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Potential for Cycling Assessment Method

Potential for Cycling Assessment Report

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1. INTRODUCTION

Worldwide, the potential of cycling for a progressively future has been acknowledge (S. Handy, Wee, & Kroesen, 2014; Pucher, Buehler, & Seinen, 2011). This acknowledgement follows examples of more experienced cities which have been leading cycling measures and policies implementation. Nevertheless, many other cities, the so-called starter cycling cities (PRESTO, 2010) are still struggling to find the right approach to increase their cycling levels. These are cities that present a residual share of cycling (below 10%), revealing a lack of cycling tradition.

Despite of the political narrative and even some symbolic policy actions in favour of a modal change towards cycling, the starter cycling cities often show some dominance of political, cultural and technical scepticism around change. Some of them have developed only limited measures towards cycling, such as, leisure-oriented cycling infrastructure or providing small scale bike-sharing systems. These Cultural and political barriers represent a challenge that needs urgent attention if a change is awaited.

With this scenario as background, this report explores the implementation of the concept of potential for cycling by developing an assessment method capable of categorizing and providing a spatial visualization of the potential for cycling in starter cycling cities according to a three-dimensional approach that considers Target-Population, Target-Areas and Political Commitment to Cycling. As such, the Potential for Cycling Assessment Method allows the identification of areas with cycling potential in the meantime it serves as a support to the development of policies.

This report presents the final version of the Potential for Cycling Assessment Method, and its application to 8 Portuguese municipalities, which were the case studies of these project: Barcelos; Braga; Cascais; Guimarães; Matosinhos; Oporto; Vila Nova de Famalicão and Vila Nova de Gaia and the application of the method to the city of Barcelona.

The report is structured as follows: Chapter 2 presents an overview of the literature reviewed to support the creation of the methodology. This review included factors that influence cycling use and similar methodologies to assess cycling potential. Chapter 3 presents a detailed description of the Method, which is divided in its three-dimensions: Target-Population, Target-Areas and Political Commitment to Cycling, culminating with the presentation of the Typology of Cities according to their cycling potential. In Chapter 4, we present a brief overview of the main geographic, demographic and modal patterns of each one of the case studies. This is then followed by Chapter 5, which displays the results of the assessment of each case study. Concluding the data analysis, the classification of the municipalities according to the developed Typology of Cities is presented, ranked according to their cycling potential.

2. Influence on Cycling Use

To assess the cycling potential of a city, it is necessary to identify the segments of the population with more propensity to cycle (the target-groups), as well as the target areas which due to their physical characteristics (built and natural environment) may facilitate cycling. Therefore, it is important to identify which factors influence the choice to use the bicycle as a mode of transport.

Previous research already provides interesting baseline information to identify these factors. According to that, four groups of factors are identified to play a key role on the choice of cycling: individual factors, which includes socioeconomic and attitudinal factors, social environment factors, as well as factors related to the physical environment (man-made and natural factors). Table 1 presents the main factors found to influence cycling in previous research, aggregated into 4 groups:

Table 1 - Factors Influencing Cycling

Individual Factors	Physical Environment: Built Environment Factors
Age	Cycling Infrastructure
Gender	Road and Traffic Conditions
Income	Land Use
Home Ownership	Presence of a University
Car Ownership	**Physical Environment: Natural Environment Factors**
Education Level	Slope
Students	Weather
Other Socioeconomic Factors	Seasons
Attitudes Towards Cycling	**Social Environment Factors**
Person's Confidence	

Some of these studies used aggregated data at the city level (Goldsmith SA. (1992); Dill & Carr (2003); Buehler & Pucher (2011); Mertens et al. (2017)), while others used disaggregated data (O. Plaut (2005); Transport for London (2010); Dill & McNeil (2013); Stinson & Bhat (2004); Handy & Xing (2011); Gatersleben & Appleton (2007); Parkin et al. (2007); Titze et al. (2010); Geus et al. (2007); Segadilha & Sanches (2014); Tilahun et al. (2007); Ma & Dill (2015); Heesch et al. (2015), at the individual level. Additionally, there were some articles that conducted literature review studies (Heinen et al. (2010) and Fraser & Lock (2010)).

2.1. Individual Factors

Several studies examined bicycle commuting focused on the individual factors. Within these, we have socio-economic factors (such as age, gender, income, home and car ownerships or education level) and attitudes towards cycling like having a positive image of cycling and the person's own confidence in using the bicycle.

Age is one of the most important factors frequent mentioned in the literature, which shows that cycling becomes less popular with age, especially regarding commuting. According to Transport for London (2010), the average cyclist in London ranges the ages between 25 and 44 years old. Moreover, Goldsmith (1992), when analysing the American census in major US cities, the age factor appeared to be the most significant demographic variable. The study shows that cycling seems to be more popular between people in their mid-twenties and it declines progressively, as by the age of 45, the reduction is significant (Goldsmith, 1992). In another American study by Plaut (2005), the ageing effect on cycling is noticed as well as only 10.5% of the bicycle commuters were older than 55 years old. Likewise, Dill & McNeil (2013) reassures what was found in previous studies, as they found an over representation of adults over 55 years old in the non-cycling groups.

Another factor commonly found in the literature is gender. Most of the authors found that women appear to cycle less than men. Dill & Carr (2003) found that 87% of bicycle commuters in the census data from 2000 in 43 cities across the United States were male. Furthermore, Gatersleben & Appleton (2007), Goldsmith SA. (1992), Stinson & Bhat (2004), O. Plaut (2005), Levinson et al. (2006); Transport for London (2010), Heinen et al. (2010); Handy & Xing (2011), Dill & McNeil (2013), all verified that male cyclists were more common than female. However, in countries with high cycling rates, such as the Netherlands and Denmark, women cycle as often as men (Heinen, Wee, & Maat, 2010; Pucher & Buehler, 2008). Pucher & Buehler (2008) argue the main reason for this fact is related to cycling being much safer in those countries than in the USA and the UK, with much lower fatality and injury rates for cyclists.

The relation between cycling and income is less clear. Dill & Carr (2003), Plaut (2005) and Litman et al. (2017) all found a positive association between bicycle commuting and lower incomes. However, Transport for London (2010) found that the average cyclist had above average incomes.

Both Plaut (2005) and Handy & Xing (2011) found a negative relation between homeownership and cycling to work. Handy & Xing (2011) justify this with the possibility of homeownership serving as an intermediary for life-cycle stage, combining the effects of age, income, and household size (which separately were not significant in their model). They also state another possibility related to the fact that renters could have more flexibility in choosing where to live, making it easier to choose shorter distances to work and therefore choosing the bicycle as a mode of transport(S. L. Handy & Xing, 2011).

Car-ownership (Stinson & Bhat, 2004; Plaut, 2005; Parkin, et al., 2007; Titze, et al., 2010) was also associated with lower cycling levels, while a positive relation between higher education levels and cycling seems to exist (Plaut, 2005; Geus, et al., 2008; Transport for London, 2010).

The identification of people as students appears to be a strong factor as well as a possible target population for promoting cycling (Goldsmith, 1992; Dill & McNeil, 2013). Higher levels of cycling were found in statistical data from 1990 U.S. census, examined by Baltes (1996), this presence was especially found in metropolitan areas where universities are located. Dill & Carr (2003) confirm those findings as their study found that 21% of the bicycling commuters were students, compared with only 11% of all commuters. Finally, Gatersleben & Appleton (2007) hypothesizes that lower car ownership rates increases the potential of students to have positive attitudes towards cycling.

Besides that, having positive attitudes towards cycling increases the odds of start cycling (Gatersleben & Appleton, 2007; Geus, Bourdeaudhuij, Jannes, & Meeusen, 2008; S. L. Handy & Xing, 2011; Heinen et al., 2010; Titze et al., 2010). Additionally, Geus et al. (2008) and Titze et al.

(2010), as well as Heine et al. (2010) and Garcia et al. (2015), all stated that people with a high level of confidence in their own ability to achieve intended results (self-efficacy or perceived behavioural control) were more likely to cycle.

Table 2 presents a summary of the main findings of each article related to the impact of the Individual factors on the bicycle commuting levels. If the impact was negative (i.e., decreases cycling) is represented by "– ", if the article found no impact or mixed impacts is represented by "0", finally if the article found a positive impact (i.e., increases cycling) is represented by a "+".

Table 2 - Main findings from the literature about the Individual factors influence on bicycle commuting (classification based on (Handy & Xing, 2011)).

Category	Definition	Impact on bicycle commuting	References
Socio-economic factors	Age	– 0 – 0 – 0 – –	(Goldsmith, 1992); (Stinson & Bhat, 2004); (Plaut, 2005); (Heinen et al., 2010); (Transport for London, 2010); (S. L. Handy & Xing, 2011); (Dill & McNeil, 2013); (Litman et al., 2017).
	Female	– – – – – – – – – – –	Goldsmith SA. (1992); Dill & Carr (2003); Stinson & Bhat (2004); Plaut (2005); Levinson et al. (2006); Gatersleben & Appleton (2007); Parkin et al. (2007); Heinen et al. (2010); Transport for London (2010); Handy & Xing (2011); Dill & McNeil (2013)
	Income	0 – 0 – + 0 + 0 0 –	Goldsmith SA. (1992); Dill & Carr (2003); Stinson & Bhat (2004); Plaut (2005); Parkin et al. (2007); Heinen et al. (2010); Transport for London (2010); Handy & Xing (2011); Dill & McNeil (2013); Litman et al. (2017)
	Home ownership	– –	Plaut (2005); Handy & Xing (2011);
	Car ownership	– – – – – – –	Stinson & Bhat (2004); Plaut (2005); Parkin et al. (2007); Heinen et al. (2010); Titze et al. (2010);(Buehler & Pucher, 2011); Litman et al. (2017)
	Education Level	+ + + 0 0	Plaut (2005); Transport for London (2010); Geus et al. (2008); Handy & Xing (2011); Dill & McNeil (2013)
	Students	+ + + +	Baltes (1996); Dill & Carr (2003); Gatersleben & Appleton (2007); Garcia et al. (2015)
	Higher professional	–	Parkin et al. (2007)
	Cycled to school as a child	+	Dill & McNeil (2013)

	Being physical active	+	Heinen, et al. (2010)
	Cycling for non-work trips	+	Stinson & Bhat (2004)
Attitudinal factors	Positive image of cycling	+ + +	Geus et al. (2008); Titze et al. (2010); Handy & Xing (2011)
	Person's confidence	+ +	Geus et al. (2008); Titze et al. (2010); Garcia et al. (2015)

2.2. Physical Environment: Built Environment Factors

Several studies have identified a great number of factors related to the physical environment, specifically man-made that influence the levels of cycling. We will divide those factors between cycling infrastructure (bicycle lanes or paths, bicycle facilities close to the workplace, etc.), other types of transport infrastructures (traffic calming/slowing devices, types of streets and intersection signalization), safety (traffic conditions, perceived lack of safety), land use patterns (density, mixture of functions, connectivity to activities, distance to workplace) and presence of a university/college.

A positive correlation between the presence of bicycle infrastructure and bicycle commuting was found in many studies (Dill & Carr, 2003; Stinson & Bhat, 2004; Tilahun, et al., 2007; Buehler & Pucher, 2011; Handy & Xing, 2011; Dill & McNeil, 2013; Segadilha & Sanches, 2014; Heesch, et al., 2015; Ma & Dill, 2015; Mertens, et al., 2017). According to Goldsmith (1992) some US cities with higher levels of bicycle commuting offered around 70% more bike lanes and/or paths per roadway mile and six times more bike lanes per arterial mile. Likewise, Dill & Carr (2003) verified that higher levels of bicycle infrastructure meet higher rates of bicycle commuting. Dill (2009), by breaking down GPS data on bicycling behaviour from 166 regular cyclists in Portland (USA), discovered that a small cycling route of only 8% of the total network was responsible for 52% of travel by commuting cyclists. Handy et al. (2014), who assessed the cycling research needs and challenges, found several studies positively associating the availability of bicycle infrastructure with cycling for transport. Although the presence of cycling infrastructure is considered to be important to influence cycling, the connectivity of the network seems to be crucial for cyclists, especially regarding more inexperienced cyclists (Segadilha & Sanches, 2014; Heesch, et al., 2015; Mertens, et al., 2016).

Besides the cycling infrastructure and its connectivity, the impact of traffic, specifically low-traffic and low speed roads also appears to have a major impact on levels of cycling (Parkin, et al., 2007; Dill & McNeil, 2013; Segadilha & Sanches, 2014; Ma & Dill, 2015; Mertens, et al., 2016). For instance, Pucher & Buehler (2008) identified traffic calming measures in residential neighbourhoods to be crucial to cycling. In relation to roads with speed limits below 30 km/h, Mertens et al. (2017) found it to be positively associated with more cycling transport.

Moreover, a negative connection between a greater trip distance and cycling shares stands out in the literature available, as it increases the trip's time and effort (Goldsmith, 1992; Stinson & Bhat, 2004; Parkin, et al., 2007; Handy & Xing, 2011; Broach, et al., 2012; Segadilha & Sanches, 2014; Sousa, et al., 2014; Heesch, et al., 2015). This factor is reinforced by findings related to the urban density, where studies demonstrate that denser urban areas and mixed-use development increases cycling levels as it shortens the distances that cyclists have to ride (Baltes, 1996; Stinson & Bhat, 2004; Parkin, et al., 2007; Heesch, et al., 2015; Ma & Dill, 2015).

Table 3 presents a summary of the main findings of each article related to the impact of the Built Environment factors on the bicycle commuting levels. If the impact was negative (i.e., decreases cycling) is represented by "– ", if the article found no impact or mixed impacts is represented by "0", finally if the article found a positive impact (i.e., increases cycling) is represented by a "+".

Table 3 - Main findings from the literature about the Built Environment factors influence on bicycle commuting [classification based on (Handy & Xing, 2011)].

Category	Definition	Impact on bicycle commuting	References
Cycling Infrastructure	Lack of cycling infrastructure	– –	Sousa et al. (2014)
	Bicycle lanes (on-road)	+ + + + + + +	Goldsmith SA. (1992); Dill & Carr (2003); Dill (2009); Buehler & Pucher (2011); Handy et al. (2014); Segadilha & Sanches (2014); Ma & Dill (2015); Mertens et al. (2017); Litman et al. (2017)
	Bicycle paths (segregated or off-road)	+ + + + + + + + + + + + + + +	Goldsmith SA. (1992); Dill & Carr (2003); Rodríguez & Joo (2004); Tilahun et al. (2007); Pucher & Buehler (2008); Dill (2009); Fraser & Lock (2010); Heinen et al. (2010); Titze et al. (2010); Buehler & Pucher (2011); Broach et al. (2012); Dill & McNeil (2013); Handy et al. (2014); Segadilha & Sanches (2014); Heesch et al. (2015); Ma & Dill (2015); Litman et al. (2017)
	Bicycle boulevards	+	Broach et al. (2012)
	Bicycle paths along heavily traffic roads and intersections	+	Pucher & Buehler (2008)
	Continuity of the cycling infrastructure	+ + + +	Heinen et al. (2010); Segadilha & Sanches (2014); Heesch et al. (2015); Mertens et al. (2016)
	Bicycle facilities (racks, showers, etc.) close to the workplace	+ + + 0	Goldsmith SA. (1992); Stinson & Bhat (2004); Heinen et al. (2010); Handy & Xing (2011); Handy et al. (2014)
Road and Traffic Conditions	Traffic calming	+ + +	Pucher & Buehler (2008); Titze et al. (2010); Ma & Dill (2015)
	Parallel parking (for cars)	–	Segadilha & Sanches (2014)
	Intersections	– – –	Heinen et al. (2010); Broach et al.

	signalization		(2012); Segadilha & Sanches (2014)
	Number of traffic lanes	–	Segadilha & Sanches (2014)
	Dangerous traffic conditions (high volume of traffic and high speeds)	– – – – – – – – – –	Parkin et al. (2007); Heinen et al. (2010); Fraser & Lock (2010); Broach et al. (2012); Dill & McNeil (2013); Segadilha & Sanches (2014); Ma & Dill (2015); Mertens et al. (2016); Mertens et al. (2017); Litman et al. (2017)
	Presence of roundabouts	–	Segadilha & Sanches (2014)
	Pavement quality	+ +	Parkin et al. (2007); Segadilha & Sanches (2014)
Land Use Pattern	Urban/Population density	0 + + + + + + +	Goldsmith SA. (1992); Baltes (1996); Stinson & Bhat (2004); Parkin et al. (2007); Fraser and Lock (2010); Heinen et al. (2010); Heesch et al. (2015); Litman et al. (2017)
	Living in a Urban Area	+ +	Stinson & Bhat (2004); Transport for London (2010);
	Mixture of functions	+ + +	Heinen et al. (2010); Ma & Dill (2015); Litman et al. (2017)
	Attractive neighbourhoods	+	Titze et al. (2010)
	Distance to work place	– – – – – – – – – –	Goldsmith SA. (1992); Stinson & Bhat (2004); Parkin et al. (2007); Heinen et al. (2010); Fraser & Lock (2010); Handy & Xing (2011); Handy et al. (2014); Segadilha & Sanches (2014); Sousa et al. (2014); Heesch et al. (2015); Litman et al. (2017)
	Living and working in an urban area	+	Stinson & Bhat (2004)
	Living and working in the city centre	+ +	Heinen et al. (2010); Transport for London (2010)
Presence of a university in the city		+ + +	Goldsmith SA. (1992); Baltes (1996); Litman et al. (2017)

2.3. Physical Environment: Natural Environment Factors

Regarding the natural factors, the most influencing factor is the absence of slopes (Goldsmith, 1992; Rodríguez & Joo, 2004; Parkin, et al., 2007; Sousa, et al., 2014), with Broach, et al. (2012) founding that cyclists would rather travel longer distances than to choose routes with slopes above 2%. Goldsmith (1992) justifies this negative impact with the additional physical effort needed for climbing hills, which would decrease the propensity for bicycle commuting.

Category	Definition	Impact on bicycle commuting	References
Topography	Slope	−−−−−−−−−−	Goldsmith SA. (1992); Rodríguez & Joo (2004); Parkin et al. (2007); Heinen et al. (2010); Fraser & Lock (2010; Broach et al. (2012); Segadilha & Sanches (2014); Sousa et al. (2014)
Climate & Weather	Mild temperature	+ + +	Baltes (1996); Parkin et al. (2007); Heinen et al. (2010)
	Rain	−−−−	Goldsmith SA. (1992); Parkin et al. (2007); Heinen et al. (2010); Sousa et al. (2014)
	Summer	+ +	Stinson & Bhat (2004); Heinen et al. (2010)
	Darkness	−	Heinen et al. (2010)

2.4. Social Environment Factors

There is some evidence about the impact of the social environment on cycling. According to Handy & Xing (2011) a negative social environment may influence bicycle commuting more than a pro-bicycling environment. In the Heinen et al. (2010) literature review employers' financial support as well as the existence of co-workers cycling were positively associated with bicycle commuting. According to Handy et al. (2014), if cycling is seen in the community as a normal way to travel, residents will be more inclined to cycle, further reinforcing the community norm. Additionally, in the analysis conducted by Geus et al. (2008), participants who had relatives who gave supported and cycled with them were more likely to cycle for transport. Finally, the impact of community attitudes on cycling was also mention by Litman et al. (2017) who argues about the importance of cycling being perceived as socially acceptable in a person's choice to start using the bicycle. Table 4 presents a summary of the literature review main findings related to the Social Environment factors impact on the bicycle commuting levels.

Table 4 - Main findings from the literature about the Social Environment factors influence on bicycle commuting (classification based on (Handy & Xing, 2011)).

Definition	Impact on bicycle commuting	References
Negative social environment of the workplace	−	Handy & Xing (2011)
Relatives support	+	Geus et al. (2008)
Community's social support	+ + +	Heinen et al. (2010); Handy et al. (2014); Litman et al. (2017)

2.5. Comprehensive assessment methods

Most of the supporting tools specific for cycling, focus on cycling infrastructure design such as models to assess overall quality and usability of streets for cycling use. It considers the geometrics of the roadway segments and intersections, pavement conditions, traffic speeds and volumes, among others. These models usually produce an index that can be compared with a rating scale to assess the specific roadway segment or intersection regarding its compatibility to cycling. Examples of these models are the Bicycle Safety Index Rating (BSIR) (Davis, 1987) or the Bicycle Level-of-Service (BLOS)(*Highway Capacity Manual*, 2010).

Regarding the cities' cycling environment, there is a scarce number of tools. One of the most established tools is the Copenhagenize Index. This index ranks the city's 'bicycle friendliness' in 14 different categories ideally for cities with an mature cycling culture: bicycle culture; advocacy; bicycle infrastructure; bicycle facilities; traffic calming; urban planning; bike share programs; gender split; modal share for bicycles; modal share increase since 2006; perception of safety; politics; social acceptance; cargo bikes and logistics ("The Criteria For The Copenhagenize Index," 2017).

Another example can be seen in the study of Zayed (2017), who developed the Index of City Readiness for Cycling and applied it to Egyptian cities. The author analysed the primary features of the top 20 cities of the Copenhagenize Index, identifying city population, city area, city form, road network length and motorized transport modal split as the fundamentals of cycling commuting.

A different number of tools focus on current and future cycling demand. For instance, the Analysis of Cycling Potential (ACP) by Transport for London (2010), identify trips currently made by motor vehicles that could be shifted to the bicycle. The study is based on mobility surveys of commuters' in London considering data such as trip distance, time of day and commuter's characteristics like age and profession. This tool enables the production of heat maps of cycling potential across London, estimating potential cycling trips (Transport for London, 2010; Lovelace, et al., 2017). In addition to that, there is the propensity to Cycle Tool (PCT). This tool is a travel forecast model that combines origin-destination (OD) data from the England's 2011 Census with route distance and hilliness to represent cycling potential (Lovelace et al., 2017).

Overall, there are quite interesting studies on cycling potential tools. However, most of them present shortcomings in the context of starter cycling cities. Some of them require a large amount of data on the street level, like the BLOS and the BSIR. Others were designed only for the macro level, as the Copenhagenize Index and the Index of City Readiness for Cycling, limiting its application to cities where cycling is at its minimum. Those which can be applied into an aggregated and disaggregated analysis, like the ACP and the PCT, are strongly based on OD data, that in the context of starter cycling city may not be available, limiting both the quality of the results and the tools' deployment to other regions.

Although research on cycling assessment methods has been increasing, its application is still limited, particularly regarding starter cycling cities. Therefore, there is a need for instruments able to assist planner practitioners identifying cycling strategies in this context, which this research tries to answer.

3. THE POTENTIAL FOR CYCLING ASSESSMENT METHOD

Based on the literature's main findings presented above, we developed a method to assess the potential for cycling specific for the context of starter cycling cities, by employing a three-dimensional approach (Figure 1):

- Target-Population – the spatial identification and quantification of the population segments with higher propensity to cycling;
- Target-Areas – the spatial identification and quantification of the areas providing suitable physical and build environment conditions for cycling;
- Political Commitment to Cycling – the evaluation of local policies on cycling regarding their capability of inducing a modal shift to cycling.

Figure 1 presents the indicators considered to assess each dimension, as well as the different weights used in the aggregated maps according to its influence in cycling.

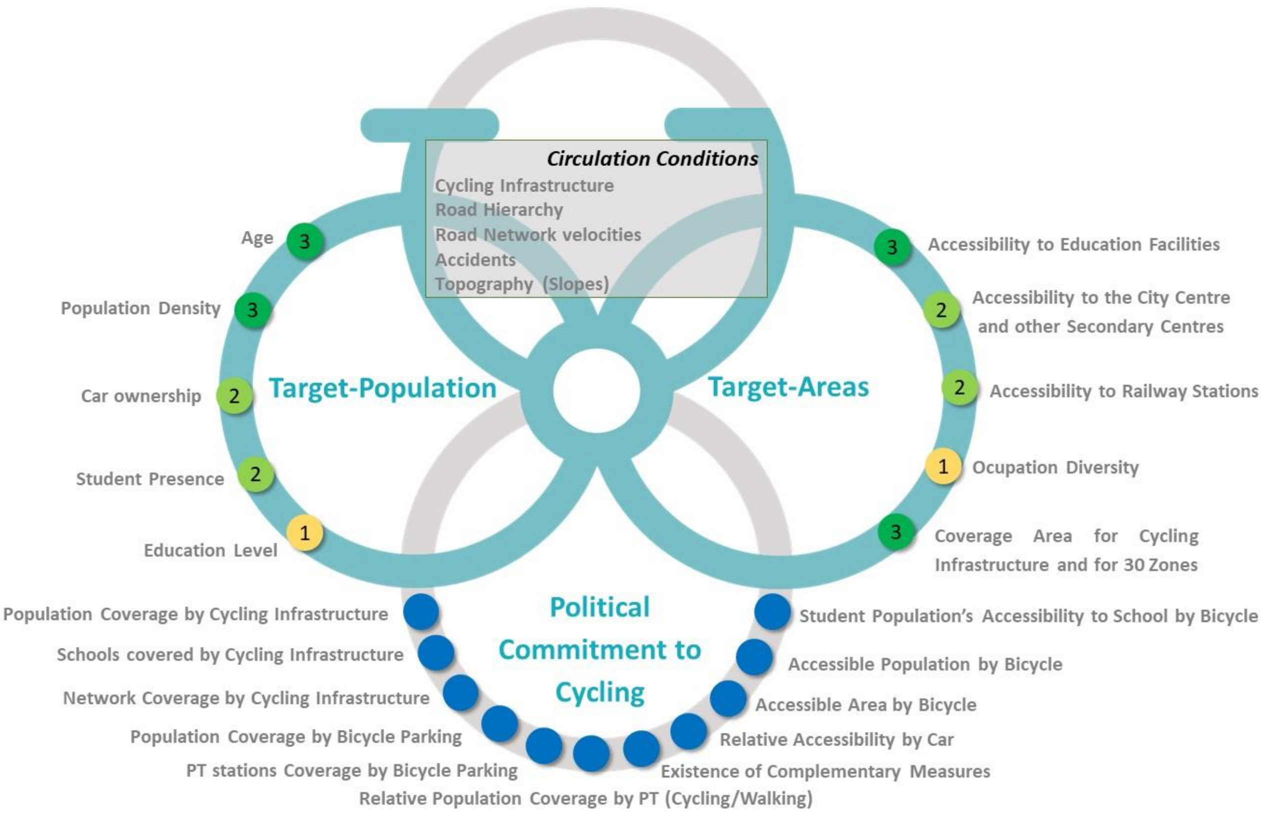


Figure 1 – The Potential for Cycling Assessment Method.

A scoring system from 1 (lowest potential) to 5 (highest potential) is used for each indicator. A detailed map revealing the scores of each indicator is produced for target population and areas, providing spatial differentiation of cycling conditions of the study area, disaggregated at the census track level (smallest statistical unit). An average score for the whole study area accompanies each map. The individual maps are combine into an aggregated map for target population and target areas, as well as an aggregated score for the whole study area (using the weights presented in Figure 1). Furthermore, the Target-Population and Target-Areas dimensions can be combined into a final map, the aggregated map, allowing the overlap of the city zones where the population has a high propensity to cycle and the areas that facilitate cycling. Regarding the Political Commitment to Cycling, no spatial analysis is produced. Aggregate indicators are used to gauge the level of commitment of policy measure to providing the necessary conditions for cycling to take place.

Lastly, a classification of the cities based on the aggregated scores by each dimension is created according to the following nomenclature: A - High (with an aggregate score of 3.7 – 5), B - Moderate (with an aggregate score of 2.3 – 3.6) and C - Low (with an aggregate score < 2.3). This, thus, enables the development of a city typology.

Each one of the dimensions, as well as the city typology development, are presented in detail in the next subchapters.

The data for this analysis was collected using the Portuguese Census of 2011, databases like OpenStreetMap and other geographical information provided by the municipalities involved.

3.1. Target-Population (TP)

The first group of indicators assess the cycling potential of the city's population identifying the locations of the population segments with more propensity to cycle. The 5 socioeconomic factors considered are:

- Age;
- Population and employment density;
- Car ownership;
- Student presence;
- Educational level.

Age is one of the factors that has the highest influence on cycling levels, as well as Population density, according to the literature. Therefore, they have the highest weight in this assessment. Employment density is also added to the Population density when data is available. Car ownership indicator follows the literature evidence that higher car ownership levels are negatively correlated with cycling. This factor is assessed by the relation of the number of cars per 1000 inhabitants and the average of car ownership of the country. Moreover, there are indications that students have a higher propensity to cycle, therefore the presence of students is taken into account in this indicator. Only students from the third level of primary education to the higher education are relevant for this analysis, as it corresponds to the age interval of people more likely to cycle. Lastly, some authors in the literature review connect higher education level, with higher cycling level. This indicator final potential per census track is given after a combination of attributes values for each of the four levels of education considered here (Without education – Basic – Secondary – and Higher education).

Some indicators are calculated comparing the census track values to the average of that interval to the city (age and student presence), while others consider a standard deviation for a group of cities that share boundaries (population and employment density and education level), see Table

6 for groups definition. Each census track is classified into a score from 1 (lowest potential) to 5 (highest potential) in accordance to the criteria defined in Table 5 below.

Table 5 - Scoring criteria for Target Population Indicators.

Indicator	Score / Weight	5	4	3	2	1
Age	3	Age 15-29 >A	Age 10-14 & 30-39>A	Age 40-44>A	Age 45-49>A	Age <10&>50>A
Population density	3	PD > σ	σ> PD > $\frac{1}{2}$ σ	$\frac{1}{2}$ σ > PD > - $\frac{1}{2}$ σ	- $\frac{1}{2}$ σ> PD > - σ	PD > - σ
Car ownership	2	CO < 124	125< CO <240	250< CO <490	500< CO <750	CO >750
Student Population	2	% SP > 2σ	2σ > % SP > σ	σ > % SP > - σ	- σ > % SP > - 2σ	% SP > - 2σ
Level of education	1	High School >A	Secondary >A		Basic >A	No Education >A
*A	City's Average for the Interval					
* σ	Standard Deviation					

Table 6 – Method distribution according to city's influence.

Cities per group		Method
1	**Barcelos**	Standard deviation (σ) of the 4 cities
	Braga	
	Guimarães	
	VN Famalicão	
2	**Matosinhos**	Standard deviation (σ) of the 3 cities
	Oporto	
	VN de Gaia	
3	**Cascais**	Standard deviation (σ)

3.2. Circulation Conditions

3.2.1. Cycling

Circulation conditions were taken into consideration when computing cycling target areas. These conditions were not taken as analysis results but instead, are used as input data to compute information on accessibility and coverage. For this, we have converted all cycling conditions considered into cycling speed, namely:

- The existence of Cycling Infrastructure;
- Road Hierarchy;
- Road Network speed;
- Accidents;
- City's topography through assessing the road's slopes.

Table 7 represents the average urban cycling speed found in the literature, ranging from 10 km/h (Menghini, Carrasco, Schüssler, & Axhausen, 2010) to 20 km/h (European Commission, 1999; Jensen, et al., 2010).

Table 7 – Literature evidence on average cycling speed.

References	Cycling Speed (km/h)
Broach, et al. (2012)	Commute trips: 19 km/h
	Non-commute trips: 16.1 km/h
Campbell, et al. (2016)	9.1 km/h
European Commission (1999)	20 km/h
IMT (2011)	Between 10 km/h and 12 km/h
Jensen, et al. (2010)	Average users: 13.5 km/h
	Shorter distances: 15 km/h
	Experience cyclists: 20 km/h
Menghini, et al. (2010)	10.1 km/h
Rutter, et al. (2008)	14 km/h
Average Speed	14 km/h

The basis for determining the cycling speed is the city's topography through considering the roads' average slopes, as steeper slopes are associated with lower levels of cycling due to the additional physical effort required. Therefore, the cycling speed considers the average streets' slopes based on the IMT (2011) classification. Table 8 presents the functions used to calculate the cycling speed and the slope range where the function is valid.

Table 8 – Functions defining the cycling speed (y) according to the streets' slope (x).

Function	Slope
Constant	< 3%
$y = -x + \text{const}$	3 - 6%
$y = -0.25x^2 + 2.53x + \text{Const}$	6 - 11%
$y = 5e^{-0.035x}$	> 11%

In addition to the slopes, the cycling speed is influenced by three other factors. Firstly, the existence of cycling infrastructure, specifically cycling lanes and paths or 30 km/h Zones, which will positively increase the cycling speed as cyclists are, overall, more comfortable and safer in these types of roads.

Secondly, the road hierarchy also influences cycling speed because it acts as a proxy for traffic speeds and volumes. As such, the roads at the top of the hierarchy will be a more hostile environment for cyclists due to high traffic speeds and volumes, therefore hindering their capability to cycle. In this sense, arterial[1] and collector[2] roads will have lower cycling speed than local roads[3] (like tertiary or residential streets). Motorways[4] are excluded from the analysis as cycling is not allowed for these roads. Finally, the number of traffic related accidents compared to the city's average will also affects negatively the cycling speed, acting as a proxy for safety.

Table 9 presents the cycling speed range used in our Method considering slopes, cycling infrastructure, road hierarchy and accidents.

Table 9 – Cycling speed in the road network considering slopes, cycling infrastructure, road hierarchy and accidents.

Factors	Slope	Speed (km/h)	Accidents
Cycling Infrastructure	<3%	16	
	3-6%	13-16	
	6-11%	5-13	
Arterial & Collector Roads	<3%	12	-1 km/h
	3-6%	9-12	
	6-11%	5-9	
Local Roads	<3%	14	-2 km/h
	3-6%	11-14	
	6-11%	5-11	
Walking Speed	>11%	< 5 (walking speed)	

3.2.2. Walking

Some indicators in the PCC dimension, besides considering cycling speed, also use walking speed. It is the case of the Population Coverage by Bicycle Parking, which is assessed by walking speeds, as the population served need to walk to the parking, and the Relative Coverage by PT, which compares the catchment areas of PT stations using cycling and walking as last mile modes.

In here, the walking speed was defined by the streets' slopes, similarly to cycling, based on Tobler (1993):

$$walking\ speed\ km/h = 5e^{-0.035\ slope}$$

3.2.3. Car

The Relative Accessibility (bicycle/car in 5 min) in the PCC dimension, in addition to the cycling speeds, also uses car speeds in the network in order to assess the competitiveness of bicycle versus the car. As such, the car speeds on the road network were defined according to the road hierarchy and the roads traffic congestion level[5] (Table 10).

Table 10 – Cycling speed in the road network considering the road hierarchy and congestion levels.

Road Hierarchy	Speed (without congestion)	Speed (with congestion)
Motorways	80 km/h	40 km/h
Arterial & Collector Roads	40 km/h	15 km/h
Other Road Types	40 km/h	20 km/h

[1] High-capacity urban road expected to carry large volumes of traffic
[2] Low-to-moderate-capacity road which serves to move traffic from local streets to arterial roads
[3] Roads with the lowest speed limit, carrying low volumes of traffic
[4] Designed for high-speed vehicular traffic
[5] The estimation of the usual car speed was done with *Google Maps* for each municipality and the traffic congestion level was assessed using the typical traffic levels on a working day during peak hours, with the support of *Google Traffic*.

3.3. Target-Areas (TA)

The second dimension of this Method is the assessment of the cycling potential of the city's urban areas, based on the built and natural environment factors identified in the literature review as positively associated with increases on cycling use.

As said before, most of these indicators are assessed based on the circulation conditions that will determine the accessibility measurements, which is the case of 4 of the 5 indicators:

- Accessibility to Education Facilities;
- Accessibility to the City Centre and other Secondary Centres;
- Accessibility to Railway Stations (metro and train stations);
- Coverage Area for Cycling Infrastructure and for 30 km/h Zones.

Additionally, the Occupation Diversity is also assessed. This indicator measures the diversity of activities, based on the CAE codes[6].

The accessibility to main urban centralities - to city centres, education institutions and public transport stations - was considered as those locations generate a large number of trips per day. Those are potential target areas for cycling, especially education institutions areas, as they concentrate one population group with high propensity for cycling. In addition to that, the accessibility to the city centres measures the city's compactness where, cycling levels are higher when cities are denser than cities with a sprawled development. The catchment areas (by cycling) of public transport stations, specifically train and metro, were also considered since the bicycle can be used to complement the public transport, which is crucial in Starter Cycling Cities. Lastly, cycling infrastructure and 30 km/h zones were also considered as they are extremely important factors to improve the cycling safety and the confidence of cyclists, particularly in starter cycling cities.

Each spatial unit is classified into a score from 1 (lowest potential) to 5 (highest potential) in accordance to the criteria defined on Table 11.

The occupation diversity assessment is different from the other indicators in this dimension and was based on the Diversity of Activity Index (Silva, 2008), which is used to measure the accessibility level by each transport mode and gauge the conditions given by the land use and transport system for mobility. The occupation diversity aims at measuring the diversity of activities available, acting as a proxy for mixed land-use, while the other indicators are all based on accessibility measures. Thus, it assesses the existence of up to 10 different types of activities based on the Portuguese Classification of Economic Activities (CAE). The activities included are: Basic education institutions; Secondary education institutions; Higher education institutions; Restaurants; Shopping (food); Shopping (others); Pharmacies; Clinics; Health centres; Hospitals.

[6] CAE – "Classificação Portuguesa de Atividades Económicas" (Portuguese Classification of Economic Activities).

Table 11 – Scoring criteria for Target Areas indicators.

Indicators	Score / Weight	5	4	3	2	1
Accessibility to Education Facilities	3	<5min B* <5min S* <10min U*	5-10 min B 5-10 min S 10-15 min U	10-15 min B 10-15 min S 15-20 min U	15-20 min B 15-25 min S 20-30 min U	>20 min B >25 min S >30 min U
Accessibility to the City Centre (CC) and Secondary Centres (SC)	2	0-10min CC* 0-5min SC*	10-15min CC 5-7.5min SC	15-20min CC 7.5-10min SC	20-30min CC 10-15min SC	>30min CC >15min SC
Accessibility to Railway Stations	2	0-2.5min	2.5-5min	5-7.5min	7.5-10min	>10min
Occupation Diversity	1	10 accessible activities	9-7 accessible activities	6-4 accessible activities	3-1 accessible activities	0 accessible activities
Coverage Area for Cycling Infrastructure and for 30 km/h Zones	3	0-2min	2-4min	4-6min	6-8min	>8min
*B	Basic Education Institutions (considering schools with the 2nd and 3rd cycles of education) [7]					
*S	Secondary Education Institutions					
*U	Higher Education Institutions					

3.4. Political Commitment to cycling (PCC)

The implementation of cycling policies that affect target areas, like cycling infrastructure, can only be fully assessed when their effectiveness is considered. These policies implemented by municipalities reveal their commitment level towards cycling by the amount of population, area and facilities covered. In that way, this dimension assesses the indirect and direct policies that promote cycling, using scales for its effectiveness, within 11 policy indicators:

- Network Coverage by Cycling Infrastructure;
- Schools covered by Cycling Infrastructure (8 min);
- Population Coverage by Cycling Infrastructure;
- Population Coverage by Bicycle Parking;
- PT stations Coverage by Bicycle Parking (5min);
- Relative Coverage by PT (Cycling/Walking);
- Accessible Student Population to School by Bicycle;
- Accessible Population by Bicycle (15 min);
- Accessible Area by Bicycle (15 min);
- Relative Accessibility (Bicycle/Car in 5 min);
- Existence of Complementary Measures.

[7] Schools with just the 1st cycle of education were not considered, due to the fact that in Starter Cycling Cities the level of cycling safety and familiarity is not enough for younger children to cycle to school safely on a daily basis.

All indicators can be represented on a map, with the exception of the Complementary Measures. The scores from 1 (lowest potential) to 5 (highest potential) are given in accordance to the criteria defined in Table 12.

Table 12 - Scoring criteria for Political Commitment to Cycling indicators.

Score Indicator	5	4	3	2	1
Network Coverage by Cycling Infrastructure	>80%	60-80%	40-60%	20-40%	<20%
Schools covered by Cycling Infrastructure (8 min)	>80%	60-80%	40-60%	20-40%	<20%
Population Coverage by Cycling Infrastructure	< 2 min	2 - 4 min	4 - 6 min	6 - 8 min	> 8 min
Population Coverage by Bicycle Parking	< 1min	1-2min	2-3min	3-5min	> 5min
PT stations Coverage by Bicycle Parking (5 min)	>80%	60-80%	40-60%	20-40%	<20%
Relative Coverage by PT (Cycling/Walking)	> 3	2.5-3	2-2.5	1.5-2	< 1.5
Accessible Student Population to School by Bicycle	<5min B* <5min S* <10min U*	5-10 min B 5-10 min S 10-15 min U	10-15 min B 10-15 min S 15-20 min U	15-20 min B 15-25 min S 20-30 min U	>20 min B >25 min S >30 min U
Accessible Population by Bicycle (15 min)	PopAcc > P_{80}	P_{80} > PopAcc > P_{60}	P_{60} > PopAcc > P_{40}	P_{40} > PopAcc > P_{20}	PopAcc < P_{20}
Accessible Area by Bicycle (15 min)	AreaAcc > P_{80}	P_{80} > AreaAcc > P_{60}	P_{60} > AreaAcc > P_{40}	P_{40} > AreaAcc > P_{20}	AreaAcc < P_{20}
Relative Accessibility (Bicycle/Car in 5 min)	>1,25 (AccCar<80%AccByc)	1-1,25 (ACar ϵ [80%AByc-100%AByc])	0,8-1 (AByc ϵ [80%ACar-100%ACar])	0,4-0,8 (AByc ϵ [40%ACar-80%ACar])	<0,4 (AByc > 40%ACar)
Existence of Complementary Measures	Several and some important	Several, at least one important	Few, at least one important	Few and of little importance	None
*B	Basic Education Institutions (considering schools with the 2nd and 3rd cycles of education) [8]				
*S	Secondary Education Institutions				
*U	Higher Education Institutions				

Network Coverage by Cycling Infrastructure takes into account the percentage of the city's road network that is served by cycling routes. Secondly, schools concentrate the most promising target population for cycling, which is the student community. To aid that transition, municipalities must have this fact in consideration when designing cycling infrastructure, by including schools in their area of coverage to allow commuting by bicycle. For that, the indicator of schools covered by cycling infrastructure considers the percentage of schools within 8min cycling travel time infrastructure.

Population Coverage by Cycling Infrastructure and Population Coverage by Bicycle Parking

[8] Schools with just the 1st cycle of education were not considered, due to the fact that in Starter Cycling Cities the level of cycling safety and familiarity is not enough for younger children to cycle to school safely on a daily basis.

emphasize the conditions for a safe transition for another travel mode or to a destination. The PT stations coverage is essential to the analyses of the potential for intermodality and for increasing bicycle and public transport competitiveness versus the car. Keeping the goal of intermodality in consideration, it is important to maintain the bicycle as a competitive and beneficial option, not only for longer distances but also for shorter distances. It is important to understand how cycling can improve accessibility levels of non-motorized modes in comparison to walking. Particularly when concerning the access to public transport cycling has the potential to significantly improve the coverage of this mode. Considering the accessible areas in 5 min by walking and by cycling from the railway stations, it is possible to measure the Relative Coverage by PT (Cycling/ Walking)

Returning to the strategy of focusing policies on the target-population, not only is vital to provide cycling infrastructure near schools to make it safer, but also to check if students can access their school under an acceptable time. For this purpose, the indicator Accessible Student Population to School by Bicycle is included. Moreover, a city's compactness and a high density of population improves its friendliness towards the bicycle, as it was mentioned in the chapter of the Target-Population. This density and urban friendliness can be further assessed by calculating the reachable population from each census track in 15 minutes within the Accessible Population by Bicycle (15 min) indicator. In the same way and serving as a comparative indicator to further evaluate compactness and density, the Accessible Area by Bicycle (15 min) indicator is included.

Starter Cycling Cities are usually car-dependent, with a high modal share in comparison to a residual use of the bicycle. To reverse this tendency, it is necessary to increase bicycle's competitiveness and, if possible, to decrease the car's advantage over it. The Relative Accessibility (Bicycle/Car in 5 min) indicator then assesses the reachable travel distance of both the bicycle and the car in 5 minutes.

Finally, The Existence of Complementary Measures indicator considers complementary measures that are not essential to support modal change towards bicycle. It considers the existence of promotional campaigns, school mobility plans, integration of the bicycle with the public transport, traffic calming initiatives and bike-sharing systems.

3.5. Typology of Cities

Table 13 presents a summary of the factors to be assessed in the 3 main groups and their classification regarding the potential for cycling, allowing the evaluation of the performance for each city.

Table 13 – Summary table of the factors evaluated in order to assess the target population, the target areas and the political commitment to cycling.

Target-Population		
Factors	1. Age	
	2. Population Density	
	3. Car Ownership	
	4. Students presence	
	5. Education Level	
Target Population Potential	High	3.7 – 5
	Moderate	2.3 – 3.6
	Low	< 2.3
Target-Areas		
Factors	1. Accessibility to Education Facilities	
	2. Accessibility to the City Centre and other Secondary Centres	
	3. Accessibility to Railway Stations	
	4. Occupation Diversity	
	5. Coverage Area for Cycling Infrastructure and for 30 Zones	
	6. Cycling Speed	
Target Areas Potential	High	3.7 – 5
	Moderate	2.3 – 3.6
	Low	< 2.3
Political Commitment for Cycling		
Factors	1. Population Coverage by Cycling Infrastructure (8min)	
	2. Schools covered by Cycling Infrastructure (8min)	
	3. Network Coverage by Cycling Infrastructure	
	4. Population Coverage by Bicycle Parking	
	5. PT stations Coverage by Bicycle Parking	
	6. Relative Coverage by PT (Cycling / Walking)	
	7. Accessible Student Population to School by bicycle	
	8. Accessible Population by Bicycle (15 min)	
	9. Accessible Area by Bicycle (15 min)	
	10. Relative Accessibility (Bicycle/ Car in 5 min)	
	11. Existence of Complementary Measures	
Policies and Measures Effectiveness	High	3.7 – 5
	Moderate	2.3 – 3.6
	Low	< 2.3
Aggregate Score		
Dimensions	**Target Population**	
	Target Area	
	Political Commitment to cycling	
Aggregate Score	High (A)	3.7 – 5
	Moderate (B)	2.3 – 3.6
	Low (C)	< 2.3

As such, by classifying the 3 dimension regarding the propensity for cycling as High - A (with an aggregate score of 3.7 – 5), Moderate - B (with an aggregate score of 2.3 – 3.6) and Low - C (with an aggregate score < 2.3), we can develop a city typology (Figure 2).

