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HOW REGIONAL ACCESSIBILITY AFFECTS LOCAL ACCESSIBILITY?

The case of Matosinhos, Portugal.

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Dissertation submitted for partial satisfaction of the requirements of the degree of

MASTER IN SPATIAL PLANNING AND URBAN PROJECT

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SETEMBRO DE 2020

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To my dear parents.

“Las ciudades son libros que lees con los pies”.

Quintin Cabrera

ACKNOWLEDGEMENTS

Three years ago, my academic journey in the Master in Planning and Urban Project at the University of Porto began. Adding complementary knowledge to my background in Architecture and Urbanism, the master's degree took me (literally and figuratively) from my "commonplace", expanding my way of seeing cities and people.

Among the disciplines, one specifically gained my interest - Urban Mobility Management - carried by Prof. Cecília Silva, who I had the pleasure to be supervised by. With her enthusiasm, the topic turned out to be my new favourite area of territory planning. Cecília closely followed my work during the dissertation year, and coordinated the research project with which I collaborated at CITTA - Research Centre for Territory, Transport and Environment, in the last six months. Thank you for sharing your theoretical and practical knowledge, as well as always encouraging and motivating me to become a better student and researcher.

This journey would not have been possible without Miguel's co-supervision. Thank you so much for always taking the time to discuss ideas and impressions, as well as patiently sharing your GIS knowledge. Miguel and Cecília were the best supervisory team I could have.

To Catarina, thank you for the rich discussions during the months we worked together on the IPTC project. To the other colleagues of CITTA: Marcelo, Ana, Isabel, João, Rui and Silvia. Thank you for the numerous funny stories [cookies and coffees] during lunch hours.

To my colleagues in the MPPU 2017-2018 class, thank you for sharing the same challenges and obstacles of this academic journey abroad. I am especially grateful to those who have gained a special place in my life outside the classroom: Ju, Daniel and Angela. Bela is also one of those, having been literally by my side for the past months - sharing house, meals and wines - with whom I could celebrate each advance, discuss ideas and share the frustrations of writing this dissertation during quarantine.

To all the friends that Porto brought me who, intensely or mildly, crossed my path in these three years. To Marco, for his contagious energy, enthusiasm and motivation. To Beatriz, who since the faculty of architecture, is one of those friends who are always around, sharing so many stories, trips and learnings in Porto, Fortaleza or somewhere else in the world.

To my dear friends who, even being on the other side of the Atlantic Ocean, have made these years and last months lighter and more relaxed. Special thanks to Julia, Barbara, Yuka, Luana and Isabela.

Finally, and most importantly, I thank my family. To my parents Marcus and Rosângela for supporting my decision unconditionally, even knowing that such a choice would imply having a daughter living thousands of kilometres away. To my dear sister Nathalie, for always motivating me to seek the answer to my questions in education, for sharing her academic knowledge with me, for the countless advice and suggestions, and for always motivating me not to be afraid of big dreams. To my brother Marcus, brother-in-law Eliezer and my nephews Gabriela and Zezé, for understanding my absence in so many special moments that I could not be physically present. It is from you all that I draw my strength, and who remind me daily the real meaning of “home”.

ABSTRACT

In the scope of accessibility, recent studies have turned attention to the importance of more active residential urban environments - allowing the local reach of people, activities and public spaces in an easy walk - in addition to acting as a planning strategy to discourage car use. Studies recognise that a car-oriented environment, despite facilitating regional accessibility, induces motorised travel behaviours and brings changes in land occupation, such as the emergence of large commercial activities and shopping centres.

Accordingly, the present study aims to investigate how regional accessibility (RA) affects local accessibility (LA) with attention to the distribution of activities and the system that facilitates walking and car trips, in the municipality of Matosinhos, in Portugal. The analysis uses *Contour* measures, which account for the number of accessible activities in a given space-time interval. Regionally, car accessibility within 30 minutes is used for RA assessment, while 10 minutes walking trips measure LA. The conditions of accessibility to population and employment, in addition to nine local activities (supermarkets, small food stores, kindergarten, primary schools, public spaces, cafes, restaurants, pharmacies and general stores) were analysed both in isolation and at an aggregated level (quantity and diversity of activities). Subsequently, the spatial and statistical analysis of RA and LA compare the results of all census tracts of the study area, evaluating similar or antagonistic patterns of the two scales under investigation.

