacity of a policy measure is enhanced by the presence of another measure. To further this relation, defining a hierarchy between measures will clarify the potential effectiveness of each. Thus, measures can be identified as Primary, if they directly address the objectives behind the cycling strategy, making them indispensable. The remaining Complementary measures increase the feasibility of the package by overcoming existing barriers and mitigating unintended effects.

"*...packaging produces better results in terms of increasing the attractiveness of alternative modes of transport.*"

Introducing a cycling strategic package can be limited by certain obstacles, namely the lack of resources, public opposition, political infeasibility (Bamberg et al., 2011; Loukopoulos et al., 2004), ineffective law enforcement and inconsistent financial incentives (Steg and Vlek, 2007). Technically, planning practitioners may also find difficulties in attaining accurate information (Litman, 2003) and identify the most appropriate measures in the vast scope of solutions available (Page et al., 2009). Therefore, knowledge and clarity become crucial at each stage of the process, facilitating its definition, acceptance, and feasibility. The literature identifies six summary steps (Figure 25) to an efficient policy packaging process (Justen et al., 2014):

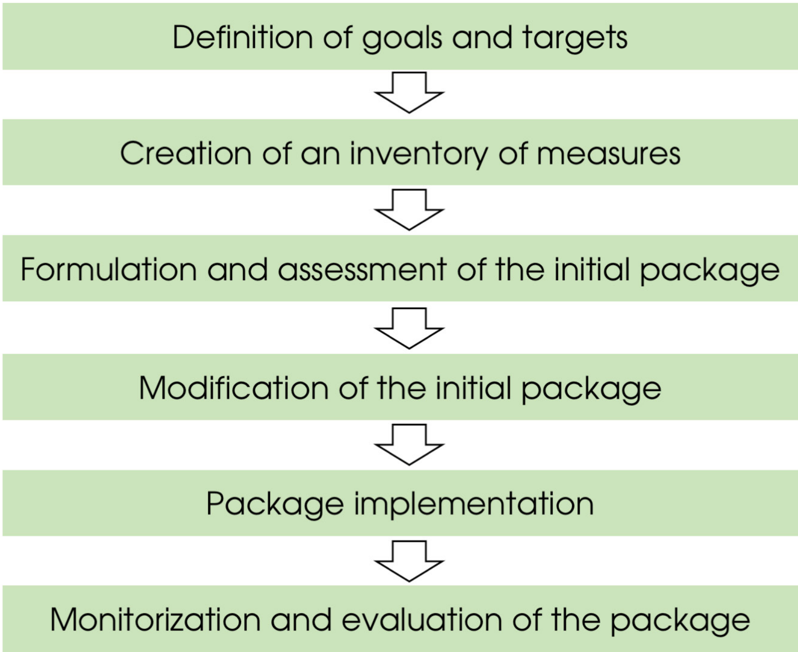

Figure 25: Workflow of the creation and implementation of a package of measures

In a first stage, it is important to have a clearly defined vision of what is necessary, how to achieve it and what would be an appropriate amount of time to do so. This will necessarily be moulded by the context in which the strategy is framed, namely by the population and territorial distribution and the resources available. This stage benefits from the cooperation between policymakers, stakeholders, and citizens. Together, it is easier to understand the community needs and how policy, businesses, schools, and other agents can collaborate in a coordinated strategy to promote bicycle use. Likewise, it will also become clearer what are the main social and political barriers to the implementation of a cycling strategy and how to overcome them. Furthermore, the creation of objective targets, e.g. cycling modal share or pollution levels, will clarify how to achieve the defined goals and how to ensure their correct implementation (Deffner et al., 2012).

It is to note that a Bicycle Mobility plan should not be conceived apart from a more general transport planning strategy. The allocation of resources for different sustainable transport modes complement each other and equally benefit from increasing restrictions on more problematic modes, such as the private car (Deffner et al., 2012).

Scientific evidence highlights the importance of creating an inventory of measures to facilitate the assessment of the large quantity of information that accompanies each of them. This way, they would be detailed and easily comparable. The relations between measures should also be clarified to promote synergies and avoid contradictions (Givoni, 2014).

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...it is important to have a clearly defined vision of what is necessary, how to achieve it and what would be an appropriate amount of time to do so.

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Focusing on measures that cater to advanced users or champion cities can discourage people with less practice in cycling and foment opposition for the bicycle, claiming it does not attract large numbers of riders.

Once a clear and useful inventory is established, is then up to planning practitioners and policy makers to define an initial combination of measures. These should consider the defined goals and existing barriers. It is also important, especially in Starter Cycling Cities, to prioritize measures which promote cycling among most groups, especially the non-cyclists. Focusing on measures that cater to advanced users or champion cities can discourage people with less practice in cycling and foment opposition for the bicycle, claiming it does not attract large numbers of riders (Enabling Cycling Cities: Ingredients for Success, 2013).

Achieving an efficient package in Starter Cycling Cities demands a context appropriate approach and a balance of different measures to overcome barriers. Social and political barriers can be tackled by information and communication measures. However, these are Soft measures, with usually lower levels of influence in bicycle promotion. Partnering them with Hard measures would provide the needed strength. Financial barriers can be addressed by including measures capable of generating profit. Depending on the implementation method, this would not only overcome their own financial needs but also the financial needs of other measures in the strategy. While promoting cycling is dependent on creating physically safe conditions to do so, Infrastructure levels are usually low in Starter Cycling Cities (Silva et al., 2018a). This requires the introduction of Hard measures, capable of transforming the physical space. Yet, only introducing Hard measures, particularly when they entail major alterations for the private vehicle, may be seen as too restrictive. As such, providing measures that appeal to voluntary changes in behaviour can increase community support for the strategy (KonSULT, n.d.).

Once the necessary goals and efficiency standards have been considered, it is necessary to ensure coherence. Planning Support Systems can be extremely useful in this phase. They enable more informed, transparent, and efficient work, contribute to the education of the users and to communication and cooperation between them (Lock et al., 2020). Furthermore, their capacity to calculate larger amounts of data can facilitate the assessment of multiple possible relations between measures. Although their usefulness is not contingent to this phase, they can inform the final considerations by clarifying the efficiency of each measure and the connection between them.

In practical terms, the order in which the measures of a package are applied can take three forms (Givoni et al., 2013):

- **Vertical packaging**, involving various measures at different jurisdictional levels.
- **Chronological packaging**, establishing a time order in the selection of measures, normally sequential progression.
- **Horizontal packaging**: involving the simultaneous deployment of two or more measures aimed at the same target group.

A plan of this nature needs constant monitoring and maintenance to guarantee that its development goals are being met or, if the opposite is true, to collect relevant information to invert the trend.

The chosen methods will depend on the context and available resources. An efficient strategy is often not depended on the immediate application of several measures, but rather on efficient choices for specific goals.

A plan of this nature needs constant monitoring and maintenance to guarantee that its development goals are being met or, if the opposite is true, to collect relevant information to invert the trend. The objective targets defined in the first stage need to be regularly analysed. This should begin before the implementation of the package, as a way to assert a base against which to compare the results (Deffner et al., 2012).

4.2 Tool Description

The Cycling Measures Selector aims to be an interactive framework for consulting details on appropriate measures for the starter context and providing guidance on efficient measure packaging. It prioritizes two concepts prevailing throughout the tools analysed: 1) providing a collection of detailed measures and 2) providing best practices. The first reaches the starter audience by focusing on context appropriate measures and extensive details on each one. The second clarifies the best implementation practices, not only for each individual measure, but also for the packaging process itself. Thus, the CMS highlights the building blocks of efficient packages of measures, boosting the know-how of cities with less resources.

The tool guides and supports decision-making through an online interactive process where users themselves select the measures and packages according to their specific context, providing evidence-based information and a set of recommendations and alerts, without predetermining the preferred approach. It is important to note that the CMS is intended to support, not substitute, the input of experienced agents in planning.

As per the other tools developed by BooST, the CMS is available on the BooST website, through the main menu and through the slider section of the project's Home page (Figure 26). The tool is divided in three stages. To navigate them, each page has, at the bottom, a Progress Bar indicating where within the tool the user is and how to advance and go back. A video explanation can also be found though the outputs option on the top bar (https://boost.up.pt/en/videos/).