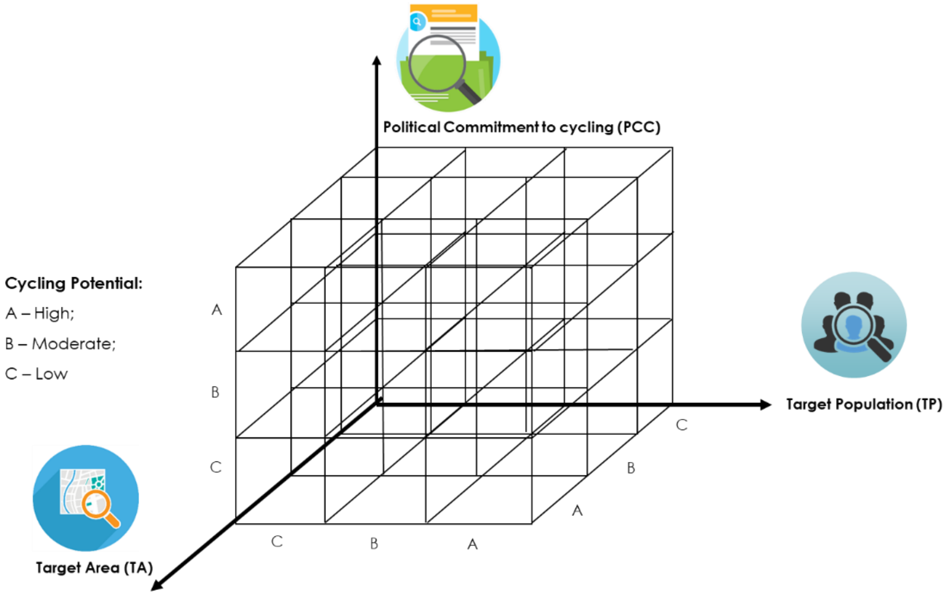


Figure 2 – Representation of the City Typology in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

The cube aggregates the score of each dimension used to classify areas regarding the propensity for cycling following the development of a city typology according to a three-code terminology based on conjugation of the 3 main groups of factors, from the best outcome (AAA) to the worst (CCC).

A Type AAA city will be the best possible scenario and will represent a city with high potential in 3 dimensions, meaning a population having a high propensity for cycling, with several target areas with high potential for cycling due to their physical characteristics, and with a comprehensive strategy involving various measures and policies to promote cycling.

In opposition (worst case scenario), there is Type CCC with its population presenting a low propensity to cycle, its physical characteristics being an impediment for cycling, and cycling promotion being inexistent and not a priority of the City Council. The remaining types of cities will present some variations of the 3 groups of factors.

4. CASE STUDIES

The referred methodology evaluates a representative number of Portuguese municipalities, ranging from some more compact and urban to the more sprawled municipalities with low density developments. Most of the selected cases present a considerably low cycling modal share and higher levels of motorization (Table 14). The selected municipalities can be classified as medium sized-cities and they also reveal a diversity of urban contexts. Municipalities located (Figure 3) close to the coastline (Matosinhos, Oporto, Vila Nova de Gaia and Cascais) happen to present a more compact development s. On the other hand, municipalities located in a transitional region between the east and west of the country (Barcelos, Braga, Guimarães and Vila Nova de Famalicão) show a more sprawled, low density urban development. The modal shares, reveal low shares of cycling (less than 0.5%), in contrast with the high levels of car use (above 50%) in all of the case-study municipalities (Table 14).

Table 14 below provides the urban population density of the cities under analysis, illustrating what was said previously.

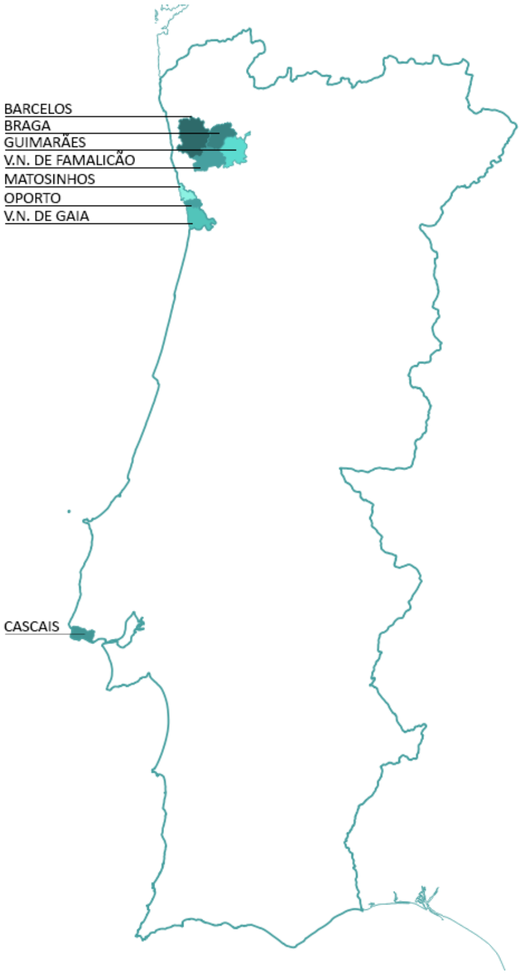


Figure 3 – Case Studies' location in Portugal

Table 14 – Case-Studies' Characteristics ("Censos 2011," 2011).

Case-study	Characteristics				Modal Share					Cycling Infra.
	Pop.	Total Area (km^2)	Urban Area (km^2)	Urban Pop. Density (inhab/ km^2)	Walking	Cycling	Public Transport	Private Motor Vehicle	Others	
Barcelos	120 391	378.9	124.2	967	15.8%	**0.4%**	18.9%	64.6%	0.3%	0 km
Braga	181 494	183.4	71.7	2 523	18.2%	**0.2%**	15.4%	66.1%	0.1%	11.6 km
Cascais	206 479	97.4	59	3 495	11.2%	**0.2%**	21.4%	67.1%	0.2%	16.4 km
Guimarães	158 124	241.0	61.8	2 492	18.2%	**0.1%**	18.2%	63.3%	0.2%	23 km
Matosinhos	175 478	62.4	39.3	4 466	16.1%	**0.4%**	21.4%	61.9%	0.3%	20 km
Oporto	237 591	41.4	39.8	5 973	21.6%	**0.2%**	26.1%	51.9%	0.2%	16 km
V.N Famalicão	133 832	201.6	97.8	1 367	14.9%	**0.3%**	15.2%	69.4%	0.2%	7.4 km
V.N Gaia	302 295	168.5	113.2	2 669	13.7%	**0.2%**	22.2%	63.7%	0.2%	17 km

The population density of the case studies cities represented in the Figure 4 to Figure 11 also illustrate what was said previously, adding value to the comparison of densities among the cities. Cities like Barcelos, Braga, Guimarães and Vila Nova de Famalicão have low population density, bigger municipalities areas plus main density around one centre and they contrast with cities that show higher population densities and more compact and polycentric urban development like Oporto, Matosinhos, Cascais and Vila Nova de Gaia. Important to say, as well, that the white areas on the map represent areas classified as non-urban, more visible in the municipalities with low population density. The figures below also provide a clear picture of the existing cycling infrastructure that is overall scarce and limited to a few parts of the territory. The extension of such infrastructure can be seen in the Table 14 above.

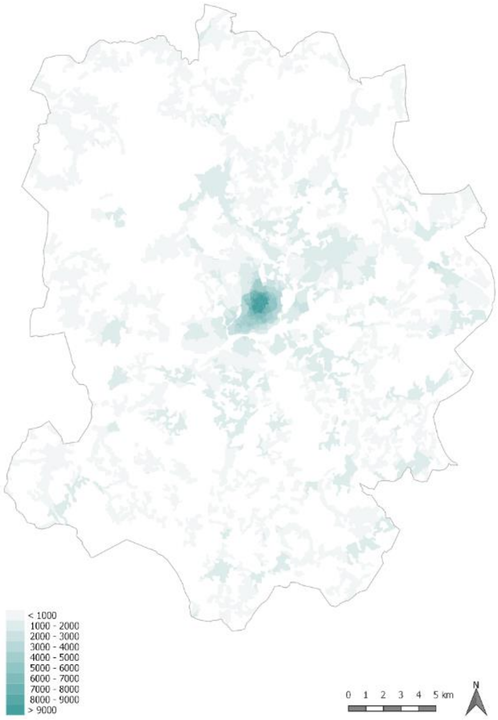


Figure 4 – Municipality of Barcelos: Population density (breaks of 1000 inhabitants/km2).

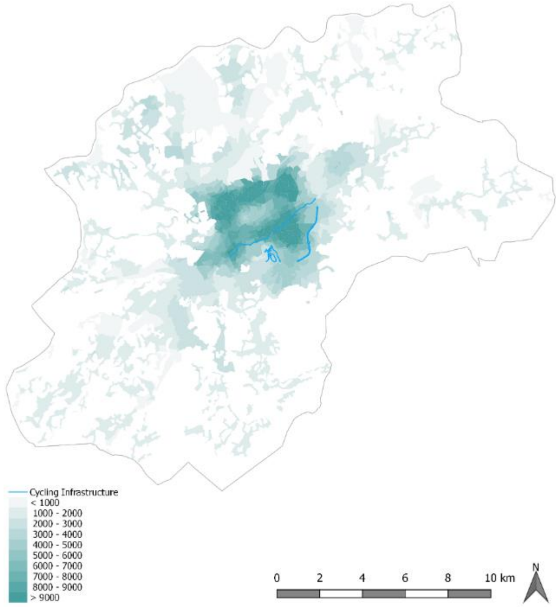


Figure 5 – Municipality of Braga: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

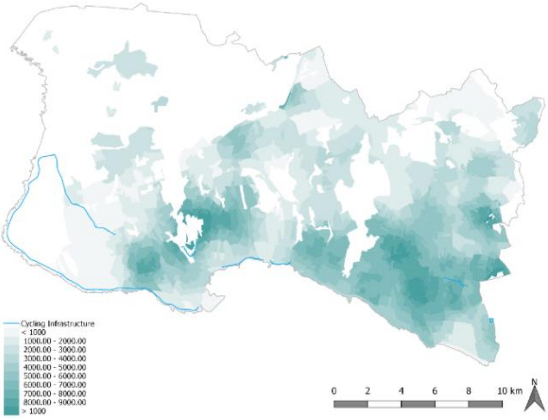


Figure 6 – Municipality of Cascais: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

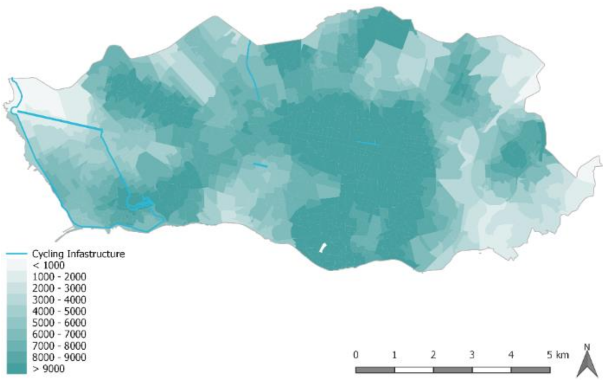


Figure 7 – Municipality of Oporto: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

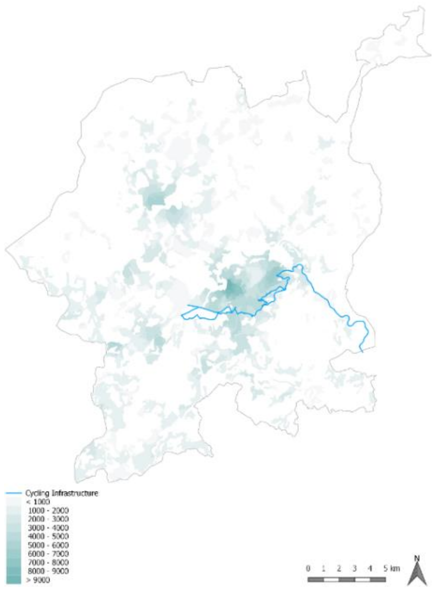


Figure 8 – Municipality of Guimarães: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

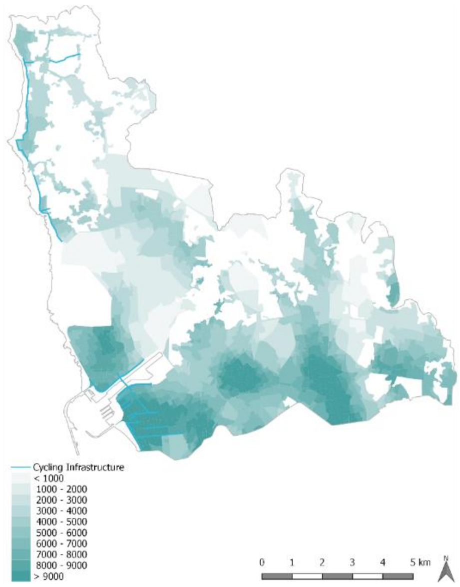


Figure 9 – Municipality of Matosinhos: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

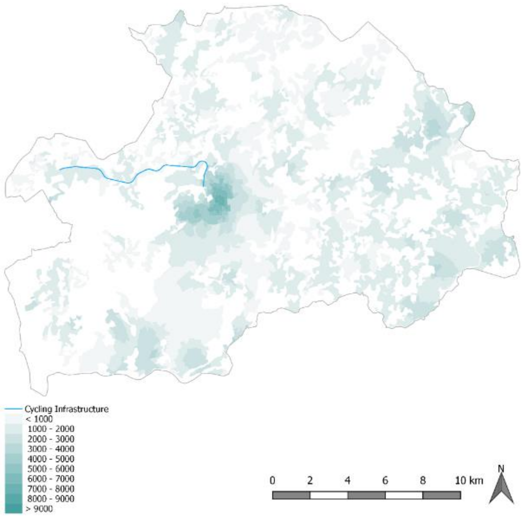


Figure 10 – Municipality of Vila Nova de Famalicão: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

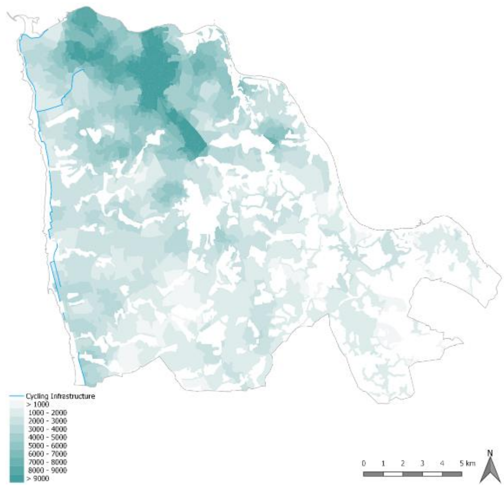


Figure 11 – Municipality of Vila Nova de Gaia: Cycling Infrastructure and population density (breaks of 1000 inhabitants/km2).

5. Results

5.1. Barcelos

5.1.1. Target Population

Figure 12 provides the spatial representation of the aggregate target population with higher propensity to cycle in Barcelos. The Population with potential to cycle is mainly concentrated in the central city (the larger area of light green that corresponds to 23.3% of the population - potential 4) and smaller scattered areas across the municipality such as in Silva, Galegos, Areias and Pousa. Indeed, Barcelos is a rural municipality with a typical mono-functional occupation characterized by low-density housing. As a result, the highest potential for cycling is concentrated in the centre, due to the predominance of population occupation.

The next figures, explore each one of the indicators applied to the municipality's cycling potential. The most significates indicators in the target population assessment are represented in Figure 13 and Figure 14. Although, there is high potential for cycling based on the average age of the municipality, there is a low potential regarding population densities. Figure 14 shows a high potential in the centre of the city, which is the zone with a great share of population with an age not so favourable towards cycling. Figure 12 provides the spatial representation of the aggregate target population with more potential for cycling in Barcelos.

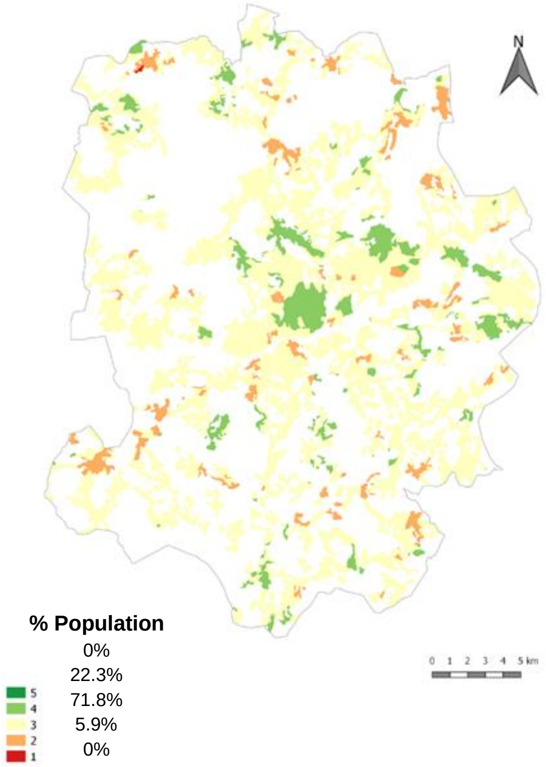


Figure 12 - Aggregated Cycling Potential of the Barcelos' Target Population, plus the population % covered by each potential.

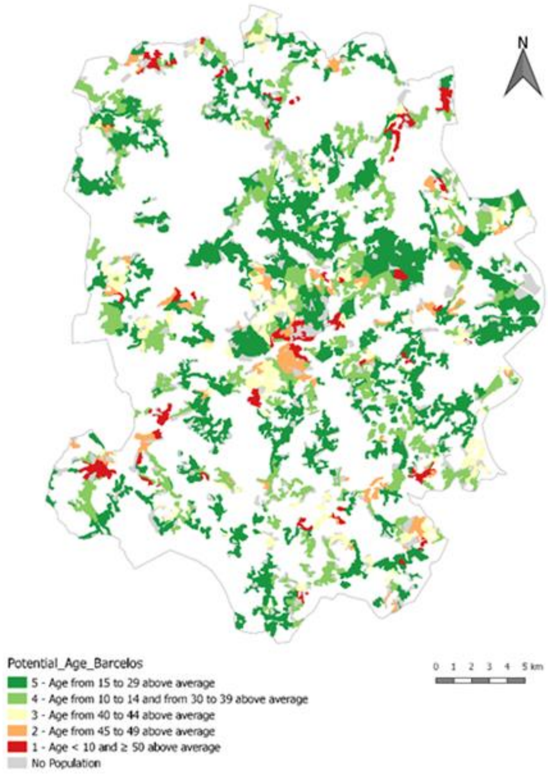


Figure 13 - Cycling Potential according to Age Concentration above Barcelos' Average.

The subsequent figures illustrate the municipality's Car Ownership rate (Figure 15), the percentage of Students among the population (Figure 16) and the Education Level (Figure 17). The Education Level and the students' presence in the resident population have their high potential in the central zone as well, which have a considerable weight in the aggregated result.

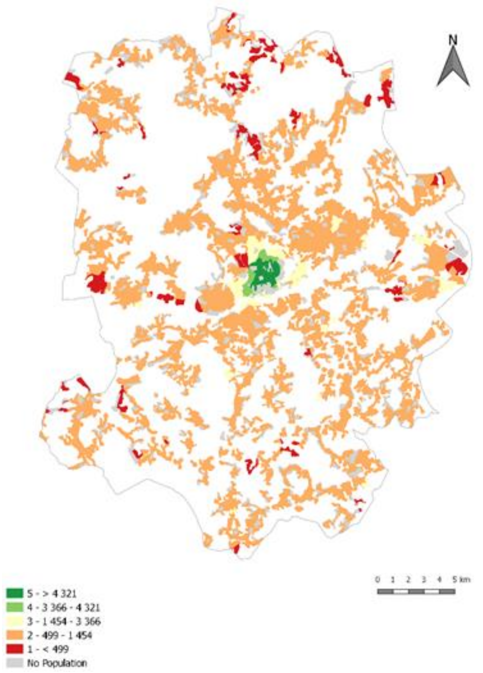


Figure 14 - Cycling Potential according to Barcelos' Population Density.

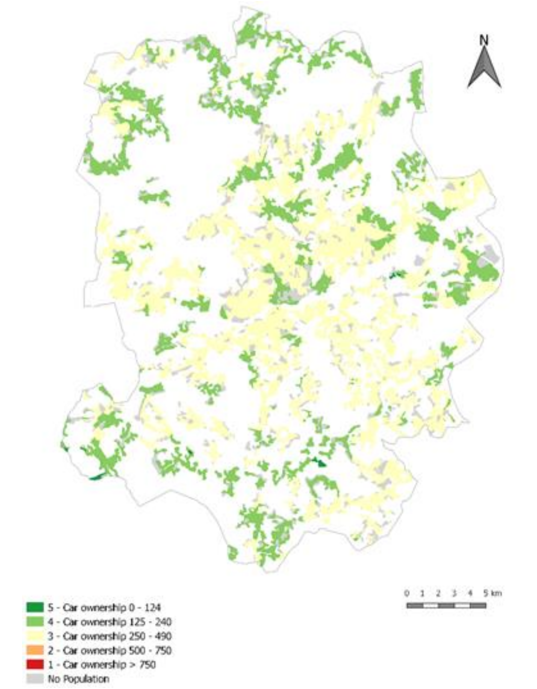


Figure 15 - Cycling Potential according to Barcelos' Car Ownership per 1000 inhabitants.

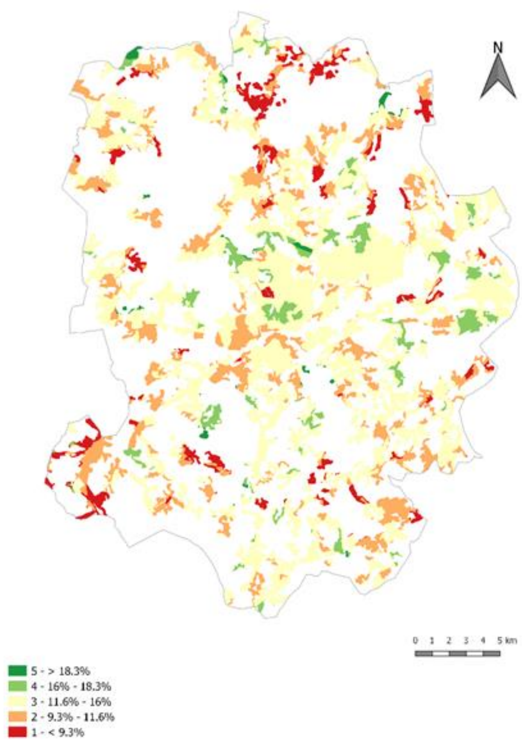


Figure 16 - Cycling Potential according to Barcelos' % of Students in the Resident Population.

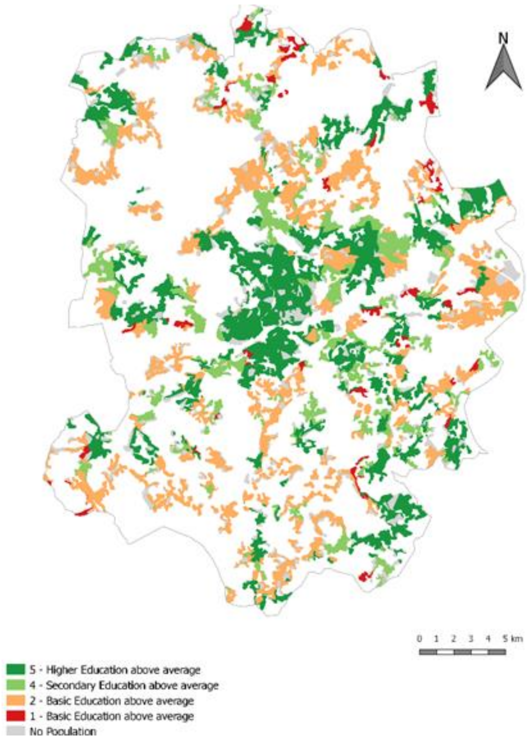


Figure 17 - Cycling Potential according to Barcelos' Education Level.

Table 15 reports firstly the aggregated potential of the municipality, followed by each one of the five indicators evaluated. Such numerical values ranges on a scale of 1 to 5. Based on the numerical output and map analysis, Barcelos has a Moderate Potential, among its population (3.2). Even though Barcelos has a substantial young population and high education level, the other indicators present lower scores, which affect the cycling potential of the city. In this case, the low potential of the Population Density has a negative impact due to its substantial weight on the final aggregated value.

Table 15 – Cycling Potential (1-5) of Barcelos' Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.2***
Age	4.1
Population Density	2.4
Car ownership	3.3
Students Presence	2.8
Education Level	3.7

5.1.2. Target Areas

The aggregated cycling potential, regarding the target areas (Figure 18) reveals a significant low potential (potential 1) of 56.4%, followed by potential 2 (26.1%). The highest potential represents just 0.2% of the territory. The next maps report in detail each one of the 4 indicators on the cycling potential of the city. They are defined as follow: Accessibility to Education Institutions (Figure 19), Accessibility to the City Centres (Figure 20), and Accessibility to the Railway Stations (Figure 21).

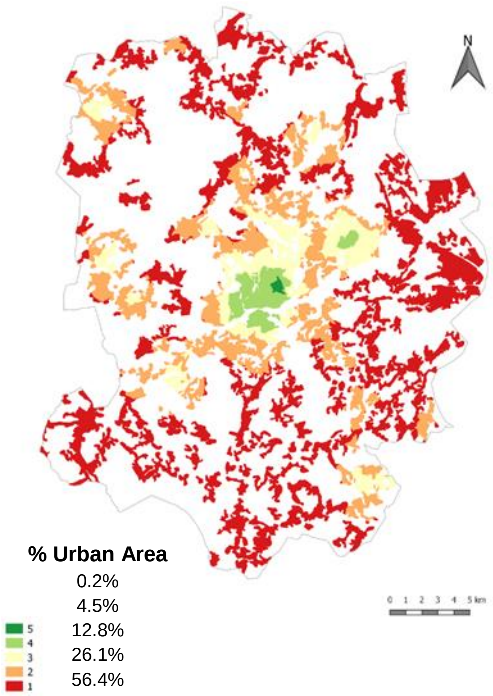


Figure 18 - Aggregated Cycling Potential of the Target-Areas of Barcelos, plus the respective urban area percentage covered by each potential.

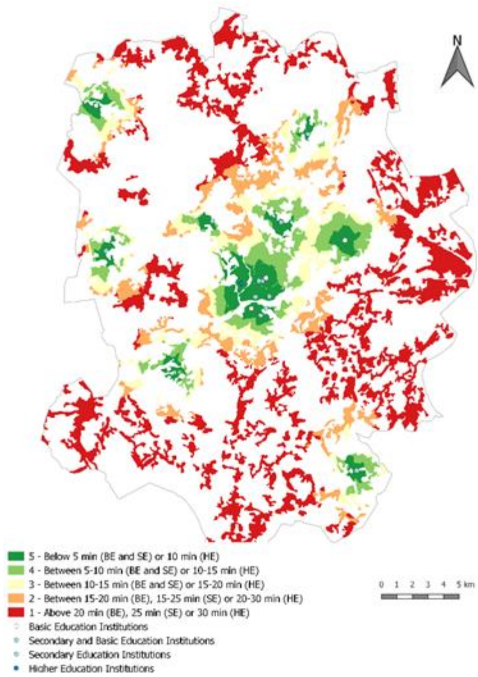


Figure 19 - Cycling Potential according to the Accessibility to Education Institutions of Barcelos.

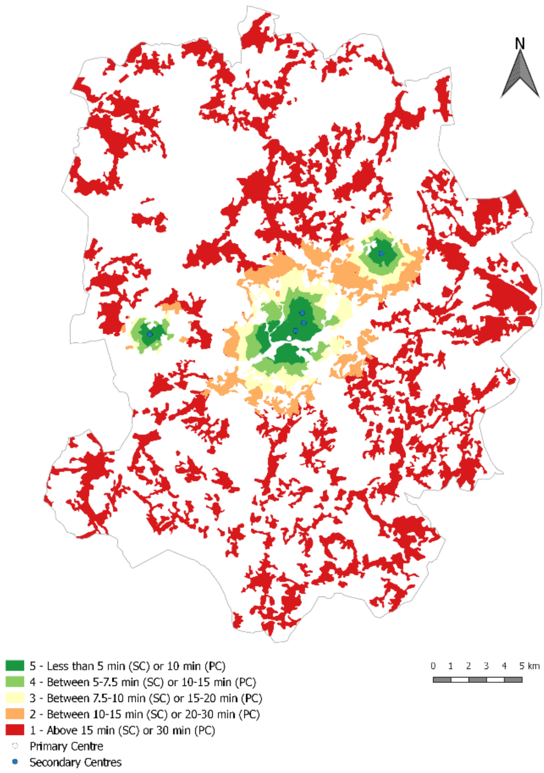


Figure 20 – Cycling Potential according to the Accessibility to City Centres of Barcelos.

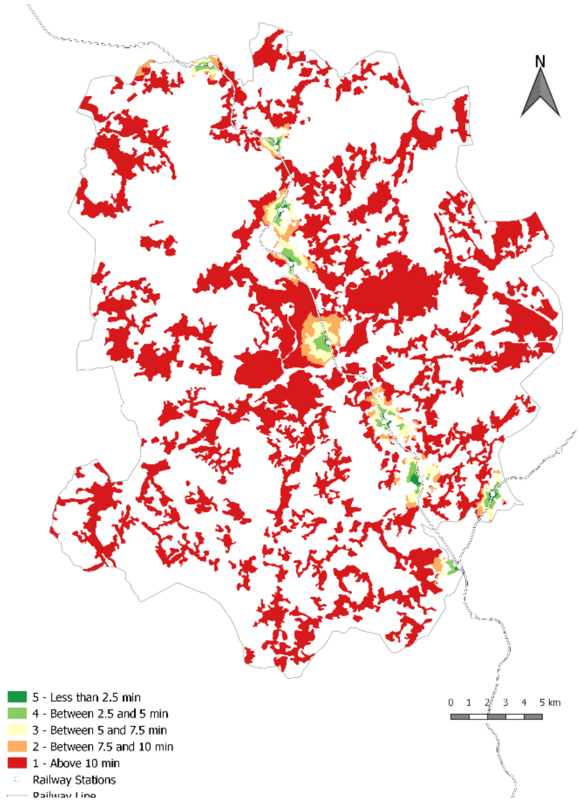


Figure 21 – Cycling Potential according to the Accessibility to Railway Stations of Barcelos.

Such findings were verified by the numerical analysis represented in Table 16, which reports the numerical values of the overall cycling potential per indicator and the final aggregated potential for the municipality.

Barcelos has a Moderate cycling potential in its target-areas (2.8), with the lower level of Accessibility to the City Centres and to Railway station affecting the final score, even though the municipality has a good coverage of education facilities. Due to lack of information about the existence of cycling infrastructure, it was considered non-existent, therefore not allowing a deeper analysis in this dimension.

Table 16 – Cycling Potential (1-5) of the Barcelos' Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***2.8***[+]
Accessibility to Education Facilities	3.2
Accessibility to the City Centres	2.8
Accessibility to Railway Stations	2.3
Occupation Diversity	-*
Coverage Area for Cycling Infrastructure and for 30 Zones	-*

Notes:

* No results were produced for these indicators due to lack of data for this municipality.

[+] The aggregate value was produced disregarding the absent indicators.

5.1.3. Target-Population & Target-Areas Aggregated Map

Figure 22 shows the aggregated map of target population and target areas for Barcelos. The centre of the municipality reveals higher potential in both dimensions than the outskirts. Indeed, only 23.8% of the population and 11.5% of the urban area have a good potential for cycling (potential 4 or 5), most have a moderated (45.8% of population and 51.2% of area at potential 3) to low potential (30.4% of population and 37.2% of area at potential 2).

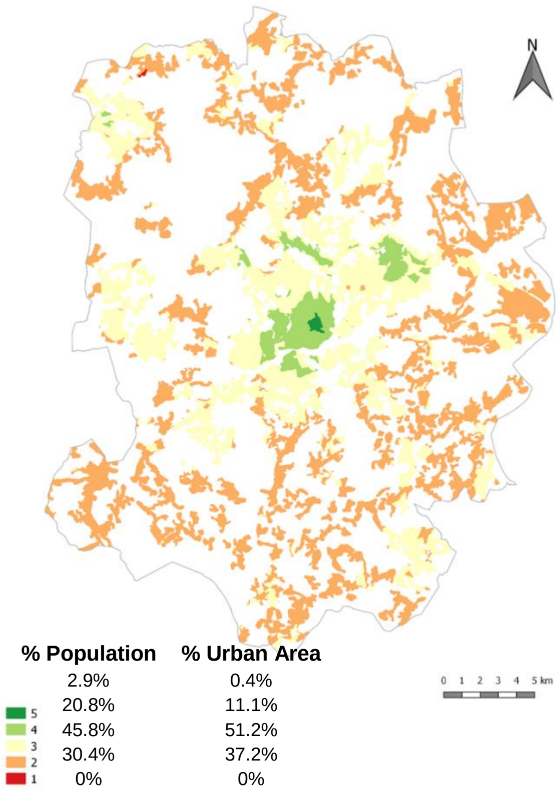


Figure 22 – Aggregated Potential of the Target Population and Target Areas of Barcelos, plus the respective population and urban area percentage covered by each potential.

5.1.4. Political Commitment to cycling

The Political Commitment to Cycling of the Municipality output is reported in the Table 17, revealing a Moderate overall cycling potential score (2.5).

Table 17 – Cycling Potential (1-5) of Barcelos' cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.5⁺***
Population Coverage by Cycling Infrastructure (8 min)	-*
Schools covered by Cycling Infrastructure (8 min)	-*
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	-*
PT stations Coverage by Bicycle Parking	-*
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	2.2
Accessible Population by Bicycle (15 min)	3.4
Accessible Area by Bicycle (15 min)	3.0
Relative Accessibility (Bicycle / Car in 5 min)	1.0
Existence of Complementary Measures	2.0

Notes:

* No results were produced for these indicators due to lack of data for this municipality.

⁺ The aggregate value was produced disregarding the indicators with *.

5.1.5. City Typology

Barcelos has a Moderate potential (B) in all dimensions (Target-population, Target-areas and Cycling Policies), being characterized as a BBB city typology (Table 18 and Figure 23). The main reason behind this result is its low population and density in the outer parts of the municipality in contrast with the city centre.

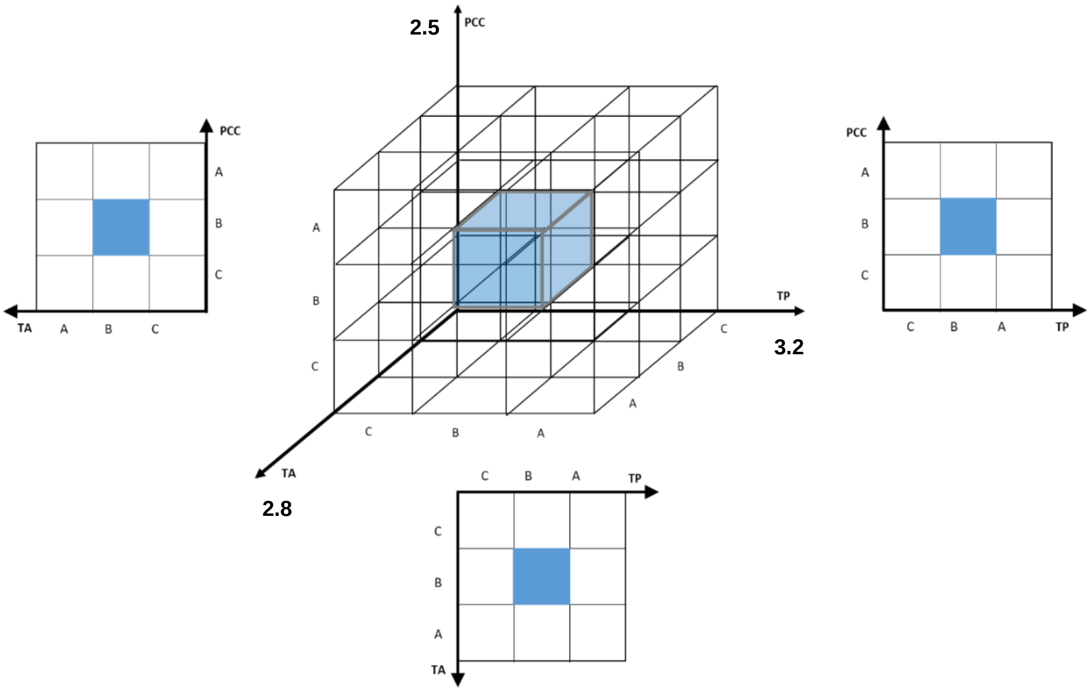


Figure 23 – Representation of the positions of Barcelos in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 18 – Typology of Barcelos and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Barcelos	BBB	3.2	2.8	2.5	

5.2. Braga

Current Scenario

5.2.1. Target Population

Figure 24 provides the spatial representation of aggregated Target-population of Braga. The population with the highest cycling potential is concentrated near its centre, representing a potential 4 (56% of the population). There are a few sporadic peaks in its outskirts, however, in such areas the potential 3 is prevalent, counting for 40.6% of the population. The assessment of Age and Populations and Employment Density, are illustrated respectively in Figure 24 and Figure 25, followed by municipalities' Car Ownership rate (Figure 27), the percentage of Students among the population (Figure 28) and the Education level (Figure 29).

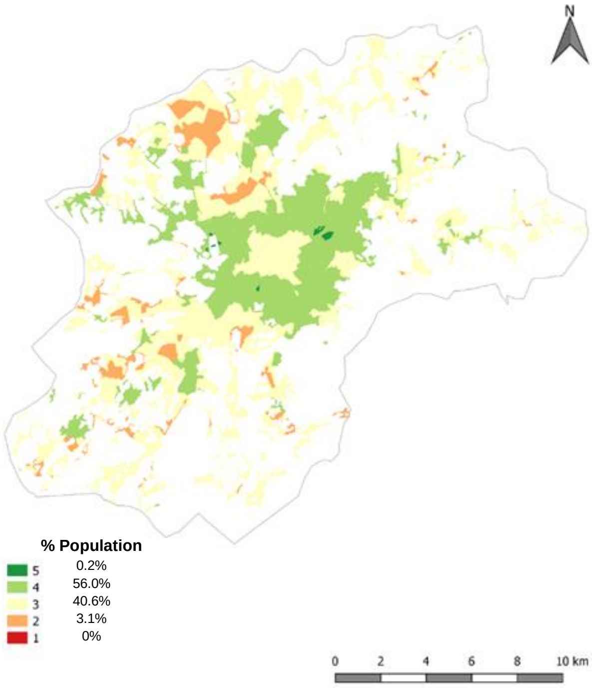


Figure 24 - Aggregated Cycling Potential of the Target Population of Braga, plus the respective population percentage covered by each potential.

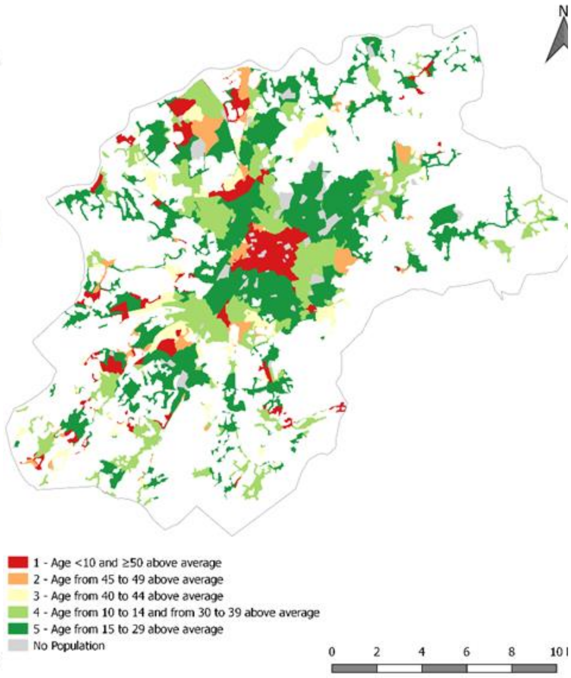


Figure 25 - Cycling Potential according to Age Concentration above Braga's Average.

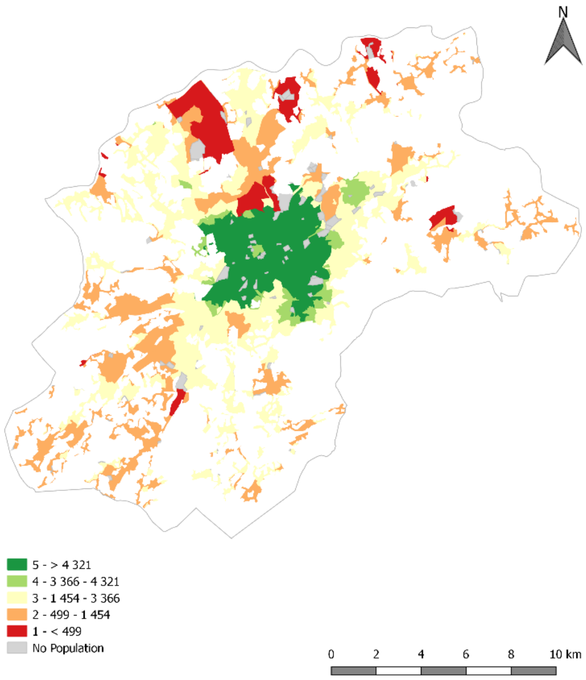


Figure 26 – Cycling Potential according to Braga's Population Density.

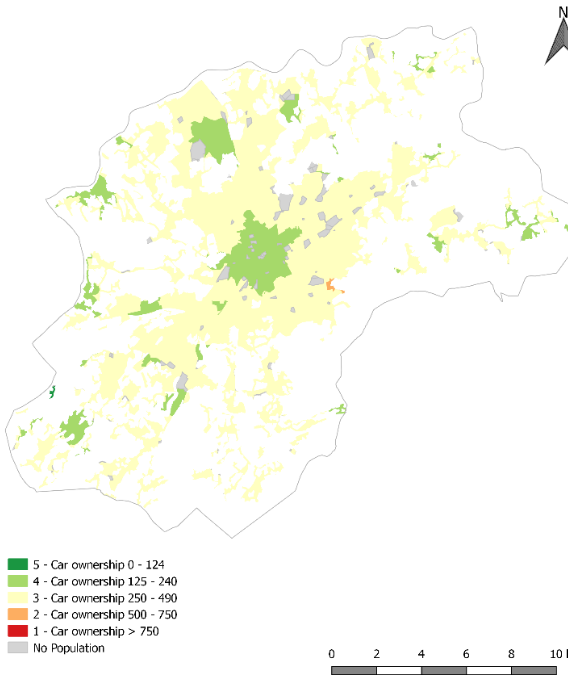


Figure 27 – Cycling Potential according to Braga's Car Ownership per 1000 inhabitants.

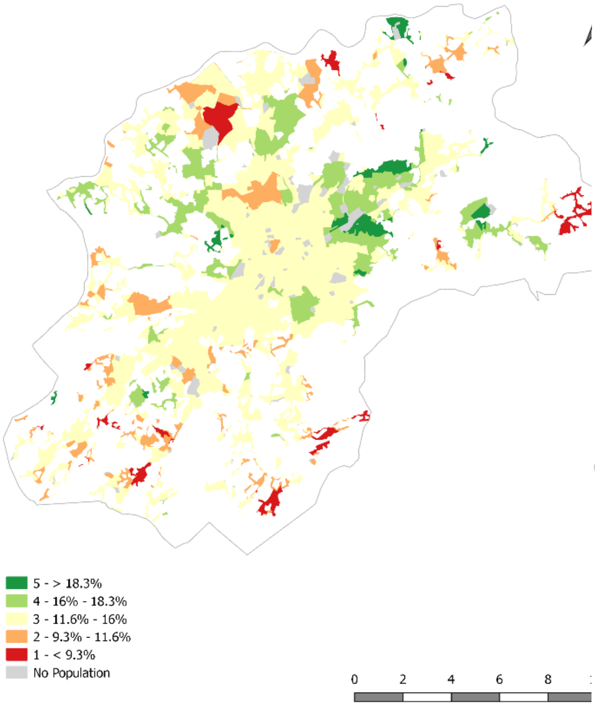


Figure 28 – Cycling Potential according to Braga's % of Students in the Resident Population.

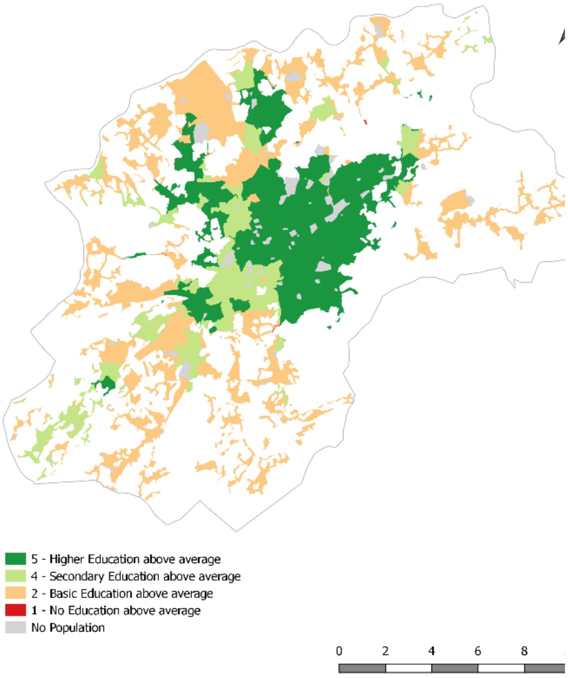


Figure 29 – Cycling Potential according to the Braga's Education Level.

The numerical values (1 to 5) of the cycling potential for each Target-population's indicators are represented on Table 19.

Overall, Braga has a Moderated potential (3.5) for cycling in such dimension of analysis, although close to the upper limit. Even though Braga has a young population and high education level, there is a high number of private vehicles per inhabitant and a low presence of students in most of favourable zones for cycling, which affected the overall cycling potential in this municipality.

Table 19 – Cycling Potential (1-5) of Braga's Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.5***
Age	3.9
Population Density	3.9
Car ownership	3.2
Students Presence	3.1
Education Level	4.1

5.2.2. Target Areas

The Target-areas assessment of Braga (Figure 30) reveals that, similarly to its target-population, the areas with higher cycling potential are located in the centre, with the decreasing of its potential in the peripheral zones.