The results showed an essentially positive relationship between RA and LA. However, after a certain value, RA starts having a negative effect on local accessibility levels. This finding partially supports the hypothesis that accessibility based on excessive car mobility affects accessibility at the local level. Such conditions also justify some of the opposing patterns of high RA and low LA found in the spatial analysis, whose attention turned to the main centralities of the municipality, suggesting that the levels of local accessibility are in part affected the presence of highways or large commercial establishments (Shopping centres). The study revealed interesting results, although with great variations in the accessibility values of each scale which highlights the need for further investigation.

In summary, this study reinforces what has been said in recent studies on the importance and the need to combine the evaluation of accessibility at different scales.

KEYWORDS: Local Accessibility, Regional Accessibility, Activities, Car, Walking.

RESUMO

No âmbito da acessibilidade, estudos recentes têm voltado a atenção à importância de ambientes urbanos residenciais mais ativos – permitindo o alcance local de pessoas, atividades locais e espaços públicos em uma fácil caminhada - além de funcionar como estratégia de planejamento para desencorajar viagens em automóvel. Estudos reconhecem que um ambiente orientado pelo carro, apesar de facilitar a acessibilidade regional, induzem comportamentos de viagem motorizados e trazem mudanças na ocupação do solo, a exemplo da emergência de grandes atividades comerciais e shopping centers.

Neste sentido, o presente estudo tem como objetivo investigar o como a acessibilidade regional (RA) afeta a acessibilidade local (LA) com atenção a características de uso do solo de transporte, nomeadamente a distribuição de atividades e o sistema que facilita o deslocamento motorizado e não motorizado. A metodologia consiste em aplicar um caso de estudo no município de Matosinhos, em Portugal, caracterizando os níveis de acessibilidade em escalas regional e local. A análise recorre a medidas de *Contour*, que contabilizam o numero de atividades acessíveis em um determinado intervalo espaço-temporal, desagregadas ao nível do setor censitário. Regionalmente, são analisadas viagens de carro em um intervalo de 30 minutos para fins de comutação, ao passo que localmente, consideram-se deslocamentos a pé de 10 minutos para "atividades de proximidade". As condições de acessibilidade à população, ao emprego, além de nove atividades locais (supermercados, pequenos comércios alimentares, creches, escolas primárias, espaços públicos, cafés, restaurantes, farmácias e lojas gerais) foram analisadas de forma isolada e agregada, expressas em quantidade e diversidade de atividades. Posteriormente, RA e LA foram analisadas espacial (em mapas) e estatisticamente (em gráficos de eixos) comparando os resultados de todas as subseções da área de estudo, avaliando padrões semelhantes ou antagônicos das duas escalas sob investigação.

Os resultados revelaram uma relação essencialmente positiva entre RA e LA, expressa pelo aumento dos níveis deste quanto maior é aquele. Contudo, a partir de certo valor, RA apresenta um efeito negativo nos níveis de acessibilidade local. Tal achado suporta parcialmente a hipótese de que acessibilidade baseada em excesso de mobilidade de automóvel afeta a acessibilidade à nível local. Tais condições justificam alguns dos padrões antagônicos de alto RA e baixo LA encontrados na análise espacial, cuja atenção voltou-se às principais centralidades do município, sugerindo que os níveis de acessibilidade local são afetados pela presença de autoestradas ou de grandes estabelecimentos comerciais (shoppings) de impacto regional. O estudo revelou resultados interessantes, embora com grandes variações nos valores de acessibilidade de cada escala o que evidencia a necessidade de investigação futuras.

A investigação reforça o que vem sendo dito em pesquisas recentes sobre a importância de estudar a acessibilidade a nível local, além de ressaltar a necessidade de analises compreensivas combinadas com escalas mais abrangentes.

PALAVRAS-CHAVE: Acessibilidade Local, Acessibilidade Regional, Atividades, Carro, A pé.

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ACRONYMS

AMP – Metropolitan Area of Oporto

CITTA – Research Centre of Territory, Transport and Environment

INE – National Institute of Statistics

GEP – Strategy and Planning Office (*Gabinete de Estratégia e Planeamento*)

GIS – Geographical Information System

LA – Local Accessibility

TDM – Travel Demand Management

RA – Regional Accessibility

SDG – Sustainable Development Goals

1
INTRODUCTION

1.1. BACKGROUND

The world is becoming increasingly urbanized. Since 2007, more than half of the world's population has lived in less than 3% of urban territory - cities and metropolitan regions - responsible for around a third of energy consumption and carbon emissions (UN, 2020). It is known that, within the various urban systems that make up cities, the transport system is one of the main generators of such outputs (EEA, 2016). On the one hand, the need of such a system makes it possible to access the various activities and services scattered in urban territories in favour of urban development, on the other, its management must be guided to mitigate the negative effects on economic, social and environmental concerns.