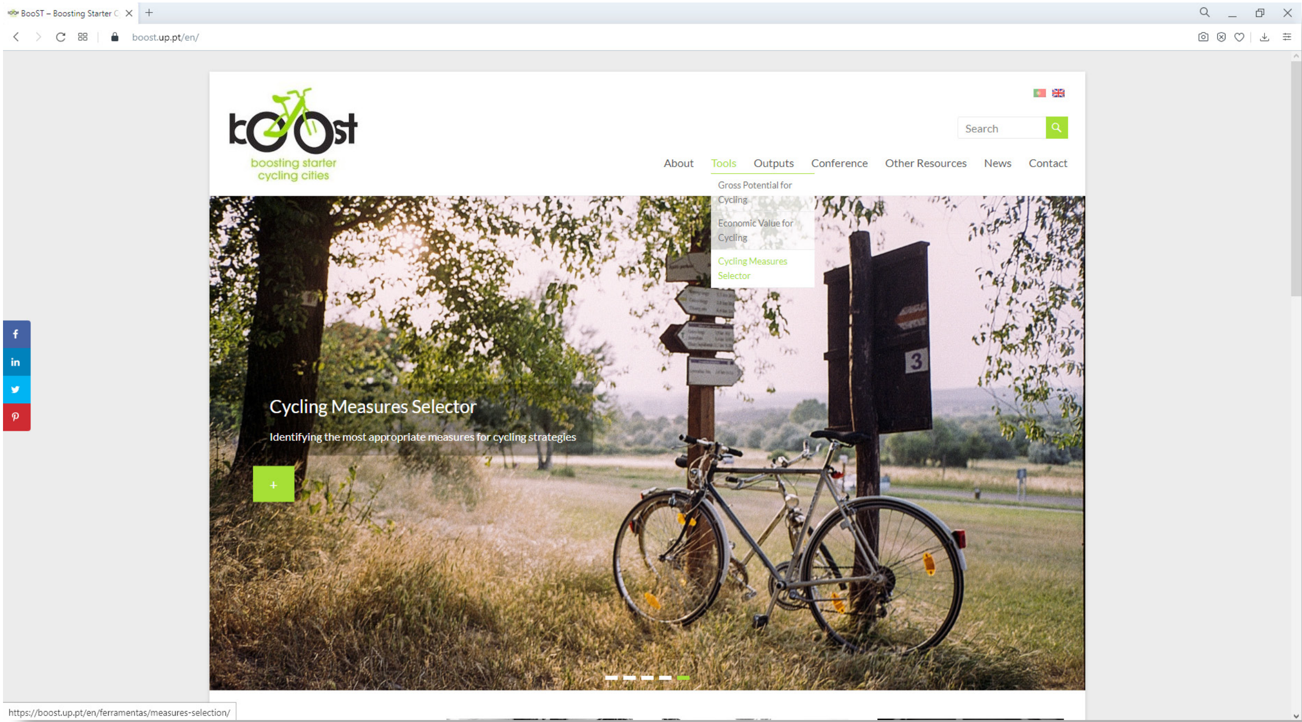

Figure 26: Location of the CMS in the BooST webpage

Step One . Selecting promotors

The initial step asks for the user category to be defined from three options. The first, Municipalities, integrates a wider range of measures simultaneously focused on the network and the cycling conditions of the city and on the provision of information, awareness raising and other stimulus for changing the mobility behaviours of its inhabitants. Schools/Universities and Organizations/Companies, are two additional options that fit the profile of institutions which have autonomy in defining a mobility plan for the institution but are more limited than municipalities in terms of budget, target-audience and scope of intervention.

The profile choice will lead to the next stage of the tool, the Measures' Library, detailing the range of possible policy options. The measures vary according to the promotor, only presenting the most suitable to their intervention capacity (Figure 27).

Figure 27: First phase of the CMS, Selecting Promotors

In addition, the promotor profile influences the Hierarchy of each measure, which was built upon the definition of Givoni (2014). In the CMS, this category defines which measures exert a Precondition relation over the others and identifies them as Primary. Their relevance comes from the capacity to establish the bases upon which the remaining measures can act. Thus, their presence in the packages in mandatory. The remaining measures, identified as Complementary, have varied intervention areas, allowing for flexible solutions.

Step two . Measures' Library

A collection of cycling mobility measures is provided based on the state-of-the-art and state-of-practice, reflecting starter cycling cities needs and challenges. In total, the CMS contains thirty-one measures, but the presented number depends on the selected promotor (Figure 28).

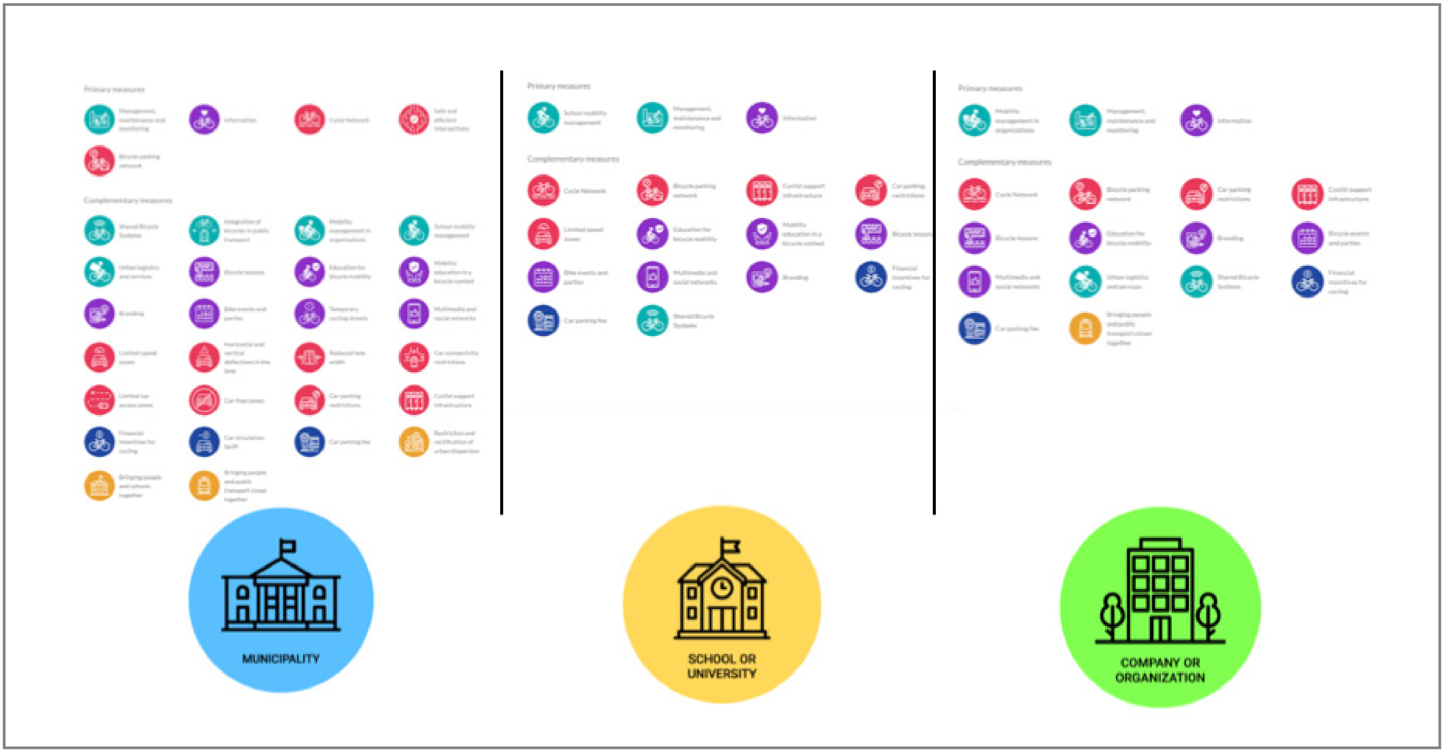

Figure 28: Second phase of the CMS, the Measures' library

To ensure that the package creation is well informed, each measure is accompanied by a report, explaining in detail the way in which it operates, accessible with a click over a specific measure in the library (Figure 29). Each report is separated in six sections: (1) Summary, where the measure, its objectives and its importance are briefly described; (2) Description, listing the good practices to have when implementing the measure and what concrete actions are in its scope; (3) Low-cost measures, which, when applicable, presents real cases where the measure was applied with limited resources; (4) Evaluation, describing the impacts and barriers of the measure and presents examples of its implementation costs; (5) Evidence, showcasing real cases where the measure was applied and evaluates the impacts it had on bicycle use; and (6) References, listing the sources for the information provided. When certain connections between measures are favourable to their implementation, links to said measures are featured. Thus, the different relations between measures and their potential are highlighted.