The spatial representation of the four indicators used to build the aggregated map, are represented in the following figures: Accessibility to Education Institutions (Figure 31), Accessibility to the City Centres (Figure 32), Accessibility to the Railway Stations (Figure 33) and Coverage Areas of existent Cycling Infrastructure (Figure 34).

There is a concentration in the centre of several points of interest, such as education institutions (Figure 31), with the university being located in that area, as well as the existent cycling infrastructure (Figure 34) and the municipality's main train station (Figure 33). In contrast, the remaining urban area is characterized by a moderate to low cycling potential, justified by the absence of such diversity of centralities.

Such findings are reinforced by the numerical analysis represented in Table 20, which presents the values of the overall cycling potential for each one of the five factors evaluated.

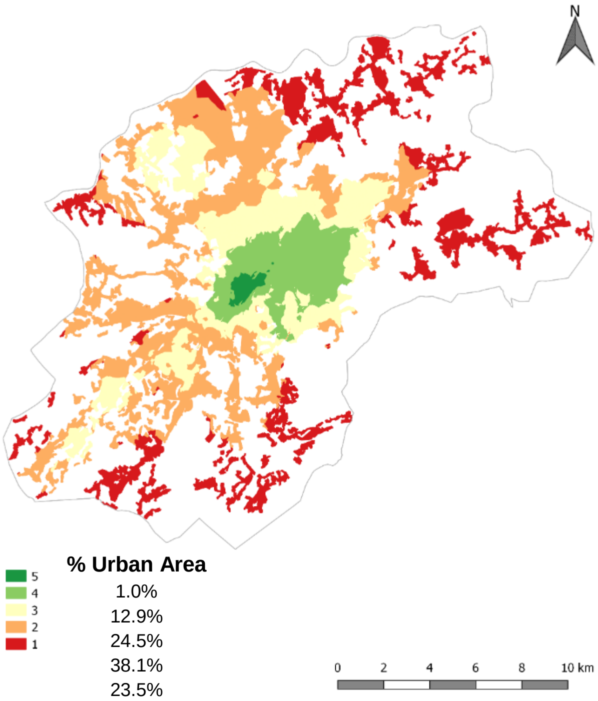


Figure 30 - Aggregated Cycling Potential of the Target-Areas of Braga, plus the respective urban area percentage covered by each potential.

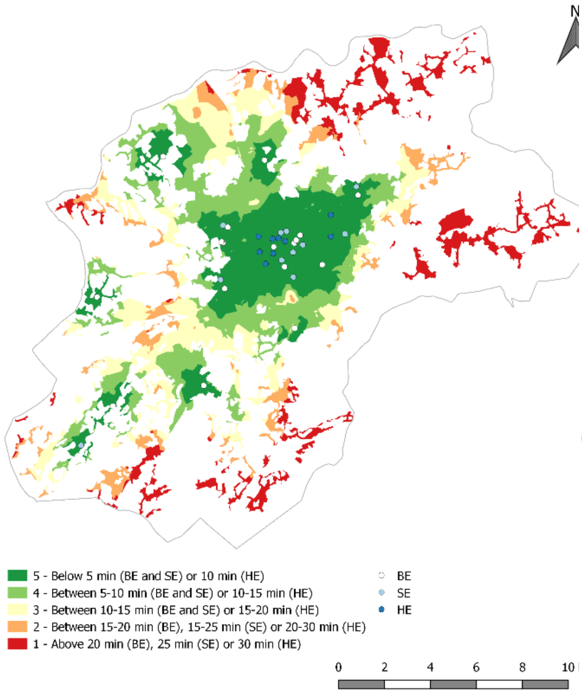


Figure 31 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education: HE: Higher Education) of Braga.

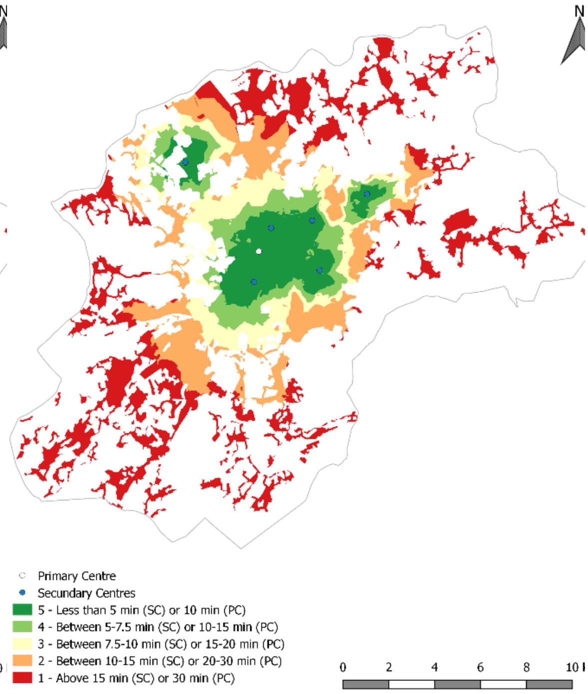
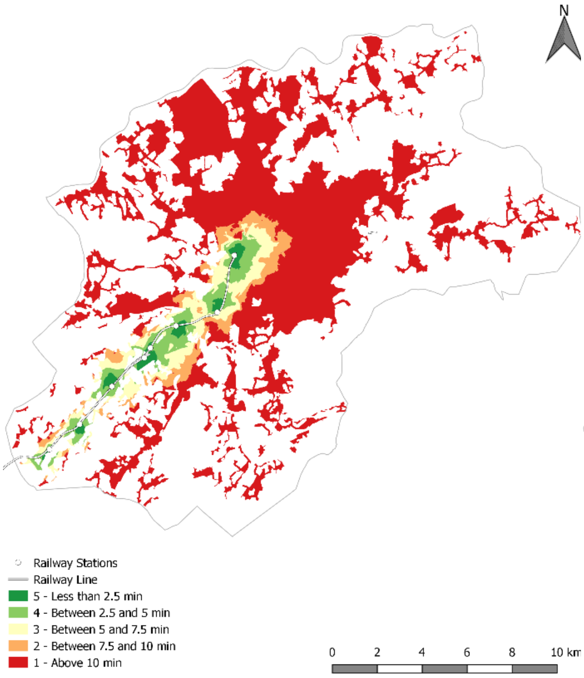


Figure 32 – Cycling Potential according to the Accessibility to City Centres of Braga.



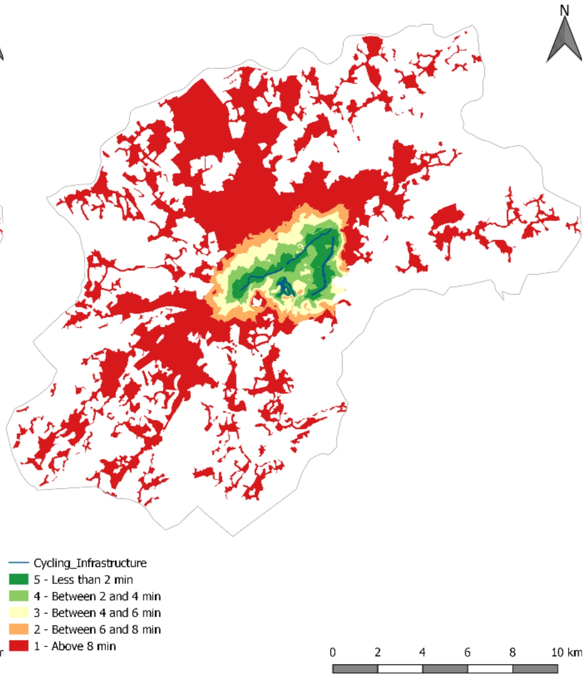


Figure 33 – Cycling Potential according to the Accessibility to Railway Stations of Braga.

Figure 34 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Braga.

Table 20 - Cycling Potential (1-5) of the Braga's Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***2.3⁺***
Accessibility to Education Facilities	3.4
Accessibility to the City Centres	2.4
Accessibility to Railway Stations	1.4
Occupation Diversity	-*
Coverage Area for Cycling Infrastructure and for 30 Zones	1.6

Notes:

* No results were produced for these indicators due to lack of data for this municipality.

$^{+}$ The aggregate value was produced disregarding the absent indicators

As already revealed by the map analysis, Braga has a Moderate cycling potential (2.3), regarding the Target-Areas. Although Braga has a good accessibility to education facilities, there is a considerable lower score in the other indicators. The accessibility to Railway stations is quite low mainly due to the existence of only on rail route. Furthermore, the municipality has low coverage by cycling infrastructure and of low-speed zones (Figure 34).

5.2.3. Target-Population & Target-Areas Aggregated Map

The following map reports the aggregated of the target-population and target-areas assessment (Figure 35), which shows a great concentration of population with higher propensity for cycling and areas with better cycling conditions, in the central part of the municipality. Indeed, such urban area (approximately 20%) counts with 49.6% of the population in the potential 4. However, a representative share of the population is in the potential 3 (30.9%) and potential 2 (19.4%), which altogether are placed in almost 80% of the urban area.

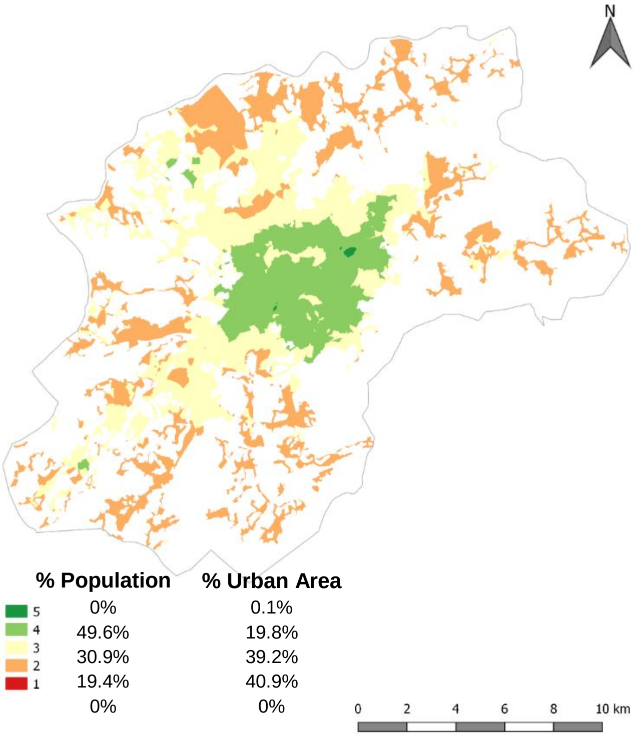


Figure 35 - Aggregated Potential of the Target Population and Target Areas of Braga, plus the respective population and urban area percentage covered by each potential.

5.2.4. Political Commitment to cycling

The assessment of the political commitment to cycling of the municipality is represented on Table 21. The effectiveness of Braga's cycling policies is Moderate (2.8).

Braga has a low potential on its outskirts, but its centre stands out as a suitable area for cycling as it is densely populated and comprises most of its municipalities' main centralities. This results in the reduced existent cycling infrastructure covering a high percentage of its population and centralities like schools.

The unavailability of bicycling parking, particularly near to the railway stations reduced its cycling potential, as it undermines the possibility of intermodality.

Overall, Braga has, so far, a limited number of measures dedicated to improving cycling, however the few implemented measures are effective due to being located near densely populated areas and centralities.

Finally, the existence of complementary measures seems to signal that Braga is increasing its commitment to cycling, with the implementation of school mobility plans on 4 pilots-schools as well as traffic calming zones in residential neighbourhoods. This in combination with a new cycling strategy to be implemented the next years, in which a comprehensive cycling network, will be built in the city centre, seems to preclude an increase on Braga's political commitment towards cycling.

Table 21 – Cycling Potential (1-5) of Braga's cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.8***
Population Coverage by Cycling Infrastructure (8 min)	2.2
Schools covered by Cycling Infrastructure (8 min)	4.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.2
PT stations Coverage by Bicycle Parking	1.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	3.6
Accessible Population by Bicycle (15 min)	4.4
Accessible Area by Bicycle (15 min)	3.9
Relative Accessibility (Bicycle / Car in 5 min)	1.2
Existence of Complementary Measures	3.0

5.2.5. City Typology

The municipality under analysis has a moderated potential on its target-population, target-areas and political commitment, resulting in a BBB city typology (Figure 36 and Table 22). The main factors negatively affecting the cycling potential of this city are both the existence of low population density areas outside its centre, and an overall limited dedicated cycling infrastructure.

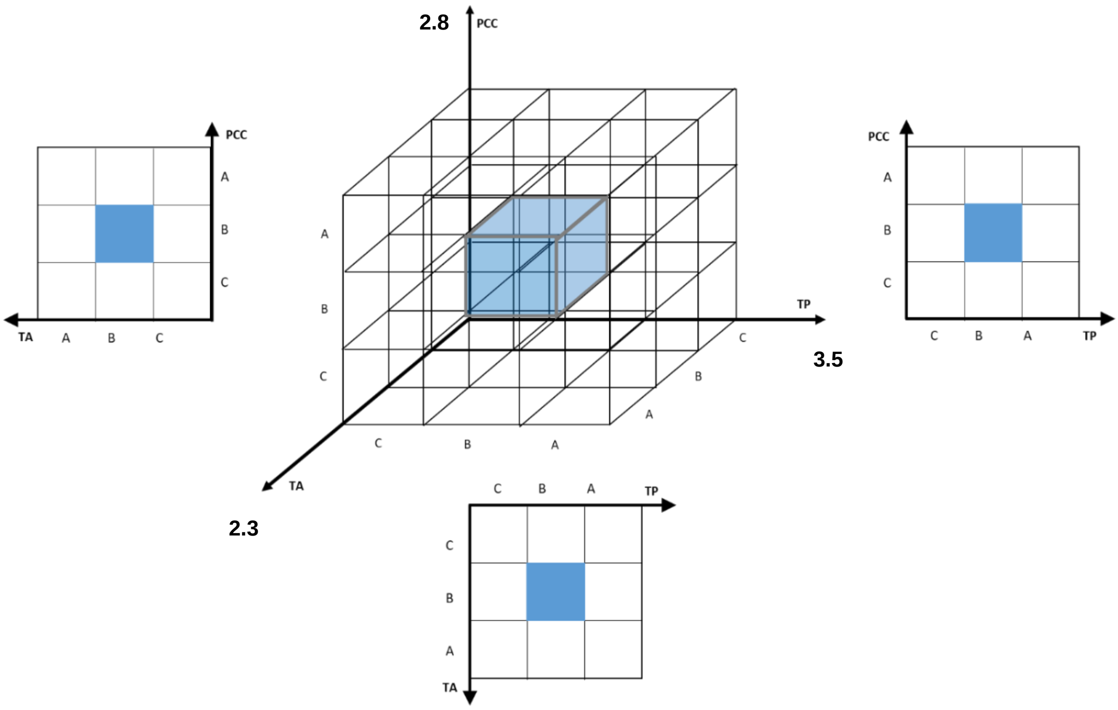


Figure 36 – Representation of the positions of Braga in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 22 – Typology of Braga and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Braga	BBB	3.5	2.3	2.8	11.6

Proposed Scenario

Braga has been increasing its commitment to cycling through the development of a cycling plan, which is based on the extension of the cycling infrastructure. The next section presents the expected results for the indicators assessed before after implementation of the plan.

5.2.6. Target-Population

There are no changes in the Target Population between the current and the future scenarios, since both are structured upon Census 2011 data collection, as well as due to the unfeasibility of inferring demographic and socioeconomic data for the future to the census track scale.

5.2.7. Target-Areas

Figure 37 shows the current Target-Areas and Figure 38 illustrates the spatial representation of the target areas' aggregated cycling potential for the Proposed Scenario.

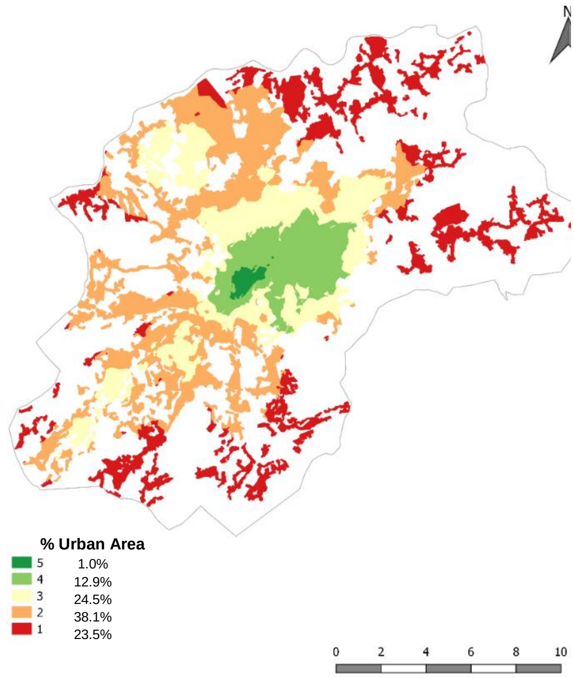


Figure 37 – Aggregated Cycling Potential of the Target-Areas of the Current Scenario for Braga, plus the respective urban area percentage covered by each potential.

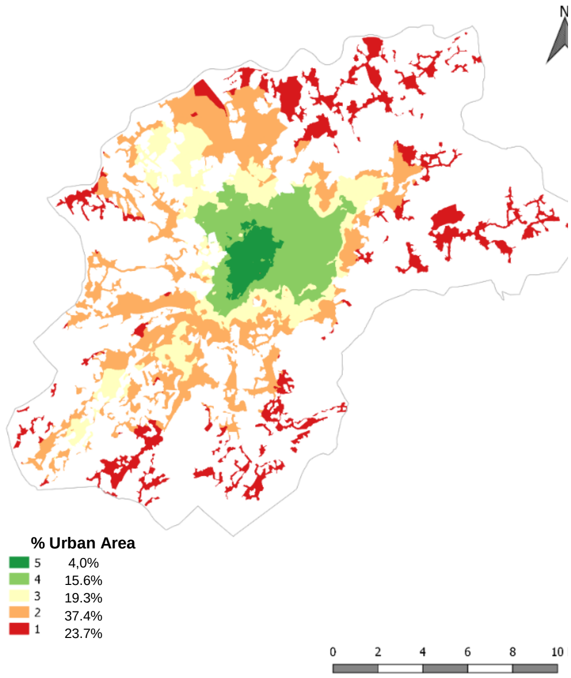


Figure 38 – Aggregated Cycling Potential of the Target-Areas of the Proposed Scenario for Braga, plus the respective urban area percentage covered by each potential.

The indicators used to build the previous aggregated map for the proposed scenario are represented in the next figures: Accessibility to Education Institutions (Figure 39), Accessibility to the City Centres (Figure 40), Accessibility to the Railway Stations (Figure 41) and Coverage Areas of the existent Cycling Infrastructure (Figure 42).

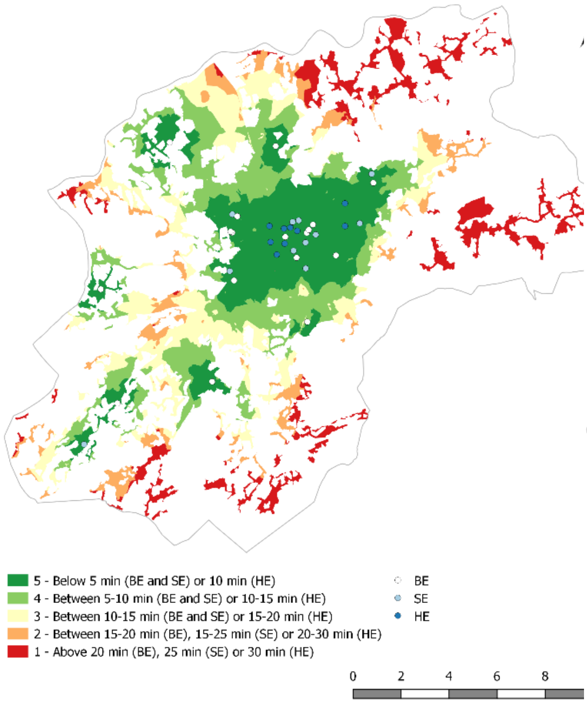


Figure 39 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education: HE: Higher Education) of Braga's Proposed Scenario.

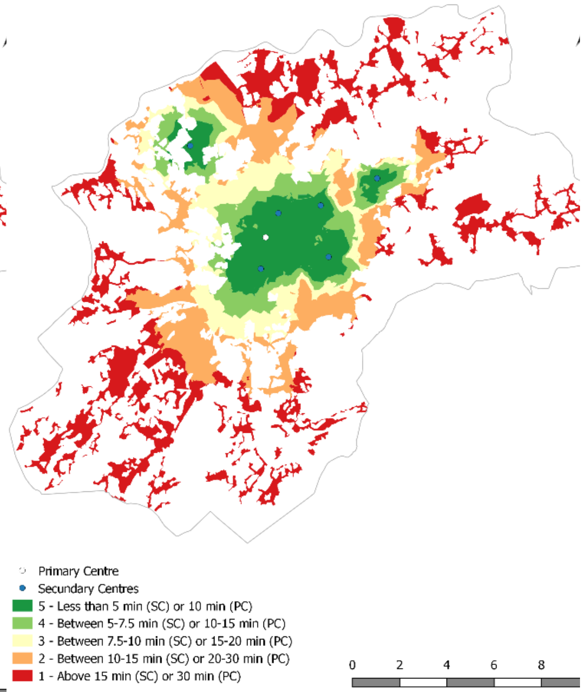


Figure 40 – Cycling Potential according to the Accessibility to City Centres of Braga's Proposed Scenario.

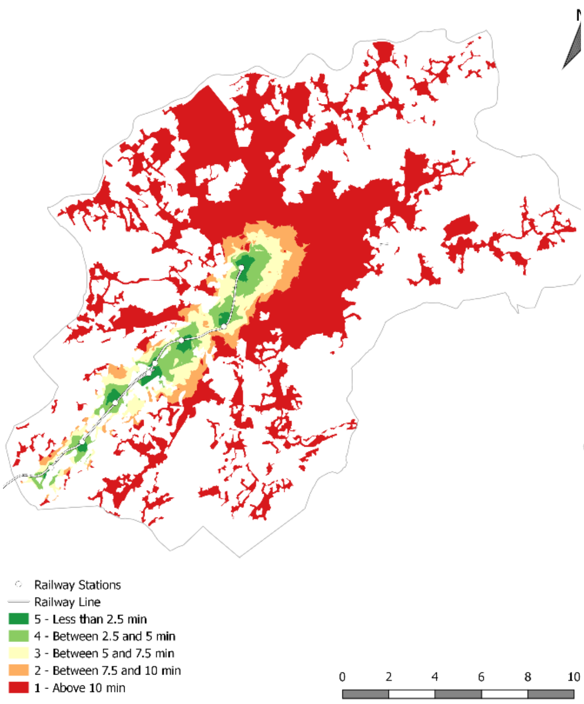


Figure 41 – Cycling Potential according to the Accessibility to Railway Stations of Braga's Proposed Scenario.

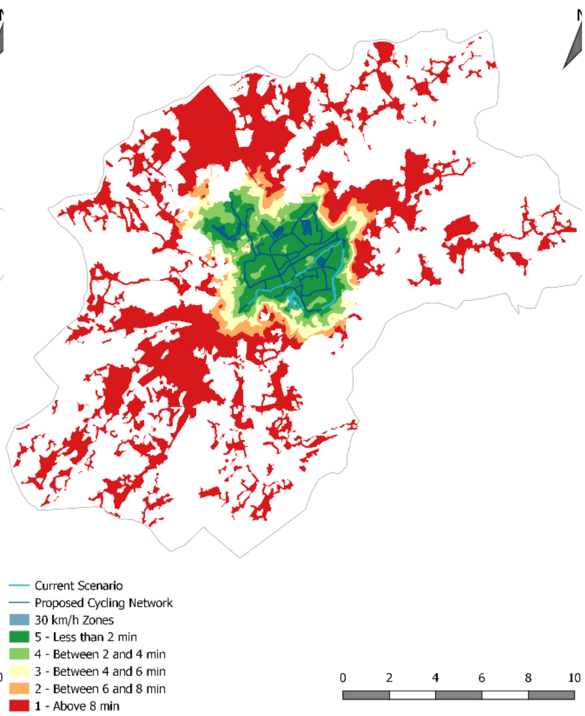


Figure 42 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Braga's Proposed Scenario.

The assessment of the Target-Areas potential for the Proposed Scenario (Figure 38) revealed a slight improvement concerning the coverage area for cycling infrastructure and for 30 zones, while the other indicators remained steady. The improvement is largely justified by the extensive proposed cycling network that will cover the city centre, increasing from the current 11.6 km of extension to 58.6 km, including 30km/h zones. The numerical analysis (Table 23) present the improvement in each indicator. In the Proposed Scenario, Braga remains with the Moderated potential (2.4), within its Target-Area dimension.

Table 23 – Cycling Potential (1-5) of the Braga's Target Areas for the Proposed Scenario.

Indicators	Overall Cycling Potential
Target-Areas	***2.4⁺***
Accessibility to Education Facilities	3.4
Accessibility to the City Centres	2.4
Accessibility to Railway Stations	1.4
Occupation Diversity	-*
Coverage Area for Cycling Infrastructure and for 30 Zones	1.9

Notes:

* No results were produced for these indicators due to lack of data for this municipality.

⁺ The aggregate value was produced disregarding the absent indicators

5.2.8. Target-Population and Target-Areas Aggregated Map

Figure 43 and presents the target-population and target-areas aggregated map for the current scenario and Figure 44 for the Proposed Scenario.

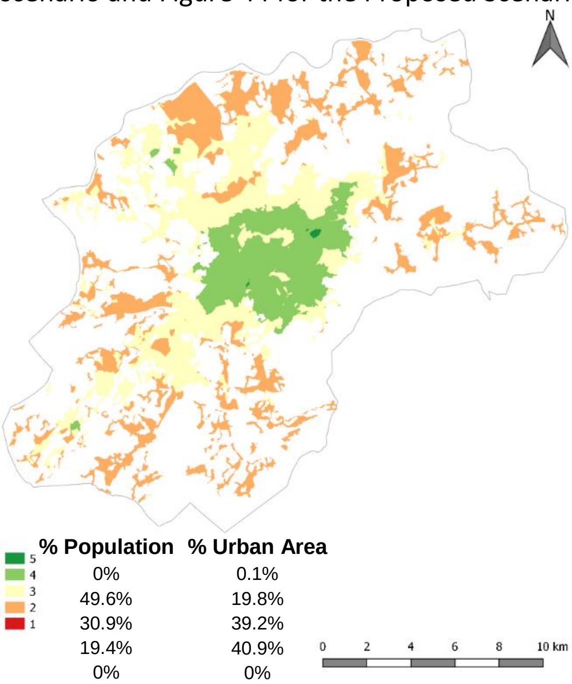


Figure 43 – Aggregated Potential of the Target Population and Target Areas of Braga for the Current Scenario, plus the respective population and urban area percentage covered by each potential.

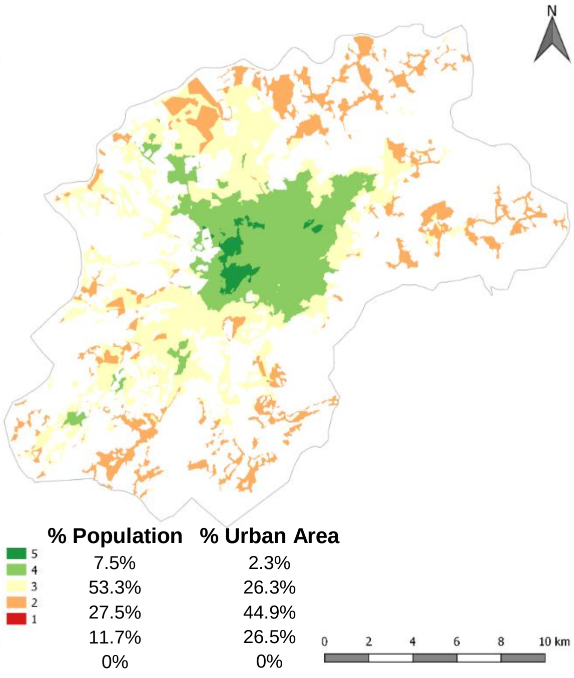


Figure 44 – Aggregated Potential of the Target Population and Target Areas of Braga for the Proposed Scenario, plus the respective population and urban area percentage covered by each potential.

In the proposed case, there is a few improvements of the cycling potential of the city, which shows a great concentration of population with higher propensity for cycling and areas with better cycling conditions, in the central part of the municipality. In the future scenario, the urban area (approximately 26%) counts with 53.3% of the population in the potential 4. However, a representative share of the population remained in the potential 3 (27.5%) and potential 2 (11.7%), which altogether are placed in almost 71% of the urban area.

5.2.9. Political Commitment to cycling

The assessment of the municipality's political commitment to cycling under the Proposed Scenario is represented on Table 24.

Table 24 – Cycling Potential (1-5) of Braga's cycling policies for the Proposed Scenario

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***3.1***
Population Coverage by Cycling Infrastructure (8 min)	3.0
Schools covered by Cycling Infrastructure (8 min)	4.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.5
PT stations Coverage by Bicycle Parking	2.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	3.7
Accessible Population by Bicycle (15 min)	4.5
Accessible Area by Bicycle (15 min)	4.0
Relative Accessibility (Bicycle / Car in 5 min)	1.3
Existence of Complementary Measures	4

In this dimension, the improvement is more significant, counting with an overall cycling potential upgrade from 2.8 to 3.1. The most significant changes are in the population coverage by cycling infrastructure followed by the average increase of the cycling infrastructure, as well as in the implementation of complementary measures with the creation of 30 km/h Zones and School Mobility Plans.

Finally, in this municipality it is expected some cycling policies and measures intended to improve the bicycle as a mode of transport, counting 4 mains measures:

- School Mobility Plans;
- Cycling infrastructure expansion;
- Traffic calming;

In the centre of the city, it is projected a coverage area of cycling infrastructure as well as 30 zones in order to increase the bicycle accessibility and mobility levels. Furthermore, safe bicycle parking near to schools and incentives to promote cycling among students will be implemented.

5.2.10. City Typology

The municipality under analysis has a moderated potential on its target-population, target-areas and political commitment for the scenario proposed, resulting in a BBB city typology (Figure 45 and Table 25). The target area got a 0.1 of increased potential and 0.3 for the political commitment to cycling dimension. This last improvement is a consequence of the cycling measures proposed to the city.

Table 25 – Typology of Braga based on the current and proposed scenarios, stratified by each dimension score

Municipality	Current Scenario					Proposed Scenario				
		TP	TA	PCC	Cycling Infrastructure		TP	TA	PCC	Cycling Infrastructure
Braga	BBB	3.5	2.3	2.8	11.6 km	BBB	3.5	2.4	3.1	58.6 km

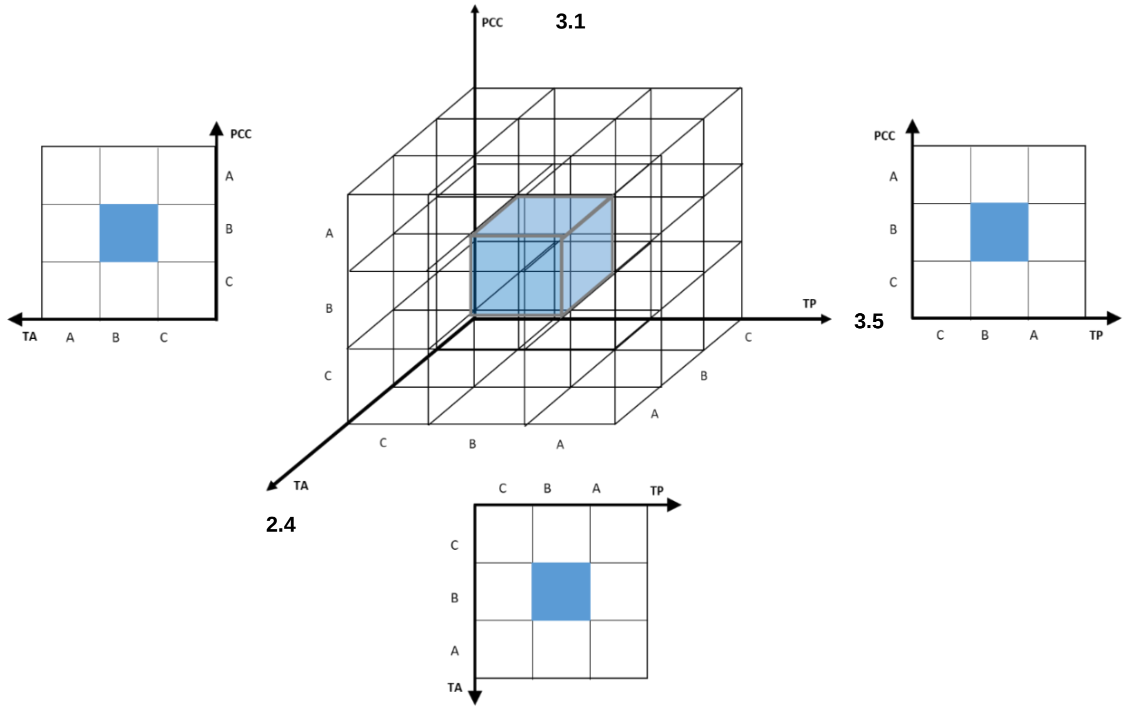


Figure 45 – Representation of the positions of Braga in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

5.3. Cascais

5.3.1. Target Population

The spatial representation of the target population aggregated cycling potential for Cascais is provided by Figure 46.

Additionally, the spatial representation of the five socioeconomic indicators used to assess the target population are represented in the next figures: Figure 47 – Age; Figure 48 - Population Density; Figure 49 - Car Ownership; Figure 50 - percentage of Students among the population and Figure 51 - Education Level.

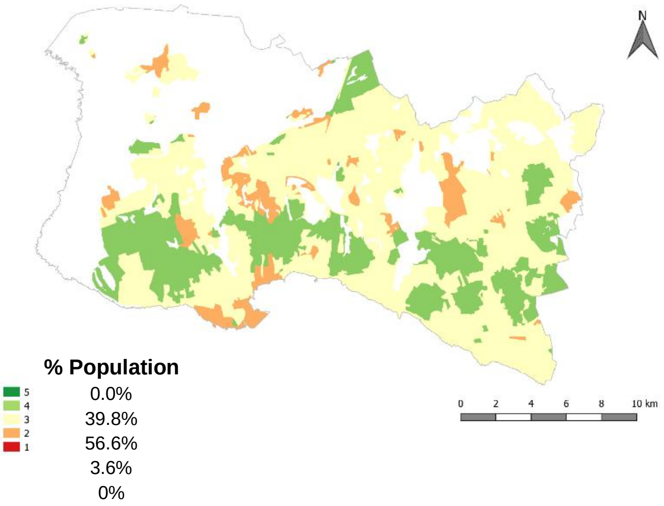


Figure 46 - Aggregated Cycling Potential of the Target Population of Cascais, plus the respective population percentage covered by each potential.

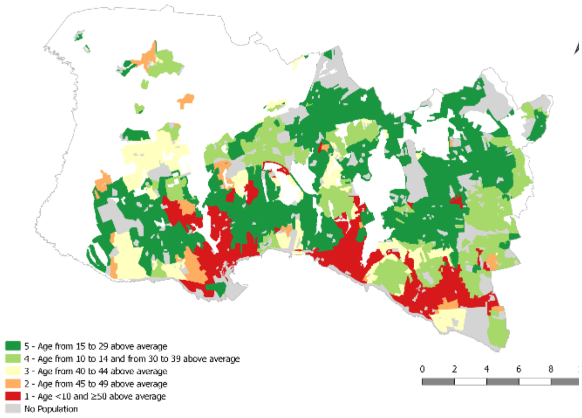


Figure 47 – Cycling Potential according to Age Concentration above Cascais' Average.

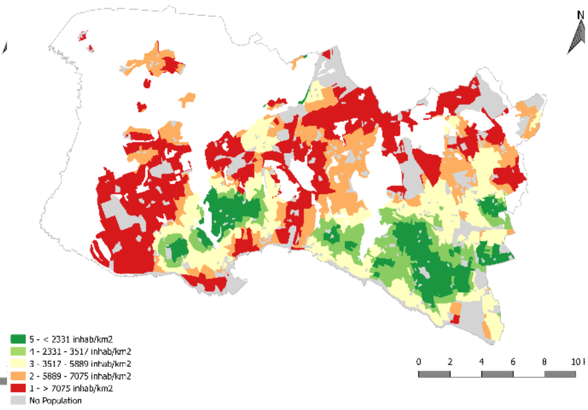


Figure 48 – Cycling Potential according to Cascais' Population Density.

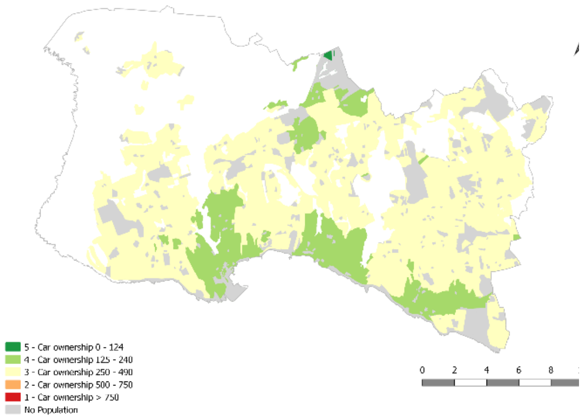


Figure 49 – Cycling Potential according to Cascais' Car Ownership per 1000 inhabitants.

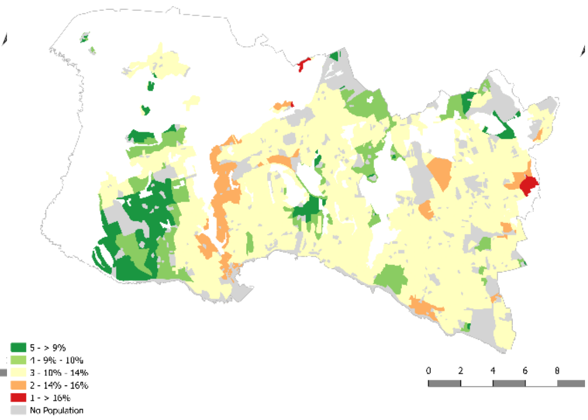


Figure 50 – Cycling Potential according to Cascais' % of Students in the Resident Population.

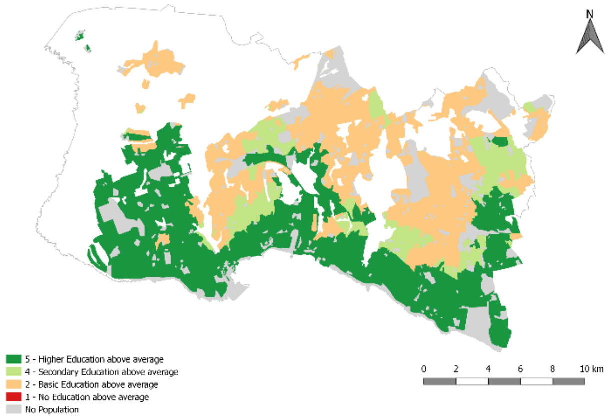


Figure 51 – Cycling Potential according to the Cascais' Education Level.

Overall, Figure 46 reveals that the municipality has a population with moderated potential for cycling (56.6% at potential 3). Nevertheless, the municipality also has a significant percentage of population with higher potential (39.8% at potential 4) living in the south, coinciding with the densely populated areas of the municipality (Figure 48) and with a concentration of younger ages (Figure 47) and students (Figure 50) in the southwest.

Next, Table 26 presents the target population aggregated value (from 1 to 5), as well as the scores of each one of the indicators.

Table 26 – Cycling Potential (1-5) of Cascais' Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.4***
Age	3.6
Population Density	3.4
Car ownership	3.3
Students Presence	3.1
Education Level	3.8

The table's results reveal that Cascais has indeed a Moderate potential among its population (3.4), although close to the upper limit, having a well education and young population, but being hindered by low populated areas in the north and southwest.

5.3.2. Target Areas

Next, we have the visual representation of the aggregated cycling potential for the Cascais' Target-Areas (Figure 52).

The representation of the indicators used to build the previous map are represented in the following figures: Accessibility to Education Institutions (Figure 53), Accessibility to City Centres (Figure 54), Accessibility to Railway Stations (Figure 55) and Coverage Areas of the Cycling Infrastructure (Figure 56).

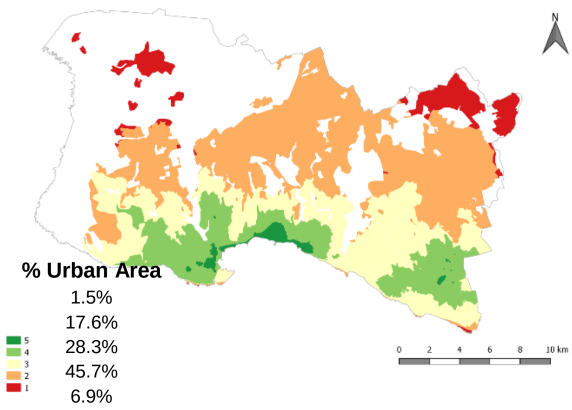


Figure 52 - Aggregated Cycling Potential of the Target-Areas of Cascais, plus the respective urban area percentage covered by each potential.

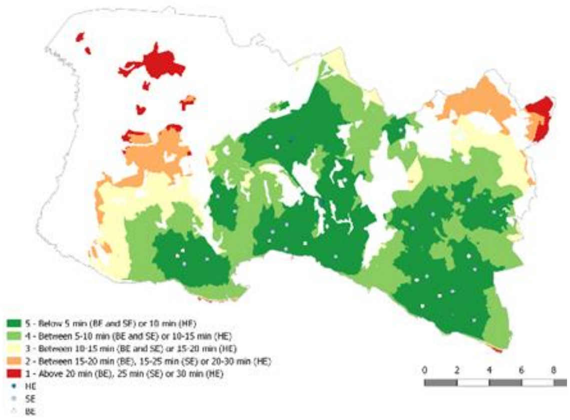


Figure 53 - Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education: HE: Higher Education) of Cascais.

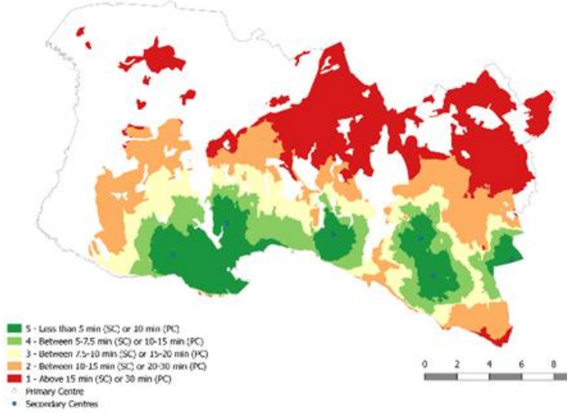


Figure 54 - Cycling Potential according to the Accessibility to City Centres of Cascais.

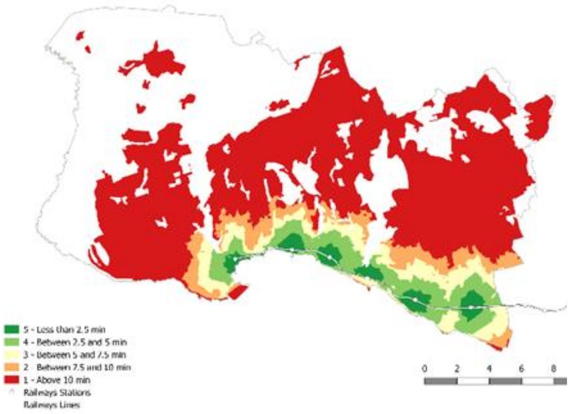


Figure 55 - Cycling Potential according to the Accessibility to Railway Stations of Cascais.

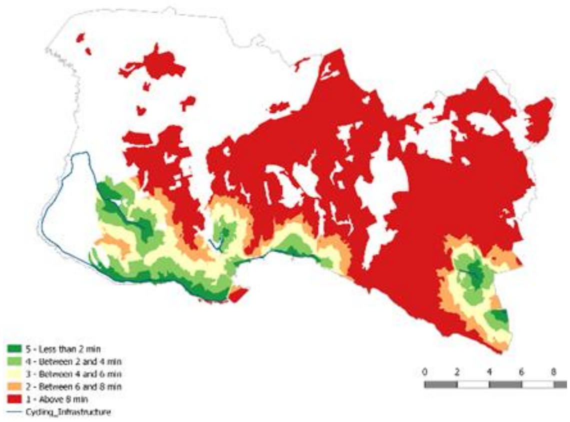


Figure 56 - Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Cascais.

The assessment of the aggregated potential (Figure 52) reveals a high potential concentration in the southern part of the municipality primarily due to the overlap of education facilities (Figure 53) with cycling infrastructure in the area (Figure 56), in addition to also having railway stations (Figure 55) and centralities (Figure 54). Although much of the municipality has a good coverage of education facilities (Figure 53), the northern part has a lack of all the other considered factors, leading to lower potentials. This translates in most of the urban area presenting moderate (28.3% at potential 3) to low cycling potential (52.6% at potential 2 and 1). In addition, Figure 56 also reveals that a significant part of the existent cycling infrastructure is leisure oriented being located outside the urban area, near the coastline and, thus, not contributing to the cycling potential assessment. Lastly, Table 27 presents the numerical scores of the target-areas.

Table 27 – Cycling Potential (1-5) of Cascais' Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***2.6***
Accessibility to Education Facilities	4.1
Accessibility to the City Centres	2.6
Accessibility to Railway Stations	1.7
Occupation Diversity	-
Coverage Area for Cycling Infrastructure and for 30 Zones	1.7

The table's analysis reveals that Cascais has a Moderated potential among its target-areas (2.6), close to the lower limit. Although its education facilities cover much of its territory, the municipality performs poorly in the remaining indicators, notably in the coverage area by cycling infrastructure.

5.3.3. Target-Population & Target-Areas Aggregated Map

Figure 57 presents the target-population and target-areas aggregated map of Cascais. Figure 57summarizes the previous analyses with a concentration of cycling potential among the target-population and target-areas in the southern part of the municipality and lower potentials in the north. As such, we have most of the population and urban area ranging from moderate to high potential for cycling, with 96.8% of the population and 89.4% of the urban area having potential 3 or 4.