As a result of the increasing provision of transport infrastructure as a means of improving the access to opportunities, supported by the *"predict and provide"* traditional transport paradigm, cities have been designed around mobility conditions very convenient for the car use. Such planning model has leading to induce more complex and unsustainable mobility patterns (Bertolini L. , 2017; Banister D. , 2008). Studies advocate for a paradigm shift – toward the *"predicting and prevent"* - which implies managing cities, streets and public spaces by making conditions less favourable to the car use, while creating better mobility conditions for pedestrians, cyclists and public transport users (Banister & Marshalls, 2000; European Comission, 2004)

Making cities and communities more sustainable, cohesive, inclusive, safe and resilient is among the Sustainable Development Goals (SDGs) established as part of the United Nations 2030 Sustainable Development Agenda (UN, 2020). In this sense, planners and practitioners are increasingly encouraging more sustainable mobility alternatives and mobility patterns in urban areas. Beyond the solutions for mitigate transport impacts based on transport infrastructure design or "clean" technologies (cleaner cars), since the 2000's, Banister & Marshals (2000) - and many other authors

since then -, advocate that actually such solutions may contribute to environmental damages as [in most of the cases] does not implies in a mindset chance. Referring specifically to the reduction of the private car use, the best approach to promote more sustainable mobility, as suggest the authors, is to attempt to reduce the amount of travel itself - worthy not only for environmental reasons but for economic efficiency and social equity.

Some mechanisms to contribute to travel reduction are by substitution or by switching (Banister & Marshalls, 2000). The substitution of travel can be achieved by linking many destinations or travel purposes in the same trip (linked or chained trips); through technology devices (trip replaced by a form of technology or communication); and by trip modification (when activities or people change the location). With relation to the second mechanism, the overall reduction of motorised travel may be achieved by switching mode of transport (from cars to public or non-motorised transport); the destination (switching from distant to local destinations); or time of travel (avoiding peak periods). Such strategies combined with a specific planning objective – to discouraging car use - have the potential to make conditions less favourable for car users, while creating more favourable conditions for other modes users of transport is what has fomented the debate around sustainable mobility in recent years. The known Travel Demand Management (TDM) combine strategies and policies to reduce or distribute the demand for travel in the space-time (Banister D. , 2008).

In the current pandemic context caused by COVID-19, the implementation of social isolation measures has caused cities around the world to have an abrupt drop in the overall daily commuting. In a situation where the population should "stay at home", the world has experimented reducing travel by both substituting and switching from long-distance trips by motorised transport to short-length trips within an easy walk. Big activities that were once major travel generators (e.g. large companies, shopping centres, schools and universities) sought new ways to adapt their employees or the public to the named ‘new normal’ thanks to the internet. Home-based telecommuting and remote study, e-commerce, and on-demand services have reaffirmed as strategies to circumvent physical distance through screens. On the other hand, the accessibility to activities related to everyday needs - such as food supply, local amenities (shops, cafes) and recreation (public spaces) have gained even more prominence, especially at the local or residential level.

In addition to support sustainable urban development and mitigate congestion and climate change concerns (Batty, 2009; Banister D. , 2008; Bertolini, le Clercq, & Kapoen, 2005), there has been a growing concern of city planners and managers in recent years to rethink their neighbourhoods and public spaces in order to provide quality of life for their residents (European Comission, 2004). Urban planners suggest that integrated urban planning has the potential to foster broader strategies, so that

land use needs are met by transport systems in a more sustainable way. The combination of the two complementary urban fields comprises the basis of the concept of accessibility.

Derived from the transport planning scope, the concept of accessibility has become very common since famous Hansen's definition (1959), as the "*potential of destinations for interaction"*. The inclusion of other – individual and temporal – components has brought the discussion closer to the person's level in recent years (Geurs & van Wee, 2004), leading to the understanding of accessibility as the "*ability of people to access destinations"* (Curl, Nelson, & Anable, 2011).