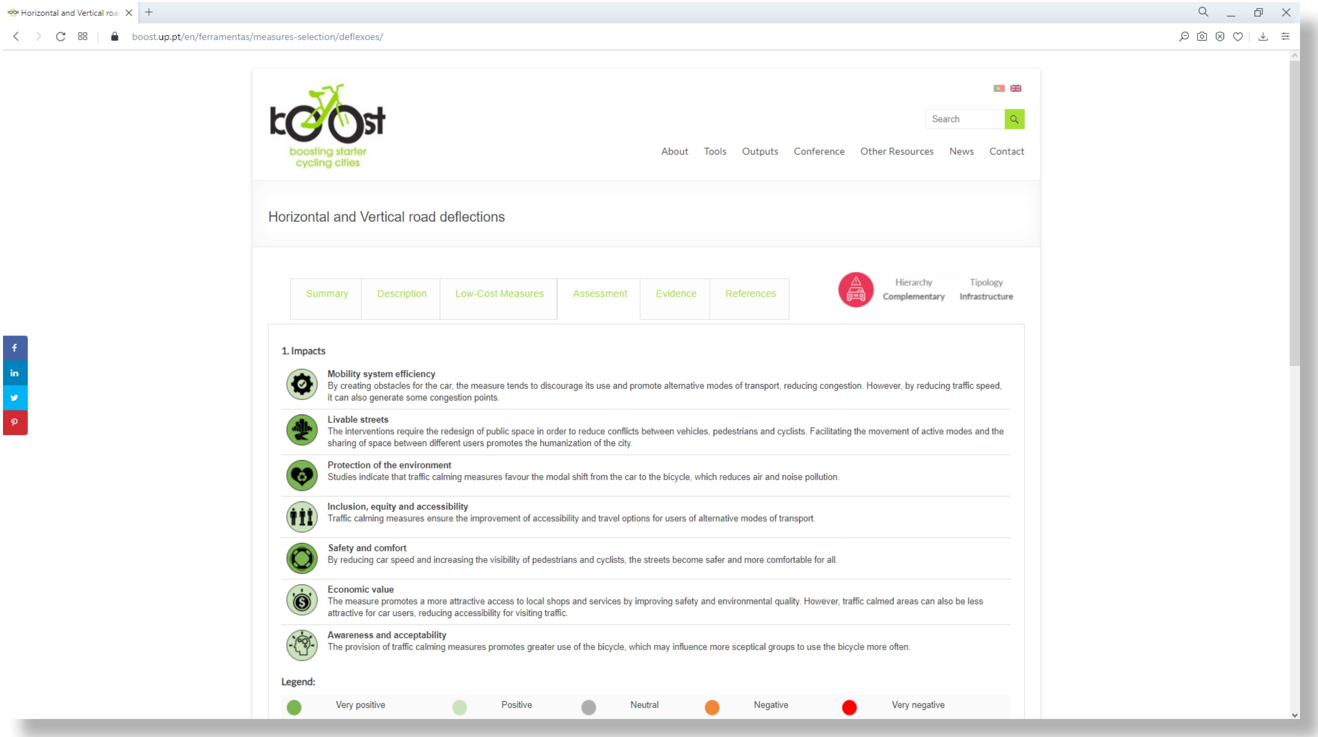

Figure 29: Example of measure report

Measure	Hierarchy	Typology	Push/Pull	Overcoming financial barriers	Score
Management, monitoring and maintenance	Primary	Management and Services	Pull	No	*
Urban logistics and services	Complementary	Management and Services	Pull	No	B
Bike Sharing Systems	Complementary	Management and Services	Pull	No	A
Integration of bicycle in public transport	Complementary	Management and Services	Pull	No	B
Organization Mobility Management	Primary/ Complementary	Management and Services	Push & Pull	No	C*
School Mobility Management	Primary/ Complementary	Management and Services	Push & Pull	No	B*
Information	Primary	Attitudes and Behaviours	Push & Pull	No	*
Cycling classes	Complementary	Attitudes and Behaviours	Pull	No	C
Education for mobility by bicycle	Complementary	Attitudes and Behaviours	Push & Pull	No	C
Education for mobility in a bicycle environment	Complementary	Attitudes and Behaviours	Push & Pull	No	C
Branding	Complementary	Attitudes and Behaviours	Pull	No	C
Bike events and festivals	Complementary	Attitudes and Behaviours	Pull	No	D
Temporary cycling streets	Complementary	Attitudes and Behaviours	Pull	No	B
Multimedia and social networks	Complementary	Complementary Attitudes and Behaviours	Pull	No	A
Financial incentives for cycling	Complementary	Finance	Pull	No	B
Road user charging	Complementary	Finance	Push	Yes	B
Parking Pricing for vehicles	Complementary	Finance	Push	Yes	B
Restriction and rectification of urban sprawl	Complementary	Land use	Push	No	B
Connecting people and schools	Complementary	Land use	Pull	No	B
Connecting people and public transport	Complementary	Land use	Pull	No	A
Cycling network	Primary/ Complementary	Infrastructure	Pull	No	A*
Safe and efficient intersections	Primary	Infrastructure	Pull	No	*

Measure	Hierarchy	Typology	Push/Pull	Overcoming financial barriers	Score
Bicycle parking network	Primary/ Complementary	Infrastructure	Pull	No	B*
Low-speed zones	Complementary	Infrastructure	Push	No	B
Horizontal and vertical road deflections	Complementary	Infrastructure	Push	No	B
Road narrowing	Complementary	Infrastructure	Push	No	B
Car connectivity restrictions	Complementary	Infrastructure	Push	No	A
Limited car access areas	Complementary	Infrastructure	Push	No	A
Car free zones	Complementary	Infrastructure	Push	No	A
Car parking restrictions	Complementary	Infrastructure	Push	No	C
Cyclists' Support Infrastructure	Complementary	Infrastructure	Pull	No	C

*For scoring purposes, Primary measures function as a single measure with an A score. Yet, there a measures which function as Primary and Complementary, depending on the selected Promotor.

Table 6: Classification of CMS' Measures

Each measure is assigned a scoring field based on the external evaluation from experts on cycling. A wide range of academics, urban planners, associations, public authorities, and professionals in the field of bicycle production or systems management evaluated the measures using a five-level scale to represent the influence of each when promoting bicycle use. The final scores – between D (less efficient) and A (most efficient) - were attained from the comparison between their responses (Table 6). This score is not available to the site users to prevent influencing their choices.

Step three . Creating Packages

To create a package of measures users may select which ones they consider more relevant among the options available for the selected promotor profile. To reach this stage, the user must use the progress bar in the top of each page of the process, and click on the "Create Packages" icon (Figure 30). This progress bar allows the user to locate within the use process of the CMS and advance and go back as needed.

In this third stage the tool pre-selects the mandatory measures and allows for up to five complementary measures to be selected. To provide more support to the creation process, calculating the result may trigger a warning system, indicating if efficiency criteria are being met (Figure 31). These, based on synergy and barrier removal concepts found in the literature (Kelly et al., 2008; KonSULT, n.d.; May et al., 2012) consist in three criteria: Self-sufficiency, Communication and Competitiveness.

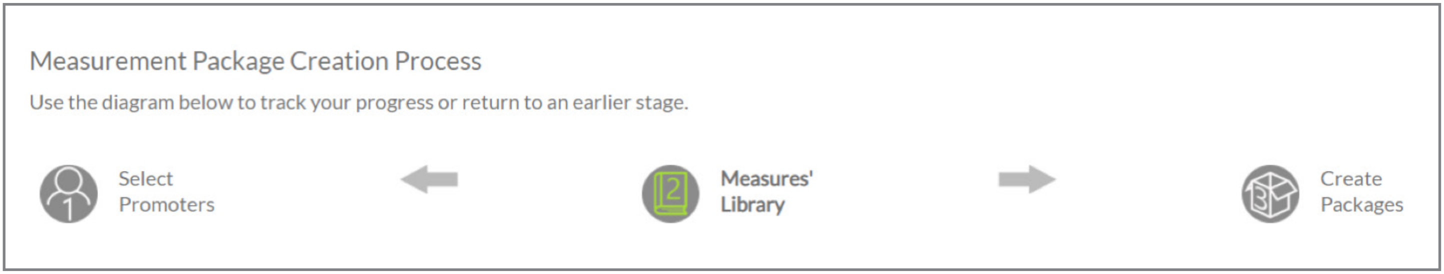

Figure 30: Progress bar, locating each phase of the process

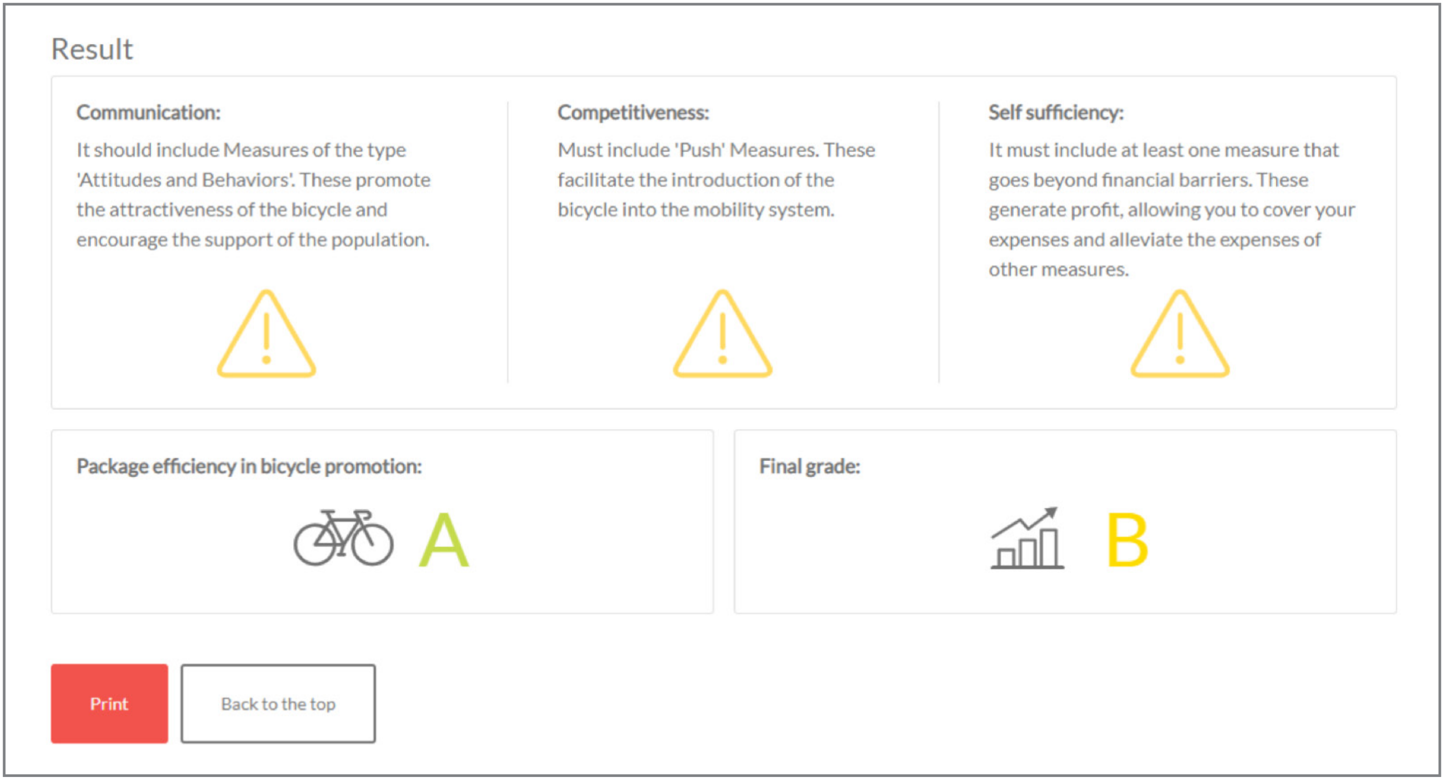

Figure 31: Example of warning system in the Third Phase of the CMS

Self-sufficiency refers to the process of overcoming financial barriers. These emerge when complex and financially demanding infrastructures are needed, and they can be overcome by measures that generate revenue. Thus, this criterion is considered as fulfilled when at least one measure that overcomes financial barriers is included in the package.

Communication is based on the inclusion of measures of the Attitudes and Behaviours typology. They promote the attractiveness of the bicycle, fostering the support of the population. Their inclusion in a package facilitates the understanding of the objectives behind a cycling plan and encourages the community to support the decisions being taken towards its implementation. Thus, not only is the cycling infrastructure used properly, but the public barriers are more easily overcome. As indicated when describing the Soft/Hard synergy in section 4.1, communication measures are more efficient if there's cycling infrastructure in place (Bamberg et al., 2011).Therefore, this criterion is only considered fulfilled when the Attitudes and Behaviours measures are associated with at least one measure of a different typology.

Finally, the last criterion, **Competitiveness**, seeks to hinder the use of the private automobile. To that end, it requires the selection of Push measures, thus facilitating the introduction of the bicycle in the mobility system. However, applying only Push measures is not sufficient to promote bicycle use. Hence, for this criterion to be fulfilled, the package cannot have a majority of Push measures.