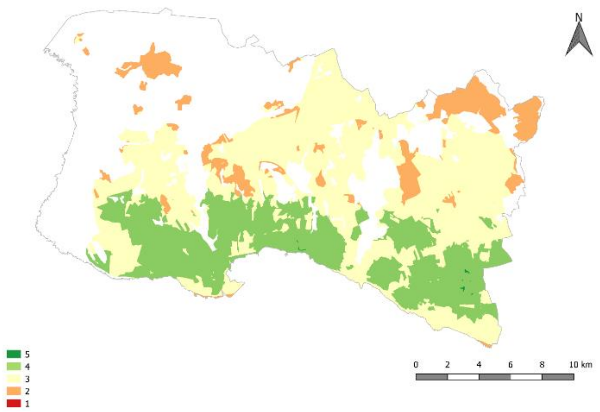


Figure 57 - Aggregated Potential of the Target Population and Target Areas of Cascais, plus the respective population and urban area percentage covered by each potential.

Target-Population & Target-Areas Aggregated Map (Figure 57) presents the target-population and target-areas aggregated map of Cascais. Figure 57 summarizes the previous analyses with a concentration of cycling potential among the target-population and target-areas in the southern part of the municipality and lower potentials in the north. As such, we have most of the population and urban area ranging from moderate to high potential for cycling, with 96.8% of the population and 89.4% of the urban area having potential 3 or 4.

5.3.4. Political Commitment to cycling

The last dimension assessment (political commitment to cycling) is present in Table 28. Cascais scores a Moderate potential on its political commitment to cycling (3.0). Although the existent cycling infrastructure, with an extension of 16.4 km, is mostly leisure-oriented, translating in a low score on its population covered by cycling infrastructure and in the relative accessibility, the municipality still has a noticeable investment on cycling policies with all its railway stations covered by bicycle parking and also with a bike-sharing system implemented, positively affecting its score.

Table 28 – Cycling Potential (1-5) of Cascais' cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***3.0***
Population Coverage by Cycling Infrastructure (8 min)	1.7
Schools covered by Cycling Infrastructure (8 min)	3.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	-
PT stations Coverage by Bicycle Parking	5.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	3.3
Accessible Population by Bicycle (15 min)	3.2
Accessible Area by Bicycle (15 min)	2.6
Relative Accessibility (Bicycle / Car in 5 min)	1.4
Existence of Complementary Measures	4

5.3.5. City Typology

In summary, Cascais presents a Moderate (B) potential on all of its 3 dimensions, translating in a BBB city typology (Figure 58). Although the municipality has some relevant cycling policies implemented, its potential is hindered by the leisure-oriented nature of its cycling infrastructure (Table 29), as well by the low population densities and general lack of centralities and activities on its northern side.

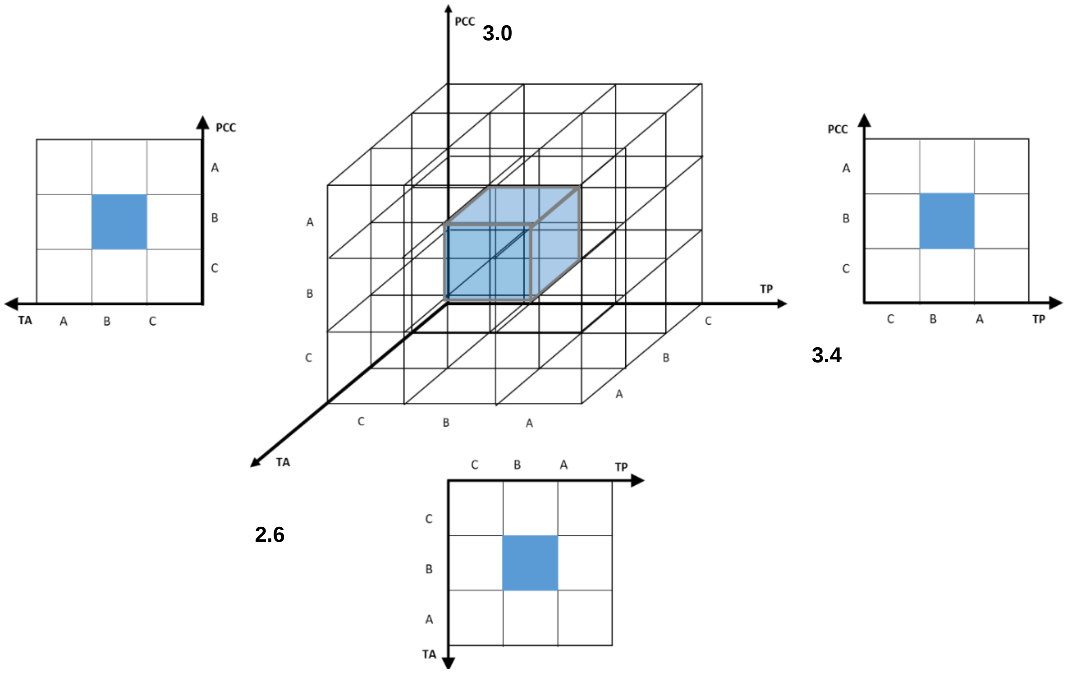


Figure 58 – Representation of the positions of Cascais in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 29 – Typology of Cascais and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Cascais	BBB	3.4	2.6	3.0	16.4

5.4. Guimarães

Current Scenario

5.4.1. Target Population

Figure 59 reports the spatial representation of where the target population with more propensity to cycling is located in Guimarães. This municipality is characterized as more sprawled with low-density development. Concerning the cycling potential among the population, it is visible the various potentials are dispersed in the territory. Overall, the percentage of the municipality's population covered by each potential reveals an expressive predominance of Potential 3 (81.3%), followed by Potential 4 (15.6%). Regarding this last case, such potential is liked with the main centralities found in the municipality.

Moreover, the spatial representation of each one of the five socioeconomic indicators used to assess the target population are reported in the following figures. Figure 60 and Figure 61assess the two indicators with more weight in the target population output, respectively Age and Population Density. The other maps represent the municipalities' Car Ownership rate (Figure 62). The percentage of Students among the population (Figure 63) and the Education Level (Figure 64).

By analysing the two indicators with more weight (Age and Population Density), it is visible that even though the centralities are densely occupied, just one of them has a predominance of students and young population. Meanwhile, the city centre is majority occupied by the population with the least propensity towards cycling. The remaining indicators have a more limited impact into the final cycling potential of the city.

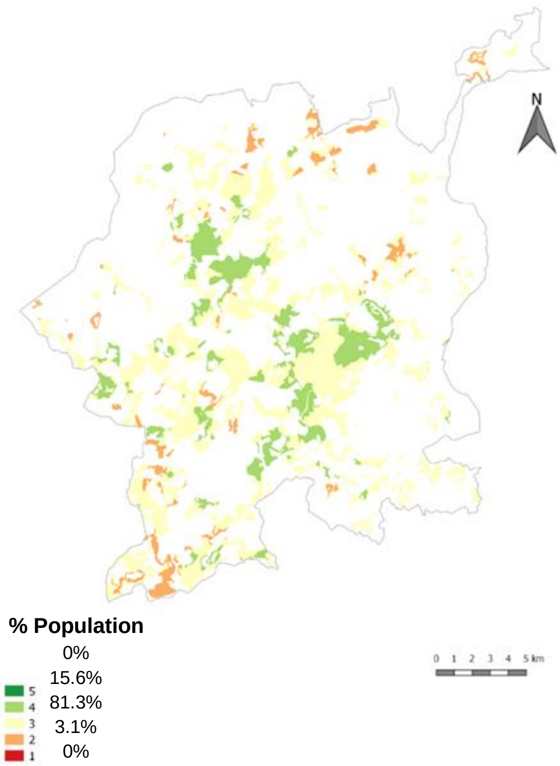


Figure 59 - Aggregated Cycling Potential of the Target Population of Guimarães, plus the respective population percentage covered by each potential.

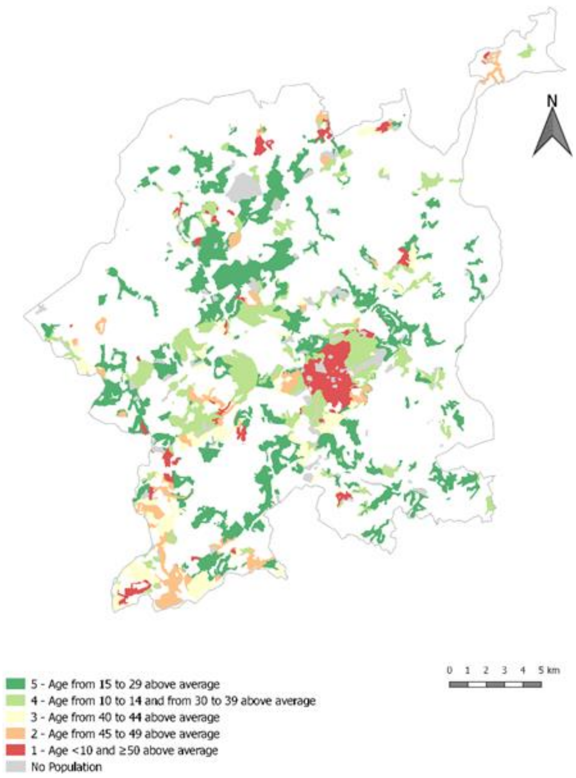


Figure 60 - Cycling Potential according to Age Concentration above Guimarães' Average.

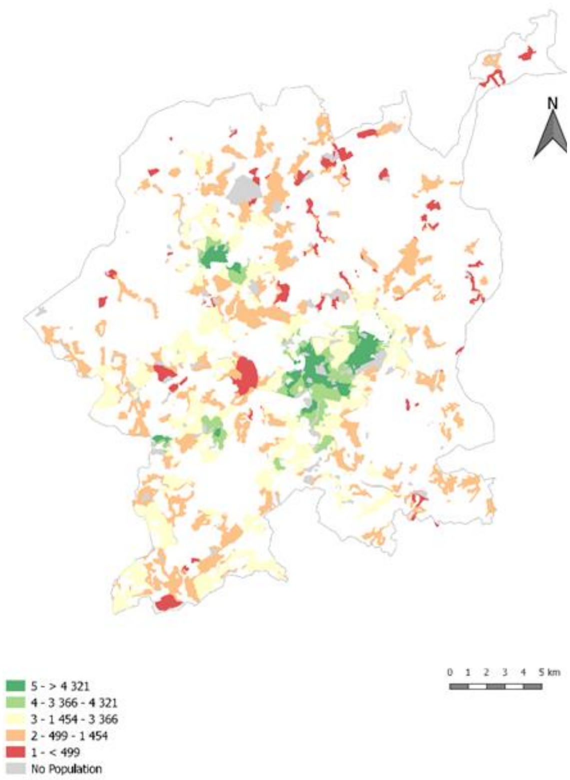


Figure 61 - Cycling Potential according to Guimarães' Population Density.

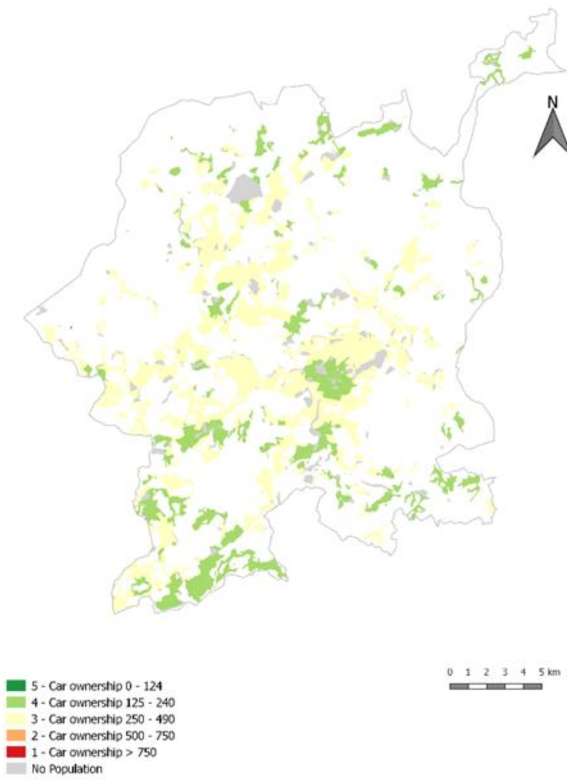


Figure 62 - Cycling Potential according to Guimarães' Car Ownership per 1000 inhabitants.

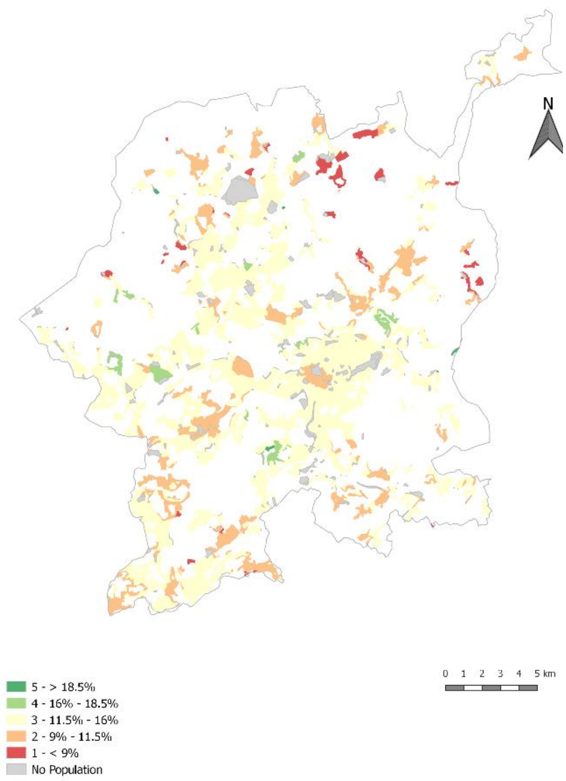


Figure 63 - Cycling Potential according to Guimarães' % of Students in the Resident Population.

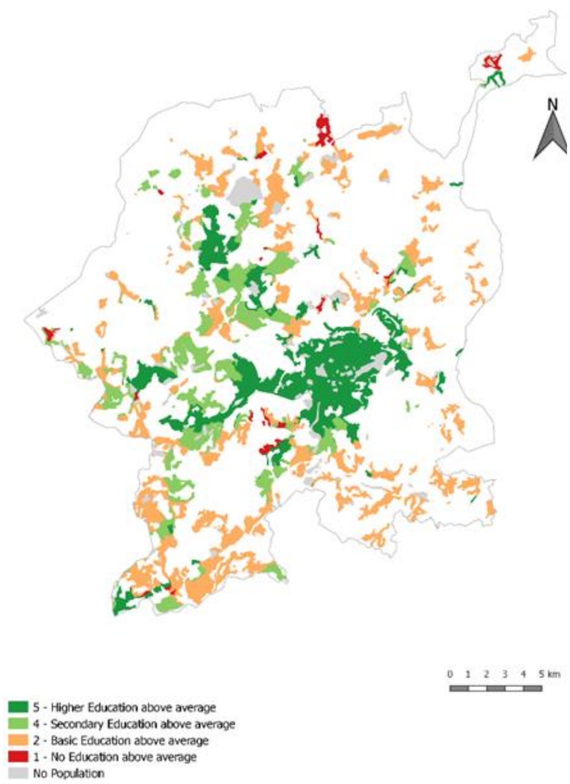


Figure 64 - Cycling Potential according to the Guimarães' Education Level.

Lastly, Table 30 presents the numerical values, on a scale of 1 to 5, for each one of the five indicators evaluated, as well as the aggregated potential for Guimarães.

According to the refereed output, this municipality has a Moderate Potential among its population. The low level within the Population Density plays an important role into the overall cycling potential. Furthermore, despite the high level of young population and education level, the students' presence indicator is the lowest one among the others. Such phenomenon indicates the extent to which the favourable target population is sprawled in the territory.

Table 30 – Cycling Potential (1-5) of Guimarães' Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.3***
Age	3.8
Population Density	3.1
Car ownership	3.3
Students Presence	2.8
Education Level	3.6

5.4.2. Target Areas

With regard to the Target-Areas, Figure 65shows the spatial description of the aggregated cycling potential. The most favourable areas, concerning cycling conditions are represented by potential 5 and potential 4, respectively 2.0% and 5.9%, are located in the central zone of the municipality. As such, most of the municipality present moderate (17.3% at potential 3) to low potential (42.4% at potential 2 and 32.4% at potential 1).

The spatial representation of the five indicators used to build such aggregated map are represented in the following figures: Accessibility to Education Institutions (Figure 66), Accessibility to the City Centres (Figure 67), Accessibility to the Railway Stations (Figure 68) and Coverage Areas of the existent Cycling Infrastructure (Figure 69).

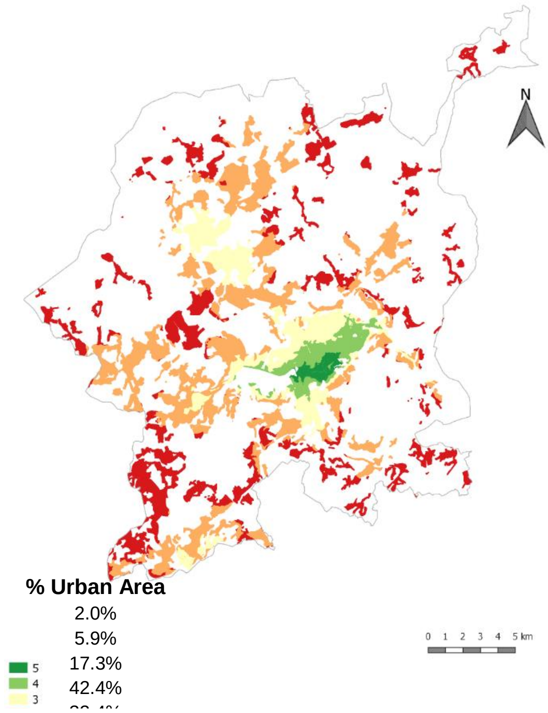


Figure 65 - Aggregated Cycling Potential of the Target-Areas of Guimarães, plus the respective urban area percentage covered by each potential.

Overall, the Target-areas assessment (Figure 65) reveals a higher potential in the central part and in the northwest (Taipas and Pontes zone), justified by the existence of favourable accessibility to education facilities and centres in both cases. Furthermore, in the central area there is cycling infrastructure currently.

As such, although Guimarães has its centralities with high potential for cycling, it also has a much larger urban area with low potential, hindering its cycling potential in a municipality scale.

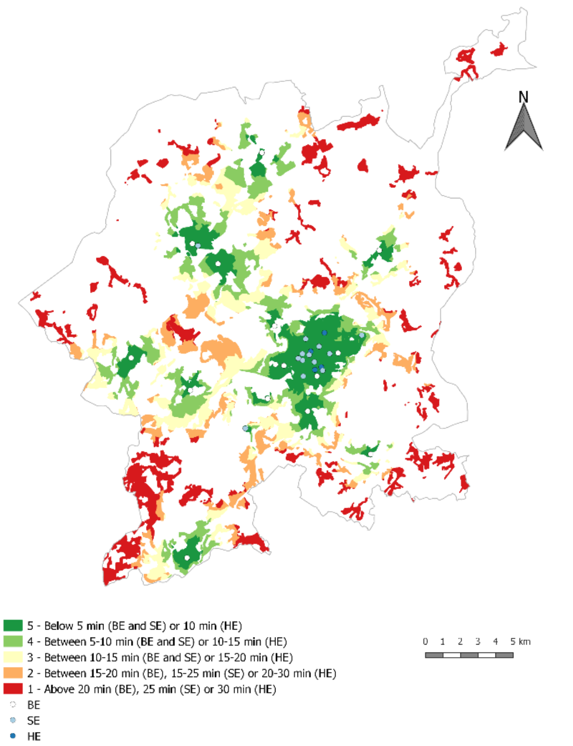


Figure 66 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Guimarães

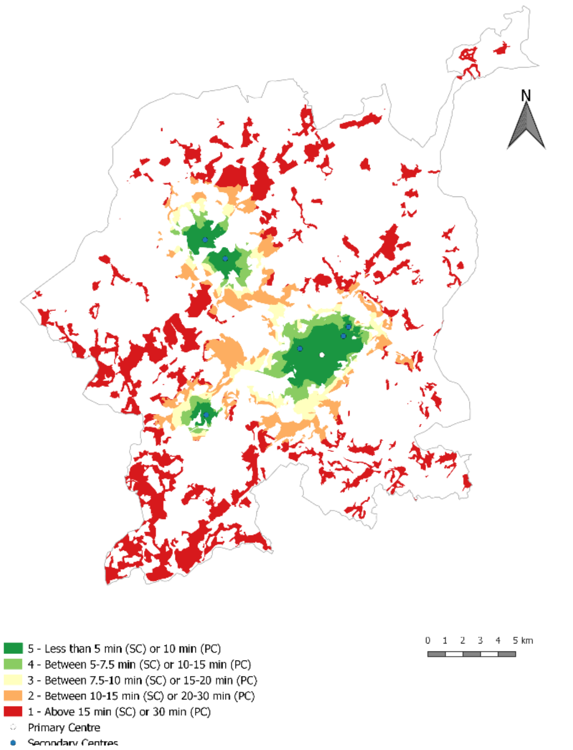


Figure 67 – Cycling Potential according to the Accessibility to City Centres of Guimarães.

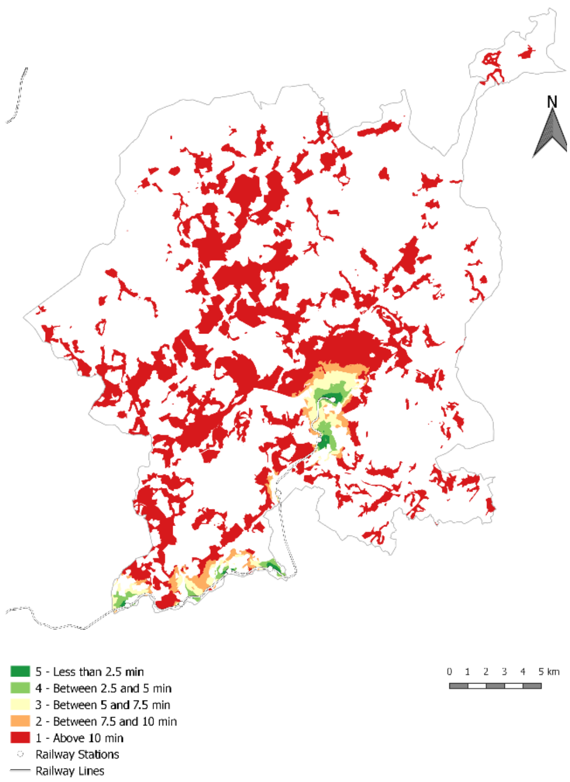


Figure 68 – Cycling Potential according to the Accessibility to Railway Stations of Guimarães.

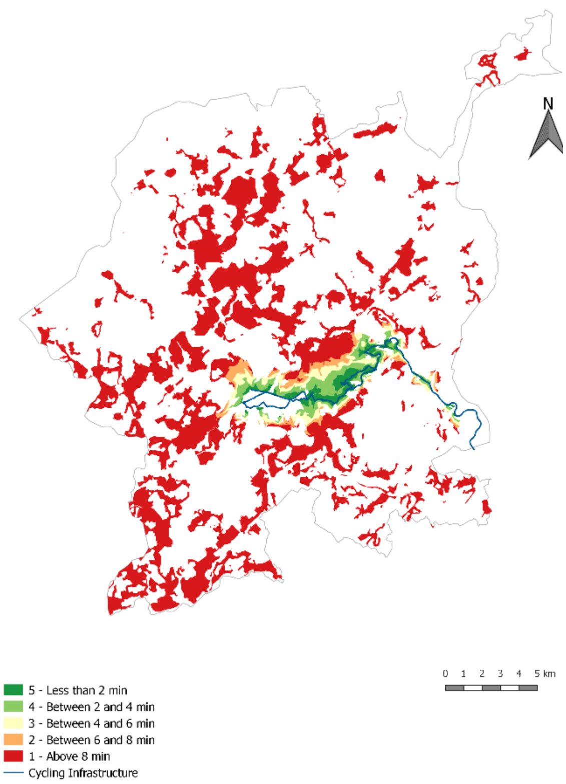


Figure 69 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Guimarães.

Table 31 presents the numerical values of the overall cycling potential of each one of the four factors evaluated, as well as the aggregated potential for the municipality.

Table 31 – Cycling Potential (1-5) of the Guimarães' Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***2.0⁺***
Accessibility to Education Facilities	3.0
Accessibility to the City Centres	2.1
Accessibility to Railway Stations	1.3
Occupation Diversity	-*
Coverage Area for Cycling Infrastructure and for 30 Zones	1.4

Notes:

* No results were produced for these indicators due to lack of data for this municipality.

⁺ The aggregate value was produced disregarding the absent indicators

Such analysis shows Guimarães with a Low cycling potential regarding its Target-areas. Although the municipality has a good accessibility level to Education Facilities, which is one of the indicators with more weight in the final score, it is affected by other indicator with a heavy influence on the final score: the area covered by cycling infrastructure and low speed zones (30zones). In fact, most part of such infrastructure is not located in a favourable zone for promoting daily cycling.

5.4.3. Target-Population & Target-Areas Aggregated Map

The following spatial representation reports the Target-population and Target-areas aggregated map (Figure 70).

Such analysis presents a concentration of population with higher propensity for cycling in two centralities of the municipality (the downtown zone and Taipas and Pontes).

Furthermore, only 26% of the population and 16.1% of the urban area have considerable potential for cycling (potential 4 to 5). Thus, such locations should be considered as good candidates for future cycling related policies.

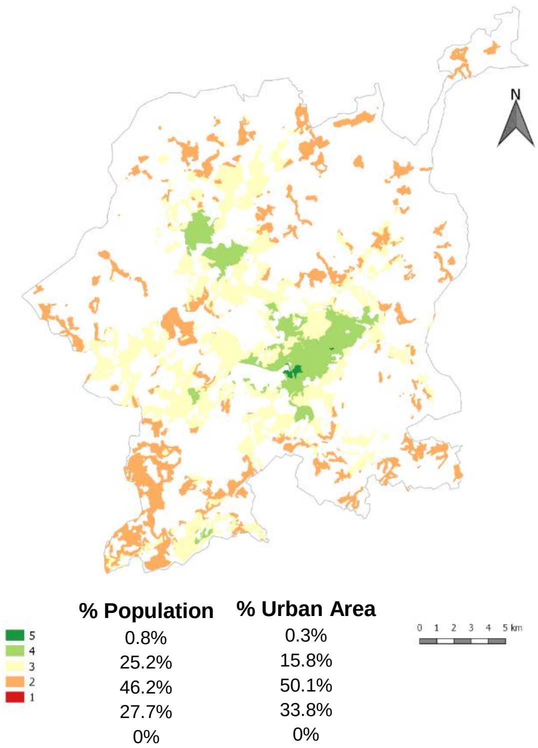


Figure 70 - Aggregated Potential of Guimarães' Target Population and Target Areas.

5.4.4. Political Commitment to Cycling

The Political commitment to cycling of the municipality is represented on Table 32 below.

Table 32 – Cycling Potential (1-5) of Guimarães' cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.3***
Population Coverage by Cycling Infrastructure (8 min)	1.6
Schools covered by Cycling Infrastructure (8 min)	3.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.0
PT stations Coverage by Bicycle Parking	1.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	2.7
Accessible Population by Bicycle (15 min)	3.4
Accessible Area by Bicycle (15 min)	3.1
Relative Accessibility (Bicycle / Car in 5 min)	1.0
Existence of Complementary Measures	3

The effectiveness of cycling policies is considered moderate (2.3) in the case of Guimarães, with 23 km of cycling infrastructure covering 22% of the population and 56% of schools under 8 minutes by bicycle. Every student can access a school by bicycle, with 64% of them living under 5 minutes from a Basic or Secondary School or 10 minutes from a Higher Education Facility, which enables them to use the bicycle as their potential mode of transport.

Overall, the current cycling infrastructure was designed mostly for leisure purposes, it does not provide great accessibility for diverse activities and connectivity with the other modes of transport. Thus, indicators which analyse the coverage of cycling facilities and bicycle parking are reported with a low score.

5.4.5. City Typology

In summary, Guimarães presents a Moderate (B) potential within TP and PCC dimensions and Low (C) in the Target-Areas dimension, translating in a BCB city typology (Figure 67). Although the municipality has some cycling policies implemented and projects under development, its potential is hindered by the leisure-oriented nature of its cycling infrastructure (Table 33) , as well by the low population densities.

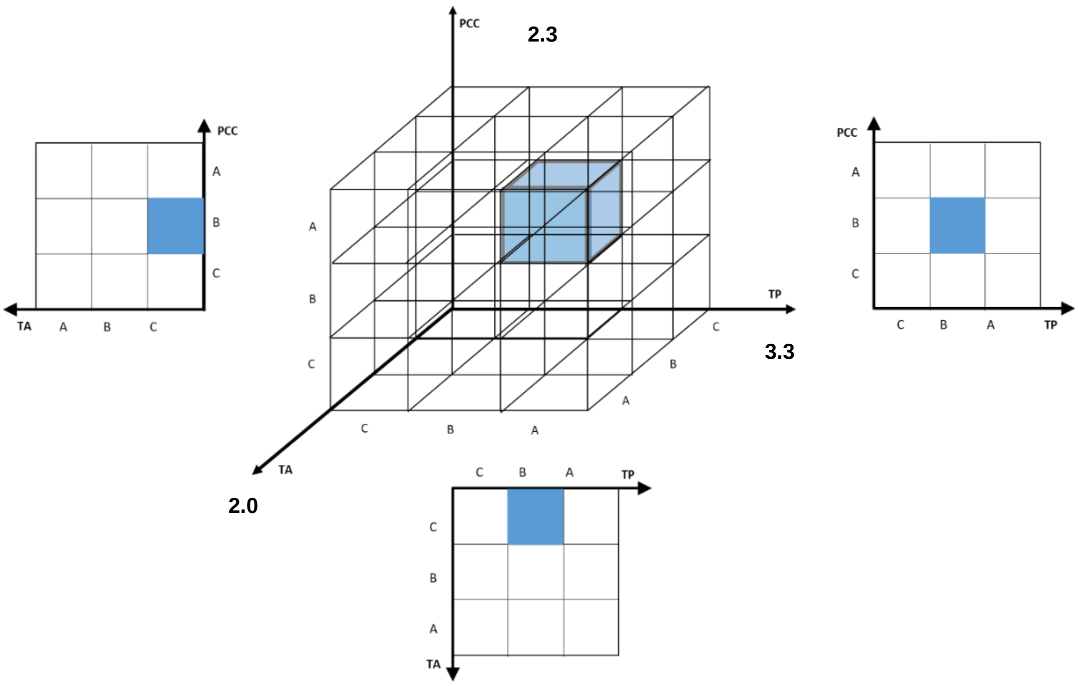


Figure 71 – Representation of the positions of Guimarães in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 33 – Typology of Guimarães and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Guimarães	BCB	3.3	2.0	2.3	23.0

Proposed Scenario

Guimarães is developing some measures intended to increase its commitment towards cycling. Such projects will be evaluated in the next sections, as well as the expected increase of the cycling potential of the city.

5.4.6. Target-Population

There are no changes in the Target Population between the current and the future scenarios, since both are structured upon Census 2011 data collection, as well as due to the unfeasibility of inferring demographic and socioeconomic data for the future to the census track scale.

5.4.7. Target-Areas

Figure 72 shows the current Target-Areas and Figure 73 illustrates the spatial representation of the target areas' aggregated cycling potential for the Proposed Scenario. The assessment of the potential of Target Areas for the proposed Scenario (Figure 73) revealed some improvement of the cycling potential in the municipality mainly due to initiatives regarding cycling infrastructure.

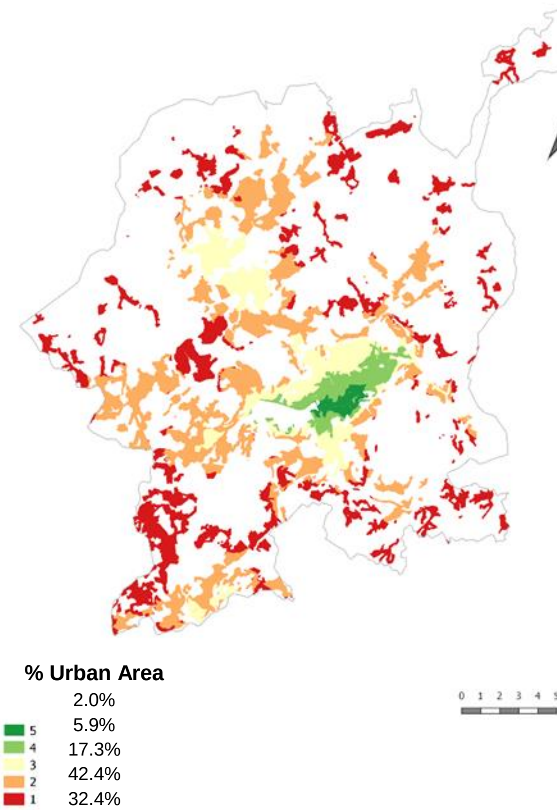


Figure 72 – Aggregated Cycling Potential of the Target-Areas of the Current Scenario for Guimarães, plus the respective urban area percentage covered by each potential.

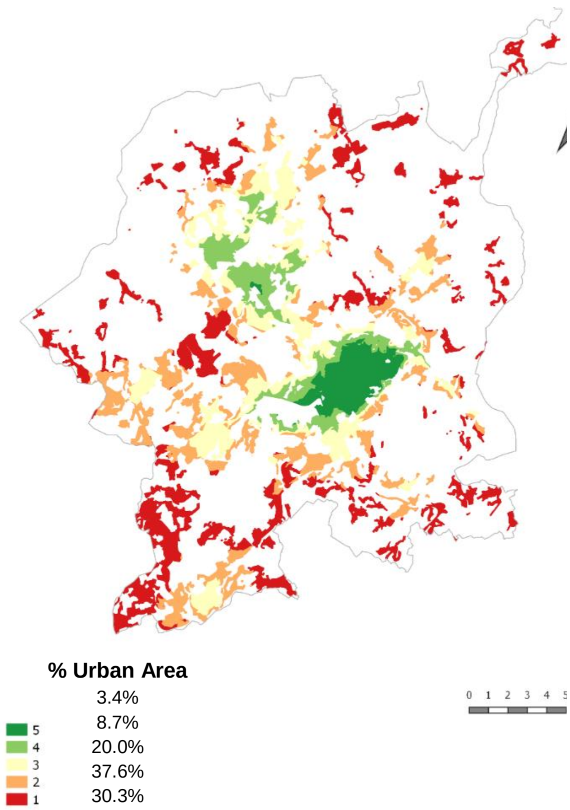


Figure 73 – Aggregated Cycling Potential of the Target-Areas of the Proposed Scenario for Guimarães, plus the respective urban area percentage covered by each potential.

The indicators used to build the previous aggregated map for the proposed scenario are represented in the next figures: Accessibility to Education institutions (Figure 74), Accessibility to the City Centres (Figure 75), Accessibility to the Railway Stations (Figure 76) and Coverage Areas of the existent Cycling Infrastructure (Figure 77).

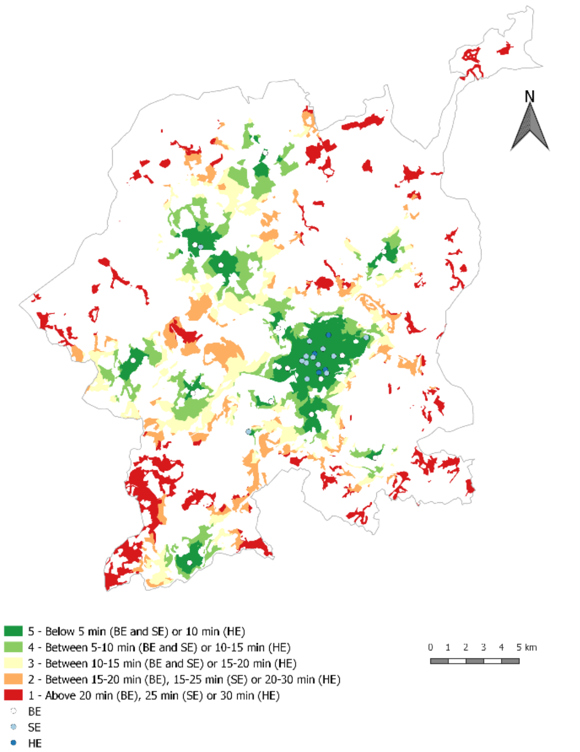


Figure 74 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Guimarães' Proposed Scenario

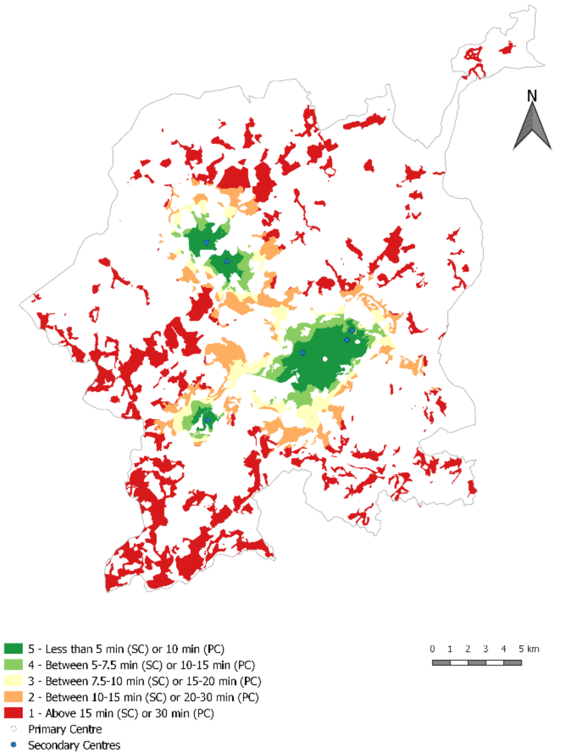


Figure 75 – Cycling Potential according to the Accessibility to City Centres of Guimarães' Proposed Scenario

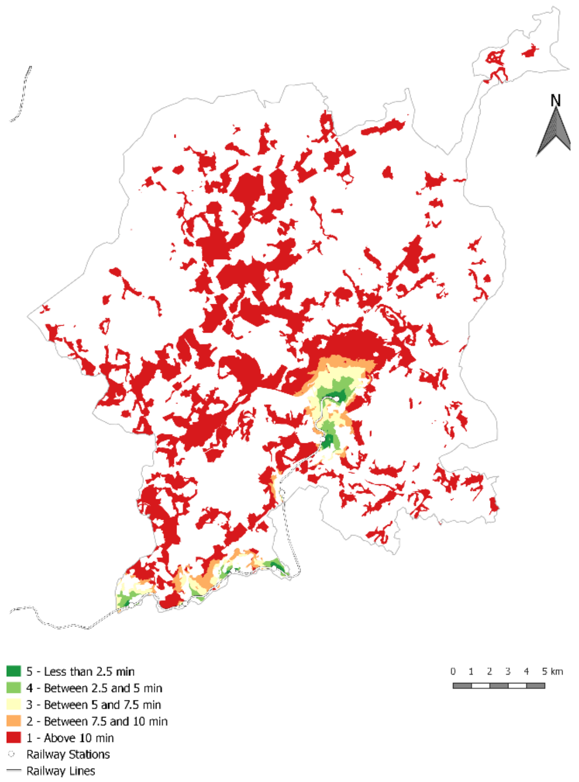


Figure 76 – Cycling Potential according to the Accessibility to Railway Stations of Guimarães' Proposed Scenario.

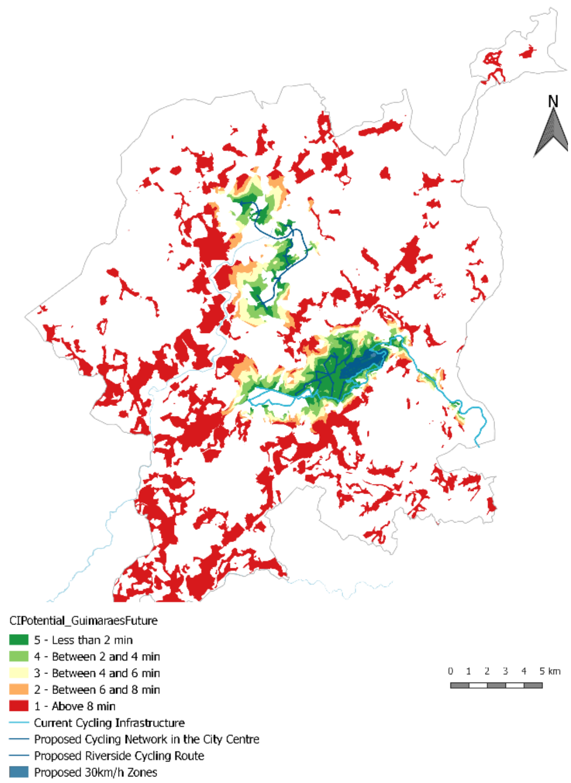


Figure 77 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Guimarães' Proposed Scenario.

Table 34 – Cycling Potential (1-5) of the Guimarães' Target Areas for the Proposed Scenario

Indicators	Overall Cycling Potential
Target-Areas	***2.2***
Accessibility to Education Facilities	3.0
Accessibility to the City Centres	2.1
Accessibility to Railway Stations	1.3
Occupation Diversity	x
Coverage Area for Cycling Infrastructure and for 30 Zones	1.8

The numerical analysis of Table 34 present the improvement in each indicator. In the Proposed Scenario, Guimarães remains with the low potential, within its Target-Area dimension, showing an improvement from 2.0 to 2.2 after implementation of the referred measures.

5.4.8. Target-Population and Target-Areas Aggregated Map

Figure 78 presents the target-population and target-areas aggregated map for the current scenario and Figure 79 for the Proposed Scenarios.

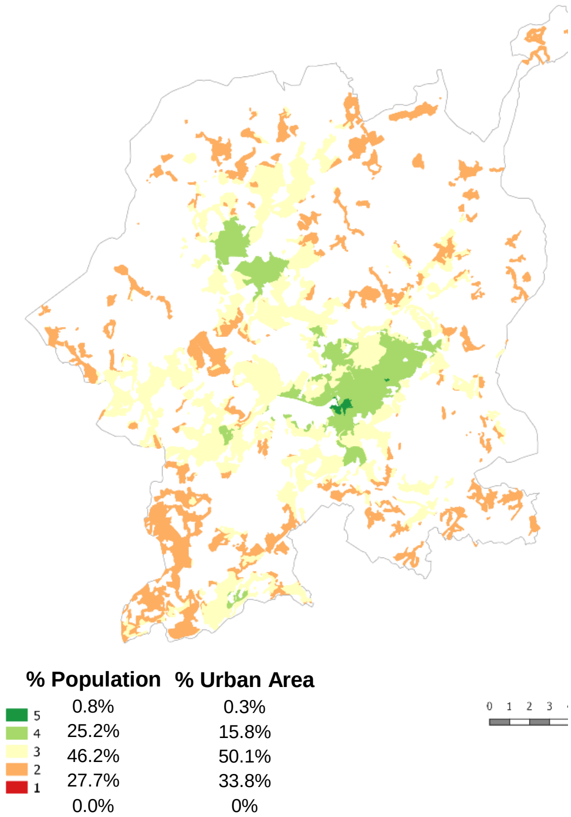


Figure 78 – Aggregated Potential of the Target Population and Target Areas of Guimarães for the Current Scenario.

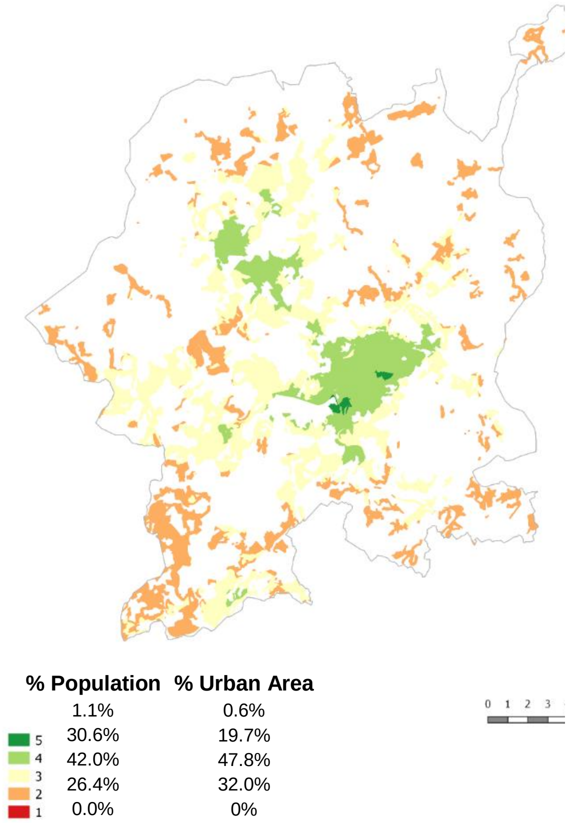


Figure 79 – Aggregated Potential of the Target Population and Target Areas of Guimarães for the Proposed Scenario.

In the future scenario, it is noticeable some improvement regarding the share of population and urban are covered by potential 4 or above. In the former there is an increase of 5.1%, and in the latter, 4.2%. Such enhancement is noticed mainly in the central part of the municipality.

5.4.9. Political Commitment to cycling

Table 35 presents the municipality's political commitment to cycling under the Proposed Scenario.

Table 35 – Cycling Potential (1-5) of Guimarães' cycling policies for the Proposed Scenario.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.6***
Population Coverage by Cycling Infrastructure (8 min)	2.0
Schools covered by Cycling Infrastructure (8 min)	4.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.0
PT stations Coverage by Bicycle Parking	1.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	2.7
Accessible Population by Bicycle (15 min)	3.4
Accessible Area by Bicycle (15 min)	3.2
Relative Accessibility (Bicycle / Car in 5 min)	1.0
Existence of Complementary Measures	4

The Political Commitment to cycling shows a value of 2.6 for the proposed scenario, in comparison with 2.3 for the current scenario. This value is mostly justified by the increase of cycling routes, that affect the population covered by it and the accessibility to some of the city facilities.

Regarding the new network, the extension of 60 km of cycling infrastructure will cover 35% of the population and 65% of schools under 8 minutes by bicycle. The lack of measures targeting the general improvement of bicycle parking, as well as along railway stations (that we were aware of), reduced the likelihood of more positive outcome in such dimension.