Despite the empirical and theoretical knowledge on the need shifting paradigm from "planning for mobility" to "planning for accessibility" in academic researches (Silva & Pinho, 2010; Banister D. , 2008), cities are still facing problems induced by mobility improvements (based mainly on the car) and recent changes in the spatial configuration associated to urban growth (Silva C. , 2020; European Comission, 2004). Theoretical evidence recognise the synergy between land use and transport changes and that only integrated urban planning allows for sustainable responses (Bertolini, le Clercq, & Kapoen, 2005; Silva & Pinho, 2010).

Since segregated planning aimed at improving the opportunities' accessibility only by mobility, particularly the car [enhancing the access to larger areas, thus it approximates to a regional scale], recent concerns suggest that such changes might be contributing to reduce the accessibility at the pedestrian perspective (Silva C. , 2020; European Comission, 2004).

1.2. RESEARCH QUESTION AND OBJECTIVES

Inspired by the aforementioned assumption, the present study aims to investigate whether the accessibility at the regional scale is somehow affecting accessibility conditions at the local or "neighbourhood" scale. Thus, the research question raised is how regional accessibility (RA) affects accessibility at the local scale (LA), applying an empirical study case to the Portuguese municipality of Matosinhos. Aiming to answer the question, the general objective of the present work will be achieved by the accomplishment of the following specifics objectives:

- Understand the concept, components and measures of accessibility, as well as the theoretical background on regional and local accessibility. This objective is intrinsic to the three following objectives;
- Characterise regional accessibility (RA) with regard to the study area and its metropolitan region (Metropolitan area of Oporto);
- Characterise local accessibility (LA) in the context of Matosinhos;
- Evaluate the relationship between RA and LA levels.

Holding the hypothesis that car-based accessibility (designed to faster surpass regional distances) is affecting accessibility at the pedestrian level (thus, at the local scale), it can be said that the expected results is a negative relationship, where the level of LA decrease as much RA values become higher.

Most of the academic evidence in this field aims to measure accessibility of a specific area or target group, according to the transport service coverage; on the access of one or several types of activities by a specific transport mode (e.g. private car, public transport, walking or cycling); or yet analyse which transport mode(s) is(are) more competitive over other(s) according to the land-use configurations (e.g. density, diversity). Little evidence was found to assess accessibility combining different geographical scales, revealing a gap in the body of the literature which reinforces the relevance of this emergent concern.

Accessibility studies, especially those focused at local scale, highlight the role of proximity as a mean to allow an efficient distribution of opportunities among the land-use systems, bringing people, activities, buildings, and public spaces together, with good walking and cycling mobility (Witten, Pearce, & Day, 2011; van Eggermond & A.B. Erath, 2016). Local accessibility is closely related to the complementary "residential" activities to help to meet daily needs, promote vibrant neighbourhoods, and strengthen communities (Barton, Horswell, & Millar, 2012). On the other hand, studies on regional accessibility focus on efficiently meeting the needs for opportunities spatially dispersed, such as housing and employment centres, by high-speed modes (public transport and private car), connecting them to the rest of the city in a sustainable way (Benenson, Martens, & Rofé, 2010). Regional accessibility is highly suggested as a comprehensive planning strategy to promote sustainable urban development in cities and metropolitan regions (Deboosere, El-Geneidy, & M. Levinson, 2018).

As cities are considered part of a global system, comprised by small communities (or neighbourhoods) and the macro scale environment (Kaplan et al., 2019), a better understanding of the urban structure is needed by both distinguishing the communities from the others and its integration to the surrounding region to which is a part (Handy, 1992). Through the relationship between local and regional scales by an accessibility perspective, it might be possible to identify the factors in land-use and transport systems with different implications in accessibility conditions in among scales. It is believed that a comparative evaluation of accessibility at both regional and local scales might bring a comprehensive understanding of whether (and if so, how) the local accessibility (LA) level is been affected by the regional accessibility (RA).

1.3. THESIS STRUCTURE

Drawn to contemplate the general and specific objectives aforementioned, the present dissertation, unfolds as follows.

This chapter, in addition to a brief background, presents the justification of the research problem, the objectives this study is aimed for and its organisational structure. Chapter 2 corresponds to the literature review that will address, in a first part, (a) the concepts, components and measures of accessibility as a strategy for integrated land use and transport planning; the second part, in turn, discusses (b) the concepts of regional and local accessibility, bringing out its manifestations in a comparative approach between the two scales. Chapter 3 presents the empirical study case, details the methodological proposal of how the analysis of accessibility between the two scales will unfold, as well as the data collection and manipulation process. Chapter 4 discuss the results of the evaluation of RA and LA, made firstly individually and subsequently comparatively (in spatial and statistical ways). Finally, Chapter 5 presents the main conclusions and recommendations for future research.