Users can select up to a maximum of five complementary measures. If more than five are selected, a popup will appear with such indication. After the selection of the intended measures, a click on the "Calculate result" button will generate the package score, that corresponds to its efficiency, between A++ (more efficient) and F (less efficient). This value depends on the score of each individual

	0 criteria fulfilled	**1 criterion fulfilled**	**2 criteria fulfilled**	**3 criteria fulfilled**
Measures with 'A' score >= 60% of package	B	A	A+	A++
Measures with 'A' e 'B' score >= 60% of package	C	B	B+	A
Measures with 'A', 'B', e 'C' score >= 60% of package	D	C	C+	B
Measures with 'A', 'B', 'C' e 'D' score >= 60% of package	E	D	D+	C
No complementary measures	F	-	-	-

Table 7: CMS's Package Scoring System

measure and the Efficiency Criteria previously described. The more measures with a high score exist, the better its performance. However, the fulfilment rate of the Efficiency Criteria can alter the final score, either up or down (Table 7). A new package can be tested by click on the "Clear " button.

Thus, the tool is organized to prioritize the acquisition of knowledge regarding the fundamental bases of efficient package construction. It goes beyond evaluating packages of measures, focusing instead on clarifying the best practices of developing a cycling mobility strategy.

4.3 Using the CMS to support cycling strategies

In practical terms, this tool can be used for multiple purposes. The detail of the Measures' Library allows it to be useful in identifying a viable alternative when creating a package. For example, when a specific goal asks for a type of measure, such as measures which decrease the competitiveness of the car, the Measures' Library presents a set of measures which fulfil that goal and lists different actions that fall in its scope. In addition, the information sheets of each measure offer links to other measures when they are compatible. This diversity allows for the promotors to choose which action and/or measure better fulfils their goals and fits their specific needs.

This variety can then be transported to the package creation phase, allowing for each of the alternatives to be tested in the framework. Each alternative can alter the efficiency results and generate different alerts and scores, highlighting the package building process. The results generated will provide varied information to substantiate a discussion among the planning team. If a team is planning the first cycling strategy for their focus area, they might decide to offer a more comprehensive solution, and thus would focus on fulfilling the three efficiency criteria. If, on the other hand, there is already a comprehensive strategy put in place, and they seek to merely strengthen their restrictions on the private vehicle, they might prefer to verify which combination of restrictive measures provides them with a better efficiency score. The different results from the CMS will provide specific information for them to build on their ideas and centralize their intent.

…the goal of the CMS is not to provide the perfect package, as not all strategies require a maximum score.

It is important to note that the goal of the CMS is not to provide the perfect package, as not all strategies require a maximum score. While strategies with greater ambition in terms of altering the modal share would benefit from higher scores combinations, each promotor must be aware of their circumstances and identify the intended goals. Furthermore, it only presents the potential efficiency of the packages. The actual efficiency is dependent on the way in which each measure is implemented. A badly designed cycleway would not guarantee as many users as a properly designed one. The same is true for every measure. Therefore, it is of the utmost importance to verify what are the good practices to implement each measure (which is also available in the information sheet of each measure) and implement a monitoring and maintenance program.

4.4 Evaluation of the tool

To evaluate how the CMS truly impacts the decision-making process, a series of workshops were devised to test its **soundness**, **user friendliness**, and **utility.** A session was organized with planning practitioners of twelve Portuguese municipalities. Participants were grouped according to their context and used the tool to develop a cycling strategy in a hypothetical municipality, with a set of issues and objectives similar to their own. All groups were asked to evaluate the tool through a survey with predetermined statements ranked in a five-point Likert scale, from 'Strongly disagree' to 'Strongly agree' (Mélice Dias et al., 2021).

Out of the analysis of the added-value of the three tools of the BooST toolkit, the Cycling Measures Selector appears to have generated the strongest consensus among practitioners. The comprehensive scope of the tool was particularly appreciated, namely regarding the detail and organization of the Measures' Library (Figure 32). On the theme of user-friendliness, more practical aspects were evaluated, mostly focused on the interface of the tool. This included its ability to facilitate the creation of create ideas, the clarity of its results and the facility it provides to their comparison. These concepts were agreed by planning practitioners, though they generated different levels of enthusiasm. The clarity of results generated some doubts among activists and academics, which might be due to different organizations between their session and those of planners, which left less opportunity to interact directly with the tool.

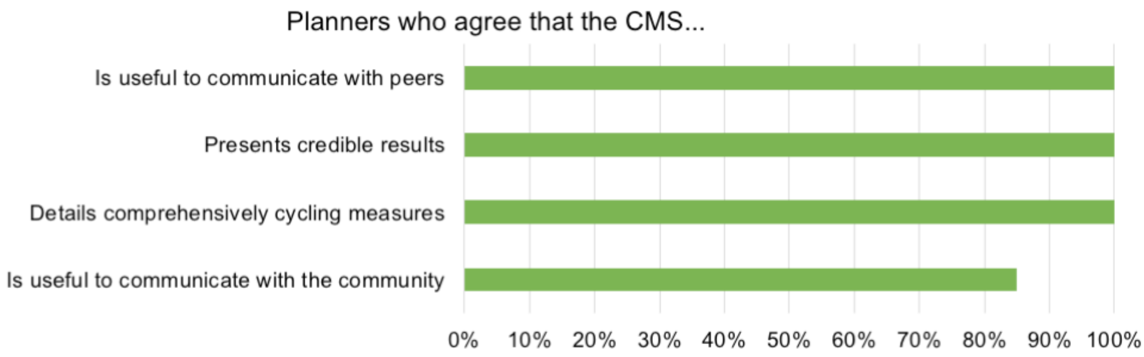

Figure 32: Summary of planners' evaluation of the CMS

Lastly, utility encompassed the impact of the tool in different dimensions of the planning process, focusing on the tool's insight on the specificities of cycling promotion measures, its insight on the strategic thinking of assembling a package, and the relevance of the provided aggregated score to substantiate the strategy. Other aspect of the utility evaluation focused on the outcomes of the tool, namely its capacity to generate consensus, facilitate communication, both within the planning team and with the community, and provide a new understanding of existing promotion measures. This dimension also encompassed the tool's capacity to renew the commitment to promoting bicycle use, by analysing the intent to use and share knowledge generated by the CMS.

This concept generated mostly positive responses, yet it also contained the greatest number of divergent answers and doubts. Within the different stages of the decision-making process, both insight on strategic thinking and the relevance of the aggregated score were well received. However, the insight on promotion measures did not fare as well, as planning practitioners felt they did not acquire new knowledge and merely felt the tool provided an organized framework for them to access it.

...the CMS emerges as particularly useful for providing explicit information on cycling measures and to substantiate municipal strategies.

Within the dimension of the tool's outcomes, the commitment to promote bicycle use was unquestionably reinforced. However, there was uncertainty regarding the tool's support of the debate, its facilitation of knowledge and communication. The last topic was split, with all planners agreeing with the support granted to communicating between peers, but a minority disagreeing with the support granted to communicating with the community.

In a different point of view, academics and activists raised some questions regarding the CMS's impact on the different stages of the decision-making process. Though the majority did still agree that the tool was useful for providing insights on promotion measures and strategic thinking, with the aggregated score playing a role in that aspect, some questioned if the tool could be wrongly used to replace expert opinions and judgments.

Considering the entirety of this participatory experience, the CMS emerges as particularly useful for providing explicit information on cycling measures and to substantiate municipal strategies. Nevertheless, some planning practitioners felt that its potential would go unrecognized among more sceptic political decision-makers.

Planning practitioners did suggest adding more layers to the tool, which would contribute further to the formulation and assessment of the initial package. This was based on the addition of pre-defined scenarios and objectives to the promotors, associating each of these combinations with its own set of a more restricted Measures' Library. They also suggested adding indicators to evaluate the proper implementation of measures, which could facilitate the 'Monitorization' and 'Evaluation' stages. However, both contributions would create greater restrictions to package creation and implementation. Given the large number of possibilities in terms of context and objectives, these restrictions could exclude some cities or influence them to create less appropriate strategies.

“

Planning practitioners did suggest adding more layers to the tool, which would contribute further to the formulation and assessment of the initial package.

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4.5 Other Tools

Several instruments have been created, with varying levels of interactivity. The focus is usually on providing information on mobility measures, especially regarding best practices in their implementation and their impact. Max Explorer (EPOMM, n.d.) and SiMPlify (WBSCD, 2016) are examples of this. The VTPI Online Encyclopedia (Litman, 2003), on the other hand, provides a less interactive platform but offers more detail on each measure and on the connections between them. In terms of packaging, KonSULT (Kelly et al., 2008; May et al., 2018, 2012) also provides an interactive platform to experiment and evaluate multiple possible combinations of measures. However, neither of these tools focuses specifically on the Starter Cycling context. Thus, the provided information lacks specificity regarding the barriers and needs of these cities, hindering the identification of the most appropriate measures (Mélice Dias et al., 2021). The CMS builds from existing support systems, namely KonSULT (Kelly et al., 2008; May et al., 2018, 2012), PRESTO (Dufour, 2010) and VTPI Online TDM Encyclopedia (Litman, 2003), but centres on the Starter Context through the measures it details and through its focus on good package building strategies.

5
Final Reflection

5.1 Concrete measures to boost bicycle use in Portugal

Currently, Portugal still lacks both a strong bicycle tradition and an urban development process towards the creation of human scale cities, and the last decades show concerning trends. In 40 years, the Portuguese population under 19 years has dropped from 3,3 million to 1,9 million. This means a reduction in 40% on the number of children that populate schools and play on street and parks. Over the same period, the number of cars on cities has more than doubled. Today, we have over 2,5 time more cars (5,2 million) than younger residents below 19 years of age (1,9 million). Cars have become dominant not only in occupying the physical space of urban areas but also within our daily lives. They now represent 14% of the total budget of families, as much as all food expenses (INE, 2017). Urban residents spend almost as much within vehicles as they dedicate to spending with family members. And all trends point to a persistent growth of car dominance.

Cycling mobility is on the governmental agenda through the National Strategy for Cycling Active Mobility (ENMAC) that contain 51 measures with the ambition to reach a modal share of 7,5%. To achieve that goal several actions are included, from the construction of new bicycle infrastructure, subsidizing bicycle purchase, the UBIKE6 project and initiatives with schools. This political commitment has also been revealed with the Portuguese government involvement in the Pan-European Master Plan for Cycling Promotion. Still, it is within the viewpoint of the central government that the direct intervention within the territory lies within the competences of municipalities, who should guarantee the operationalization of the ENMAC actions.