Finally, in this municipality it is expected some cycling policies and measures intended to improve the bicycle as a mode of transport, counting 4 mains measures:

- Promotion Campaigns;
- Integration with public transport;
- Traffic calming;
- Bike-Sharing system;

In the case of promotion campaigns, attention is given to a school mobility project called "EducaBicla", which provides incentives to a share of students towards cycling for commuting purposes. Regarding the integration with public transport, it is expected that train always allow bicycle users, and in the case of bus, foldable bicycles. In the centre of the city, it is projected a coverage area of cycling infrastructure as well as 30 zones. Finally, there is a Bike-sharing system under development for this municipality.

5.4.10. City Typology

The municipality of Guimarães shows a moderated potential on its target-population and political commitment, and low potential for target areas for the scenario proposed, resulting in a BCB city typology (Figure 80 and Table 36). The target area got a 0.2 of increased potential and 0.3 for the political commitment to cycling dimension. This increase is a consequence of the extension of the cycling routes.

Table 36 – Typology of Guimarães based on the current and proposed scenarios, stratified by each dimension score

Municipality	Current Scenario					Proposed Scenario				
		TP	TA	PCC	Cycling Infrastructure		TP	TA	PCC	Cycling Infrastructure
Guimarães	BCB	3.3	2.0	2.3	23.0 km	BCB	3.3	2.2	2.6	64.0 km

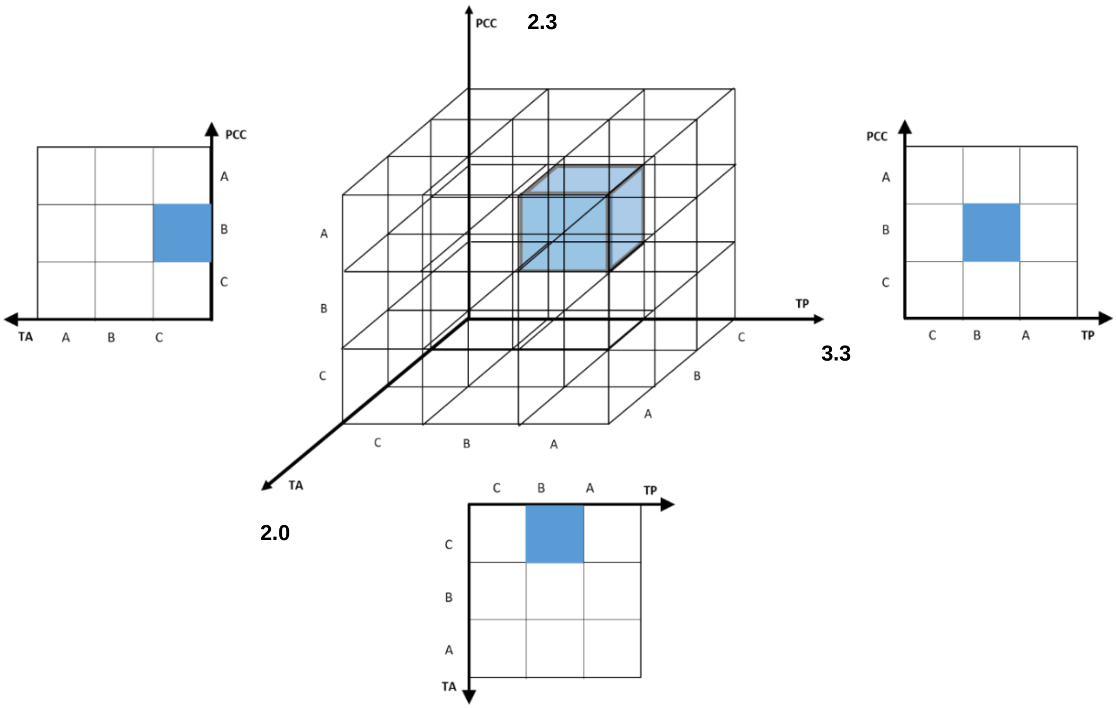


Figure 80 – Representation of the positions of Guimarães' Proposed Scenario in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

5.5. Matosinhos

Current Scenario

5.5.1. Target Population

Figure 81 gives the spatial representation of where the target population with more propensity to cycling is located in Matosinhos.

Regarding the distribution of the cycling potential among the population of Matosinhos (Figure 81), we can see that the southwest has a higher potential, mainly due to the predominance of the population occupation in the southern part of the municipality, particularly near the border with Oporto. In contrast, the northern part of the municipality has a lower cycling potential due to a predominantly mono-functional occupation characterized by low density housing. The percentage of the municipality's population covered by each potential reveals a predominance of potential 4 (46.6%) and 3 (46.6%).

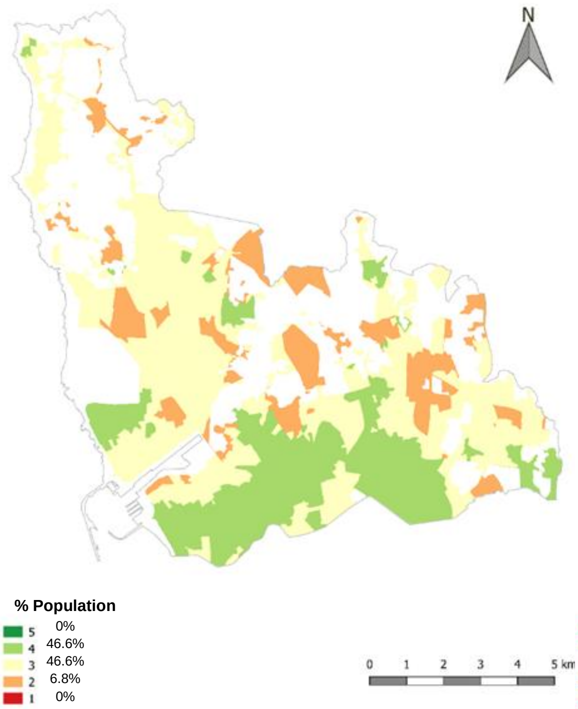


Figure 81 - Aggregated Cycling Potential of the Target Population of Matosinhos, plus the respective population percentage covered by each potential.

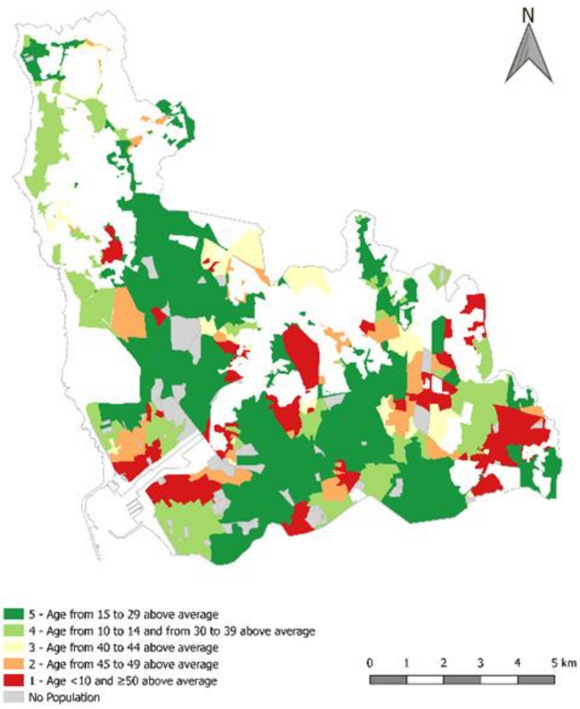


Figure 82 - Cycling Potential according to Age Concentration above Matosinhos' Average.

Additionally, the spatial representation of each one of the five socioeconomic indicators used to assess the target population are represented in the next figures. Firstly, the two indicators with more weight in the target population assessment: Age and Population (and Employment) Density are represented, respectively, in Figure 82 and Figure 83. The remaining figures represent the municipalities' Car Ownership rate (Figure 84), the percentage of Students among the population (Figure 85) and the Education Level (Figure 86). The first finding is the positive correlation between the population with a higher propensity for cycling and the areas with higher population and employment densities (Figure 83) as well as the areas where younger ages (15-29) are above average (Figure 82), which was expected as these two indicators have more weight in the aggregated result. The remaining indicators have a more limited impact.

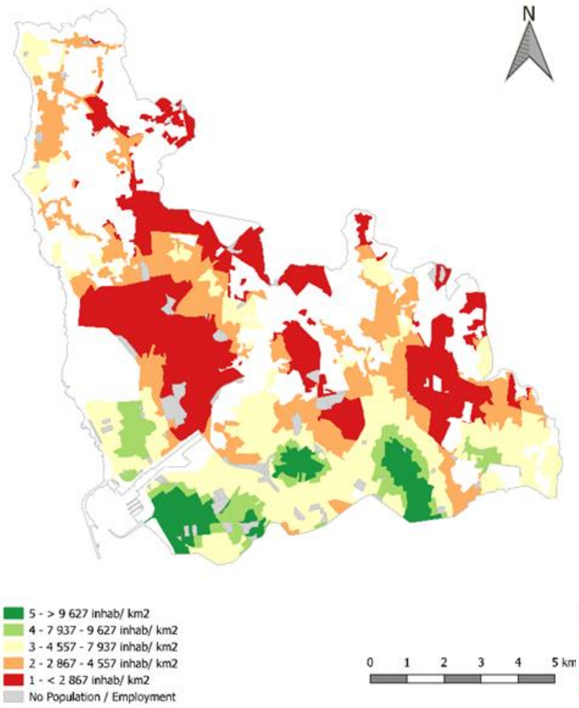


Figure 83 - Cycling Potential according to Matosinhos' Population and Employment Density.

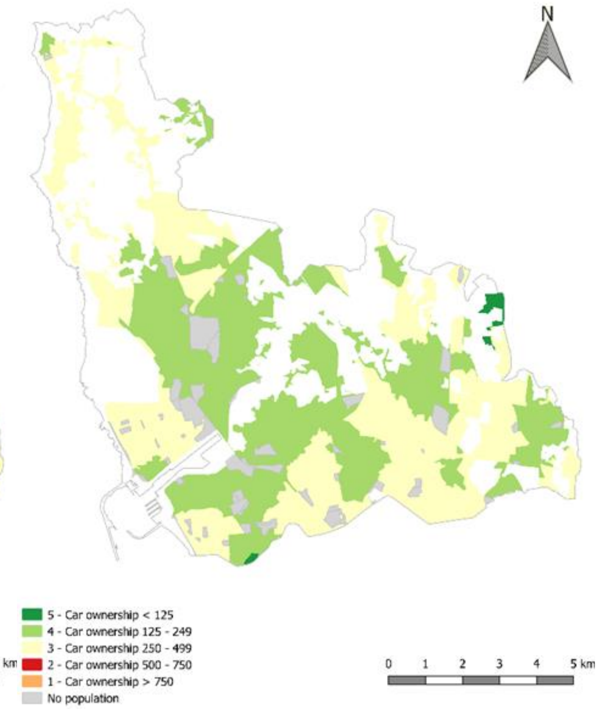


Figure 84 - Cycling Potential according to Matosinhos' Car Ownership per 1000 inhabitants.

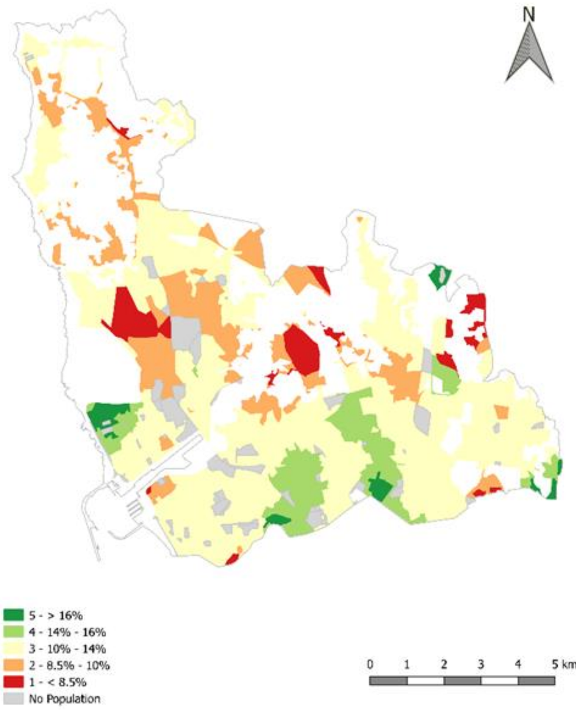


Figure 85 - Cycling Potential according to Matosinhos' % of Students in the Resident Population.

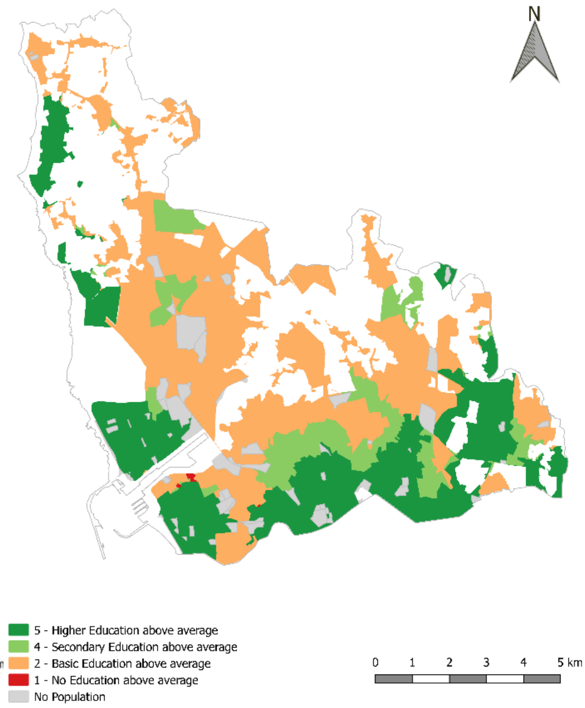


Figure 86 - Cycling Potential according to the Matosinhos' Education Level.

Finally, the numerical values, on a scale of 1 to 5, of the cycling potential for each one of the five indicators evaluated, as well as the aggregated potential for the municipality are represented on Table 37.

The numerical values reinforce the map analysis, revealing that Matosinhos has, according to our classification, a Moderate Potential among its population. Despite having a young population and a high education level, Matosinhos has a lower score on the remainder indicators. This is particularly true regarding the population density (which has a substantial weight on the final aggregated value) with the low density northern part of the municipality hindering the final result.

Table 37 – Cycling Potential (1-5) of Matosinhos' Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.5***
Age	3.9
Population Density	3.4
Car ownership	3.4
Students Presence	3.0
Education Level	3.7

5.5.2. Target Areas

Regarding the target areas, Figure 87 illustrates the spatial representation of their aggregated cycling potential. The spatial representation of the five indicators used to build the previous aggregated map are represented in the figures that follow: Accessibility to Education Institutions (Figure 88), Accessibility to the City Centres (Figure 89), Accessibility to the Railway Stations (Figure 90), Activity Diversity (Figure 91) and Coverage Areas of the existent Cycling Infrastructure (Figure 92).

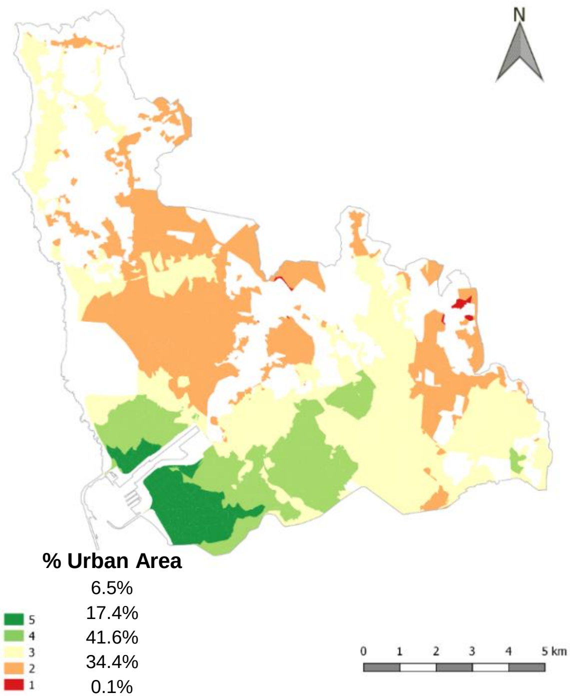


Figure 87 – Aggregated Cycling Potential of the Target-Areas of Matosinhos, plus the respective urban area percentage covered by each potential.

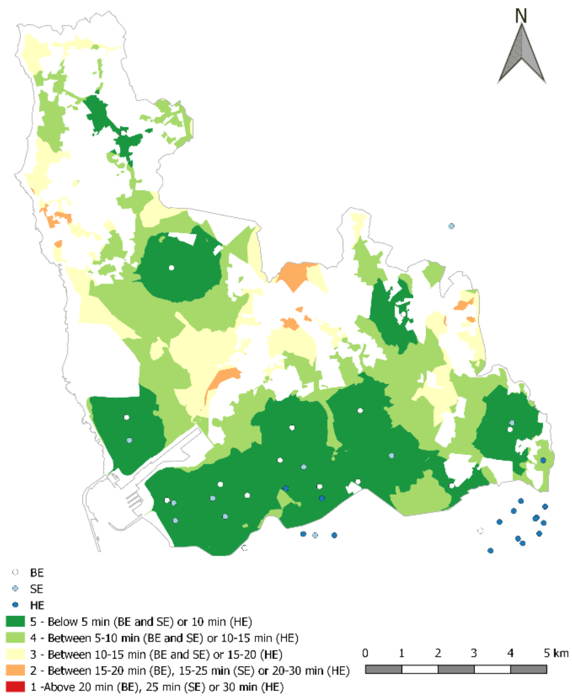


Figure 88 – Cycling Potential according to the Accessibility to Education Institutions of Matosinhos[9].

[9] We also considered some Education Institutions outside Matosinhos due to their proximity to the municipality.

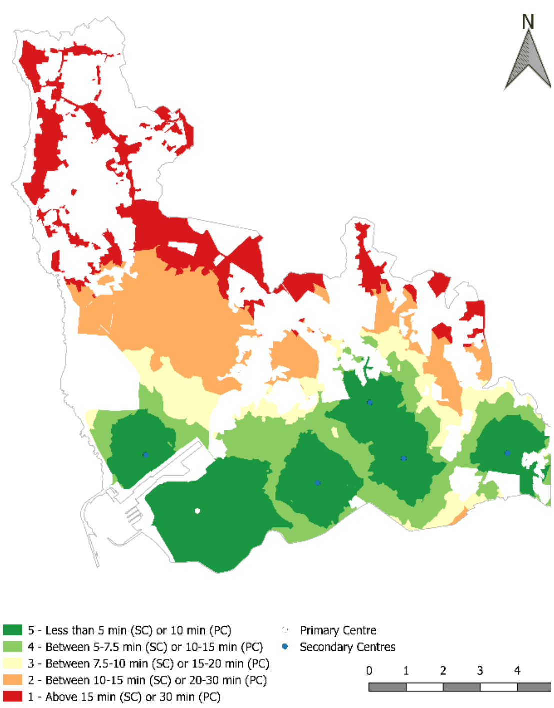


Figure 89 – Cycling Potential according to the Accessibility to City Centres of Matosinhos

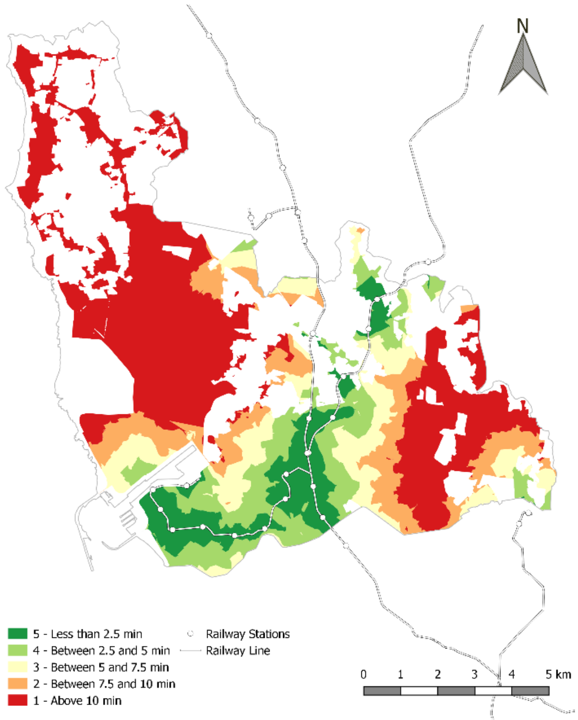


Figure 90 – Cycling Potential according to the Accessibility to Railway Stations of Matosinhos.

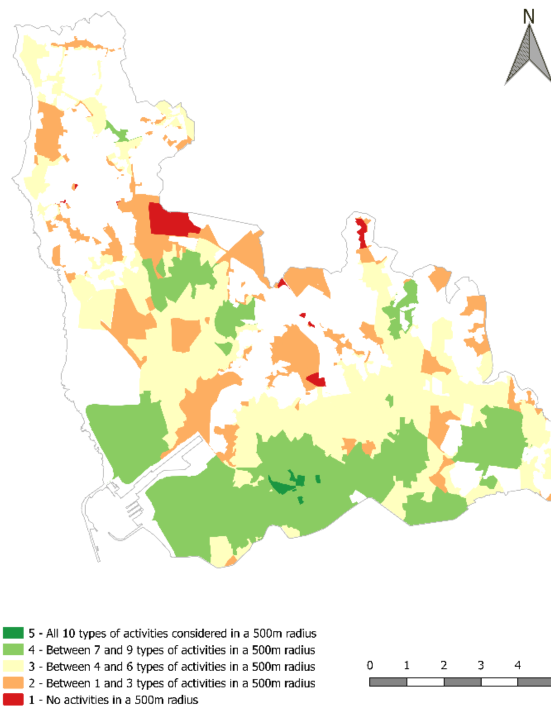


Figure 91 – Cycling Potential according to Activity Diversity in Matosinhos.

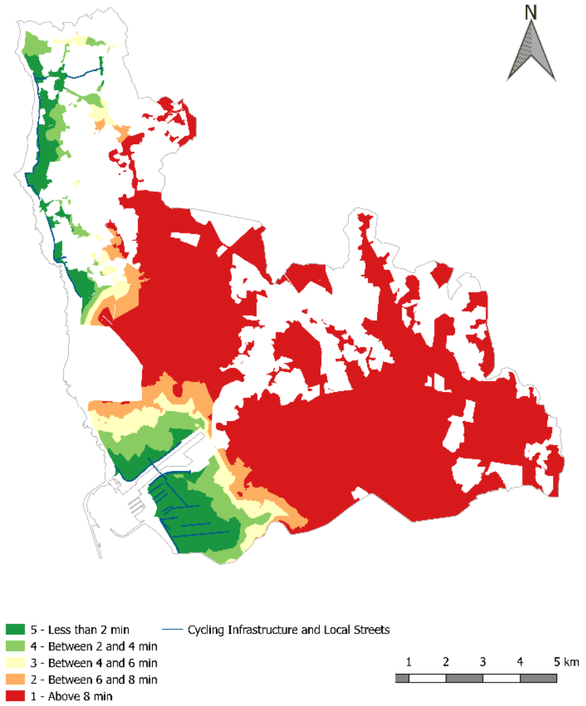


Figure 92 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Matosinhos.

The Target-Areas assessment (Figure 87) reveals that Matosinhos has a higher potential in its south-western part, specially near the harbour and its centres, justified by the existence of cycling infrastructure (Figure 92) and metro stations (Figure 90) in the vicinities, as well as a wide diversity of available activities (Figure 91) and education institutions (Figure 88). In contrast, the northern part of the municipality does not have this kind of activity diversity, and moreover has a deficit on public transport coverage, with no metro lines available.

As such, although Matosinhos has some areas with the highest potential (6.5% at potential 5), it also has a much larger urban area with low potential (34.5% at potentials 1 and 2), thwarting its cycling potential in a municipality scale.

This finding is reinforced by the numerical analysis represented in Table 38, which presents the numerical values of the overall cycling potential for each one of the five factors evaluated, as well as the aggregated potential for the municipality.

Table 38 – Cycling Potential (1-5) of the Matosinhos' Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***3.0***
Accessibility to Education Facilities	4.3
Accessibility to the City Centres	3.3
Accessibility to Railway Stations	2.3
Occupation Diversity	3.1
Coverage Area for Cycling Infrastructure and for 30 Zones	1.8

The analysis of the table above shows Matosinhos (3.0) has a Moderate cycling potential in its target-areas. Although the municipality has a good coverage of education facilities (see also Figure 88), which is one of the indicators with more weight in the final score, it fails on the other indicator with more influence on the final score: the area covered by cycling infrastructure and low speed zones (30 Zones). This limited dedicated cycling infrastructure such as bicycle lanes or bicycle paths (Figure 92) hindered the overall cycling potential.

In relation to the rest of the indicators, the Accessibility to Railway Stations score is hindered by the overall lack of rail based public transport in the northern part of the municipality.

5.5.3. Target-Population & Target-Areas Aggregated Map

The last spatial representation consists in the target-population and target-areas aggregated map (Figure 93). The figure shows a clear concentration of population with higher propensity for cycling and areas with good conditions near the city centre, as well as around the port and in the south, near the border with Oporto. Furthermore, 57.4% of the population and 38.1% of the urban area have considerable potential for cycling (potential 4 to 5). As such, these locations should be considered as good candidates for future cycling related policies.

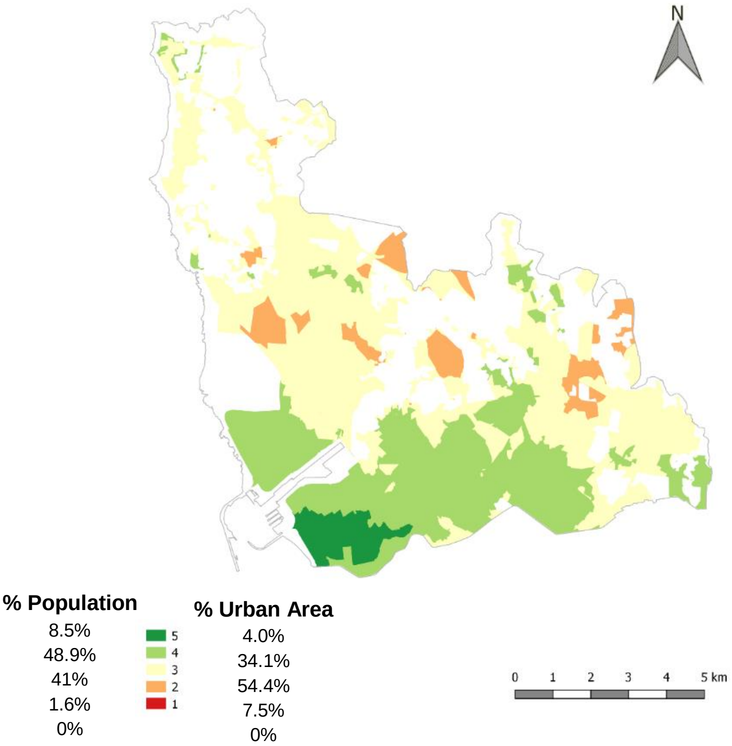


Figure 93 - Aggregated Potential of the Target Population and Target Areas of Matosinhos, plus the respective population and urban area percentage covered by each potential.

5.5.4. Political Commitment to Cycling

The assessment of the political commitment to cycling of the municipality is represented on Table 39. We can see that the overall effectiveness of Matosinhos' cycling policies is Low (2.2). The municipality has a general lack of specific mobility management measures incentivising cycling, namely specific cycling infrastructure such as cycling lanes and low-speed zones, as well as the availability of bicycling parking, particularly near railway stations, which translates on an overall limited performance on almost all of the indicators. The only exception is the accessible student population to school by bicycle with most of the students living near enough their schools, enabling them to use the bicycle as their potential mode of transport.

Table 39 – Cycling Potential (1-5) of Matosinhos' cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.2***
Population Coverage by Cycling Infrastructure (8 min)	2.1
Schools covered by Cycling Infrastructure (8 min)	2.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.1
PT stations Coverage by Bicycle Parking	1.0
Relative Coverage by PT (Cycling/Walking)	3.0
Accessible Student Population to School by Bicycle	4.0
Accessible Population by Bicycle (15 min)	3.3
Accessible Area by Bicycle (15 min)	3.1
Relative Accessibility (Bicycle / Car in 5 min)	2
Existence of Complementary Measures	2

5.5.5. City Typology

Summarizing, Matosinhos has shown to have a moderated potential both on its target-population (B) as well as in its target-areas (B), and a low potential on its cycling policies (C), leading to a BBC city typology (Figure 94 and Table 40). The main factors negatively affecting this municipality's cycling potential are both the existence of low population and density areas especially on its northern part, and an overall limited dedicated cycling infrastructure and promotion measures. Moreover, the existent cycling infrastructure is located near the least densely populated areas and therefore covering a small percentage of its population, being mainly used for recreation purposes and not for transport travelling. The unavailability of bicycling parking particularly near the railway stations also impaired the cycling potential of the municipality, as it limits the ability for intermodality, undermining one of the advantages of cycling that is the increased catchment areas of the public transport stations.

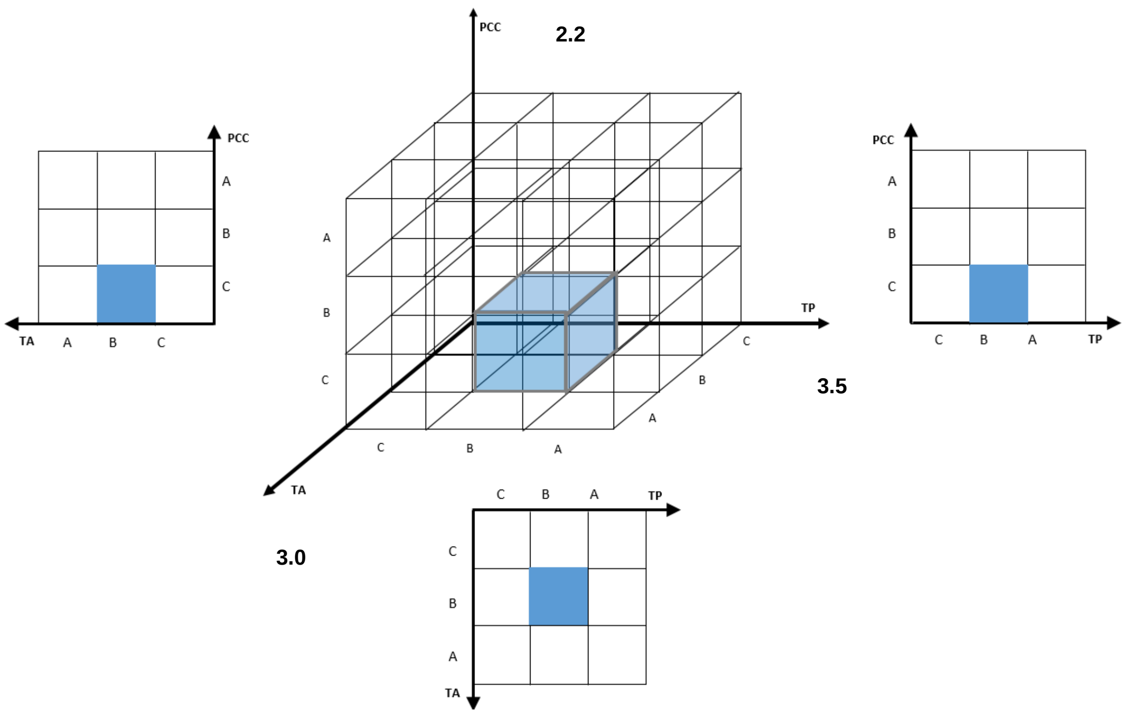


Figure 94 – Representation of the positions of Matosinhos in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 40 – Typology of Matosinhos and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Matosinhos	BBC	3.5	2.0	2.2	20.0

Proposed Scenario

Matosinhos has developed a comprehensive mobility plan for the next twelve years, where cycling as a mode of transport has been given a prominent role. As such, in this section we will evaluation the cycling potential gains if this plan is implemented.

5.5.6. Target Population

Due to the impossibility of extrapolating demographic and socioeconomic data for the future to the census track scale, there are no changes in the Target Population between the current and the future situations (the proposed scenario considers the Census 2011 data as in the current scenario).

5.5.7. Target-Areas

Figure 95 and Figure 96 shows , respectively the current and future spatial representation of the target areas' aggregated cycling potential for the municipality of Matosinhos.

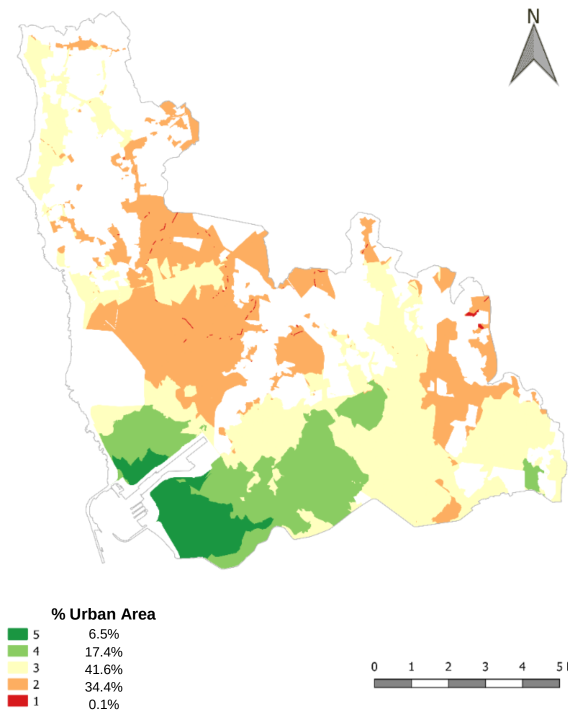


Figure 95 – Aggregated Cycling Potential of the Target-Areas of the Current Scenario for Matosinhos, plus the respective urban area percentage covered by each potential.

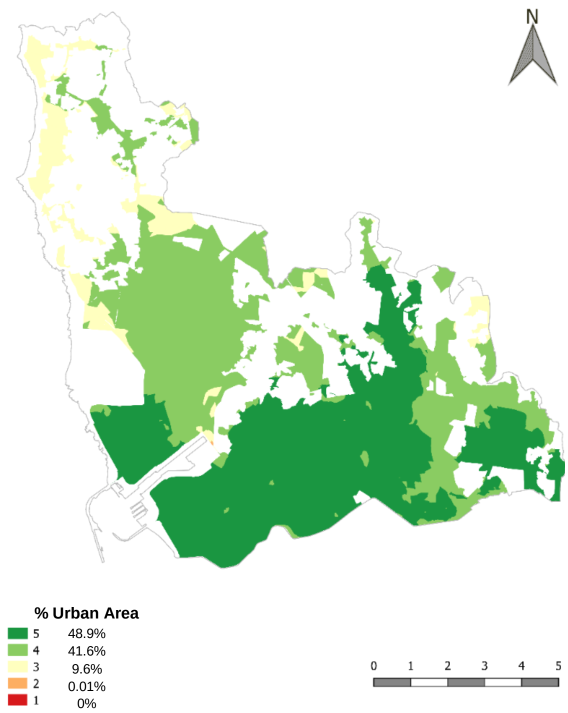


Figure 96 – Aggregated Cycling Potential of the Target-Areas of the Proposed Scenario for Matosinhos, plus the respective urban area percentage covered by each potential.

The indicators used to build the previous aggregated map for the proposed scenario are represented in the next figures: Accessibility to Education Institutions (Figure 97), Accessibility to the City Centres (Figure 98), Accessibility to the Railway Stations (Figure 99) and Coverage Areas of the existent Cycling Infrastructure (Figure 100). The Activity Diversity indicator does not change between scenarios.

The assessment of the Target-Areas potential for the Proposed Scenario (Figure 96) reveals a clear improvement, with most of the municipality's urban area now having the highest potential (90.4% between potential 4 and 5). This improvement is largely justified by the extensive proposed cycling network that will cover virtually all the municipality (Figure 100), increasing from the current 20 km of extension to 143 km (including 30 km/h Zones).

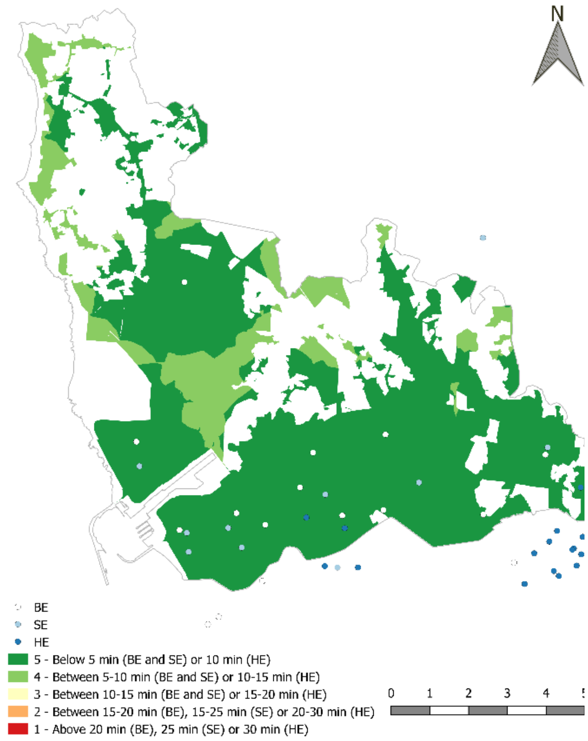


Figure 97 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Matosinhos' Proposed Scenario[10].

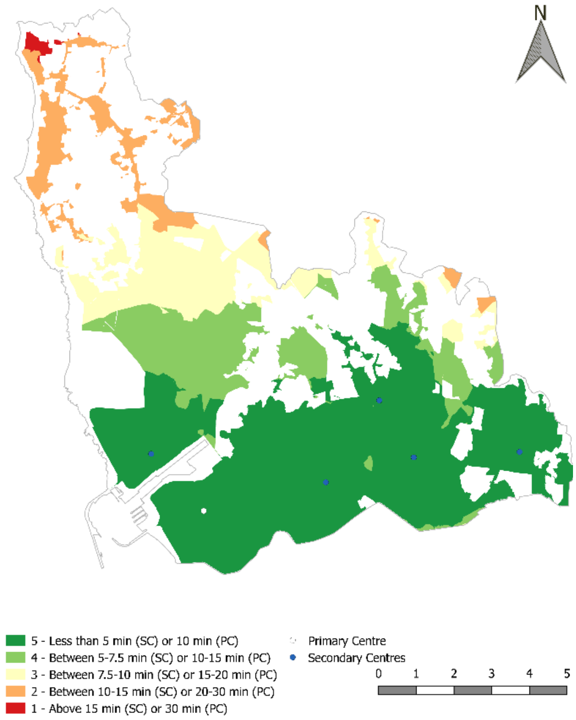


Figure 98 – Cycling Potential according to the Accessibility to City Centres of Matosinhos' Proposed Scenario.

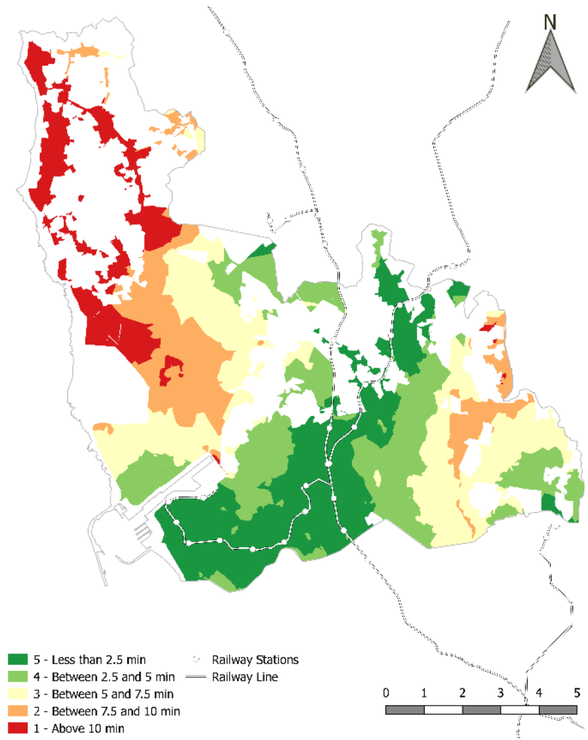


Figure 99 – Cycling Potential according to the Accessibility to Railway Stations of Matosinhos' Proposed Scenario.

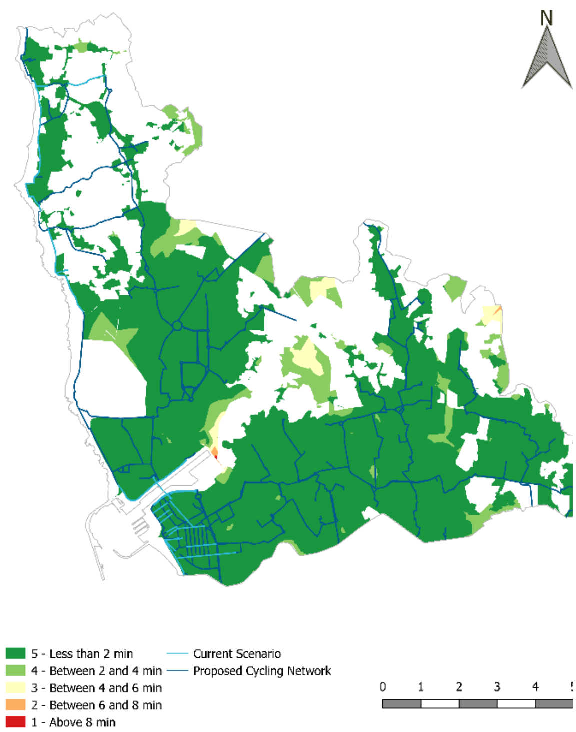


Figure 100 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Matosinhos' Proposed Scenario.

[10] We also considered some Education Institutions outside Matosinhos due to their proximity to the municipality.

The numerical analysis (Table 41) further illustrates the improvements.

Table 41 – Cycling Potential (1-5) of the Matosinhos' Target Areas for the Proposed Scenario.

Indicators	Overall Cycling Potential
Target-Areas	***4.4***
Accessibility to Education Facilities	4.8
Accessibility to the City Centres	4.2
Accessibility to Railway Stations	3.4
Occupation Diversity	3.1
Coverage Area for Cycling Infrastructure and for 30 Zones	4.9

In the Proposed Scenario, Matosinhos now has a High potential on its target-areas, with the biggest improvement being, by far, on its coverage area for cycling infrastructure and for 30 Zones that is now almost at the highest possible score, highlighting this project's ambition.

5.5.8. Target-Population & Target-Areas Aggregated Map

Figure 101 presents the target-population and target-areas aggregated map for the current scenario and Figure 102 for the Proposed Scenarios.

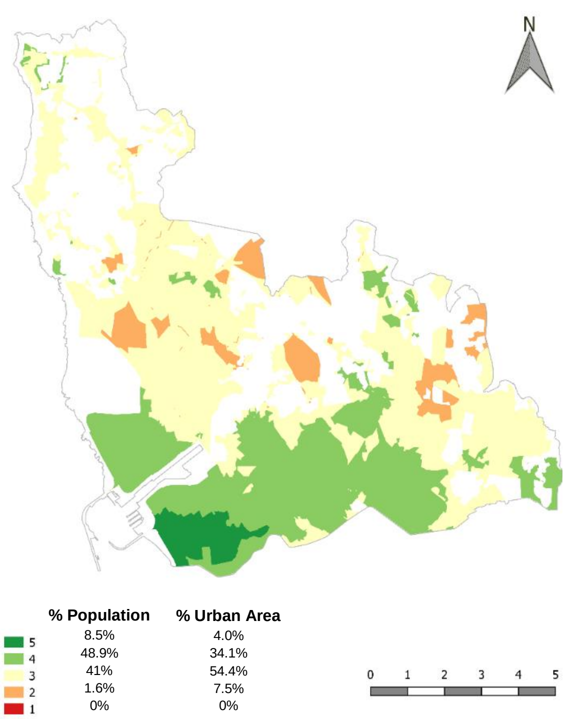


Figure 101 – Aggregated Potential of the Target Population and Target Areas of Matosinhos for the Proposed Scenario, plus the respective population and urban area percentage covered by each potential.

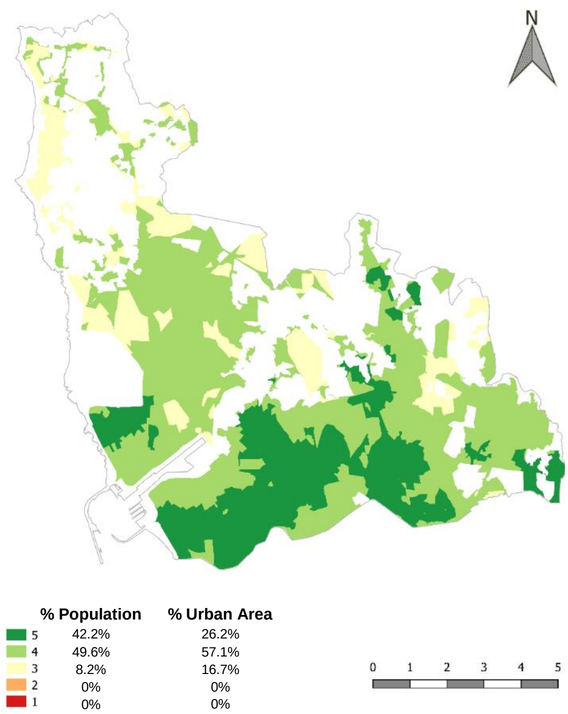


Figure 102 – Aggregated Potential of the Target Population and Target Areas of Matosinhos for the Proposed Scenario, plus the respective population and urban area percentage covered by each potential.

The cycling potential improvement under this Proposed Scenario is evident when analysing Figure 102. Under the Proposed Scenario almost all of Matosinhos' population now reside in areas with a potential for cycling scoring 4 or above (increasing from 57% to 92%). The improvement is also noticeable on the municipality's urban area, which increases from 38% to 83% of the total urban area covered by potential 5 or 4.

5.5.9. Political Commitment to Cycling

The assessment of the municipality's political commitment to cycling under the Proposed Scenario is represented on Table 42.