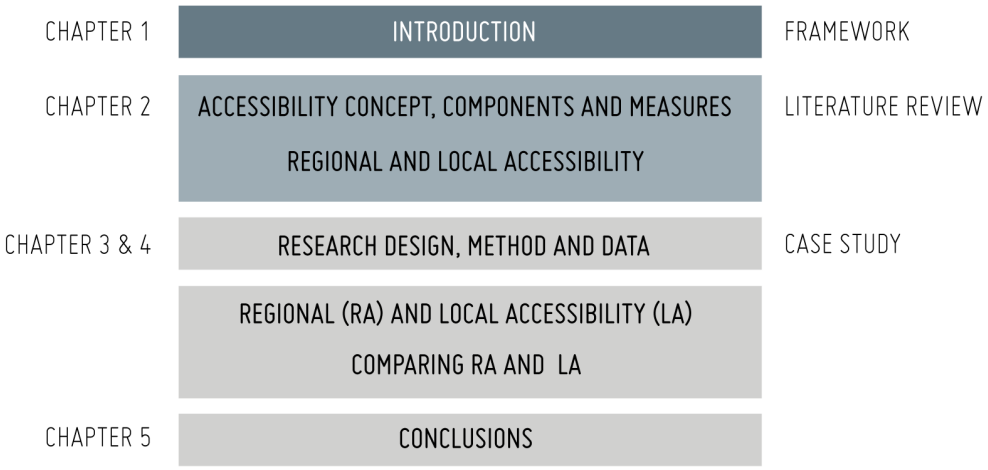


Figure 1 - Research structure.

2
LITERATURE REVIEW

This chapter presents a literature review on accessibility and develops into two sections: the first aims to understand the concept of accessibility and its components, in addition to presenting some of the measures commonly used to measure accessibility; the second section is aimed to present [the few] studies found that analyse accessibility combining different scales in the city, specifically at the local and regional levels. It is intended to present an academic contribution to this debate.

2.1. ACCESSIBILITY CONCEPT, COMPONENTS AND MEASURES

2.1.1. UNDERSTANDING THE CONCEPT

Derived originally from transport planning field, accessibility is a multidisciplinary concept which becomes commonly known since the 1950s by Hansen's (1959) definition. In his words, accessibility is *the 'potential of destinations for interaction'*, where destinations are understood as opportunities - represented by people and places -, enabled by a mean for interaction - traditionally represented by the transport system.

Since then, the concept has been increasingly studied and playing an important role to integrated spatial policies aiming at more sustainable goals (Bertolini, le Clercq, & Kapoen, 2005; Banister D., 2008; Straatemeier, 2008; Batty, 2009). Other definitions have emerged in the literature over time as *'the way the spatial structure allows access to the activities sprayed in the city'* (Silva & Pinho, 2010), where spatial structure consists of the land-use and transport systems. Accessibility is also seen as *'the ease of reaching an end'* (Banister, 2000) – again, where the 'end' is the opportunities dispersed in the urban environment, and the 'mean' is the manner people move between them. There are many types of 'ends' and 'means' (Straatemeier, 2008). An end, or opportunity, represents e.g. houses,

jobs, educational, leisure and health activities; a mean, or mobility, refers to the transport mode allowing such movement (i.e. car, public transport, cycling or walking).

It is recognised that people's transport choices are very related to the way the transport and land-use systems allows reciprocal connections enabling the interaction between individuals and activities (Hansen, 1959). Since people travel to access the desired activities, when nearby activities are available, 'less' mobility is needed to surpass the distance between origin and destination (Batty, 2009). Although this dichotomy between proximity and mobility is considered crucial for understanding the nature of the concept of accessibility (Straatemeier, 2008; Batty, 2009; Silva and Pinho, 2010; Silva, 2018), is necessary yet to distinguish the concepts of transport, mobility and accessibility (Figure 2).