The pandemic, despite all the negative outcomes, has allowed for the experimentation of new urban solutions, namely those with a temporary nature and focused on pedestrianization and increase bicycle use (Figure 33). The examples of Porto and Lisbon appear as important efforts from municipalities to change the current car dominant modal distribution. These actions have shown that it is possible to test new forms of rescuing public space, providing new forms to take advantage of the city. Despite some criticisms over its implementation, it was possible to have a glimpse of a new model for urban development, less dependent on the car and more inclusive of pedestrians and cyclists. In some cases, even with collaboration with living forces such as associations and activists. The enforcement of these new policies for the bicycle will certainly benefit from the boost provided by the Recovery and Resilience Plan (PRR), the PT 2030 and the new municipal cycle 2021-2025. However, currently little evidence exists on how these will see the light of day.

“*Portugal still lacks both a strong bicycle tradition and an urban development process towards the creation of human scale cities...*”

“

The pandemic, despite all the negative outcomes, has allowed for the experimentation of new urban solutions, namely those with a temporary nature and focused on pedestrianization and increase bicycle use.

”

Figure 33: Temporary pedestrian street in Porto during the summer of 2020

Over the several sessions hosted by the BooST project, it became clear that the transition to the decarbonization of the urban model will generate inevitable conflicts. Additional venues for dialogue and concertation are paramount, as the longer lasting solutions will be the ones that can benefit from the adoption of co-creation strategies. In this path several contradictions will be exposed, especially among those that "want a better world, but that are not available to change mobility, leisure and consumption habits".

There is also the conviction that this change will not take place by decree as mobility is part of a complex urban system. Overlapping geographies of residence, work, study, shopping, and leisure will have to rebuilt over solutions that prioritize the reduction of distances, speeds, and frequency of trips. In response to the complexity of the urban system, additional recommendations lie in the definition of incremental actions, allowing time for proper testing and acceptance.

The 15-minute city, presented at the final conference of the project (https://boost.up.pt/en/conferencia) by Carlos Moreno, can provide a good contribution in that regard. The concept put forth by Carlos Moreno is "a narrative to a new urban life" and a motto to transform cities using a proximity scale. It is not a ready to use global recipe, but rather a challenge to decision makers, technicians, citizens, and local actors within the search to most suited path to each territorial reality, and its underlying social and economic context. This concept introduces the necessity to look towards the idea of proximity under multiple dimensions (Moreno et al., 2021). First, the ecological one, based on a reduction of motorized travel and CO2 emissions. Second, a spatial dimension, sustained on the recovery of public space to the promotion of leisure, social gathering, and urban biodiversity. Third, a social dimension that can foster the creation of new local businesses (aiming to short urban circuits) and neighbourhood activities. Finally, it also entails a civic dimension that can stimulate experimental actions of tactical urbanism and community funding.

"*...the transition to the decarbonization of the urban model will generate inevitable conflicts... There is also the conviction that this change will not take place by decree as mobility is part of a complex urban system.*"

…"a narrative to a new urban life" and a motto to transform cities using a proximity scale… there are risks that this narrative of the proximity city can generate vicious effects…

However, the blind acceptance of narratives has its own risks, as Marco te Brömmelstroet has alerted in the project's final conference. If properly used they can have a mobilizing and transformative role of imaginaries, practices, and paradigms. If poorly applied they can be vague statements devoid of consequences. As a result, there are risks that this narrative of the proximity city can generate vicious effects, such as the accentuation of hyper qualification of central city areas, concentrating public investments, fostering gentrification trends, expelling those with less income and reinforcing asymmetries between privileged areas and forgotten peripheries. Additional remarks can be pointed to a possible lack of consideration with the diversity and contexts and the reasons that explain urban inequality, with a technocratic and top-down structure that disregards the involvement of communities.

As several participants have pointed out during the first day of the conference, it is important to accelerate changes, both on active mobility and urban policies. Marco te Brömmelstroet has left three suggestions to reinforce the weight of cycling mobility and reach the 7,5% target that the Portuguese government established within the National Strategy for Cycling Active Mobility. First, articulate mobility with territorial planning, focusing on the approval of new functions, ensuring that travel under active modes is prioritized. Second, articulate new cycling networks with public transport and reduce traffic speed in central city areas, creating a more favourable context to all travel modes. Third, experiment with new solutions (particularly through tactical urbanism), observing behaviours and results and fine-tune the most perennial cycling infrastructure plans.

5.2 The contribution of the BooST toolkit

The focus of this project – Starter Cycling Cities – illustrates very well the starting position of Portugal (currently with less than 1% of cycling modal share) and shows how long is the path ahead to reach the ENMAC goal of 7,5%.

Several concerted efforts are necessary to accelerate this approach, combining the Government, municipalities, employers and key stakeholders of large traffic generators, the bicycle industry, local organizations and citizens. The BooST project provides a set of tools that can assist in the much-awaited transition, and there is the expectations that its proper use can support planners, capacitate citizens and raise awareness among decision makers. The importance of evidence-based tools were clearly highlighted throughout the project with many local practitioners pointing out the value of providing clear technical evidence even to support implicit knowledge.

Being a scientific research project, promoted within a partnership between the University of Porto and Aveiro, it is a good example on how academia can demonstrate the existence of both alternatives and choices on how cities and mobility are looked upon. The project and its tools can also help to focus the discussion on the cities on which we would like to live in (liveable city with short distances, a sense of community and more space for children, youths, and the elderly) and on the methodologies that can be used to make them possible (language, communication and participative tools).

References

Aldred, R., Jungnickel, K., 2014. Why culture matters for transport policy: The case of cycling in the UK. J. Transp. Geogr. 34, 78–87. https://doi.org/10.1016/j.jtrangeo.2013.11.004

Alexander, C., 1965. A City is Not a Tree. Archit. Forum 122, 58–62.

Baker, L., 2009. How to Get More Bicyclists on the Road: To boost urban bicycling, figure out what women want. Sci. Am. 301, 28–29.

Baltes, M., 1996. Factors Influencing Nondiscretionary Work Trips by Bicycle Determined from 1990 U.S. Census Metropolitan Statistical Area Data. Transp. Res. Rec. 1538, 96–101.

Bamberg, S., Fujii, S., Friman, M., Gärling, T., 2011. Behaviour theory and soft transport policy measures. Transp. Policy 18, 228–235. https://doi.org/10.1016/j.tranpol.2010.08.006

Banister, D., 2008. The sustainable mobility paradigm. Transp. Policy 15, 73–80. https://doi.org/10.1016/j.tranpol.2007.10.005

Banister, D., Marshall, S., 2000. Encouraging transport alternatives: good practice in reducing travel. London.

Bertolini, L., 2017. Planning the Mobile Metropolis: Transport for People, Places and the Planet. Palgrave, London.

Blondel, B., Mispelon, C., Ferguson, J., 2011. Cycle more oiften 2 cool down the Planet!, European Cyclists' Federation.

Blondiau, T., Van Zeebroeck, B., 2014. Cycling works.

Blondiau, T., Van Zeebroeck, B., Haubold, H., 2016. Economic Benefits of Increased Cycling. Transp. Res. Procedia 14, 2306–2313. https://doi.org/10.1016/j.trpro.2016.05.247

Bond, A., Steiner, R.L., 2006. Sustainable campus transportation through transit partnership and transportation demand management: A case study from the University of Florida. Berkeley Plan. J. 19, 125–142. https://doi.org/10.5070/bp319111492

Börjesson, M., Eliasson, J., Hugosson, M.B., Brundell-Freij, K., 2012. The Stockholm congestion charges-5 years on. Effects, acceptability and lessons learnt. Transp. Policy 20, 1–12. https://doi.org/10.1016/j.tranpol.2011.11.001

Broach, J., Dill, J., Gliebe, J., 2012. Where do cyclists ride? A route choice model developed with revealed preference GPS data. Transp. Res. Part A 46, 1730–1740.

Buehler, R. & Pucher, J., 2011. Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. Transportation (Amst). 39, 409–432.

Buehler, R., 2012. Determinants of bicycle commuting in the Washington, DC region: The role of bicycle parking, cyclist showers, and free car parking at work. Transp. Res. Part D Transp. Environ. 17, 525–531. https://doi.org/10.1016/j.trd.2012.06.003

Bullock, C., Brereton, F., Bailey, S., 2017. The economic contribution of public bike-share to the sustainability and efficient functioning of cities. Sustain. Cities Soc. https://doi.org/10.1016/j.scs.2016.08.024

BYPAD, 2008. Cycling, the European approach: Total quality management in cycling policy. Results and lessons of the BYPAD-project.

Cantell, A.M., 2012. Assessing the Active Transportation Potential of Neighbourhood Models Using GIS. University of Waterloo, Ontario.

Cervero, R., Denman, S., Jin, Y., 2019. Network design, built and natural environments, and bicycle commuting: Evidence from British cities and towns. Transp. Policy 74, 153–164. https://doi.org/10.1016/j.tranpol.2018.09.007

Chapman, L., 2007. Transport and climate change: a review. J. Transp. Geogr. 15, 354–367. https://doi.org/10.1016/j.jtrangeo.2006.11.008

Colville-Andersen, M., 2018. Copenhagenize: the definitive guide to global bicycle urbanism. Island Press, Washington DC. https://doi.org/10.1080/01441647.2019.1656679

Da Silva, D.C., King, D.A., Lemar, S., 2020. Accessibility in practice: 20-minute city as a sustainability planning goal. Sustain. 12, 1–20. https://doi.org/10.3390/SU12010129

de Hartog, J.J., Boogaard, H., Nijland, H., Hoek, G., 2010. Do the health benefits of cycling outweigh the risks? Environ. Health Perspect. 118, 1109–1116. https://doi.org/10.1289/ehp.0901747

de Souza, A.A., Sanches, S.P., Ferreira, M.A.G., 2014. Influence of Attitudes with Respect to Cycling on the Perception of Existing Barriers for Using this Mode of Transport for Commuting. Procedia - Soc. Behav. Sci. 162, 111–120. https://doi.org/10.1016/j.sbspro.2014.12.191

Deenihan, G., Caulfield, B., 2015. Do tourists value different levels of cycling infrastructure? Tour. Manag. 46, 92–101. https://doi.org/10.1016/j.tourman.2014.06.012

Deenihan, G., Caulfield, B., 2014. Estimating the health economic benefits of cycling. J. Transp. Heal. 1, 141–149. https://doi.org/10.1016/J.JTH.2014.02.001

Deffner, J., Hefter, T., Rudolph, C., Ziel, T., 2012. Handbook on cycling inclusive planning and promotion: Capacity development material for the multiplier training within the Mobile2020 project. Frankfurt/Hamburg.