Table 42 – Cycling Potential (1-5) of Matosinhos' cycling policies for the Proposed Scenario.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***4.3***
Population Coverage by Cycling Infrastructure (8 min)	5.0
Schools covered by Cycling Infrastructure (8 min)	5.0
Network Coverage by Cycling Infrastructure	2.0
Population Coverage by Bicycle Parking	2.8
PT stations Coverage by Bicycle Parking	5.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	4.6
Accessible Population by Bicycle (15 min)	4.8
Accessible Area by Bicycle (15 min)	4.9
Relative Accessibility (Bicycle / Car in 5 min)	3.3
Existence of Complementary Measures	5

The improvement in this dimension is even more remarkable than in the target-areas, with Matosinhos moving to a High Potential on its political commitment to cycling (from a low potential under the current scenario). All the indicators improve, specially the population and school covered by cycling infrastructure which now have the maximum score, meaning all the population and school have cycling infrastructure available at less than 8 min by cycling. Furthermore, all PT stations now have dedicated bicycle parking which also translates in high catchment areas for PT. Finally, the complementary measures also increase for the maximum score due to a proposed comprehensive strategy for all of the municipality entitled "Cidade de Matosinhos Ciclável" with 6 main measures:

- Awareness and dissemination campaigns about the new cycling infrastructure;
- Car free days;
- Bicycle tours, organisation of cycling friendly events;
- Incentive program for the municipality's employees who adopt sustainable modes of transportation;
- Incentive program for the companies who implement sustainable mobility plans;
- School Mobility plans for all the municipality's schools.

5.5.10. City Typology

The City Typology of Matosinhos under the Proposed Scenario and its comparison with the Current Scenario is represented on Figure 103.

According to Table 43, it is noticeable an increase in the values of TA and PCC dimensions, counting 1.4 and 2.1, respectively. As such, Matosinhos proposed a plan that the Political Commitment to Cycling turned from Low to High and the Target-Areas from a Moderate to a High, evolving from a BBC to a BAA classification. This progress is mostly due to the proposed cycling infrastructure, that if implemented would reach virtually all its population and urban area.

Table 43 – Typology of Matosinhos based on the current and proposed scenarios, stratified by each dimension score

Municipality	Current Scenario					Proposed Scenario				
		TP	TA	PCC	Cycling Infrastructure		TP	TA	PCC	Cycling Infrastructure
Matosinhos	BBC	3.5	3.0	2.2	20.0 km	BAA	3.5	4.4	4.3	143.0 km

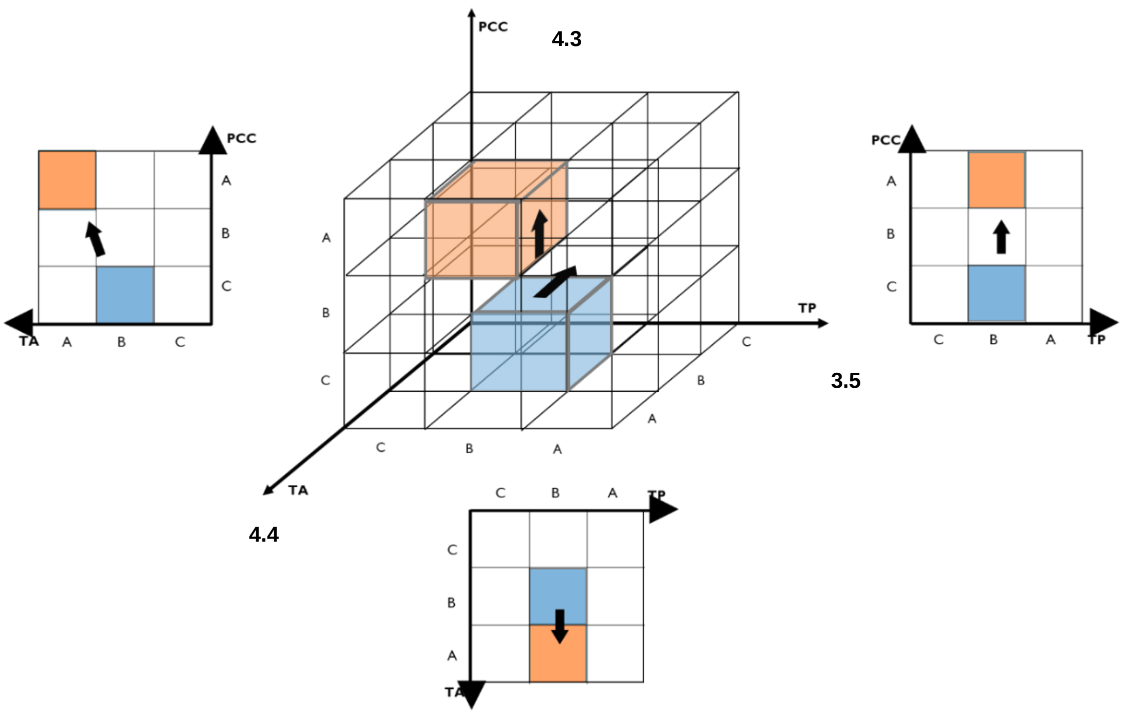


Figure 103 – Representation of the positions of Matosinhos in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low) between the Current (blue) and Proposed (orange) Scenarios.

5.6. Oporto

Current Scenario

Target Population Figure 104 gives the spatial representation of where the target population with more propensity to cycling is located in Oporto. The following figures present the spatial representation of the five socioeconomic indicators within the target population dimension: Age (Figure 105), Population and Employment Density (Figure 106), Car Ownership rate (Figure 107), the percentage of Students among the population (Figure 108) and the Education Level (Figure 109).

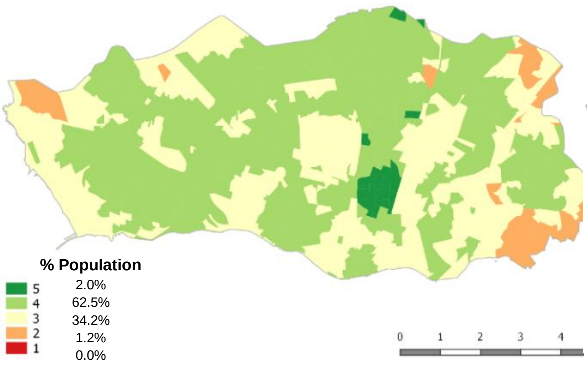


Figure 104 – Aggregated Cycling Potential of the Target Population of Oporto, plus the respective population percentage covered by each potential.

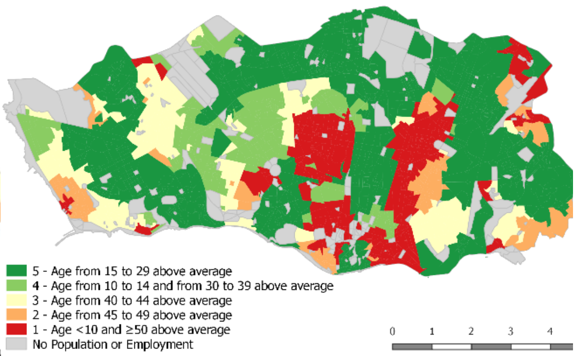


Figure 105 – Cycling Potential according to Age Concentration above Oporto's Average.

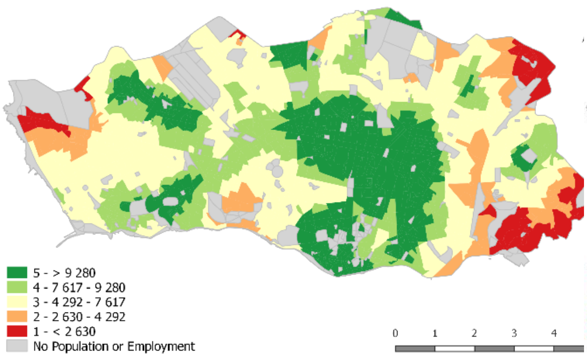


Figure 106 – Cycling Potential according to Oporto's Population and Employment Density.

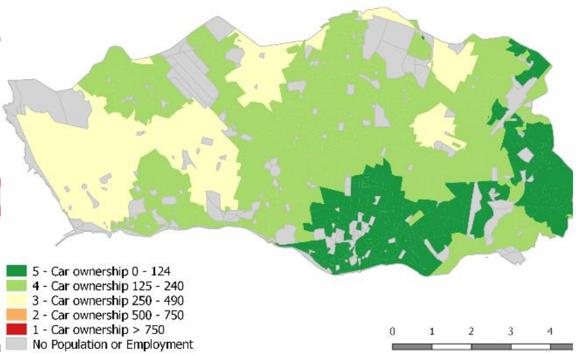


Figure 107 – Cycling Potential according to Oporto's Car Ownership per 1000 inhabitants.

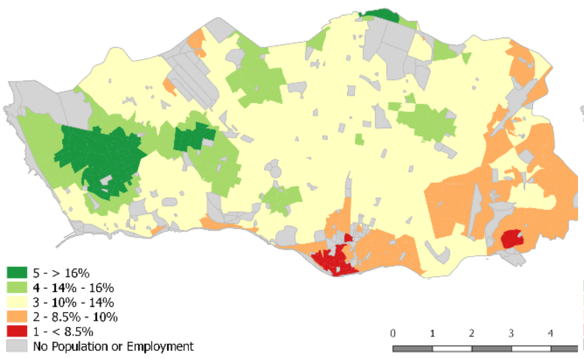


Figure 108 – Cycling Potential according to Oporto's % of Students in the Resident Population.

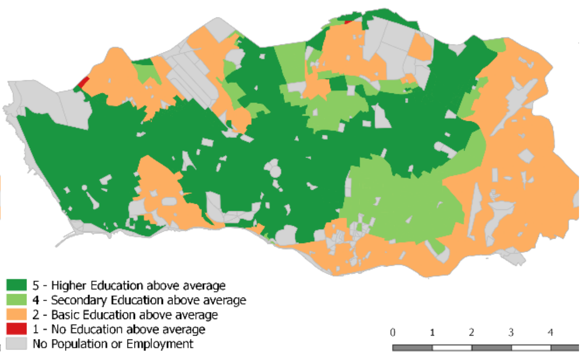


Figure 109 – Cycling Potential according to the Oporto's Education Level.

As we can observe in Figure 104, the potential among the population is relatively distributed across the municipality, with the largest area presenting potential 5 or 4 (64.5%), with a peak near the city centre and a lower potential near the city park (northwest) and in the southeast (Campanhã). These results can be further explained by analysing the specific indicators.

The first finding is the positive correlation between the population with a higher propensity for cycling and the areas with higher population and employment densities (Figure 106) as well as the areas where younger ages (15-29) are above average (Figure 105), which was expected as these two indicators have more weight in the aggregated result. Nevertheless, the remaining indicators, specifically car ownership (Figure 107) and students' density (Figure 108), turned out to be the differential factor that led to the existence of areas with potential 5 in Oporto. Those are the areas where in addition to having very high population densities (Figure 106) and younger ages (Figure 105), also possess either car ownership (Figure 107) or students' density (Figure 108) with the highest potential. Although the city centre has a high concentration of older residents, due to its high population concentration, combining with a higher concentration of students and parking restrictions, translates in a very good potential for cycling.

Table 44 presents the numerical values, on a scale from 1 to 5, for each one of the evaluated indicators, as well as the aggregated potential.

Table 44 – Cycling Potential (1-5) of Oporto's Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.7***
Age	3.7
Population Density	3.8
Car ownership	4.0
Students Presence	3.1
Education Level	3.9

As already shown by the previous map analysis, Oporto has, overall, a population with a high propensity for cycling (3.7). The main factors positively contributing for these results are the high population density and the low car ownership rates. Oporto's compactness (when compared with the other municipalities), effective public transport coverage and parking restrictions justify this result, particularly in the city's centres. Education Level, even though it revealed a high score, had the lowest weight on the calculation of the final Target-Population. Student's presence has the lowest result, which may not be a true representation of reality, because there is a large temporary university students' population that we were not able to include due to lack of data.

5.6.1. Target Areas

Regarding the target areas, Figure 110 shows the spatial representation of the aggregated cycling potential. The following figures present the spatial representation of each one of the target population indicators: Accessibility to Education Institutions (Figure 111), Accessibility to the City Centres (Figure 112), Accessibility to the Railway Stations (Figure 113), Activity Diversity (Figure 114) and Coverage Areas of the existent Cycling Infrastructure (Figure 115).

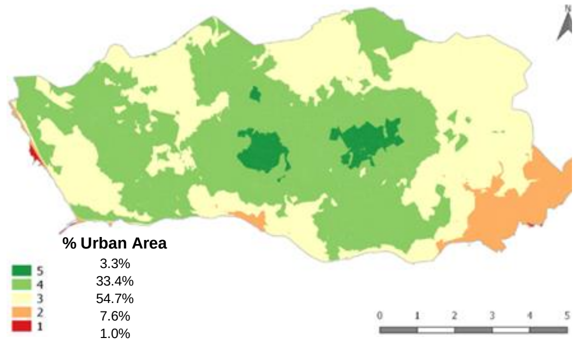


Figure 110 - Aggregated Cycling Potential of the Target-Areas of Oporto, plus the respective urban area percentage covered by each potential.

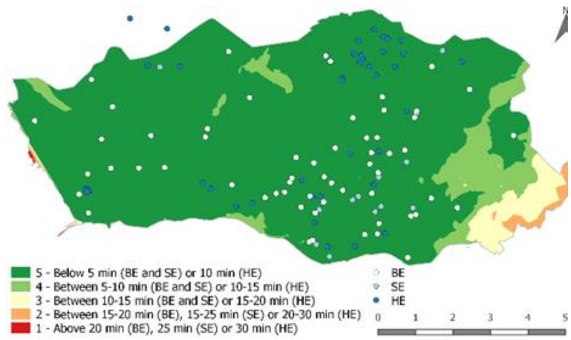


Figure 111 - Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Oporto.

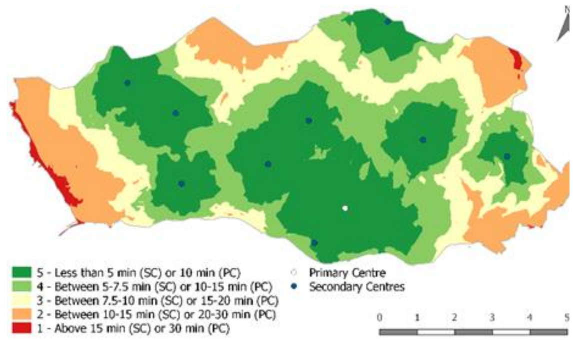


Figure 112 - Cycling Potential according to the Accessibility to City Centres of Oporto.

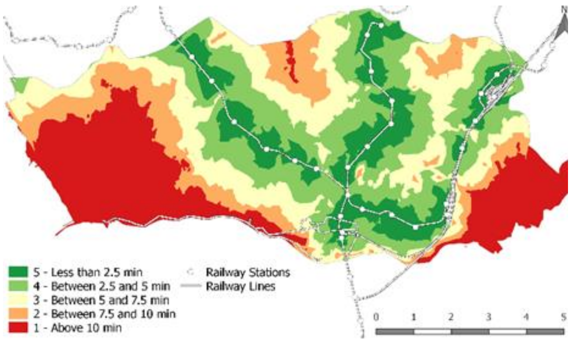


Figure 113 - Cycling Potential according to the Accessibility to Railway Stations of Oporto.

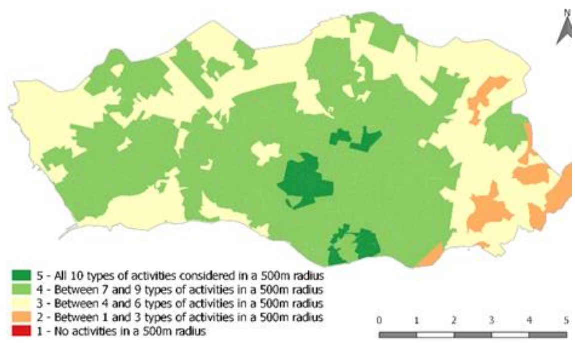


Figure 114 - Cycling Potential according to Activity Diversity in Oporto.

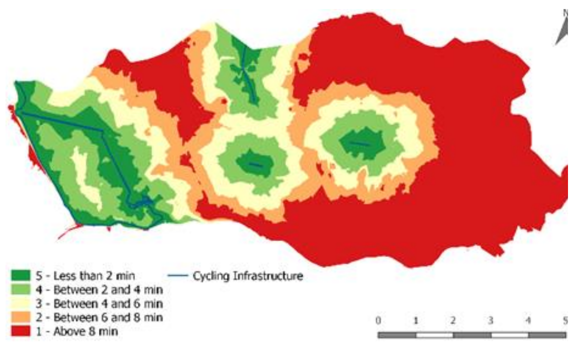


Figure 115 - Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Oporto.

The target-areas assessment of Oporto (Figure 110) reveals that this potential is dispersed, the highest potential is located close the centralities due to the existence of cycling infrastructure (Figure 115) and railway stations (Figure 113), there is also a wide range of activities (Figure 114) and education institutions (Figure 111). Contrary to that, the southeast city area (Campanhã) has the lowest potential as it is one of the poorest areas of Oporto, affected by an overall lack of facilities and services, and also regarding schools.

The overall potential of the Target-Areas seems to be particularly influenced by the location of the cycling infrastructure, which even though small and fragmented still improves accessibility and travel times, factors that are decisive in most of the target-area indicators. The city centre, similarly to the Target-Population, benefits from the extensive public transport network that connects the main centres and by the diversity of activities, which can reach up to ten different activities in a 500 m radius.

These findings are supported by the numerical analysis represented in Table 45, which presents the numerical values of the overall cycling potential for each one of the factors evaluated, as well as the aggregated potential.

Table 45 – Cycling Potential (1-5) of the Oporto's Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***3.3***
Accessibility to Education Facilities	4.8
Accessibility to the City Centres	2.8
Accessibility to Railway Stations	3.0
Occupation Diversity	3.6
Coverage Area for Cycling Infrastructure and for 30 Zones	2.3

The analysis of the table above shows that Oporto's Target-Areas fall into the Moderate category regarding their propensity for cycling. The fact that Oporto has a good coverage of education institutions (see also Figure 111) was not strong enough to increase the potential in comparison with the other indicators, especially the coverage area by cycling infrastructure and low speed zones (30 Zones). This lack of dedicated cycling infrastructure such as bicycle lanes or bicycle paths was expected as Oporto is a Starter Cycling City, therefore hindering the overall cycling potential.

5.6.2. Target-Population & Target-Areas Aggregated Map

The last spatial representation consists in the target-population and target-areas aggregated map (Figure 116).

The figure shows a clear concentration of population with higher propensity for cycling and areas with good conditions near the city centre, as well as other centralities. In fact, 87% of the population live in potential 4 areas or above, representing 75% of the total urban area. For this reason, these locations should be considered as good candidates for future cycling related policies.

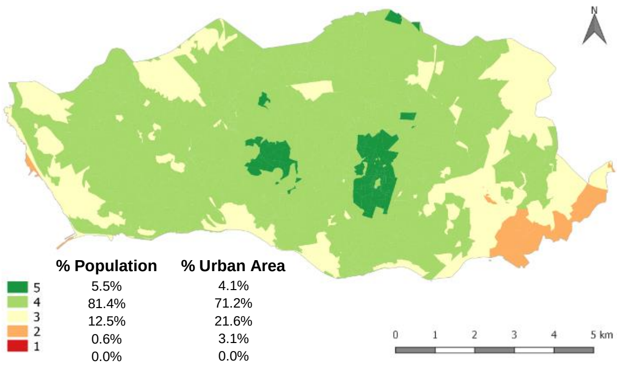


Figure 116 - Aggregated Potential of the Target Population and Target Areas of Oporto, plus the respective population and urban area percentage covered by each potential.

5.6.3. Political Commitment to Cycling

Table 46 presents the assessment of Oporto's political commitment to cycling.

Table 46 – Cycling Potential (1-5) of Oporto's cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.8***
Population Coverage by Cycling Infrastructure (8 min)	2.4
Schools covered by Cycling Infrastructure (8 min)	3.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	1.2
PT stations Coverage by Bicycle Parking	2.0
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	4.8
Accessible Population by Bicycle (15 min)	3.6
Accessible Area by Bicycle (15 min)	3.5
Relative Accessibility (Bicycle / Car in 5 min)	2
Existence of Complementary Measures	2

According to the political commitment to cycling assessment, Oporto's commitment is classified as Moderated (2.8). Its 15.8 km of cycling infrastructure covers 62% of the population and 51% of schools under 8 minutes. It means, every student can access a school by bicycle, and 82% of them lives under 5 minutes from a Basic or Secondary School or 10 minutes from a Higher Education Facility, which enables them to use the bicycle as their main mode of transport.

Although the implemented cycling infrastructure is not very extensive, the fact that Oporto is densely populated improves its influence and effectiveness. However, the cycling potential is hindered by the unavailability of bicycling parking, mostly near the railway stations, as this factor confines the public transport catchment area and the ability for intermodality.

5.6.4. City Typology

Oporto's analysis reveals High Potential for Target-Population (A), and a Moderate Potential (B) both on its Target Areas and Political Commitment to Cycling, leading to an ABB city typology, which is represented in Figure 117 and Table 47.

The higher propensity for cycling on its population is explained by the municipality being densely populated and, as a consequence, also having its (limited) existent cycling infrastructure covering a high percentage of its population, subsequently also rising the target areas and the cycling policies' potential. In fact, the deficiency of cycling infrastructure, like cycling lanes or low-speed zones, was evident, with a residual percentage of their road network being covered by this kind of infrastructure and therefore hindering their overall cycling potential. Thus, the cycling potential can be increased if more dedicated cycling infrastructure is built.

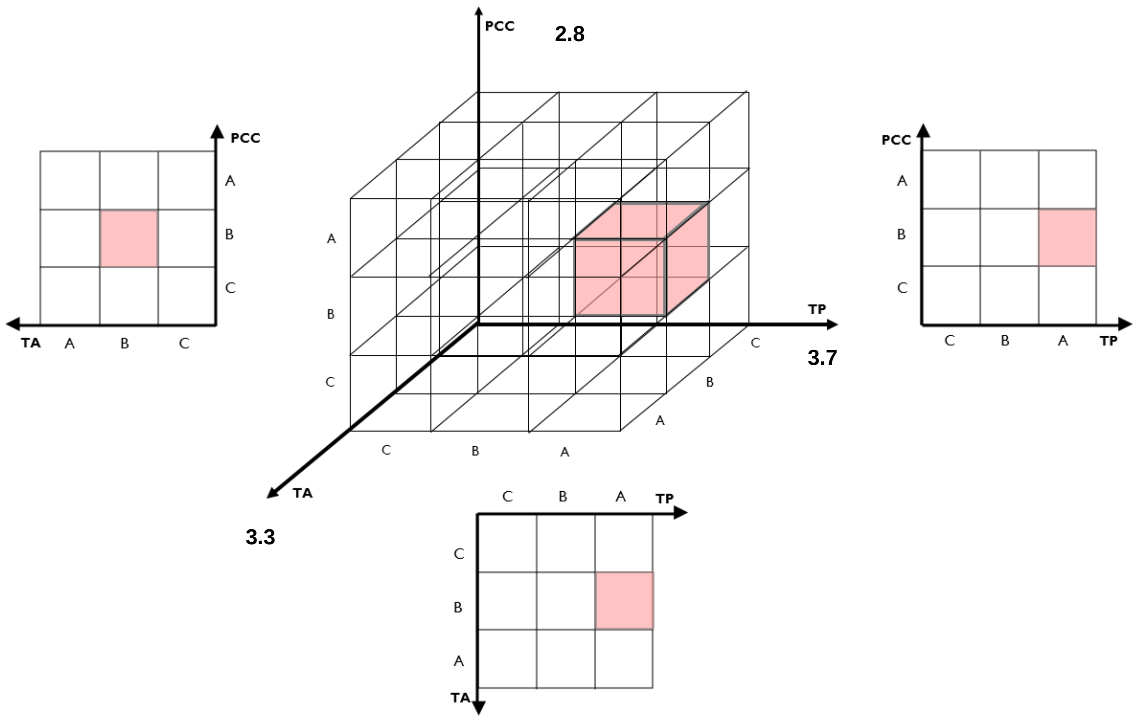


Figure 117 – Representation of the positions of Oporto in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 47 – Typology of Oporto and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
Oporto	ABB	3.7	3.3	2.8	16.0

Proposed Scenario

Oporto has developed several scenarios for implementation of cycling infrastructure in different parts of the city. As such, in this section we will evaluation the expected gains in cycling potential following the implementation of these measures.

5.6.5. Target Population

Similarly, to other municipalities, due to the impossibility of extrapolating demographic and socioeconomic data for the future to the census track scale, there are no changes in the Target Population between the current and the future situations (the proposed scenario considers the Census 2011 data as in the current scenario).

5.6.6. Target-Areas

Figure 118 shows the current Target-Areas and Figure 119 illustrates the spatial representation of the target areas' aggregated cycling potential for the Proposed Scenario.

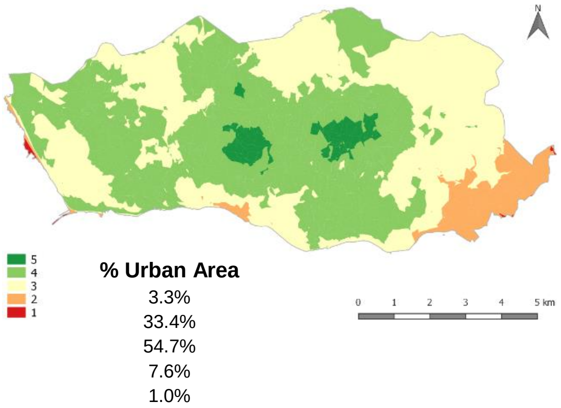


Figure 118 – Aggregated Cycling Potential of the Target-Areas of Oporto, plus the respective urban area percentage covered by each potential.

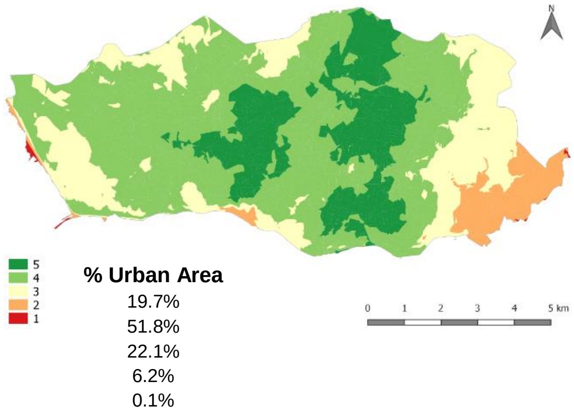


Figure 119 – Aggregated Cycling Potential of the Target-Areas of the Proposed Scenario for Oporto, plus the respective urban area percentage covered by each potential.

The indicators used to build the previous aggregated map for the proposed scenario are represented in the next figures: Accessibility to Education Institutions (Figure 120), Accessibility to the City Centres (Figure 121), Accessibility to the Railway Stations (Figure 122) and Coverage Areas of the existent Cycling Infrastructure (Figure 123). The Activity Diversity indicator does not change between scenarios.

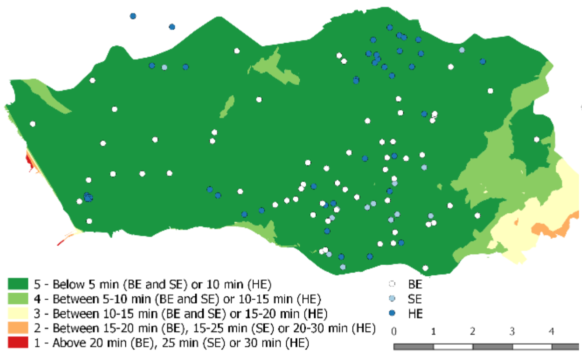


Figure 120 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Oporto's Proposed Scenarios.

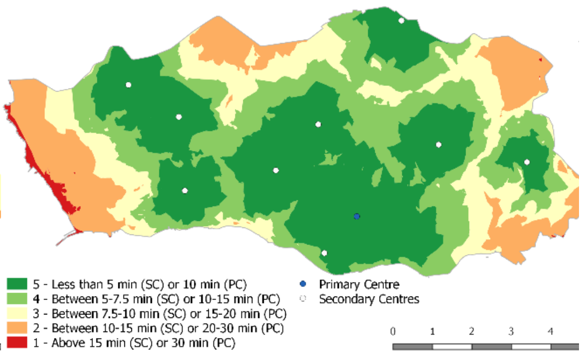


Figure 121 – Cycling Potential according to the Accessibility to City Centres of Oporto's Proposed Scenarios.

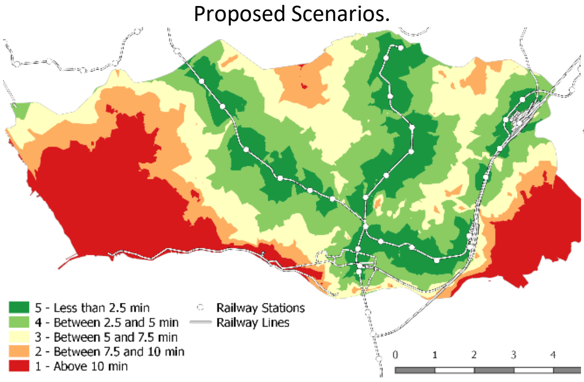


Figure 122 – Cycling Potential according to the Accessibility to Railway Stations of Oporto's Proposed Scenarios.

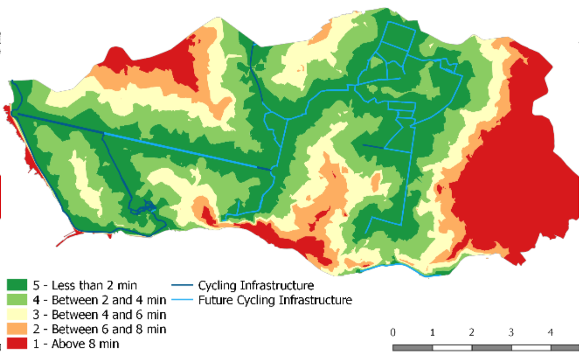


Figure 123 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Oporto's Proposed Scenarios.

The analysis of the Target-Areas potential for the Proposed Scenario (Figure 119) reveals an improvement, with a visible expansion of the areas with higher potential. This improvement is justified by the proposed cycling networks (Figure 123) that will be expanded from 16 km to 48.6 km. The numerical analysis (Table 48) further illustrates these improvements.

Table 48 – Cycling Potential (1-5) of the Oporto's Target Areas for the Proposed Scenarios.

Indicators	Overall Cycling Potential
Target-Areas	***3.8***
Accessibility to Education Facilities	4.8
Accessibility to the City Centres	3.9
Accessibility to Railway Stations	3.0
Occupation Diversity	3.6
Coverage Area for Cycling Infrastructure and for 30 Zones	3.4

With the implementation of the proposed scenarios, Oporto goes from Moderate to High potential on its target-areas, with the biggest improvement being on its coverage area for cycling infrastructure and for 30 Zones.

5.6.7. Target-Population & Target-Areas Aggregated Map

Figure 124 presents the target-population and target-areas aggregated map for the current scenario and Figure 125 for the Proposed Scenarios.

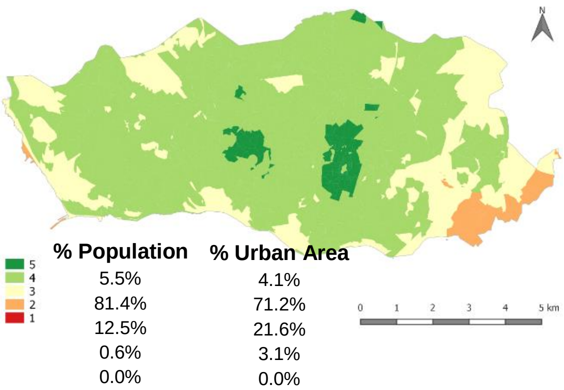


Figure 124 – Aggregated Potential of the Target Population and Target Areas of Oporto.

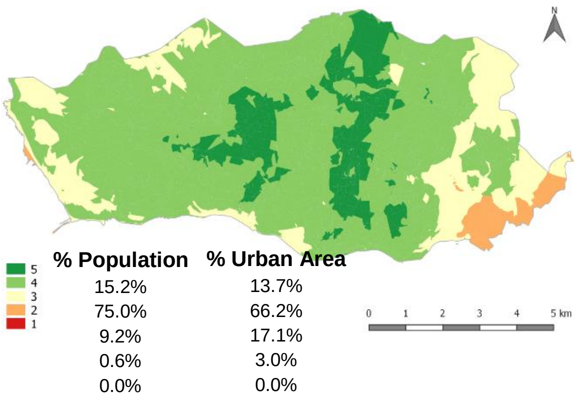


Figure 125 - Aggregated Potential of the Target Population and Target Areas of Oporto for the Proposed Scenario.

The implementation of new Cycling Infrastructure complements and expands the positive potential areas, which are around the main centralities and where the new cycling strategies are focusing. Potential 5 goes from 5.5% to 15.2% regarding population and from 4.1% to 13.7% regarding area.

5.6.8. Political Commitment to Cycling

Oporto' political commitment to cycling under the Proposed Scenario is represented on Table 49.

Table 49 – Cycling Potential (1-5) of Oporto's cycling policies for the Proposed Scenario.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***3.2***
Population Coverage by Cycling Infrastructure (8 min)	3,6
Schools covered by Cycling Infrastructure (8 min)	5,0
Network Coverage by Cycling Infrastructure	1,0
Population Coverage by Bicycle Parking	1,2
PT stations Coverage by Bicycle Parking	2,0
Relative Coverage by PT (Cycling/Walking)	5,0
Accessible Student Population to School by Bicycle	4,8
Accessible Population by Bicycle (15 min)	3,8
Accessible Area by Bicycle (15 min)	3,8
Relative Accessibility (Bicycle / Car in 5 min)	2,1
Existence of Complementary Measures	3

The implementation of a more inclusive cycling infrastructure throughout the municipality allowed an improvement of their political commitment for cycling, since their strategy affects more population and all the schools will be covered by infrastructure, with 82% of students having potential 5 in their accessibility. However, this improvement was not enough to evolve from Moderate to High Potential.

Finally, in this municipality it is expected some cycling policies and measures intended to improve the bicycle as a mode of transport, counting 3 mains measures:

- New cycling infrastructure;
- Traffic calming;
- Bike-sharing pilot within university campus;

In the centre of the city, it is projected an extension of the current cycle path, as well as an integration between bus and cycle lanes. Finally, there is a Bike-sharing system under development and test within the university campus.

5.6.9. City Typology

The City Typology of Oporto for the proposed scenario is represented on Figure 126. According to Table 50, the municipality assessment shows an increase on the target area of 0.5 points. Regarding, the PCC dimension, there is also an increase of 0.4 point. These differences are mainly a result of the increase of population covered by cycling infrastructure, due to the presences of high population density in the municipality.

Table 50 – Typology of Oporto based on the current and proposed scenarios, stratified by each dimension score

Municipality	Current Scenario					Proposed Scenario				
		TP	TA	PCC	Cycling Infrastructure		TP	TA	PCC	Cycling Infrastructure
Oporto	ABB	3.7	3.3	2.8	16.0 km	AAB	3.5	3.8	3.2	48.6 km

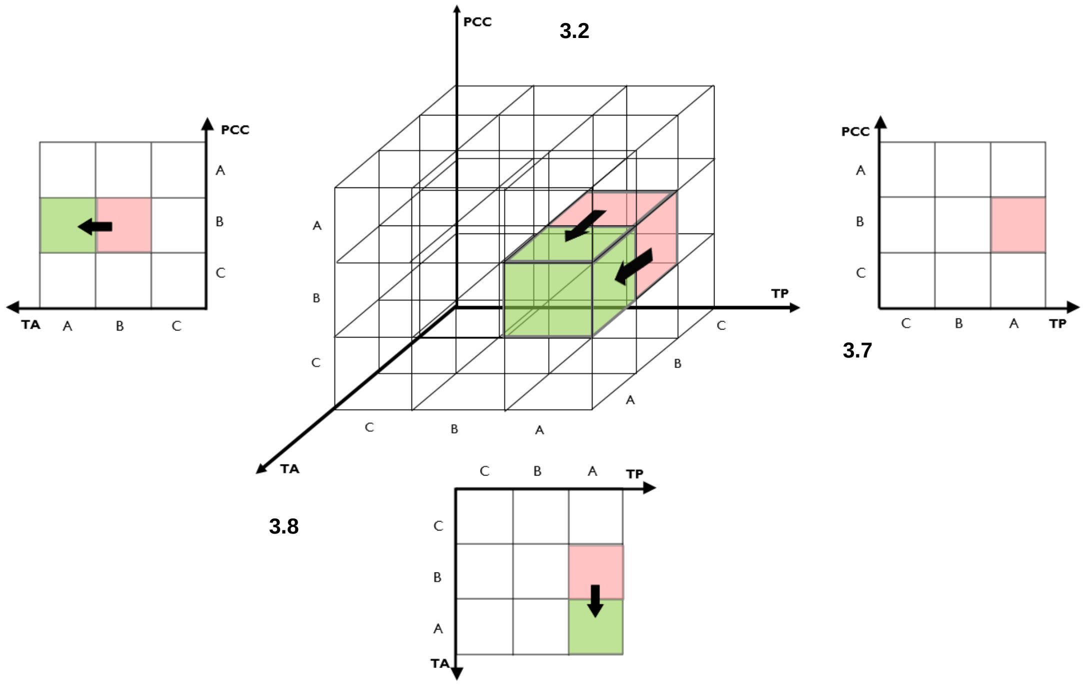


Figure 126 – Representation of the positions of Oporto in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low) between the Current (pink) and Proposed (green) Scenarios.

5.7. Vila Nova de Famalicão

5.7.1. Target Population

Figure 127 gives the spatial representation of where the target population with more propensity to cycling is located in VN Famalicão. The following figures present the five socioeconomic indicators used to assess the target population: Figure 128 represents Age, Population Density is represented in Figure 129, while Car Ownership is represented in Figure 130. Finally, Figure 131 and Figure 132 represent, respectively, the percentage of Students among the population and the Education Level.

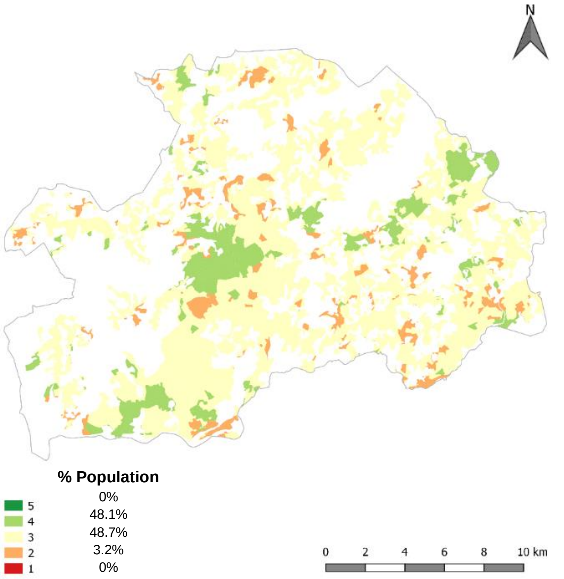


Figure 127 – Aggregated Cycling Potential of the Target Population of VN Famalicão, plus the respective population percentage covered by each potential.

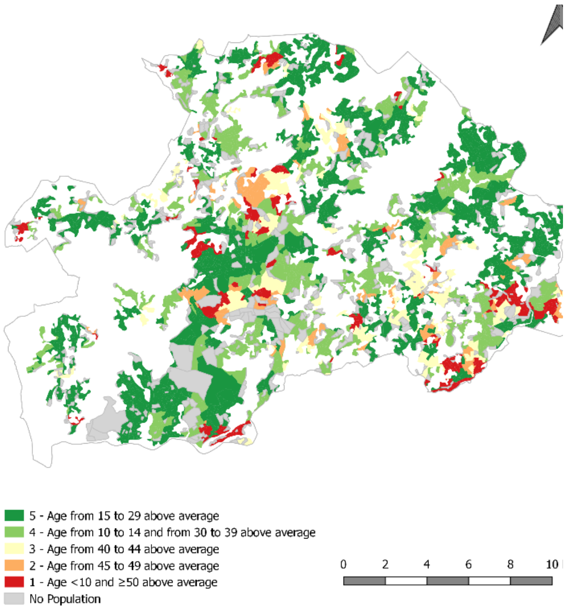


Figure 128 – Cycling Potential according to Age Concentration above VN Famalicão's Average.

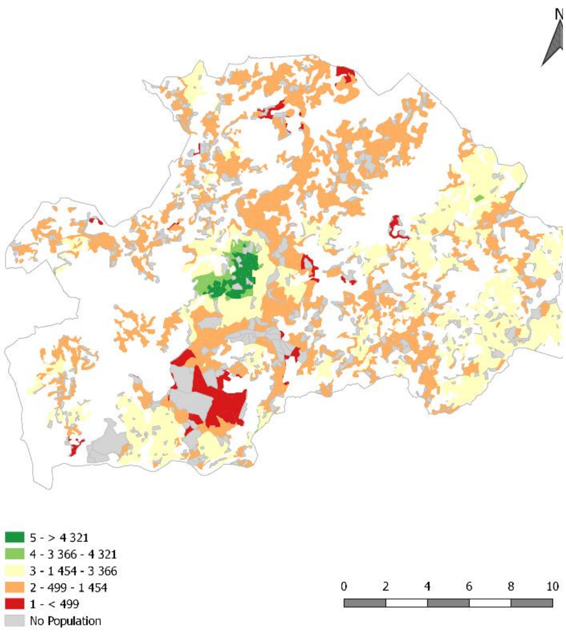


Figure 129 – Cycling Potential according to VN Famalicão's Population Density.

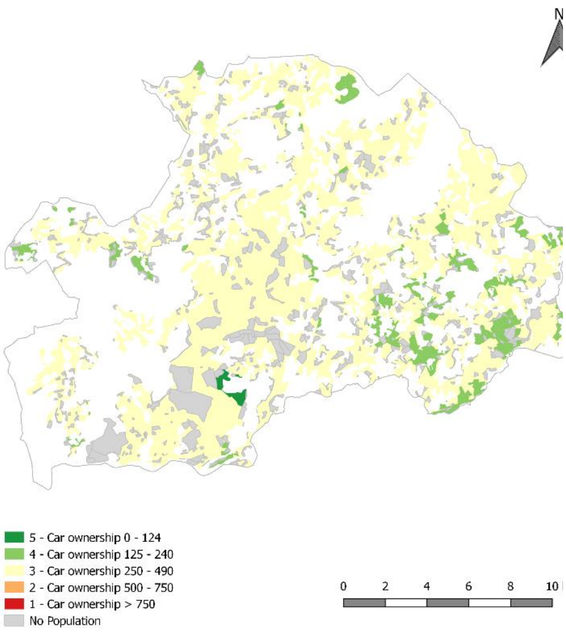


Figure 130 – Cycling Potential according to VN Famalicão's Car Ownership per 1000 inhabitants.

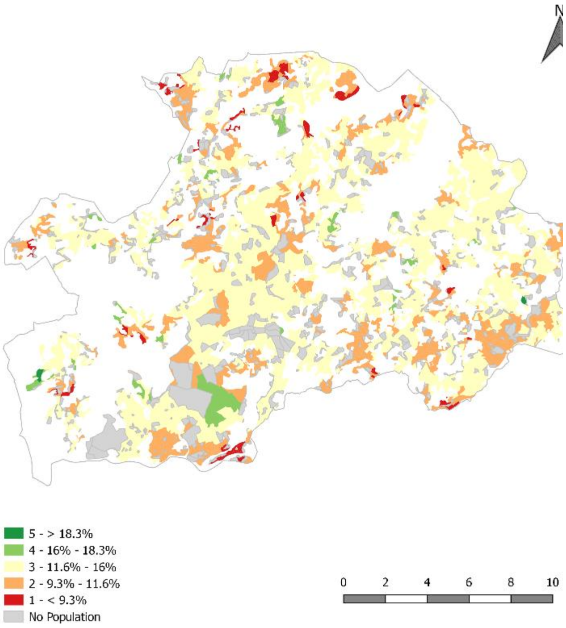


Figure 131 – Cycling Potential according to VN Famalicão's % of Students in the Resident Population.

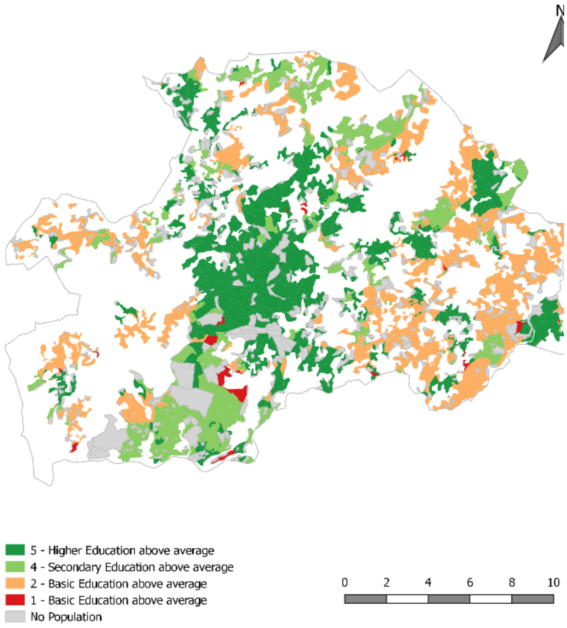


Figure 132 – Cycling Potential according to the VN Famalicão's Education Level.

The analysis of the aggregated cycling potential (Figure 127) reveals that the municipality's population with higher propensity to cycling is located in segregated centres, with a large concentration in the main city centre, mainly due to the higher population density (Figure 129). The surrounding areas are mainly neutral in potential, justified by lower population densities, student presence and education level, although with a more youthful population. The percentage of the municipality's population covered by each potential reveals a great predominance of potential 4 and 3 (48.1% and 48.7% of the population). For further analysis, the final score of each indicator is presented on Table 51.

Table 51 – Cycling Potential (1-5) of VN Gaia's Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.3***
Age	4.1
Population Density	2.8
Car ownership	3.1
Students Presence	2.7
Education Level	3.8

The numerical values reveal that VN Famalicão's population has a Moderate Potential for cycling. Although it has a young population, VN Famalicão is too segregated with separate centres of density, with decreasing education level as we move away from the main centre. This fact hinders the aggregated potential score.

5.7.2. Target Areas

Regarding the target areas, Figure 133 illustrates the spatial representation of their aggregated cycling potential.

The following figures present the spatial representation of the four indicators used to build the previous aggregated map: Accessibility to Education Institutions (Figure 134), Accessibility to the City Centres (Figure 135), Accessibility to the Railway Stations (Figure 136) and Coverage Areas of the existent Cycling Infrastructure (Figure 137). The indicator for Activity Diversity was not considered for lack of data.