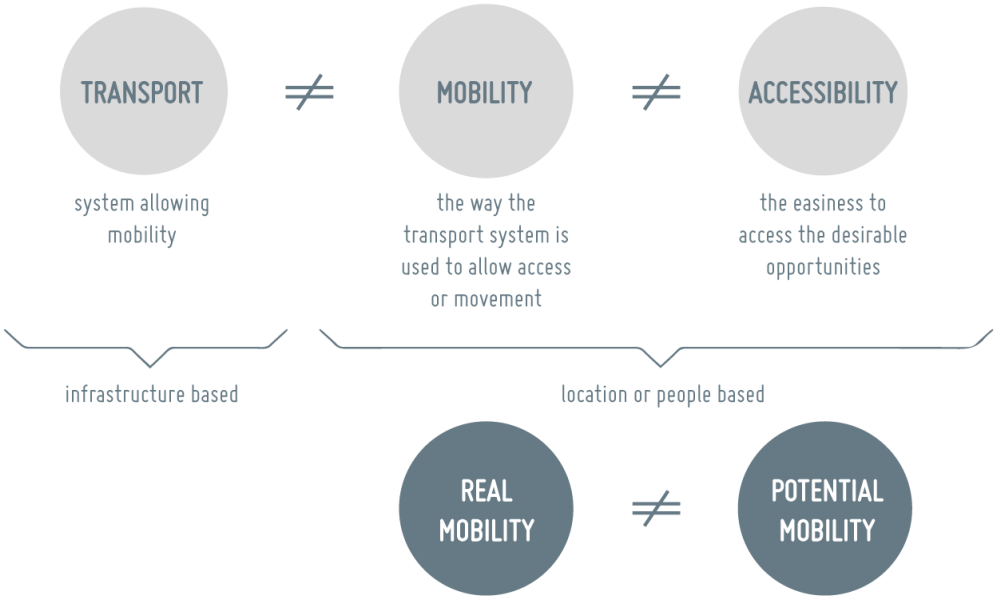


Figure 2 - Transport, mobility and accessibility concepts. Adapted by the author based on Silva (2018).

Based on Silva (2018) the transport concept refers to the system that allows people to move or, in other words, the infrastructure that provides people's mobility; the mobility concept, in turn, is defined as the way that the transport system allows people's movement; and finally, accessibility concept refers to the easiness to access the desired opportunities. This easiness, as mentioned before, depends on how close or distant these opportunities are apart, which determines people's mobility choices. Hence, transport is the infrastructure-based system allowing mobility which represents the individual's real choices, while accessibility represents the various possibilities available for individuals. Thus, in this work, mobility refers to real mobility (given people's real choices) and accessibility to potential mobility (given people's available choices).

Another important point is that the demand for mobility is derived from the directed need to participate in the opportunities sprawled in the urban structure, and not for the mobility itself (Kockelman, 2014) – the opposite of undirected travel when people travel because of the travel itself (for further information see (Mokhtarian & Salomon, 2001). People's travel choices are made because they need a mean to access their jobs, education, shopping or leisure activities. If accessibility is the potential mobility choices determined by the urban structure characteristics (land-use and transport systems), it is understood that improvements in accessibility are not necessarily achieved only by improving mobility, but with a combination of mobility and proximity (Silva C. , 2018). Increasing accessibility must be achieved by proximity between people and places, and by mobility when proximity is not an option. The urban environment at a regional scale, for example, is comprised of a large extent in which increased mobility is needed to permit people's interactions, differently of the urban environment at a local scale in which people's interactions are likely allowed by proximity.

From the start point of the derived demand concept by Kockelman (2014), Silva (2018) brings a clear distinction between real demand and derived demand and the dichotomy between mobility and proximity. As stated, these concepts are in turn related to regional and local accessibility, but this will be better addressed in the following section of this chapter (2.2). For now, the Figure 3 below illustrates the idea of derived demand as a means of accessing opportunities through proximity and mobility. In turn, the real demand for these opportunities is given by the level of accessibility (local and regional) defined by the proximity, mobility or combination of both.