Delso, J., Martín, B., Ortega, E., 2018. Potentially replaceable car trips: Assessment of potential modal change towards active transport modes in Vitoria-Gasteiz. Sustain. 10. https://doi.org/10.3390/su10103510

Dickinson, J.E., Kingham, S., Copsey, S., Hougie, D.J.P., 2003. Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? Transp. Res. Part D 8, 53–67. https://doi.org/10.1016/S1361-9209(02)00018-4

Dill, J., 2004. Measuring Network Connectivity for Bicycling and Walking, in: Transportation Research Board 83rd Annual Meeting. Portland, pp. 1–21. https://doi.org/citeulike-article-id:8426565

Dill, J., Carr, T., 2003. Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them. Transp. Res. 1828, 116–123.

Dill, J., McNeil, N., 2013. Four Types of Cyclists? Examination of Typology for Better Understanding of Bicycling Behavior and Potential. Transp. Res. Board 2387, 129–138.

Dill, J., McNeil, N., 2012. Four types of cyclists? Examination of typology for better understanding of bicycling behavior and potential. Transp. Res. Rec. J. Transp. Res. Board. https://doi.org/10.3141/2387-15

Dufour, D., 2010. PRESTO Cycling Policy Guide: General Framework, PRESTO Project: Promoting Cycling for Everyone as a Daily Transport Mode.

EC Directorate-general for Mobility and Transport, 2017. Support study on data collection and analysis of active modes use and infrastructure in Europe - Country Reports. Publications Office of the European, Luxembourg.

ECF, 2011a. Cycle more Often 2 cool down the planet! Quantifying CO2 savings of Cycling. Brussels.

ECF, 2011b. Cycle more Often 2 cool down the planet! Quantifying CO2 savings of Cycling. Brussels.

ECF, WCA, 2015. "Cycling Delivers to the Global Goals – Shifting towards a better economy, society, and planet for all."

El-geneidy, A., Lierop, D. Van, Was, R., 2016. Do people value bicycle sharing? A multilevel longitudinal analysis capturing the impact of bicycle sharing on residential sales in Montreal, Canada. Transp. Policy 51, 174–181. https://doi.org/10.1016/j.tranpol.2016.01.009

Ellison, R.B., Greaves, S., 2011. Travel time competitiveness of cycling in Sydney, Australia. Transp. Res. Rec. 99–108. https://doi.org/10.3141/2247-12

Enabling Cycling Cities: Ingredients for Success, 2013.

EPOMM, n.d. EPOMM Max Explorer [WWW Document]. URL http://epomm.eu/index.php?id=2745

Eriksson, L., Nordlund, A.M., Garvill, J., 2010. Expected car use reduction in response to structural travel demand management measures. Transp. Res. Part F Traffic Psychol. Behav. 13, 329–342. https://doi.org/10.1016/j.trf.2010.06.001

European Cyclists' Federation, 2017. EU Cycling Strategy - Recommendations for Delivering Green Growth and Effective Mobility System in 2030, EU Cycling Strategy. https://doi.org/10.1177/1060028017712725

Fernández-Heredia, Á., Jara-Díaz, S., Monzón, A., 2014. Modelling bicycle use intention: the role of perceptions. Transportation (Amst). https://doi.org/http://dx.doi.org/10.1007/ s11116-014-9559-9

Ferreira, J.P., Barata, E., Ramos, P.N., Cruz, L., 2014. Economic, social, energy and environmental assessment of inter-municipality commuting: The case of Portugal. Energy Policy 66, 411–418.

Ferreira, J.P., Isidoro, C., Moura, F., Carlos, J., 2020. The economic value for cycling – a methodological assessment for Starter Cities 29–45.

Fishman, E., 2016. Cycling as transport. Transp. Rev. 36, 1–8. https://doi.org/10.1080/01441647.2015.1114271

Fishman, E., Garrard, J., Ker, I., Litman, T., 2011. Cost and health benefit of active transport in Queensland, Stage One report, Health Promotion Queensland, Brisbane.

Fishman, E., Washington, S., Haworth, N., 2014. Bike share ' s impact on car use : Evidence from the United States , Great Britain , and Australia. Transp. Res. PART D 31, 13–20. https://doi.org/10.1016/j.trd.2014.05.013

Flusche, D., 2009. Bicycling Means Business: The Economic Benefits of Bicycle Infrastructure. Washington D.C.

Flynn, B.S., Dana, G.S., Sears, J., Aultman-Hall, L., 2012. Weather factor impacts on commuting to work by bicycle. Prev. Med. (Baltim). 54, 122–124. https://doi.org/10.1016/j.ypmed.2011.11.002

Fraser, S., Lock, K., 2010. Cycling for transport and public health: a systematic review of the effect of the environment on cycling. Eur. J. Public Heal. Vol. 21, 738–743.

Garrard, J., Rissel, C., Bauman, A., 2012. Health benefits of cycling, in: Pucher, J., Buehler, R. (Eds.), City Cycling. MIT Press, Cambridge, pp. 287–318.

Gatersleben, B., Appleton, K., 2007. Contemplating cycling to work: Attitudes and perceptions in different stages of change. Transp. Res. Part A 41, 302–312.

Gatersleben, B., Haddad, H., 2010. Who is the typical bicyclist? Transp. Res. Part F Traffic Psychol. Behav. 13, 41–48. https://doi.org/10.1016/j.trf.2009.10.003

Geus, B. d., Bourdeaudhuij, I.D., Jannes, C., Meeusen, R., 2008. Psychosocial and environmental factors associated with cycling for transport among a working population. Health Educ. Res. 23, 697–708.

Geus, B. De, Hendriksen, I., 2015. Cycling for Transport, Physical Activity and Health: What about Pedelecs? Cycl. Futur. From Res. into Pract. 17–32.

Givoni, M., 2014. Addressing transport policy challenges through policy-packaging. Transp. Res. Part A Policy Pract. 60, 1–8. https://doi.org/10.1016/j.tra.2013.10.012

Givoni, M., Macmillen, J., Banister, D., Feitelson, E., 2013. From Policy Measures to Policy Packages. Transp. Rev. 33, 1–20. https://doi.org/10.1080/01441647.2012.744779

Goldsmith, S.A., 1992. National bicycling and walking study, Case study no. 1- Reasons why Bicycling and Walking are not being used more Extensively As Travel Modes.

Gössling, S., Choi, A., Dekker, K., Metzler, D., 2019a. The Social Cost of Automobility, Cycling and Walking in the European Union. Ecol. Econ. 158, 65–74. https://doi.org/10.1016/j.ecolecon.2018.12.016

Gössling, S., Choi, A., Dekker, K., Metzler, D., 2019b. The Social Cost of Automobility , Cycling and Walking in the European Union. Ecol. Econ. 158, 65–74. https://doi.org/10.1016/j.ecolecon.2018.12.016

Gössling, S., Cohen, S., 2014. Why sustainable transport policies will fail: EU climate policy in the light of transport taboos. J. Transp. Geogr. 39, 197–207. https://doi.org/10.1016/j.jtrangeo.2014.07.010

Gössling, S., Cohen, S., Higham, J., Peeters, P., Eijgelaar, E., 2018. Desirable transport futures. Transp. Res. Part D Transp. Environ. 61, 301–309. https://doi.org/10.1016/j.trd.2018.01.008

Gössling, S., S. Choi, A., 2015. Transport transitions in Copenhagen: Comparing the cost of cars and bicycles. Ecol. Econ. 106–113. https://doi.org/10.1016/j.ecolecon.2015.03.006.

Götschi, T., Garrard, J., Giles-Corti, B., 2016. Cycling as a Part of Daily Life: A Review of Health Perspectives. Transp. Rev. 36, 45–71. https://doi.org/10.1080/01441647.2015.1057877

Handy, S., Butler, K. and Paterson, R.G., 2003. Planning for Street Connectivity - Getting from Here to There. American Planning Association, Chicago.

Handy, S., Wee, B. v. & Kroesen, M., 2014. Promoting Cycling for Transport: Research Needs and Challenges. Transp. Rev. 34, 4–24.

Handy, S., van Wee, B., Kroesen, M., 2014. Promoting Cycling for Transport: Research Needs and Challenges. Transp. Rev. 34, 4–24. https://doi.org/10.1080/01441647.2013.860204

Handy, S.L., Xing, Y., Buehler, T.J., 2010. Factors associated with bicycle ownership and use: A study of six small U.S. cities. Transportation (Amst). 37, 967–985. https://doi.org/10.1109/TDEI.2015.005356

Haubold, H., 2014. Commuting : Who Pays the Bill?

Heesch, K., Corti, B., Turrell, G., 2015. Cycling for transport and recreation: Associations with the socio-economic, natural and built environment. Health Place 36, 152–161.

Heinen, E., van Wee, B., Maat, K., 2010. Commuting by bicycle: An overview of the literature. Transp. Rev. 30, 59–96. https://doi.org/10.1080/01441640903187001

Hoedl, S., Titze, S., Oja, P., 2010. The Bikeability and Walkability evaluation table: Reliability and application. Am. J. Prev. Med. 39, 457–459. https://doi.org/10.1016/j.amepre.2010.07.005

Hull, A., O'Holleran, C., 2014. Bicycle infrastructure: can good design encourage cycling? Urban, Plan. Transp. Res. 2, 369–406. https://doi.org/10.1080/21650020.2014.955210

INE, 2018. Mobilidade e funcionalidade do território nas Áreas Metropolitanas do Porto e de Lisboa, 2017.