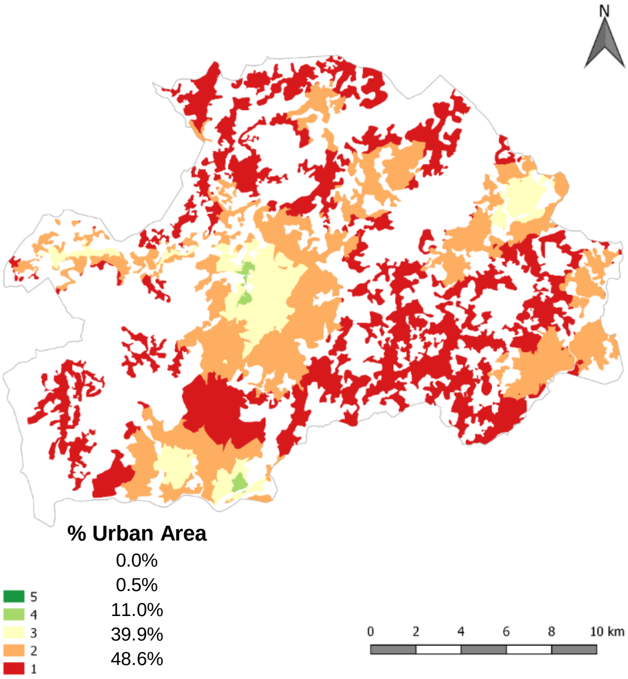


Figure 133 - Aggregated Cycling Potential of the Target-Areas of VN Famalicão, plus the respective urban area percentage covered by each potential.

In similarity to the target-population, the target-areas analysis (Figure 133) reveals concentrations of cycling potential in the identified city centres, achieving a potential 4 in the main city centre and in the south.

The existent cycling infrastructure has some influence in the final aggregated result (Figure 137), but due to being leisure-oriented, the final potential only reaches a neutral score. The positive potential around the city centres is caused by a concentration of education facilities (Figure 134). Unfortunately, most of the municipality's urban areas have a low potential for cycling with 88.5% having potential 2 or 1.

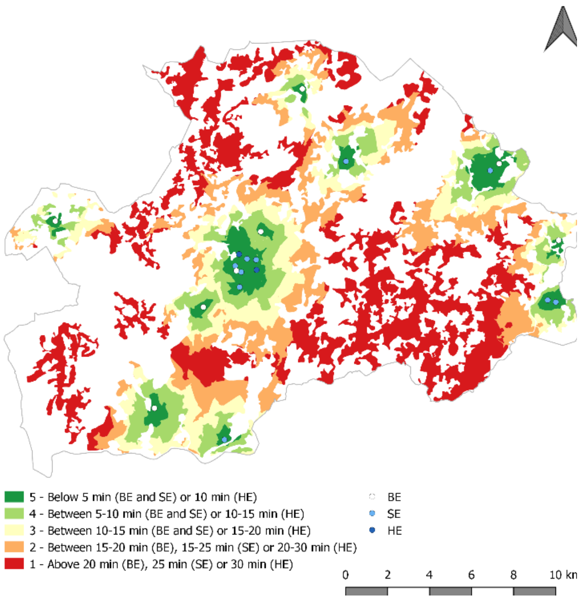


Figure 134 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of VN Famalicão.

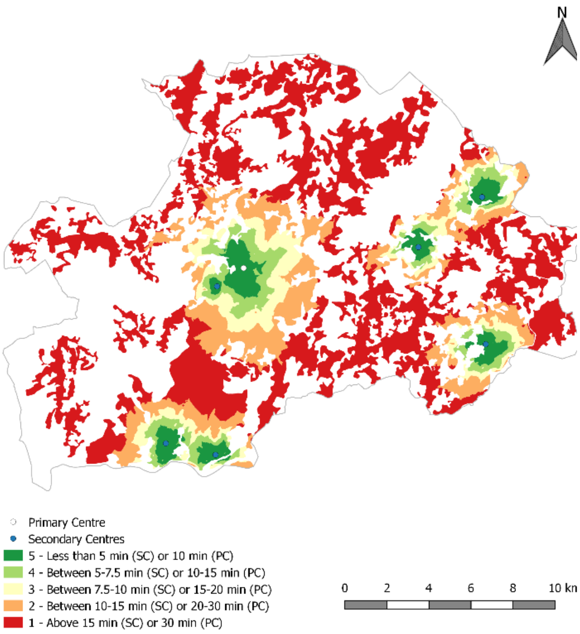


Figure 135 – Cycling Potential according to the Accessibility to City Centres of VN Famalicão.

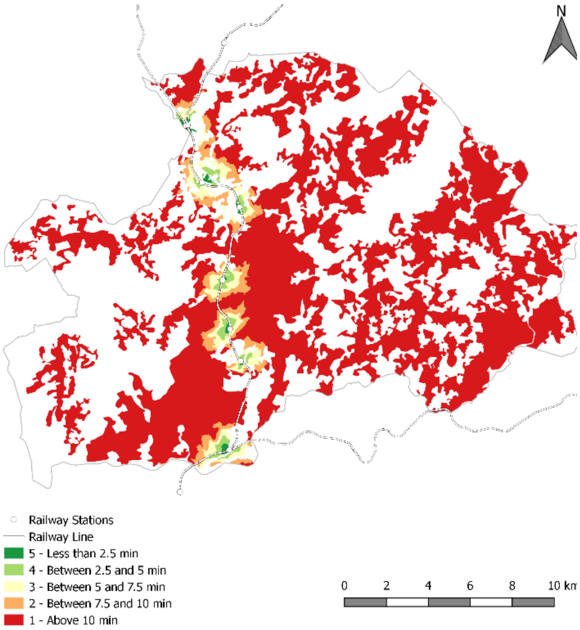


Figure 136 – Cycling Potential according to the Accessibility to Railway Stations of VN Famalicão.

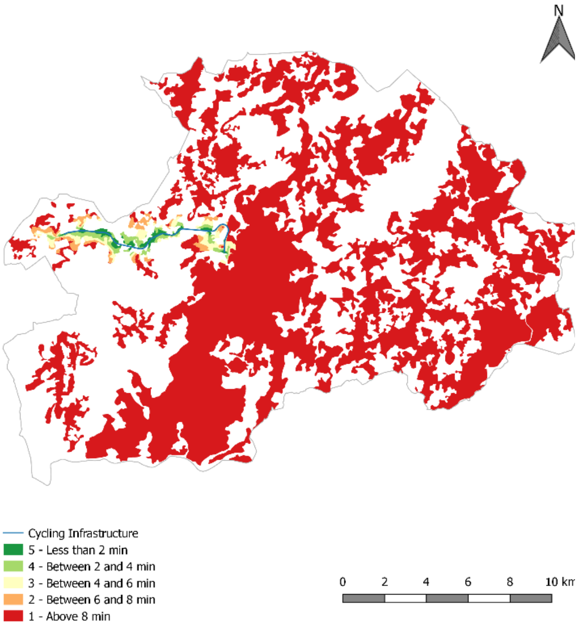


Figure 137 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of VN Famalicão.

This result is further analysed on Table 52, which presents the numerical values of the overall cycling potential for the four factors assessed, along with the aggregated potential value for the municipality.

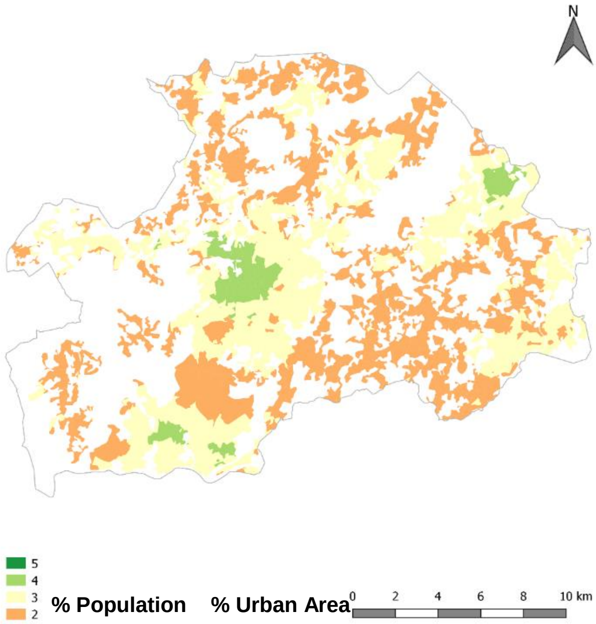
Table 52 – Cycling Potential (1-5) of the VN Famalicão's Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***1.6***
Accessibility to Education Facilities	2.3
Accessibility to the City Centres	1.6
Accessibility to Railway Stations	1.2
Occupation Diversity	x
Coverage Area for Cycling Infrastructure and for 30 Zones	1.1

According to our classification, and as we already suspected by the maps analyses, Vila Nova de Famalicão has a Low potential on its target-areas. Due to its fragmented and centralised nature, all the indicators underperformed, which most of its area with a negative potential. The existent cycling infrastructure (7.4 km) is inefficient to be useful for the population's commuting and to elevate the municipality's potential.

5.7.3. Target-Population & Target-Areas Aggregated Map

Figure 138 presents the target-population and target-areas aggregated map. The figure presents a summary of the previous main findings: a concentration of cycling potential in the city centres, especially in the main centre, in the south and northeast. This again reinforces the low-moderated potential of this municipality, with most of its population having potential 3 and urban area having potential 2.



Potential	% Population	% Urban Area
5	0.0%	0.0%
4	14.9%	5.9%
3	47.9%	45.4%
2	37.1%	48.8%
1	0.0%	0.0%

Figure 138 – Aggregated Potential of the Target Population and Target Areas of VN Famalicão, plus the respective population and urban area percentage covered by each potential.

5.7.4. Political Commitment to Cycling

The assessment of the municipality's political commitment to cycling is represented on Table 53. Since data regarding bicycle parking was not complete, the population coverage of Bicycle Parking was not calculated. Only the data regarding the coverage of PT stations was available.

Table 53 – Cycling Potential (1-5) of VN Famalicão's cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Political Commitment to Cycling	***2.2***
Population Coverage by Cycling Infrastructure (8 min)	1,1
Schools covered by Cycling Infrastructure (8 min)	1,0
Network Coverage by Cycling Infrastructure	1,0
Population Coverage by Bicycle Parking	-
PT stations Coverage by Bicycle Parking	2,0
Relative Coverage by PT (Cycling/Walking)	5,0
Accessible Student Population to School by Bicycle	2,2
Accessible Population by Bicycle (15 min)	3,4
Accessible Area by Bicycle (15 min)	3,0
Relative Accessibility (Bicycle / Car in 5 min)	1,0
Existence of Complementary Measures	2

The table above reveals that the overall effectiveness of VN Famalicão's cycling policies is Low (2.2). Although the municipality has a high potential on the catchment areas gains around railway stations when using cycling instead of walking, the rest of the indicators are negative. The lack of investment in cycling infrastructure, such as cycling lanes and low-speed zones, in the city centres and near schools, reduce the bicycle's competiveness against the car. Without this measure, a municipality as fragmented and irregular in density cannot achieve a promising cycling potential.

5.7.5. City Typology

In sum, VN Famalicão revealed a Moderated potential in its target-population (B), a Low potential on its target-areas (C) and a Low political commitment (C), leading to a BCC city typology (Figure 139 and Table 54). The lack of cycling infrastructure allied with a fragmented population throughout its centres reduces the municipality's cycling potential. The Municipality shows lack of political commitment to cycling, which affects the potential of the target-areas.

Table 54 – Typology of Vila Nova de Famalicão and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
V.N Famalicão	BBC	3.3	1.6	2.6	7.4

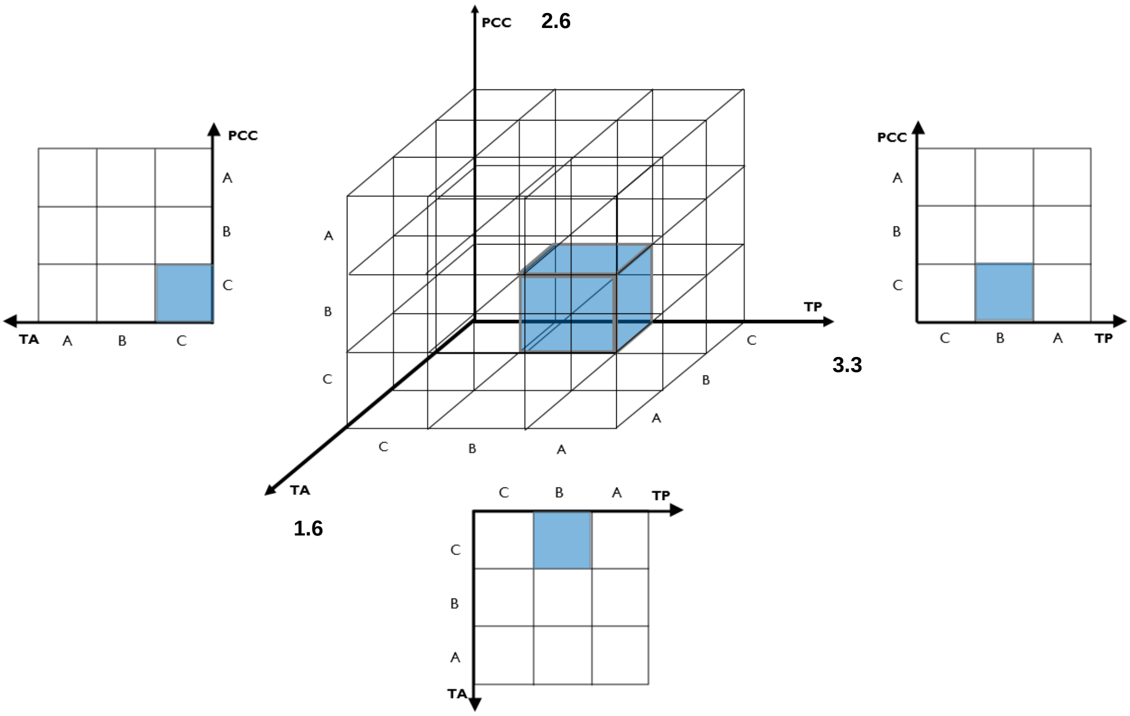


Figure 139 – Representation of the positions of VN Famalicão in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

5.8. Vila Nova de Gaia

5.8.1. Target Population

Target Population (Figure 140) gives the spatial representation of where the target population with more propensity to cycling is located in VN Gaia. Additionally, the next figures present the spatial representation of each one of the five socioeconomic indicators within the target population: Figure 141 represents Age, Population (and Employment) Density is represented in Figure 142, while Car Ownership is represented in Figure 143. Finally Figure 144 and Figure 145 represent, respectively, the percentage of Students among the population and the Education Level.

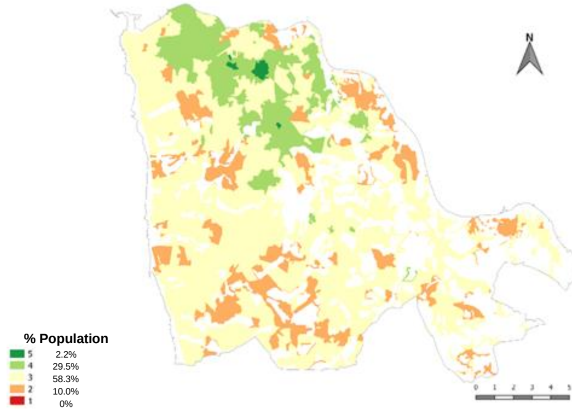


Figure 140 - Aggregated Cycling Potential of the Target Population of VN Gaia, plus the respective population percentage covered by each potential.

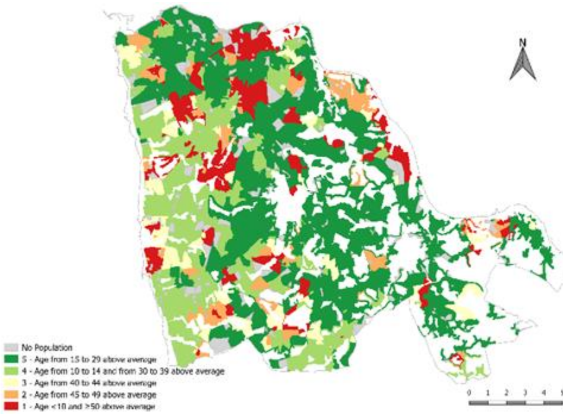


Figure 141 - Cycling Potential according to Age Concentration above VN Gaia's Average

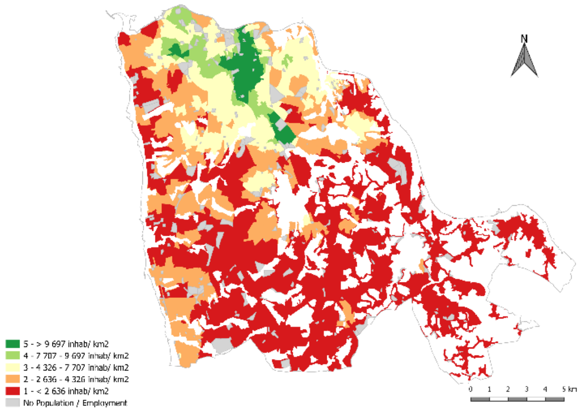


Figure 142 – Cycling Potential according to VN Gaia's Population and Employment Density.

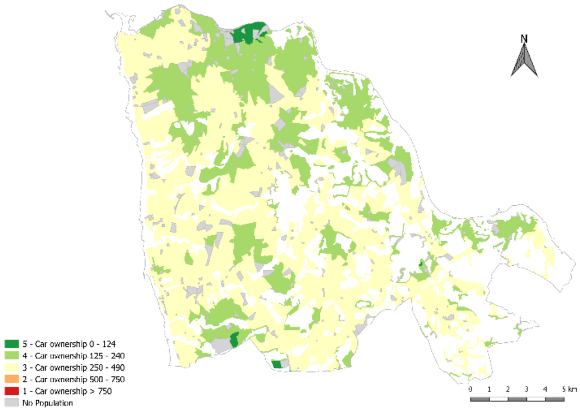


Figure 143 – Cycling Potential according to Gaia's Car Ownership per 1000 inhabitants.

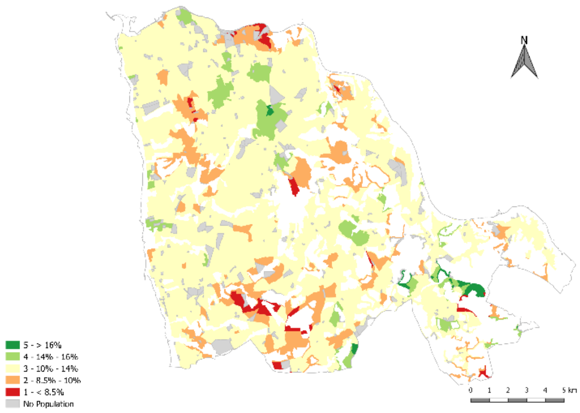


Figure 144 – Cycling Potential according to VN Gaia's % of Students in the Resident Population.

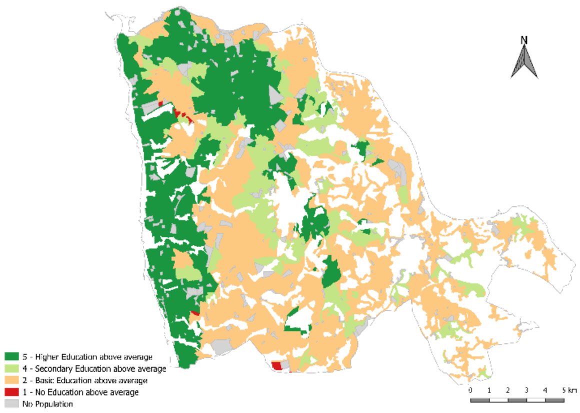


Figure 145 - Cycling Potential according to the VN Gaia's Education Level.

The analysis of the aggregated cycling potential (Figure 140) reveals that the municipality's population with higher propensity to cycling is located more on its the northern side, mainly due to the higher population and employment densities (Figure 142). In contrast, the southwest has much lower cycling potentials justified by lower population densities. The percentage of the municipality’s population covered by each potential reveals a predominance of potential 3 (58.3% of the population) followed by potential 4 (29.5%). Additionally, the numerical analysis is presented on Table 55.

Table 55 – Cycling Potential (1-5) of VN Gaia’s Target Population.

Indicators	Overall Cycling Potential
Target-Population	***3.2***
Age	4.0
Population Density	3.4
Car ownership	3.7
Students Presence	2.6
Education Level	3.0

The numerical values complement the map analysis, revealing that VN Gaia’s population has a Moderate Potential for cycling. Despite having a young population, VN Gaia scores poorly on the remaining indicators. Particularly, the Population Density, with a substantial weight on the final aggregated value, hinders the aggregated score due to the municipality’s lower population densities on its southern part.

5.8.2. Target Areas

Figure 146 illustrates the spatial representation of their aggregated cycling potential. The five indicators used to build the aggregated map are represented in the following figures: Accessibility to Education Institutions (Figure 147), Accessibility to the City Centres (Figure 148), Accessibility to the Railway Stations (Figure 149), Activity Diversity (Figure 150) and Coverage Areas of the existent Cycling Infrastructure (Figure 151).

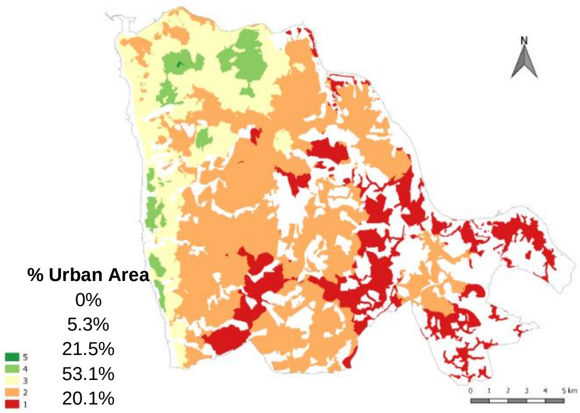


Figure 146 – Aggregated Cycling Potential of the Target-Areas of VN Gaia, plus the respective urban area percentage covered by each potential.

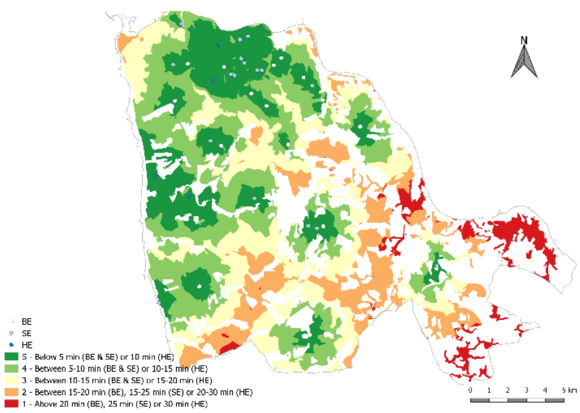


Figure 147 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of VN Gaia.

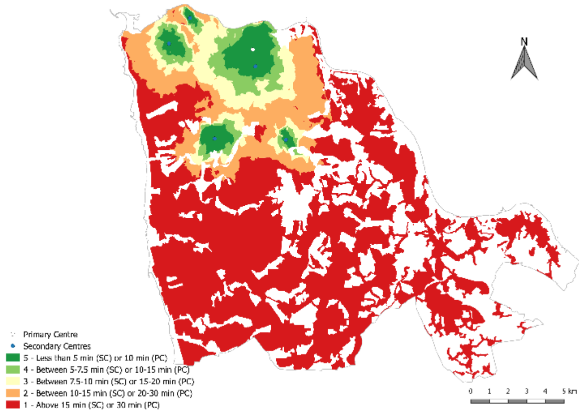


Figure 148 – Cycling Potential according to the Accessibility to City Centres of VN Gaia.

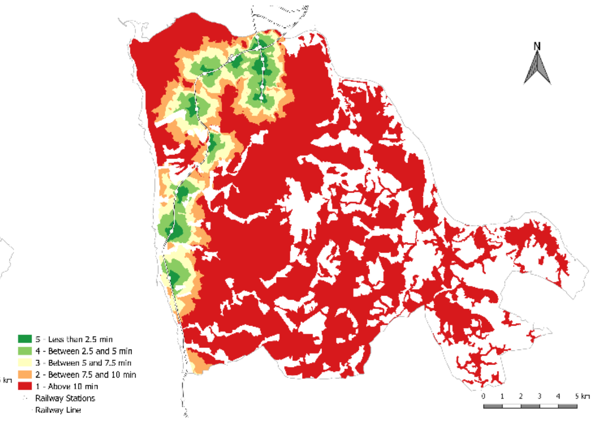


Figure 149 – Cycling Potential according to the Accessibility to Railway Stations of VN Gaia.

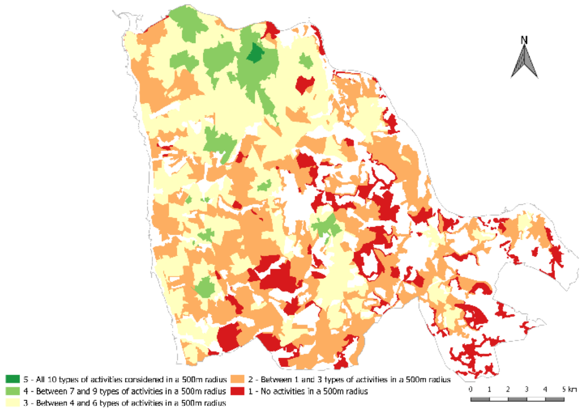


Figure 150 – Cycling Potential according to Activity Diversity in VN Gaia.

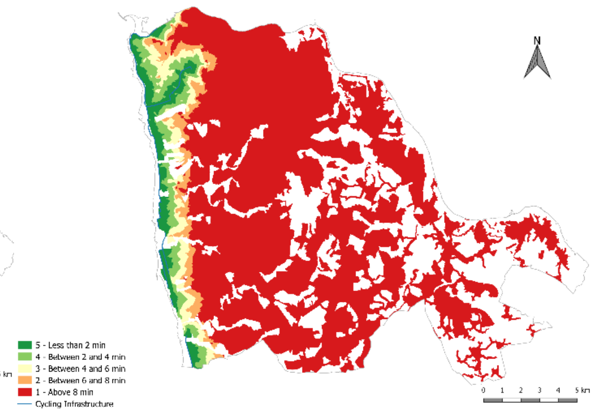


Figure 151 - Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of VN Gaia.

The target-areas assessment (Figure 146) reveals a concentration of cycling potential along the coastline (west side) and on the northern part, near the city centre. The potential in the coastline is mainly justified by the existence of cycling infrastructure (Figure 151), which is predominantly concentrated along the coast, also revealing their leisure-oriented function. The centre spike of cycling potential is caused by a concentration of education facilities (Figure 147), the metro line and train stations (Figure 149), plus a wide diversity of available activities (Figure 150). Nevertheless, most of the municipality's urban areas have a low potential for cycling with 73.2% having potential 2 or 1.

This outcome is reinforced by the numerical analysis represented on Table 56, which presents the numerical values of the overall cycling potential for each one of the five factors assessed, along with the aggregated potential for the municipality.

Table 56 – Cycling Potential (1-5) of the VN Gaia' Target Areas.

Indicators	Overall Cycling Potential
Target-Areas	***2.1***
Accessibility to Education Facilities	3.5
Accessibility to the City Centres	1.6
Accessibility to Railway Stations	1.5
Occupation Diversity	2.4
Coverage Area for Cycling Infrastructure and for 30 Zones	1.4

According to this classification, and as already suspected by the maps analyses, VN Gaia has a Low potential on its target-areas. Even though most of the municipality is fairly covered by Education Facilities, the remaining indicators all underperformed, particularly the accessibility to city centres and railway stations, as well as the coverage by cycling infrastructure. In fact, although the municipality has some dedicated cycling infrastructure (17 km), it is mainly located on the coast, thwarting its ability to be used to bicycle commuting.

5.8.3. Target-Population & Target-Areas Aggregated Map

Additionally, Figure 152 presents the target-population and target-areas aggregated map.

The figure presents a summary of the mains previous main observations: a concentration of cycling potential on the northern part, particularly in the city centre, plus small pockets along the coastline. This again reinforces the moderated potential of this municipality, with most of its population and urban area having potential 3.

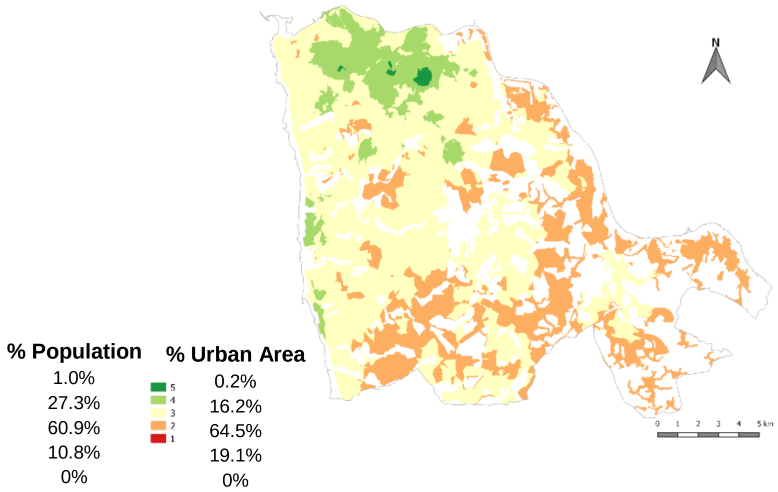


Figure 152 – Aggregated Potential of the Target Population and Target Areas of VN Gaia, plus the respective population and urban area percentage covered by each potential.

5.8.4. Political Commitment to Cycling

The assessment of the municipality's political commitment to cycling is represented on Table 57. Data regarding bicycle parking was not possible to obtain, therefore the related indicators were not calculated.

Table 57 – Cycling Potential (1-5) of VN Gaia's cycling policies and their subsequent effectiveness.

Indicators	Overall Cycling Potential
Effectiveness of Cycling Policies	***2.3***
Population Coverage by Cycling Infrastructure (8 min)	1.4
Schools covered by Cycling Infrastructure (8 min)	1.0
Network Coverage by Cycling Infrastructure	1.0
Population Coverage by Bicycle Parking	-
PT stations Coverage by Bicycle Parking	-
Relative Coverage by PT (Cycling/Walking)	5.0
Accessible Student Population to School by Bicycle	3.1
Accessible Population by Bicycle (15 min)	3.5
Accessible Area by Bicycle (15 min)	3.1
Relative Accessibility (Bicycle / Car in 5 min)	1.0
Existence of Complementary Measures	2

The table analysis shows that the overall effectiveness of VN Gaia's cycling policies is Moderate (2.3.), though in the lower limit. Although the municipality has a high potential on the catchment areas gains when using cycling as complementing PT, most of the remaining indicators do not contribute to it. The municipality has an overall lack of specific mobility management measures targeting cycling, namely specific cycling infrastructure such as cycling lanes and low-speed zones, translating in poor scores on the population and schools covered by bicycle infrastructure, as well as on the bicycle's competitiveness against the car.

5.8.5. City Typology

Summarizing, VN Gaia has shown to have a Moderated potential on its target-population (B), a Low potential on its target-areas (C) and a Moderated political commitment (B), leading to a BCB city typology (Figure 153 and Table 58). The main factors negatively affecting this municipality's cycling potential are both the existence of low population and employment density areas outside its centre, and an overall lack of dedicated cycling infrastructure. Moreover, the existent cycling infrastructure is leisure-oriented located on the coastline, hindering its effectiveness on being used to bicycle commuting.

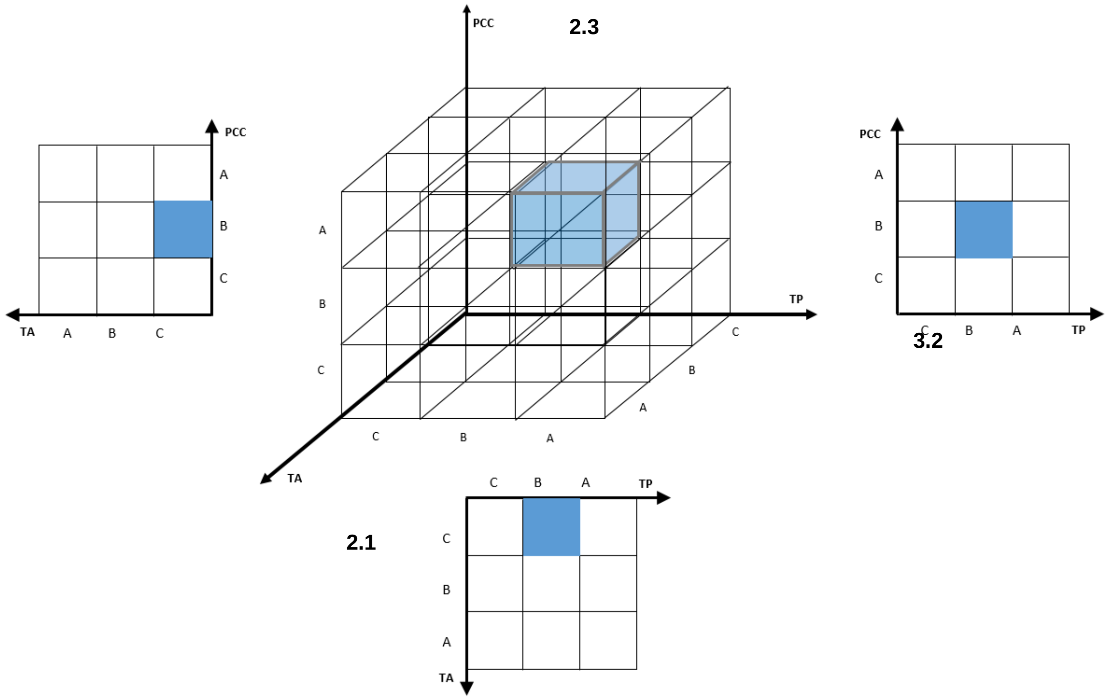


Figure 153 – Representation of the positions of VN Gaia in the 3 dimensions (TP: Target-Population, TA: Target-Areas and PCC: Political Commitment to Cycling) according to their scores (A: High, B: Moderate, C: Low).

Table 58 – Typology of Vila Nova de Gaia and current cycling infrastructure extension

Municipality	Typology	Dimensions			
	Current Scenario	TP	TA	PCC	Cycling Infrastructure (km)
V.N Gaia	BCB	3.2	2.1	2.3	17.0

5.9. Typology of Cities – Final Discussion

Table 59 classifies all municipalities for both current and proposed scenarios for the municipalities, which are considering to implement cycling plans and policies, as well as the cycling potential score by each dimensions of analysis. The classification follows the three-code nomenclature defined for the three dimensions of analysis (A – High, B – Moderate, C – Low).

In the current scenario, there are 4 main combinations of typologies: Oporto appears with one High and two Moderate dimensions; Braga, Cascais and Barcelos presented all Moderate scores in their dimensions; Matosinhos, Guimarães, and Gaia reported two Moderate and one Low dimensions; and Famalicão, two Low dimensions and one Moderate.

Table 59 – Typologies of cities based on the current and proposed scenarios, stratified by each dimension of analysis

Municipalities	Typology	Dimensions			Typology	Dimensions		
	Current Scenario	TP	TA	PCC	Proposed Scenario	TP	TA	PCC
Matosinhos	BBC	3.5	3.0	2.2	BAA	3.5	4.4	4.3
Oporto	ABB	3.7	3.3	2.8	AAB	3.7	3.8	3.2
Braga	BBB	3.5	2.3	2.8	BBB	3.5	2.4	3.1
Cascais	BBB	3.4	2.6	3.0				
Barcelos	BBB	3.2	2.8	2.5				
Guimarães	BCB	3.3	2.0	2.3	BCB	3.3	2.2	2.6
V.N Gaia	BCB	3.2	2.1	2.3				
V.N Famalicão	BCC	3.3	1.6	2.6				

By comparing all cities in the current scenario (Table 59), Oporto emerges as the most favourable city in terms of Target-Population and Target-Area, with a High score of 3.7 in the former and Moderate score of 3.3 in the latter. In such municipality, there is a positive correlation between the population with a higher propensity for cycling and the areas with higher population and employment densities, as well as the areas where younger ages (15-29) are above average. Regarding the Political Commitment to Cycling, Cascais appears as the most favourable municipality towards cycling, with a moderate score of 3.0. In this case, there is a noticeable investment on cycling policies such as bicycle parking along all railway station, as well as a bike-sharing system already implemented.

Among the Municipalities with an overall moderate typology, Braga appears as the most favourable regarding its Target-Population, and in the same time, as the municipality with the lowest Target-Area score. Indeed, this research revealed that even though Braga has a good accessibility to education facilities, the accessibility to railway stations is quite low due to the absence of a metro line. Furthermore, there is a lack of cycling infrastructure and low-speed zones. Famalicão is reported as the typology with the lowest score, with attention to its Target-Area, due to its lower densities and cycling infrastructure serving lower proportion of the population.

By analysing and comparing the current and future scenarios (Table 59), Matosinhos and Oporto are the cities showing changes in typology (Figure 154). Matosinhos presents the highest improvements in both TA and PCC. Regarding its target-area there is an impressive increase from 3.0 to 4.4 points. Such improvement is largely justified by the extensive proposed cycling network that will cover the municipality in a large extension (from 20 km of extension to 143 km). The Political Commitment to Cycling also increased expressively from 2.2 to 4.3 points. In the proposed scenario, all the population and schools have cycling infrastructure available in less than 8 min by cycling, all PT stations have dedicated bicycle parking and there is a set of complementary measures within such comprehensive strategy.

Oporto, Braga and Guimarães also showed improvements regarding TA and PCC but more modest in nature when compared to the cycling plan of Matosinhos.

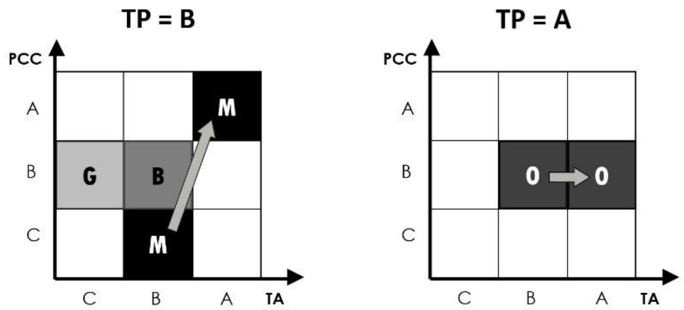


Figure 154 – Representation of the positions of the 4 municipalities (B – Braga, G – Guimarães, O – Oporto, M – Matosinhos) in the 3 dimensions (Target- Population, Target-Areas and Political Commitment to Cycling) according to their scores (A – High, B – Moderate, C – Low) in the current and the future scenario.

The most visible change between the current and future scenarios consists on the proposed expansions plans for the cycling networks. Table 60 reports the current cycling infrastructure amongst the cities under study, as well as the proposed expansion in the cities for which future scenarios were explored. Overall, it is noticeable that all cities have an emerging cycling network. The most ambitious scenario was set by Matosinhos with a proposed cycling network reaching up to 143 km. Braga and Guimarães plan expansions or around 60km each. Regardless of the investment in infrastructure and accompanying measures, these municipalities have a harder time covering large amounts of population than Matosinhos and Oporto, due to lower population densities, leading to weaker improvements to the cycling potential scores.

Table 60 – Extension of the current Cycling Infrastructure versus the extension brought by the proposed projects.

Municipalities	Cycling Infrastructure		
	Current Extension (km)	Proposed Extension (km)	Expansion (km)
Matosinhos	20.0	143.0	+ 123.0
Guimarães	23.0	64.0	+ 41.0
Braga	11.6	58.6	+ 47.0
Oporto	16.0	48.6	+ 32.0
Gaia	17.0		
Cascais	16.4		
Famalicão	7.4		
Barcelos	0		

Table 61 illustrates the percentage of population and of urban area, offering an aggregate target population and target area score of 4 or higher (high scores) for each municipality for the current and the future scenarios (for those municipalities for which future scenarios were analysed).

In the current scenario, Oporto counts with the highest percentage (86.9%) of the population living in potential 4 areas or above retarding TP, followed by Matosinhos (57.4%) and Cascais (56,6%). Oporto also holds the higher percentage of area (75.3%) scoring 4 or above. This value is considerably higher than Matosinhos and Cascais, with around 35% each regardless of the similar extension of cycling network.

Higher urban sprawl and less density, sometimes in association with recreational purposes of existing infrastructure resulted in coverage by cycling facilities. Vila Nova de Famalicão (5.9%), Barcelos (11.5%) and Guimarães (16.1%) are a clear example of this.

Regarding the purpose of the cycling infrastructure, in all cases the current network is leisure oriented as it is located near the sea and riverfronts in the case of Oporto and Matosinhos, and more rural in Braga and Guimarães. In contrast, the future plans are located near more densely populated areas, resulting in a significant improvement with regard to the population and areas covered.

After analysing the proposed scenarios, Matosinhos has the most significant improvement, increasing from 38.1% to 83.3% of the total urban area covered by scores 4 or higher(TA) as well as the most impressive improvement in the target population, providing almost all of its population a cycling potential 4 or above (91.8%). Such positive upgrade is result of a significant increase of the cycling infrastructure and a set of complementary measures targeting the increase of cycling modal share.

Table 61 – Percentage of Population and Urban Area covered by Potentials 4 and 5, for cycling score

Municipalities	Typology					
	Current Scenario	%Pop	%Urban Area	Proposed Scenario	%Pop	%Urban Area
Matosinhos	BBC	57.4	38.1	BAA	91.8	83.3
Oporto	ABB	86.9	75.3	AAB	90.2	79.9
Braga	BBB	49.9	19.9	BBB	60.8	28.6
Cascais	BBB	56.6	35.3			
Barcelos	BBB	23.7	11.5			
Guimarães	BCB	26.0	16.1	BCB	31.7	20.3
V.N Gaia	BCB	28.3	16.4			
V.N Famalicão	BCC	14.9	5.9			

5.10. Case Barcelona – Methodology Application

Besides the Portuguese cities examined within this project, the referred methodology was applied to Barcelona, which is the capital and largest city of Catalonia, in Spain. Such opportunity was valuable to assess the methodology application in such different environment context, with the main goal of assessing the cycling potential of the city of Barcelona in 2006 and 2016, and compare its improvement. Such year gap brings some interesting results, since the bicycle share has largely increased in recent years.

2006 Scenario

5.10.1. Target Population

Figure 155 gives the spatial representation of where the target population with more propensity to cycling is located in Barcelona in 2006.

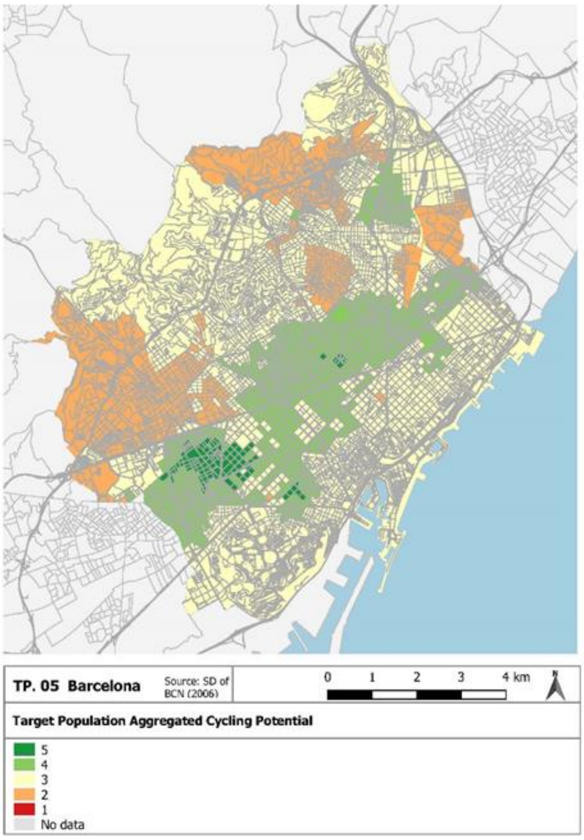


Figure 155 - Aggregated Cycling Potential of the Target Population of Barcelona in 2006

The following figures present the spatial representation of each one of the five socioeconomic indicators used to assess the: Age (Figure 156), Population Density (Figure 157), Car Ownership rate (Figure 158)and the Education Level (Figure 159).

Figure 156 presents the age above average of the population within the different subsections of the city. The spatial distribution is heterogeneous. Overall, Barcelona has a great share of young population along the territory, which results in a high cycling potential for this dimension. Figure 157 illustrates the cycling potential according to the city's population density in percentiles, which means that where the population density is higher, the cycling potential is also higher. By analysing the map, it is observed better potential in the middle zone of the territory. In the peripheral areas the density of population is lower, since such areas comprehends mostly the beach zone and the mountain of Collserola. The car ownership parameter (Figure 158) reports the total number of cars per 1000 habitants. The majority of the population of the city is level 3, which means 250 to 499 cars per 1000 habitants. There are two stains of level 2, which range from 500 to 750 of cars per 1000 habitants. In fact, in such zone of the city, the income is higher and there is not a good service of public transport. Regarding the education level (Figure 159), the population with Basic Education above the average is located in the coastal area, in Montjuic and in the north part of the city. The Higher Education above the average is formed by a big and uniform stain located in the middle-left part of the city.

Table 62 presents the numerical values, on a scale of 1 to 5, for each one of the indicators previously assessed, along with the aggregated potential for the municipality.

Figure 155 and Table 62 represent the cycling potential for the Target Population of Barcelona in 2006. Such map reports four levels of potentials: potential 2,3,4 and 5. Potential 3 appears more often and it is mainly located in the coastal area and upper part of the city. The area with potential 4 is a continuous stain crossing the middle centre of the city.

Table 62 – Cycling Potential (1-5) of Barcelona's Target Population in 2006.