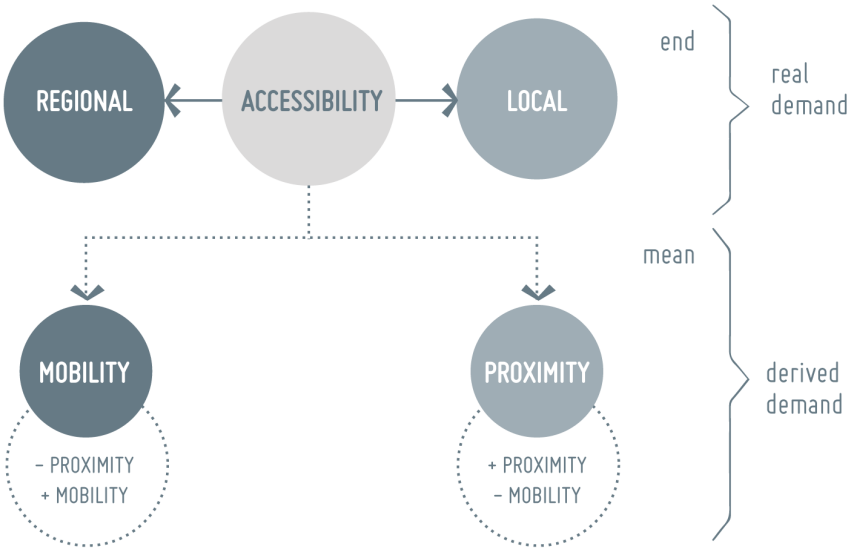


Figure 3 - Mobility-proximity dichotomy and their relation with regional and local scales.
Adapted by the author based on Silva (2020) and (2018).

2.1.2. Accessibility Components

In recent years, the inclusion of other two components – individual and temporal – has brought the discussion to the person's level (Geurs & van Wee, 2004). According to Geurs & van Wee (2004), "individuals and groups of individuals resort to land-use and transport systems by (a combination) of transport mode(s) because they need to reach activities or destination spatially dispersed." People's mobility choices to access such destination are made based on a variety of constraints according to land-use and transport conditions but also depending on individual needs which might vary according to time. A full assessment of accessibility conditions comprises four interdependent components – land use, transport, temporal and individual (Geurs & van Wee, 2004) - which combined determine the different types of accessibility instruments in various levels of complexity. Thus, the land use and transport components reveal the spatial structure conditions potential to attract or constraint access to activities (Silva & Pinho, 2010) while the temporal and individual elements express the circumstances that may influence the chosen opportunities (Geurs & van Wee, 2004).

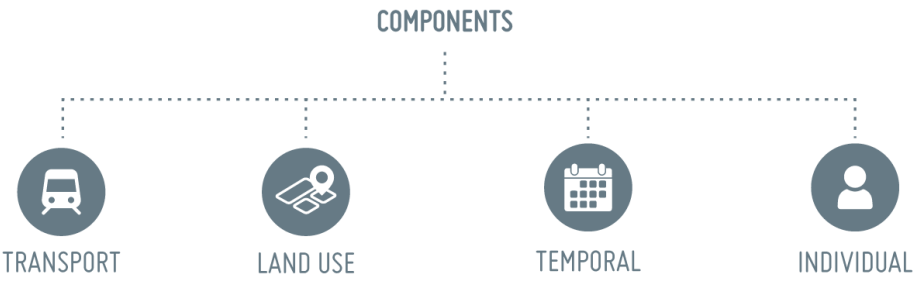


Figure 4 - Accessibility components. Based on Geurs & van Wee, 2004.

The land use and transport components are easy to understand by the demand and supply concepts – for opportunities and mobility (Silva & Pinho, 2010). The land use component measures the distribution of potential destinations, magnitude and character of the activities, expressing the motivational or attractional factor relying on the offer of activities. The transport component represents the resistance or impedance factor measured by travel time and/or cost, expressing the disutility by mode depending on the demand and supply of the transport system. The other two components consist of the temporal aspect that reveals the availability of the activities at different times during the day/week, and the individual one which reflects personal preferences or (physical and economic) capabilities to access these activities (Geurs & van Wee, 2004).

The incorporation of all these aspects can bring more accuracy to assess the accessibility level of people and places but also results in more complex and sophisticated methods (Geurs & van Wee, 2004). In planning practice, studies recognise that such trend has been pushing away practitioners to use such instruments to support planning decisions, which has led to several authors to advocate in favour of using measures that are simple to understand, operationalise and communicate (Curl, Nelson, & Anable, 2011; te Brömmelstroet, Curtis, Larsson, & Milakis , 2016; Curtis & Scheurer, 2017). However, it is important the understanding of the implications of excluding one or more components to measure accessibility (Silva C. , 2018). For instance, the lack of temporal and individual components offers an incomplete picture of accessibility experienced by some individuals (Iacono, Krizek, & El-Geneidy, 2010; Department for Transport, b, 2014).