INE, 2017. Inquérito às Despesas das Famílias 2015/2016. Lisboa.

IPCC, 2014. Climate Change 2014. Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. New York.

Jacobs, J., 1961. The Death and Life of Great American Cities. Random House, New York.

Justen, A., Fearnley, N., Givoni, M., Macmillen, J., 2014. A process for designing policy packaging: Ideals and realities. Transp. Res. Part A Policy Pract. 60, 9–18. https://doi.org/10.1016/j.tra.2013.10.016

Kager, R., Bertolini, L., Te Brömmelstroet, M., 2016. Characterisation of and reflections on the synergy of bicycles and public transport. Transp. Res. Part A Policy Pract. 85, 208–219. https://doi.org/10.1016/j.tra.2016.01.015

Kelly, C., May, A., Jopson, A., Gawthorpe, S., 2008. DISTILLATE A KonSULT-based strategy option generator.

KonSULT, n.d. Decision Makers' Guidebook. Leeds.

Krizec, K.J., 2007. Estimating the economic benefits of bicycling and bicycle facilities: An interpretive review and proposed methods, in: Coto-Millán, P., Inglada, V. (Eds.), Contributions to Economics. Physica-Verlag HD, Heidelberg, pp. 219–248. https://doi.org/10.1007/978-3-7908-1765-2-14

Krizek, K.J., 2007. Estimating the economic benefits of bicycling and bicycle facilities: An interpretive review and proposed methods., in: Coto-Millán, P., Inglada, V. (Eds.), Essays on Transport Economics. Physica-Verlag HD, Heidelberg, pp. 219–248.

Krizek, K.J., Johnson, P.J., 2006. Proximity to trails and retail: Effects on urban cycling and walking. J. Am. Plan. Assoc. 72, 33–42. https://doi.org/10.1080/01944360608976722

Kuzmyak, J.R., Walters, J., Bradley, M., Kockelman, K.M., 2014. Estimating Bicycling and Walking for Planning and Project Development: A Guidebook. National Cooperative Highway Research Program, Washington D.C. https://doi.org/10.17226/22330

Leyden, K.M., 2003. Social Capital and the Built Environment: The Importance of Walkable Neighborhoods. Am. J. Public Health 93, 1546–1551. https://doi.org/10.2105/AJPH.93.9.1546

Litman, T., 2010. Quantifying the Benefits of Nonmotorized Transportation For Achieving Mobility Management Objectives, Victoria Transport Policy Institute.

Litman, T., 2003. The Online TDM Encyclopedia: Mobility management information gateway. Transp. Policy 10, 245–249. https://doi.org/10.1016/S0967-070X(03)00025-8

Litman, T., Blair, R., Demopoulos, B., Eddy, N., Fritzel, A., Laidlaw, D., Maddox, H., Forster, K., 2018. Pedestrian and bicycle planning: a guide to best practices. Victoria, Canada.

Loukopoulos, P., Jakobsson, C., Gärling, T., Schneider, C.M., Fujii, S., 2004. Car-user responses to travel demand management measures: Goal setting and choice of adaptation alternatives. Transp. Res. Part D Transp. Environ. 9, 263–280. https://doi.org/10.1016/j.trd.2004.02.003

Lovelace, R., Goodman, A., Aldred, R., Berkoff, N., Abbas, A., Woodcock, J., 2017. The Propensity to Cycle Tool: An open source online system for sustainable transport planning. J. Transp. Land Use 10, 505–528. https://doi.org/10.5198/jtlu.2016.862

Lowry, M.B., Furth, P., Hadden-Loh, T., 2016. Prioritizing new bicycle facilities to improve low-stress network connectivity. Transp. Res. Part A Policy Pract. 86, 124–140. https://doi.org/10.1016/j.tra.2016.02.003

Lunke, E.B., Aarhaug, J., de Jong, T., Fyhri, A., 2018. Cycling in Oslo, Bergen, Stavanger and Trondheim. TØI Report 1667/2018. Oslo.

Ma, L. & Dill, J., 2015. Associations between the objective and perceived built environment and bicycling for transportation. J. Transp. Heal. 2, 248–255.

Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., Woodward, A., 2014. The societal costs and benefits of commuter bicycling: Simulating the effects of specific policies using system dynamics modeling. Environ. Health Perspect. https://doi.org/10.1289/ehp.1307250

Maibach, M., Schreyer, C., Sutter, D., van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B., Bak, M., 2008. Handbook on estimation of external costs in the transport sector. CE Delft 336. https://doi.org/07.4288.52

Marije de Boer, M.A.H., Caprotti, F., 2017. Getting Londoners on two wheels: A comparative approach analysing London's potential pathways to a cycling transition. Sustain. Cities Soc. 32, 613–626. https://doi.org/10.1016/j.scs.2017.04.019

Marqués, R., Hernández-Herrador, V., Calvo-Salazar, M., García-Cebrián, J.A., 2015. How infrastructure can promote cycling in cities: Lessons from Seville. Res. Transp. Econ. 53, 31–44. https://doi.org/10.1016/j.retrec.2015.10.017

May, A., 2016. Quick facts on measure selection - Selecting the most effective packages of measures for.

May, A.D., Kelly, C., Shepherd, S., Jopson, A., 2012. An option generation tool for potential urban transport policy packages. Transp. Policy 20, 162–173. https://doi.org/10.1016/j.tranpol.2012.01.012

May, A.D., Khreis, H., Mullen, C., 2018. Option generation for policy measures and packages: An assessment of the KonSULT knowledgebase. Case Stud. Transp. Policy 6, 311–318. https://doi.org/10.1016/j.cstp.2018.03.002

Médard de Chardon, C., 2016. A Geographical Analysis of Bicycle Sharing Systems. University of Luxembourg and Université catholique de Louvain.

Mekuria, M.C., Furth, P.G., Nixon, H., 2012. Low-Stress Bicycling and Network Connectivity - MTI Report 11-19. San José, CA.

Mélice Dias, A., Lopes, M., Silva, C., 2021. More than cycling infrastructure: supporting the development of policy packages for starter cycling cities. Transp. Res. Rec.

Mertens, L., Compernolle, S., Deforche, B., Mackenbach, J.D., Lakerveld, J., Brug, J., Roda, C., Feuillete, T., Oppert, J.-M., Glonti, K., Rutterg, H., Bardos, H., Bourdeaudhuij, I. De, Dyck, D. Van, 2017. Built environmental correlates of cycling for transport across Europe. Health Place 44, 35–42.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., Pratlong, F., 2021. Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. Smart Cities 4, 93–111. https://doi.org/10.3390/smartcities4010006

Mueller, N., Rojas-rueda, D., Salmon, M., Martinez, D., Ambros, A., Brand, C., Nazelle, A. De, Dons, E., Gaupp-berghausen, M., Gerike, R., Götschi, T., Iacorossi, F., Int, L., Kahlmeier, S., 2018. Health impact assessment of cycling network expansions in European cities 109, 62–70. https://doi.org/10.1016/j.ypmed.2017.12.011

Mulley, C., Tyson, R., McCue, P., Rissel, C., Munro, C., 2013. Valuing active travel: Including the health benefits of sustainable transport in transportation appraisal frameworks. Res. Transp. Bus. Manag. 7, 27–34. https://doi.org/10.1016/j.rtbm.2013.01.001

Muñoz, B., Monzon, A., López, E., 2016. Transition to a cyclable city: Latent variables affecting bicycle commuting. Transp. Res. Part A Policy Pract. 84, 4–17. https://doi.org/10.1016/j.tra.2015.10.006

Neun, M., Haubold, H., 2016a. The EU Cycling Economy – Arguments for an Integrated EU Cycling Policy. Brussels.

Neun, M., Haubold, H., 2016b. THE EU CYCLING ECONOMY - Arguments for an integrated EU cycling policy. Brussels.

Oja, P., Titze, S., Bauman, A., de Geus, B., Krenn, P., Reger-Nash, B., Kohlberger, T., 2011. Health benefits of cycling: A systematic review. Scand. J. Med. Sci. Sport. 21, 496–509. https://doi.org/10.1111/j.1600-0838.2011.01299.x

Otero, I., Nieuwenhuijsen, M.J., 2018. Health impacts of bike sharing systems in Europe. Environ. Int. 115, 387–394. https://doi.org/10.1016/j.envint.2018.04.014

Page, M., Kelly, C., May, A., Jones, P., Forrester, J., 2009. Enhancing appraisal methods to support sustainable transport and land use policies. Eur. J. Transp. Infrastruct. Res. 9, 296–313. https://doi.org/10.18757/ejtir.2009.9.3.3312

Parkin, J., Wardman, M., Page, M., 2008. Estimation of the determinants of bicycle mode share for the journey to work using census data. Transportation (Amst). 35, 93–109. https://doi.org/10.1007/s11116-007-9137-5

Pelechrinis, K., Zacharias, C., Kokkodis, M., Lappas, T., 2017a. Economic impact and policy implications from urban shared transportation: The case of Pittsburgh's shared bike system. PLoS One 12. https://doi.org/https://doi.org/10.1371/journal.pone.0184092

Pelechrinis, K., Zacharias, C., Kokkodis, M., Lappas, T., 2017b. Economic impact and policy implications from urban shared transportation: The case of Pittsburgh's shared bike system. PLoS One. https://doi.org/10.1371/journal.pone.0184092

Perry, C.A., 1929. City Planning for Neighbourhood Life. Soc. Forces 8, 98–100.

Piket, P., Eijgelaar, E., Peeters, P., 2013. European cycle tourism: a tool for sustainable regional rural development. Appl. Stud. Agribus. Commer. 7, 115–119. https://doi.org/10.19041/Apstract/2013/2-3/19

Plaut, P.O., 2005. Non-motorized commuting in the US. Transp. Res. Part D 10, 347–356.

Pnina, O.P., 2005. Non-motorized commuting in the US. Transp. Res. Part D Transp. Environ. 10, 347–356. https://doi.org/10.1016/j.trd.2005.04.002

Pooley, C., Tight, M., Jones, T., Horton, D., Scheldeman, G., Jopson, A., Mullen, C., Chisholm, A., Strano, E., Constantine, S., 2011. Understanding walking and cycling: Summary of key findings and recommendations. Lancaster.