Indicators	Overall Cycling Potential
Target-Population	***3.3***
Age	3.7
Population Density	3.1
Car ownership	2.9
Education Level	3.8

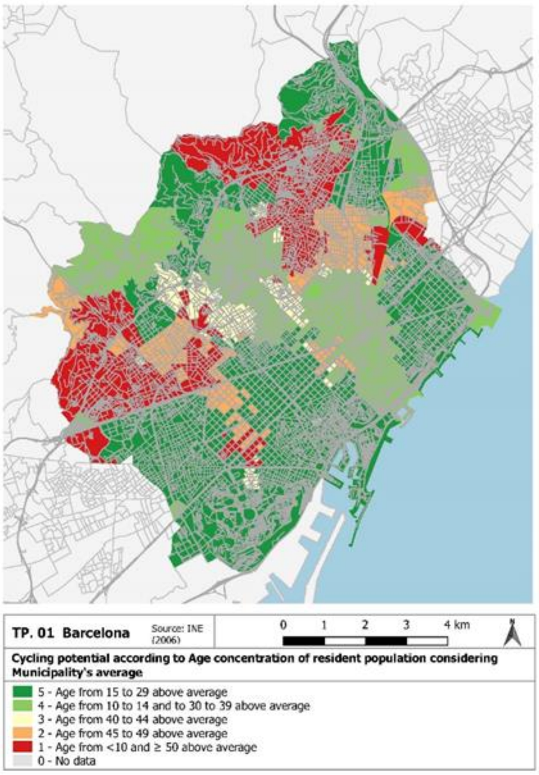


Figure 156 - Cycling Potential according to Age Concentration above Barcelona's Average in 2006

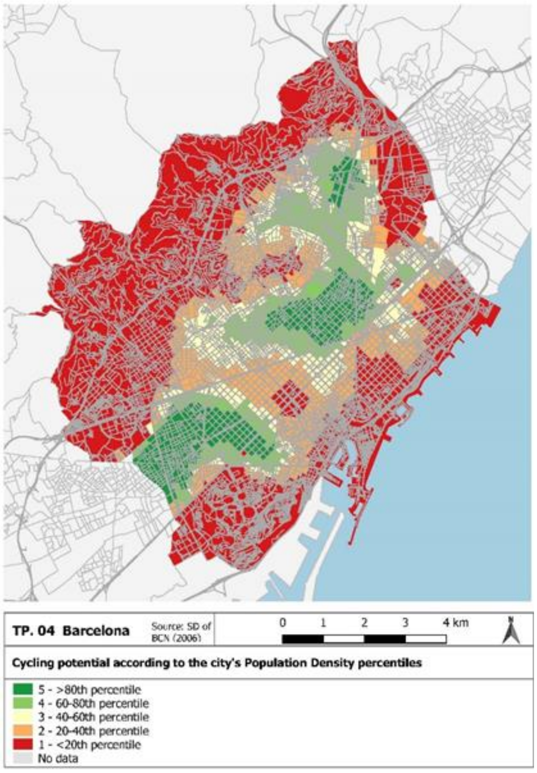


Figure 157 - Cycling Potential according to Barcelona's Population Density in 2006.

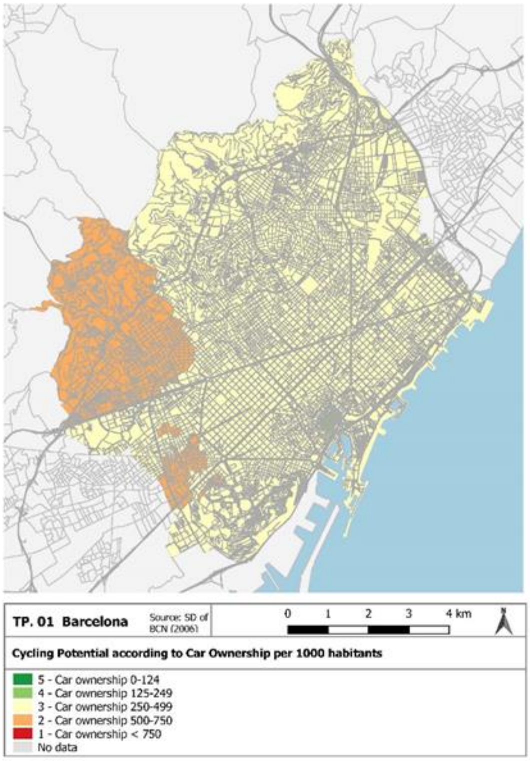


Figure 158 - Cycling Potential according to Barcelona's Car Ownership per 1000 inhabitants in 2006.

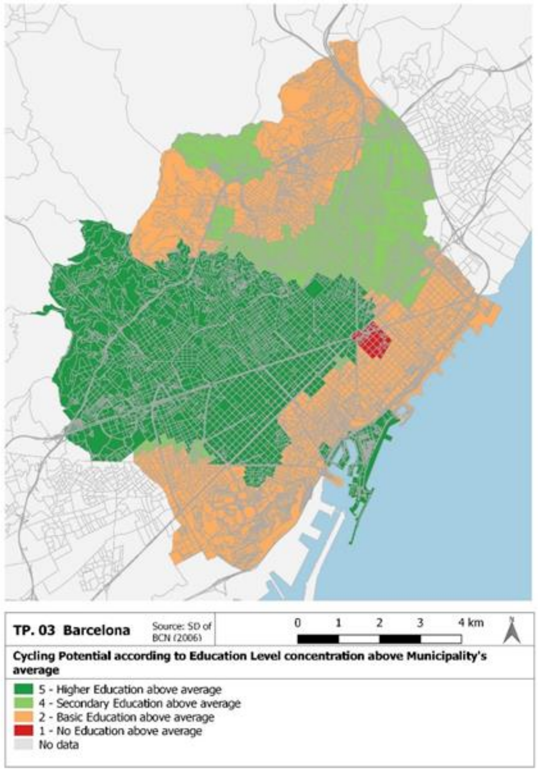


Figure 159 - Cycling Potential according to Barcelona's Education Level in 2006.

2016 Scenario

5.10.2. Target Population

Figure 160 gives the spatial representation of where the target population with more propensity to cycling is located in Barcelona in 2016.

The following figures present the spatial representation of each one of the five socioeconomic indicators used to assess the target: Age (Figure 161), Population Density (Figure 162), Car Ownership rate (Figure 163), and the Education Level (Figure 164).

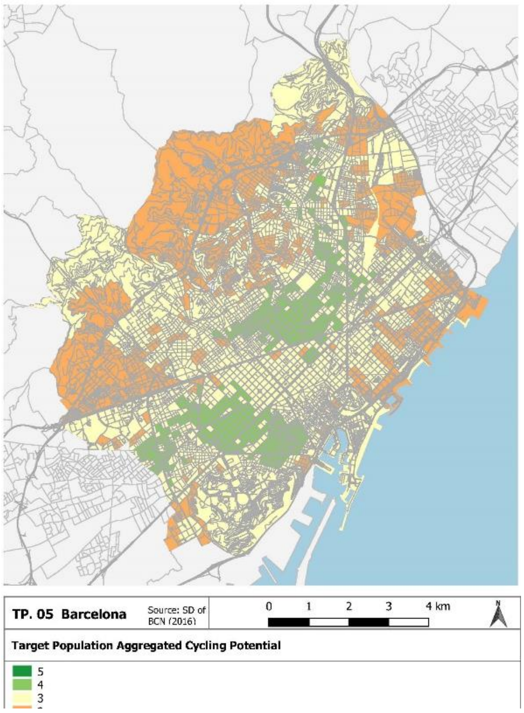


Figure 160 - Aggregated Cycling Potential of the Target Population of Barcelona in 2016

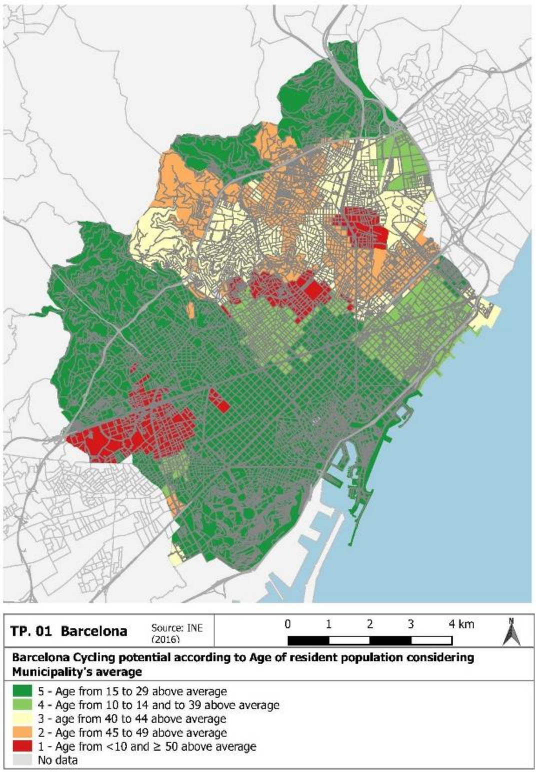


Figure 161 – Cycling Potential according to Age Concentration above Barcelona's Average in 2016.

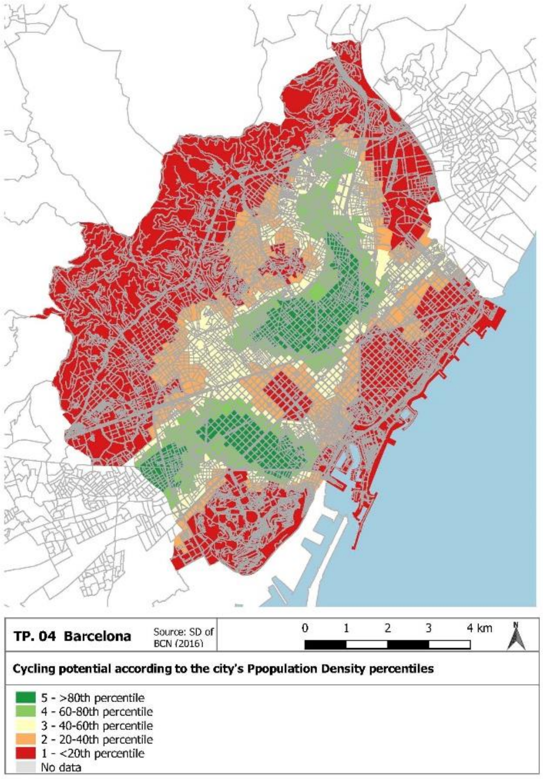


Figure 162 – Cycling Potential according to Barcelona's Population Density in 2016.

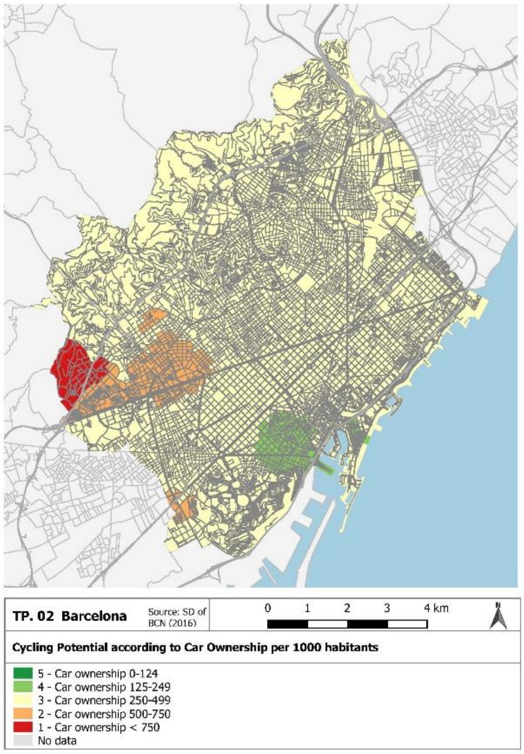


Figure 163 – Cycling Potential according to Barcelona's Car Ownership per 1000 inhabitants in 2016.

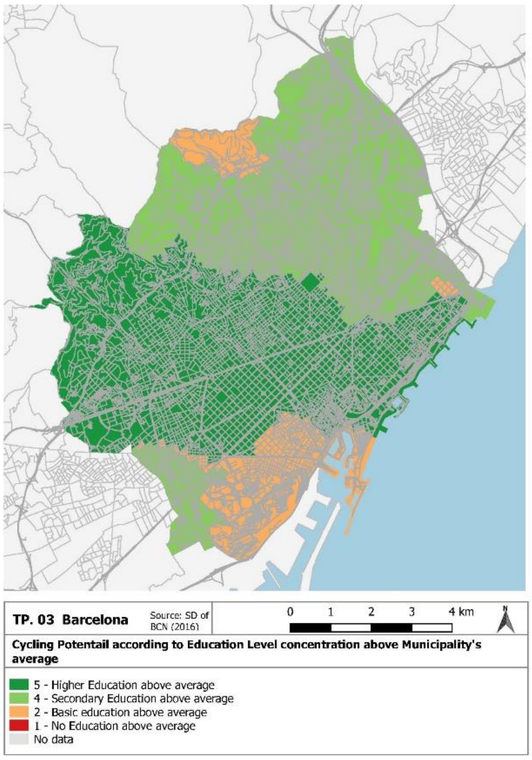


Figure 164 – Cycling Potential according to Barcelona's Education Level in 2016.

Regarding the cycling potential of the city according to the age concentration (Figure 161). It is noticeable the right part of this map is very heterogeneous, with all kinds of potentialities, while the left part of the map is mainly green – potential 5, except for a notorious red stain – potential 1. Figure 162 reports clear and differentiate areas of density. On one hand, there is low density in the mountain and coast zones. On the other hand, there are higher densities in the middle zone. The cycling potential according to Barcelona's car ownership (Figure 163) reports a predominance of potential 3, which means 250-499 automobiles for every 1000 inhabitants. The next map (Figure 164) shows a distribution for the potentials divided in three main stains. The potential 2 was found in the area of Sants, Montjuic and the port. One big stain of potential 5 (Higher education) in the coast zone and city centre. By comparing with the year of 2006, it its visible an improvement in such dimensions, with none subsections in potential 1.

Table 63 reveals the numerical values, on a scale of 1 to 5, for the assessed indicators, along with the aggregated potential for the municipality are represented on .

Table 63 – Cycling Potential (1-5) of Barcelona's Target Population in 2016.

Indicators	Overall Cycling Potential
Target-Population	*3.4*
Age	3.9
Population Density	3.0
Car ownership	3.0
Education Level	4.0

5.10.3. Target Areas

The spatial representation of the indicators used to assess the target areas are represented in the figures that follow: Accessibility to Education Institutions (Figure 165), Accessibility to the City Centres (Figure 166), Accessibility to the Railway Stations (Figure 167) and Coverage Areas of the existent Cycling Infrastructure (Figure 168).

Figure 165 illustrates the cycling potential according to the accessibility to education institutions. Due to the great presence of all types of institutions spread all over the territory under analysis, most part of the map is covered by potential 5. Which means from any point of the city within such potential, it takes less than 5 minutes by bicycle to the nearest basic or secondary institution and, a maximum of 10 minutes to the higher education institutions.

The next map (Figure 166) represents the accessibility level to the main city centre and other secondary centres by bicycle. The primary centre is located in the city hall which is in the middle part of the historic centre of Barcelona. The other two secondary centres are more peripheral but still have a great amount of social and economic activity. Figure 167 illustrates a total of 315 railway station distributed along the city. Due to such high coverage, a great portion of the city is covered by potential 5, in a distance from 0 to 2.5 minutes to any railway station. The last map (Figure 168) illustrates the cycling velocities in the road network considering the topography and the cycling infrastructure.

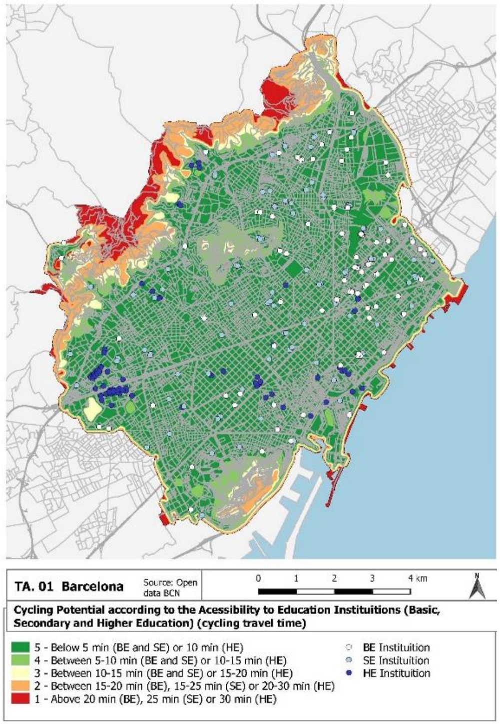


Figure 165 – Cycling Potential according to the Accessibility to Education Institutions (BE: Basic Education; SE: Secondary Education, HE: Higher Education) of Barcelona in 2016

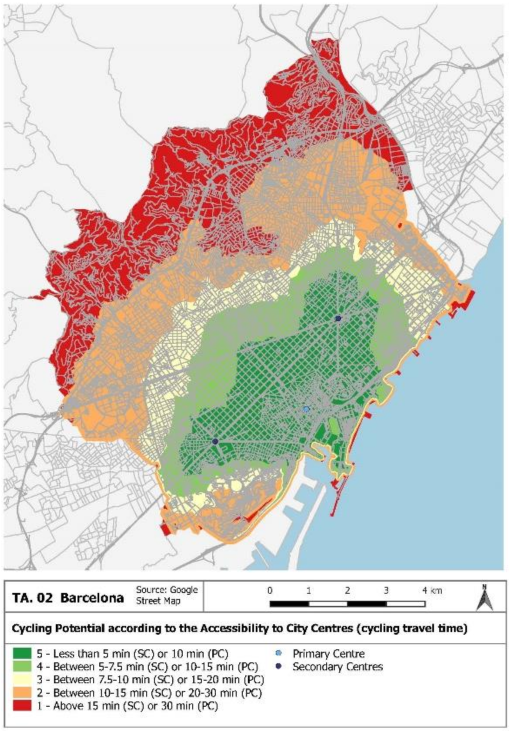


Figure 166 – Cycling Potential according to the Accessibility to City Centres of Barcelona in 2016.

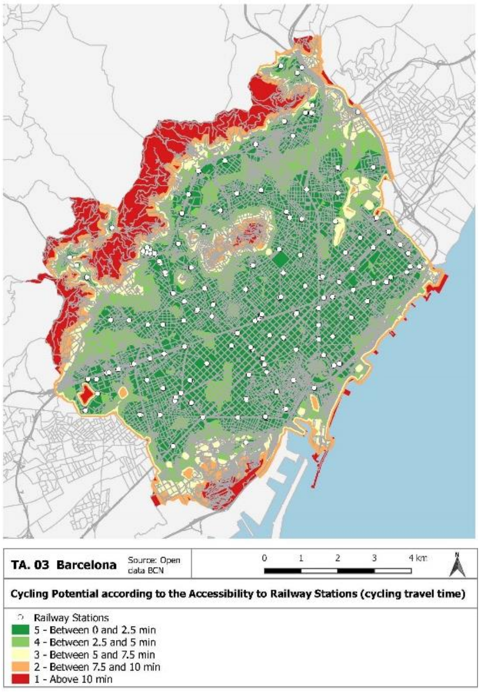


Figure 167 – Cycling Potential according to the Accessibility to Railway Stations of Barcelona in 2016.

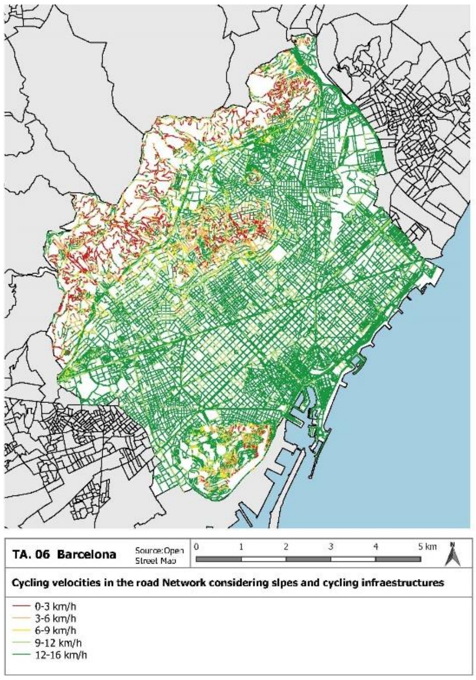


Figure 168 – Cycling Potential According to the Coverage Areas of the existent Cycling Infrastructure of Barcelona in 2016.

6. WORKSHOPS

In addition to the cycling potential assessment, we conducted workshops with planning practitioners of 4 municipalities (Braga, Guimarães, Matosinhos and Oporto). Each municipality was involved in two workshops, in a total of 8, involving 24 planning practitioners from transport and mobility departments (Table 64).

The first workshop had the objective of presenting the Potential for Cycling Assessment Method to the municipalities' planning practitioners and the results of the current cycling environment, as well as to receive feedback to improve the Method itself.

The second workshop aimed at evaluating cycling policies being studied by the municipalities and exercising the development of new cycling policies supported by the Method. The exercise intended to encourage the developing new cycling policies (or the improvement of existence ones assessed previously by the method) based on the maps presented.

Table 64 – Dates and Location of the workshops conducted with Braga, Guimarães, Matosinhos and Oporto municipalities.

Municipalities	Dates		Location
	1st Workshop	*2nd Workshop*	
Braga	06/12/2017	30/01/2018	Braga City Hall
Guimarães	11/05/2018	20/06/2018	Guimarães City Hall
Matosinhos	12/07/2018		Matosinhos City Hall
Oporto	04/12/2017	02/02/2018	Oporto City Hall

Besides testing the Method, we also conducted surveys in each workshop with two purposes:

- To evaluate the perceived usefulness of the tool in assessing the potential for cycling and in supporting the development and the evaluation of cycling policies in improving the cycling potential in Starter Cycling Cities;
- To assess the Method's potential on changing the planners' attitudes regarding the cycling potential of the city.

The main findings are revealed below.

6.1. Usefulness of the concept of potential for cycling

The assessment of the usefulness of the Potential for Cycling Assessment Method follows the method developed by te Brömmelstroet (2013) as applied by Silva et al. (2017), and the procedures developed for a European and Australia wide assessment of the usability of a number Accessibility Instruments (te Brömmelstroet, Silva, & Bertolin, 2014). The practitioners responded to a series of statements according to a Likert-type scale ranging from 1 'strongly disagree' to 4 'strongly agree'.

Figure 169 summarizes the surveys' main results reporting the perceived usefulness.

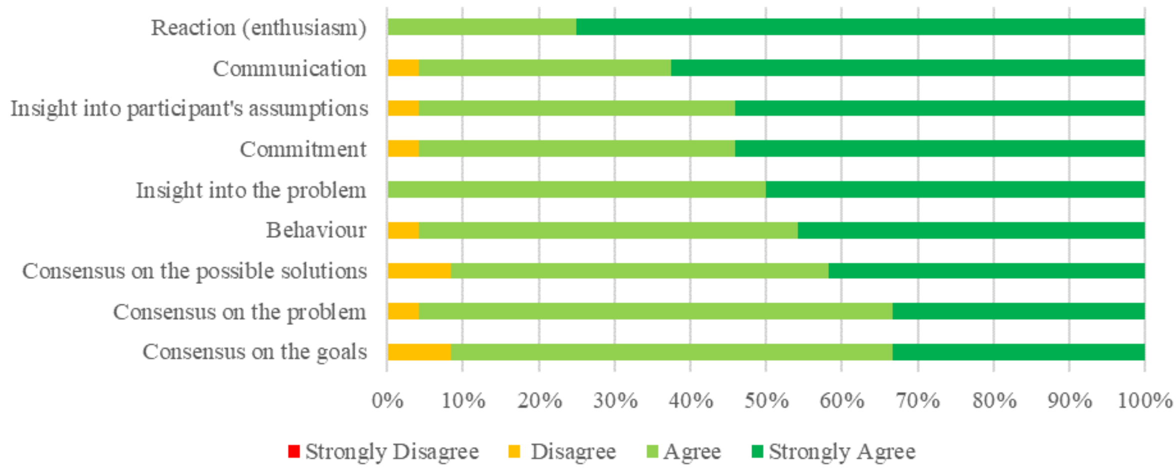


Figure 169 – Perceived Usefulness of the Assessment Method in the 4 Case-Studies. (N=24). Source: (Silva, Teixeira, Proença, Bicalho, & Aguiar, 2018a)

The results suggest that the participants believe in the relevance of the Method for planning practice, with most of the dimensions showing a positive response in all case-studies, especially regarding Reaction, Insight and Communication. As such, it is realistic to say that the Method was found to be useful for the planning practitioners regarding the cycling potential of the municipalities. In fact, in Braga, the participants even reported that the Method helped them validate their new cycling strategy and, in Matosinhos, the outcomes from the Method offered support for their new Mobility Plan.

Figure 170 reveals the results of the 'useful for what' statements.

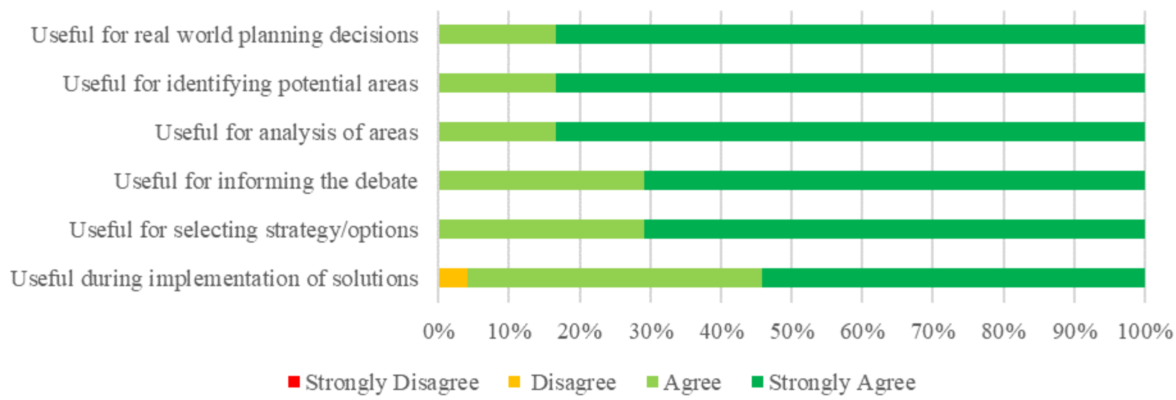


Figure 170 – Additional perceptions on the Perceived Usefulness of the Assessment Method in the 4 Case-Studies. (N=24). Source: (Silva et al., 2018a)

Overall, the Potential for Cycling Assessment Method performed in a positive way in all the analysed statements, particularly in identifying and analysing potential areas and supporting real world planning decisions (83% of the sample agrees with this statement).

The fact that some municipalities were already starting to implement a strategy, may have influenced their opinion on the Method's usefulness for selecting strategies and implementing solutions, as the Method was only used to make adjustments to those strategies afterwards.

Nonetheless, the general view on the Method's usefulness was positive, the participants appeared to be convinced that the Cycling Potential was useful for their planning practice.

6.2. Changing Planners' attitudes

Understanding that political and technical scepticism around modal change towards cycling are still dominant in cities with low cycling rate, depicted in the lack of interventions and initiatives, and that this scenario can be commonly expected from the planners of the cities studied here, a research conducted within this project, aimed at exploring the potential of the outputs of the methodology "Potential for Cycling Assessment Method" in generating change in planning practitioner's attitudes towards the cycling potential of their cities. In other words, this research attempted to foster better attitudes while creating awareness on the potential of the cities to cycling.

The assessment of attitude change followed a methodology developed by Bicalho and Silva (2019) that required a three-moment approach, as noticed in the literature regarding attitude change (Albarracin & Shavitt, 2018; Olson & Maio, 2003; Richard E. Petty, Wegener, & Fabrigar, 1997; Richard E. Petty, Wheeler, & Tormala, 2003) where the attitudes were assessed in two moments, before and after the second moment defined as the persuasive technique. This method was conducted in the course of the workshops described previously, where two similar surveys were applied. One at the beginning of the first workshop (first moment), before the presentation and discussion of the methodology results (second moment) and the other at the end of the second workshop (third moment).

The attitudes were analysed according to a set of 5 stages, Resistant, Sceptic, Interested, Enthusiastic and Committed, adapted in Bicalho and Silva (2019) from the Transtheoretical Model of Change by Prochaska and DiClemente (1983). The stages represent the process of attitude change through a scale of less positive to a more positive attitude to the cycling potential of the city.

The Attitudinal Survey was used to assess the change in the perceptions of local planners of the city's cycling potential and the assessment of the first and the second professional stage. The first survey included a series of belief-based statements regarding attitudes towards the environment, perceptions of cycling conditions and feelings on the benefits the mode could bring to the city. The second survey included the same set of statements from the first as well as a self-evaluation section, which allowed a self-analysis of change and perceived analysis of change.

The Potential for Cycling Assessment Method showed a significant potential in changing planning practitioners' perceptions and attitudes towards cycling. As illustrated in Figure 171, this research revealed that 47% of the continuously assessed sample moved to more positive stages towards the cycling potential of their cities, which means that planners developed a better perception of their city in terms of potential for cycling. Moreover, it was also found that 37% of the sample is considered to remain in the same stages before and after the persuasion process, mainly represented by enthusiastic and committed.

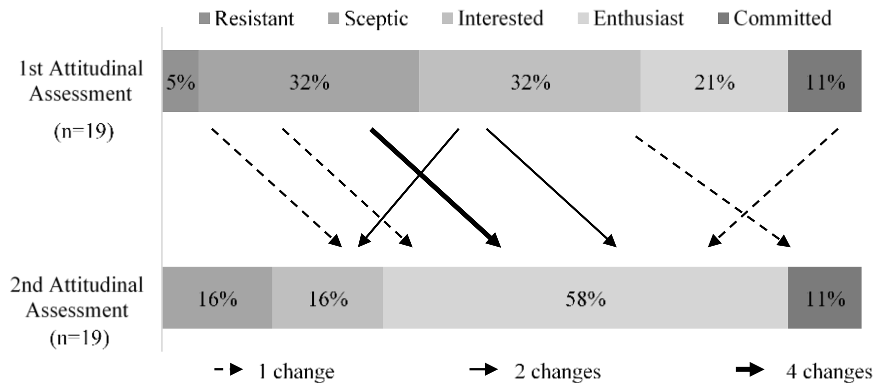


Figure 171 – Sample distribution and changes throughout the attitudinal stages (N=19). Source: Bicalho (2019)

As could be expected for starter cycling cities, the research also found that the planners involved showed higher rates of belonging in the less favourable stages at the beginning of the process. This finding could suggest that the Potential for Cycling Assessment Method and the subsequent discussion of its main outputs may support a higher improvement in awareness in the early stages: resistant, sceptic and interested.

Another interesting finding is that, although there is an increase of participants in more positive stages, 16% (n=3) of the participants recede to less positive stages. This happened only in context where the tool revealed less potential due to the characteristics of the city and what it offers (the case of Braga and Guimarães) or where the tool showed lower effect of cycling strategies on such potential (the case of Guimarães). This may suggest that the tool plays a dual role in influencing attitude change towards a cyclable city. On the one hand, when the participants visualise a medium or high potential of their cities, the tool is capable of fostering better attitudes. On the other hand, if the potential revealed is not as favourable as expected, the tool is actually responsible for breaking those expectations, what reflects in a less favourable attitude to the development of a cycling city. Regardless, by the end of the research, the majority of participants found themselves in more favourable stages towards cycling.

The self-assessment previously mentioned also revealed interesting facts, including that 47% of the sample recognise the tool as responsible for the changes in their perception towards the potential of the city for cycling.

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8. ANNEXES

Cycling Speed Maps

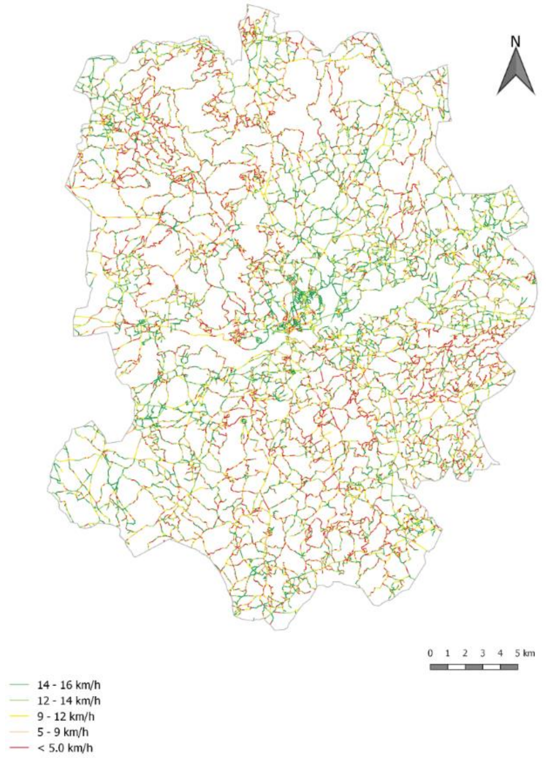

Figure 172 – Cycling Speeds in the Road Network of Barcelos considering slopes, cycling infrastructure and road hierarchy.

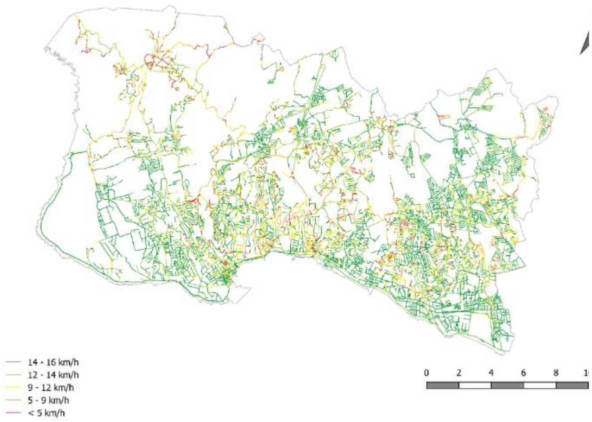

Figure 173 – Cycling Speeds in the Road Network of Cascais considering slopes, cycling infrastructure and road hierarchy

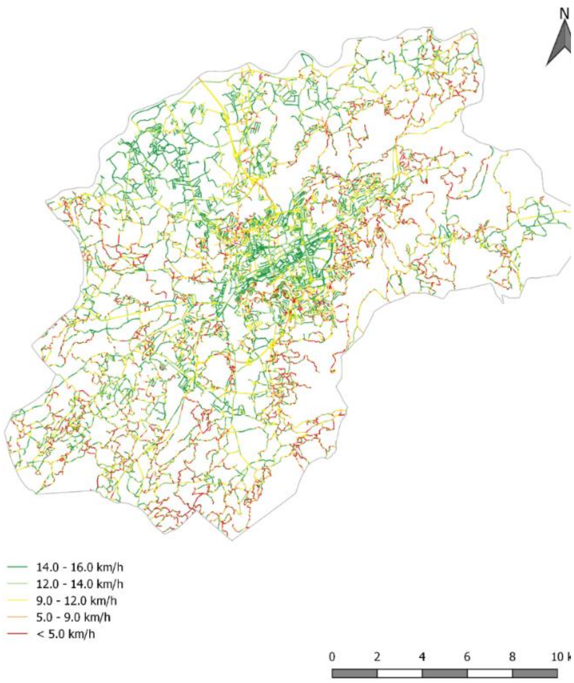

Figure 174 – Cycling Speeds in the Road Network of Braga considering slopes, cycling infrastructure, road hierarchy and accidents for the current scenario.

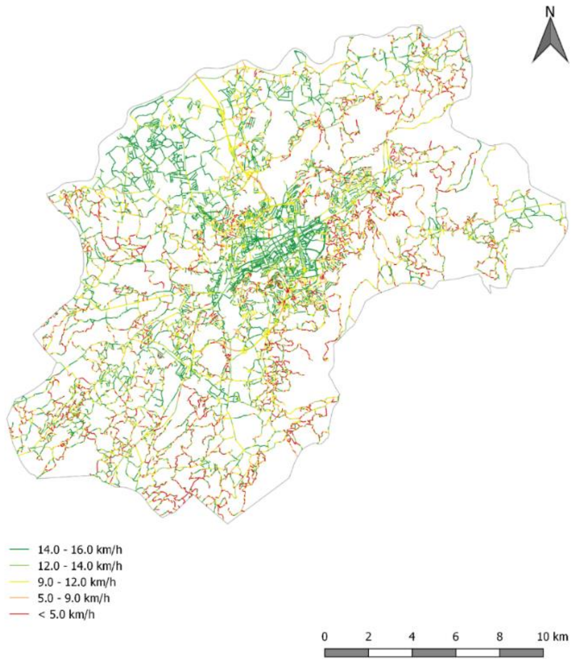

Figure 175 – Cycling Speeds in the Road Network of Braga, considering slopes, cycling infrastructure, road hierarchy and accidents for the proposed scenario.

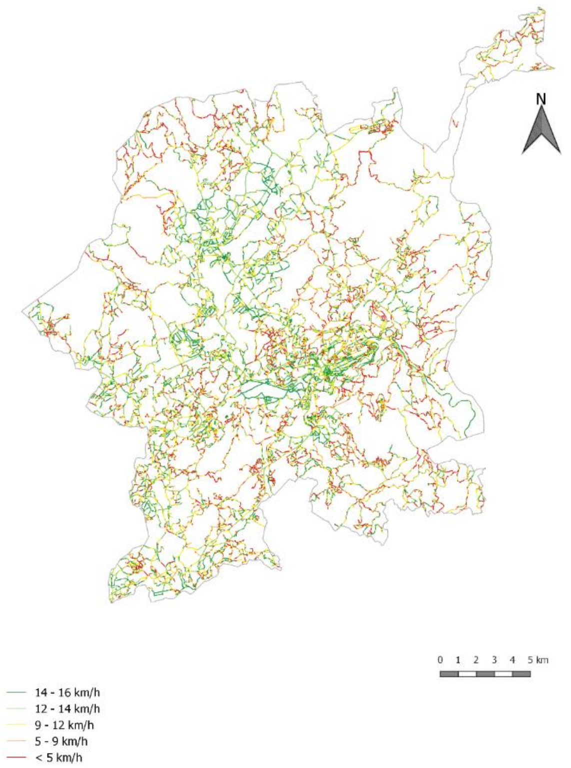

Figure 176 – Cycling Speeds in the Road Network of Guimarães considering slopes, cycling infrastructure, road hierarchy and accidents for the current scenario.

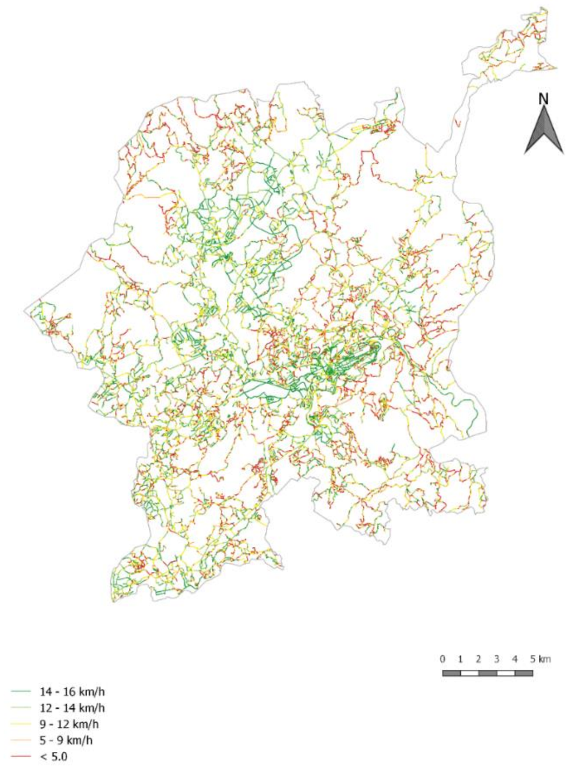

Figure 177 – Cycling Speeds in the Road Network of Guimarães, considering slopes, cycling infrastructure, road hierarchy and accidents for the proposed scenario.

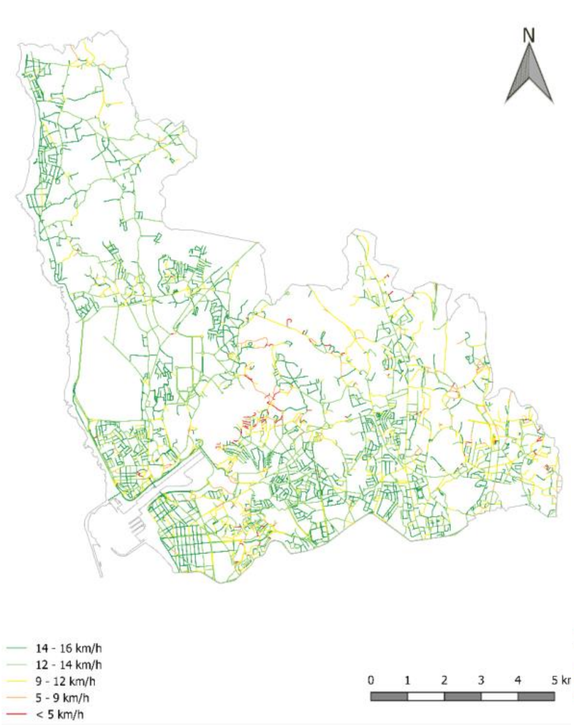

Figure 178 – Cycling Speeds in the Road Network of Matosinhos considering slopes, cycling infrastructure, road hierarchy and accidents for the current scenario.

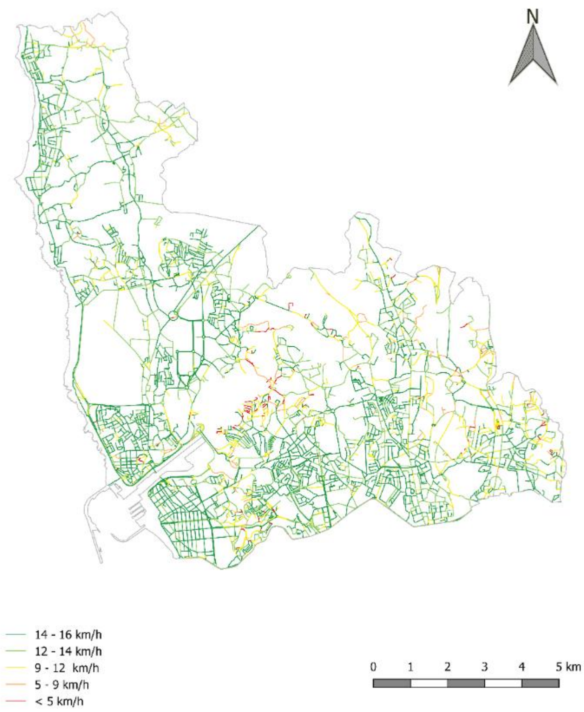

Figure 179 – Cycling Speeds in the Road Network of Matosinhos, considering slopes, cycling infrastructure, road hierarchy and accidents for the proposed scenario.

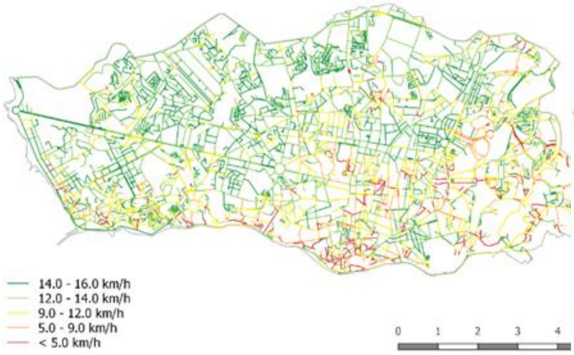

Figure 180 - Cycling Speeds in the Road Network of Oporto considering slopes, cycling infrastructure, road hierarchy and accidents for the current scenario

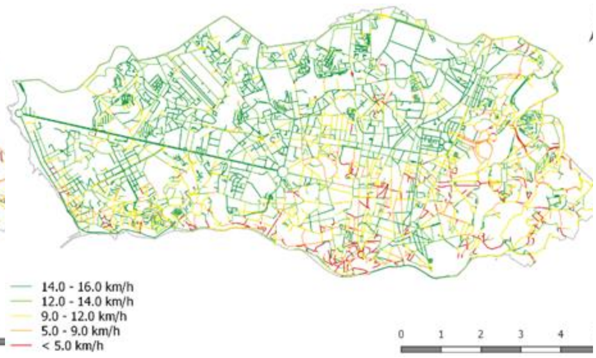

Figure 181 - Cycling Speeds in the Road Network of Oporto considering slopes, cycling infrastructure, road hierarchy and accidents for the proposed scenario.

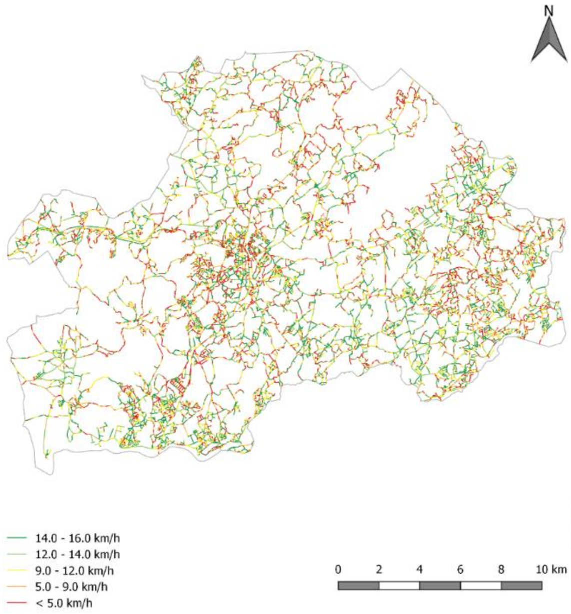

Figure 182 – Cycling Speeds in the Road Network of VN Famalicão considering slopes, cycling infrastructure and road hierarchy.

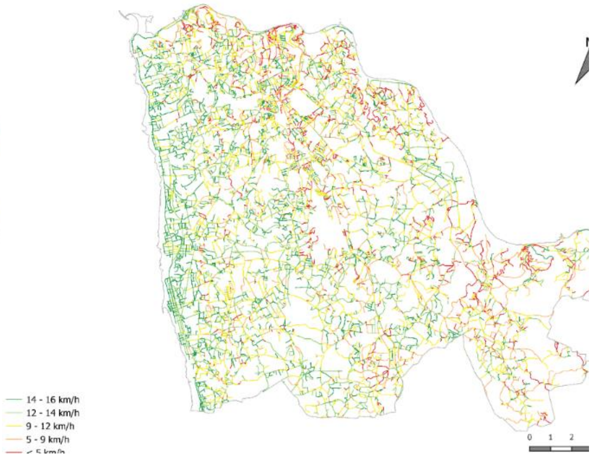

Figure 183 – Cycling Speeds in the Road Network of VN Gaia considering slopes, cycling infrastructure and road hierarchy.