Prati, G., 2018. Gender equality and women's participation in transport cycling. J. Transp. Geogr. 66, 369–375. https://doi.org/10.1016/j.jtrangeo.2017.11.003

Prati, G., 2017. Gender equality and women's participation in transport cycling. J. Transp. Geogr. 66, 369–375. https://doi.org/10.1016/j.jtrangeo.2017.11.003

Prud'homme, R., Bocarejo, J.P., 2005. The London congestion charge: A tentative economic appraisal. Transp. Policy 12, 279–287. https://doi.org/10.1016/j.tranpol.2005.03.001

Pucher, J., Buehler, R., 2009. Integrating Bicycling and Public Transport in North America. J. Public Transp. 12, 79–104. https://doi.org/10.1051/0004-6361/201219426

Pucher, J., Buehler, R., 2008. Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany. Transp. Rev. 28, 495–528. https://doi.org/10.1080/01441640701806612

Pucher, J., Dill, J., Handy, S., 2010. Infrastructure, programs, and policies to increase bicycling: An international review. Prev. Med. (Baltim). 50, S106–S125. https://doi.org/10.1016/j.ypmed.2009.07.028

Rabl, A., de Nazelle, A., 2012. Benefits of shift from car to active transport. Transp. Policy 19, 121–131. https://doi.org/10.1016/j.tranpol.2011.09.008

Raje, F., Saffrey, A., 2008. The Value of Cycling. Https://Www.Gov.Uk/Government/Uploads/System/Uploads/Attachment_Data/File/509587/Value-of-Cycling.Pdf 10–11. https://doi.org/10.1002/bjs.9465.

Rietveld, P., Daniel, V., 2004. Determinants of bicycle use: Do municipal policies matter? Transp. Res. Part A Policy Pract. 38, 531–550. https://doi.org/10.1016/j.tra.2004.05.003

Rissel, C., Greaves, S., Wen, L., Capon, A., Crane, M., Standen, C., 2013. Evaluating the transport, health and economic impacts of new urban cycling infrastructure in Sydney, Australia - protocol paper. BMC Public Health 13, 963.

Rojas-Rueda, D., de Nazelle, A., Tainio, M., Nieuwenhuijsen, M.J., 2011. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. BMJ 343. https://doi.org/10.1136/bmj.d4521

Rojas-Rueda, D., de Nazelle, A., Teixidó, O., Nieuwenhuijsen, M.J., 2013. Health impact assessment of increasing public transport and cycling use in Barcelona: A morbidity and burden of disease approach. Prev. Med. (Baltim). 57, 573–579. https://doi.org/10.1016/j.ypmed.2013.07.021

Rueda, S., 2019. Superblocks for the Design of New Cities and Renovation of Existing ones: Barcelona's Case, in: Nieuwenhuijsen, M., Khreis, H. (Eds.), Integrating Human Health into Urban and Transport Planning. Berlin, pp. 135–153.

Rutter, H., Cavill, N., Racioppi, F., Dinsdale, H., Oja, P., Kahlmeier, S., 2013. Economic impact of reduced mortality due to increased cycling. Am. J. Prev. Med. 44, 89–92. https://doi.org/10.1016/j.amepre.2012.09.053

Savan, B., Cohlmeyer, E., Ledsham, T., 2017. Integrated strategies to accelerate the adoption of cycling for transportation. Transp. Res. Part F Traffic Psychol. Behav. 46, 236–249. https://doi.org/10.1016/j.trf.2017.03.002

Schwartz, W., Porter, C., Payne, G., Suhrbier, J., Moe, P., Wilkinson, W., 1999. Guidebook on Methods to Estimate Non-Motorized Travel: Cambridge, MA.

Segadilha, A., Sanches, S., 2014. Identification of factors that influence cyclists´ route choice. Procedia - Soc. Behav. Sci. 160, 372 – 380.

Shaheen, S.A., Guzman, S., Zhang, H., 2010. Bikesharing in Europe, the Americas, and Asia: Past, Present, and Future. Transp. Res. Rec. J. Transp. Res. Board 1, 159–167. https://doi.org/10.3141/2143-20

Shearlaw, M., 2017. Harassment , stigma and fatwas: what is it like to cycle as a woman? Guard.

Silva, C., 2008. Comparative Accessibility for Mobility management. University of Oporto.

Silva, C., Lopes, M., Mélice Dias, A., 2021. Revealing the Gross Potential for Cycling as Planning Support for Starter Cycling Cities. Environ. Plan. B Plan. Des. forthcoming.

Silva, C., Teixeira, J., Proença, A., 2018a. Revealing the Cycling Potential of Starter Cycling Cities, in: International Scientific Conference on Mobility and Transport - Mobil.TUM 2018. Elsevier, Munich.

Silva, C., Teixeira, J., Proença, A., Bicalho, T., Cunha, I., 2018b. The Potential for cycling assessment method -final report. Oporto.

Song, Y., Knaap, G.J., 2004. Measuring the effects of mixed land uses on housing values. Reg. Sci. Urban Econ. 34, 663–680. https://doi.org/10.1016/j.regsciurbeco.2004.02.003

Spotswood, F., Chatterton, T., Tapp, A., Williams, D., 2015. Analysing cycling as a social practice: An empirical grounding for behaviour change. Transp. Res. Part F Traffic Psychol. Behav. 29, 22–33. https://doi.org/10.1016/j.trf.2014.12.001

Steenberghen, T., Tavares, T., Richardson, J., Himpe, W., Crabbé, A., 2017. Support study on data collection and analysis of active modes use and infrastructure in Europe.

Steg, L., Vlek, C., 2007. The role of problem awareness in willingness-to-change car use and in evaluating relevant policy measures, in: Steg, L., Vlek, C. (Eds.), Threats to the Quality of Urban Life from Car Traffic. Problems, Causes and Solutions. Emerald Publishing, pp. 425–449.

Stinson, M.A., Bhat, C.R., 2004. Frequency of Bicycle Commuting: Internet-Based Survey Analysis, in: TRB 2004.

Sustrans, 2019. Bike Life - The potential of everyday cycling.

Teixeira, J.F., Lopes, M., 2020. The link between bike sharing and subway use during the COVID-19 pandemic: The case-study of New York's Citi Bike. Transp. Res. Interdiscip. Perspect. 6, 100166. https://doi.org/10.1016/j.trip.2020.100166

TfL, 2017. Analysis of Cycling Potential 2016. London.

TfL, 2012. Understanding the travel needs of London ' s diverse communities: Black, Asian and minority ethnic (BAME) people. London.

TfL, 2010. Analysis of Cycling Potential – Travel in London. London.

Tight, M., Timms, P., Banister, D., Bowmaker, J., Copas, J., Day, A., Drinkwater, D., Givoni, M., Gühnemann, A., Lawler, M., Macmillen, J., Miles, A., Moore, N., Newton, R., Ngoduy, D., Ormerod, M., O'Sullivan, M., Watling, D., 2011. Visions for a walking and cycling focussed urban transport system. J. Transp. Geogr. 19, 1580–1589. https://doi.org/10.1016/j.jtrangeo.2011.03.011

Titze, S., Giles-Corti, B., Knuiman, M.W., Pikora, T.J., Timperio, A., Bull, F.C., van Niel, K., 2010. Associations between intrapersonal and neighborhood environmental characteristics and cycling for transport and recreation in adults: baseline results from the RESIDE study. J. Phys. Act. Health 7, 423–31.

Tresidder, M., 2005. Using GIS to measure connectivity: An exploration of issues. Sch. Urban Stud. Planning, Portl. State ….

Urry, J., 2004. The system of automobility. 2Theory, Cult. Soc. 21, 25–39.

Vale, D.S., 2017. A cidade e a bicicleta : uma leitura analítica. Finisterra 51. https://doi.org/10.18055/finis7077

WBSCD, 2016. Integrated sustainable mobility in cities - a practical guide. Geneva.

Weng, M., Ding, N., Li, J., Jin, X., Xiao, H., He, Z., Su, S., 2019. The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China. J. Transp. Heal. 13, 259–273. https://doi.org/10.1016/j.jth.2019.05.005

Weston, R., Davies, N., Lumsdon, L., McGrath, P., Peeters, P., Eijgelaar, E., Piket, P., 2012. The European Cycle Route Network EuroVelo - Challenges and Opportunities for Sustainable Tourism.

Whalen, K.E., Páez, A., Carrasco, J.A., 2013. Mode choice of university students commuting to school and the role of active travel. J. Transp. Geogr. 31, 132–142. https://doi.org/10.1016/j.jtrangeo.2013.06.008

WHO, 2011. Health economic assessment tools (HEAT) for walking and for cycling - Methodology and user guide.

Winters, M., Teschke, K., Brauer, M., Fuller, D., 2016. Bike Score®: Associations between urban bikeability and cycling behavior in 24 cities. Int. J. Behav. Nutr. Phys. Act. 13, 1–10. https://doi.org/10.1186/s12966-016-0339-0

Zayed, M.A., 2017. Towards an index of city readiness for cycling. Int. J. Transp. Sci. Technol. 5, 210–225. https://doi.org/10.1016/j.ijtst.2017.01.002

Zhao, C., Carstensen, T.A., Nielsen, T.A.S., Olafsson, A.S., 2018. Bicycle-friendly infrastructure planning in Beijing and Copenhagen - between adapting design solutions and learning local planning cultures. J. Transp. Geogr. 68, 149–159. https://doi.org/10.1016/j.jtrangeo.2018.03.003

Zheng, F., Gu, F., Zhang, W., Guo, J., 2019. Is bicycle sharing an environmental practice? Evidence from a life cycle assessment based on behavioral surveys. Sustain. 11. https://doi.org/10.3390/su11061550

Zhu, J., Fan, Y., 2018. Daily travel behavior and emotional well-being: Effects of trip mode, duration, purpose, and companionship. Transp. Res. Part A Policy Pract. 118, 360–373. https://doi.org/10.1016/j.tra.2018.09.019

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