Beyond the components, accessibility measures assume different approaches regarding the aim or planning goals they are supposed to overcome. The literature shows different ways to classify the different types of measures. According to Silva (2018), the accessibility measures can consider (1) the activities (or people) at their origin or destination locations; or (2) the access of a group of people or assume a specific location based on the demand to access it; or (3) taken into account the number of activities or the size or relevance of each activity reflecting its utility. The same measure can identify distinct results regarding different types of approach that, at first sight, are seen as antagonists (Silva C. , 2018). Figure 5 presents the types of measures, based on Silva's work.

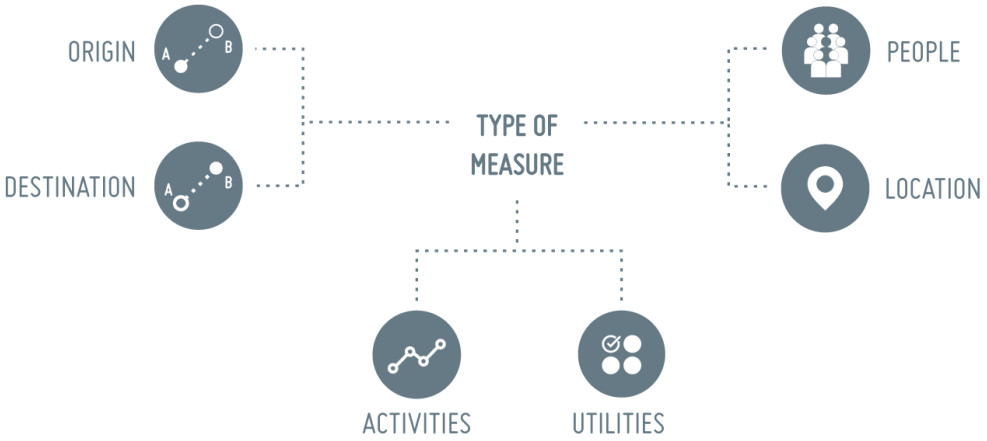


Figure 5 – Type of measures and approaches. Based on Silva (2018).

Several additional operational details can be introduced to overcome possible shortcomings, but have little relevance for this study. For instance, more accurate measures can account for *distance decay* - reflecting different activities' weight depending on their proximity/locations -, or the *competition effect* - revealing relevance and size of such activities (Silva C. , 2018).

Given these points, the final definition of an operational accessibility measure depends on three 'steps' taken in the design of such instruments, which are interdependent and mutually influence themselves considering a) the accessibility components, b) the type of measures, and some c) additional operational details. Aligned with the main objective of this study - to analyse how regional accessibility is affecting the accessibility at the local scale -, we focus on the transport and land use components only, using activity-based and location-based measures, and no additional details are considered.

2.1.3. Measuring Accessibility

There is a variety of accessibility measures and instruments that we can find in the literature aimed at different planning purposes and level of complexity. Most of these planning tools are based on basic accessibility measures by combining or using them as indicators in such instruments. This subsection presents the basic measures of accessibility, based on Silva (2018), namely *Distance - Time, Isochrone and Contour* (or Cumulative Opportunities), as well as *Potential* and *Gravity* measures.

2.1.3.1. Distance - Time

The Distance-Time measure is seen as the simplest measure of accessibility, from which most of the other measures derive (Silva C. , 2018). This measure is used as standards for the maximum travel time distance between two given points, representing origin and destination locations (or transport infrastructure) (Geurs & van Wee, 2004). The distance (or time) to overcome them can be measured as a simple straight line (Euclidean distance) or taking in account the street network to a more precise assessment of the distance and/or time between the two locations. A practical example of this type of measure is to provide a map that represents the impedance factor (time, distance and/or cost) spent to access certain activity considering a transport mode. Although a very simple measure, lots of information can be extracted using a Distance – Time measure. For instance, by combining a map representing the time to access certain activity (e.g. school) by transport mode with a population density map can give enough information if such activity is accessible in a dense or dispersed area.

This measure is commonly used as one of the UK planning system indicators to measure access to key services and activities (e.g. primary schools, health centres or job centralities) in British municipalities (Department for Transport, a, 2014).

2.1.3.2. Isochrones

We can also measure accessibility using an isochrone reference. The spatial representation of an Isochrone measure is an equidistance line from a given origin, where the 'distance' is measured based on an impedance factor – in time or metres (Silva C. , 2018). As the *Distance-Time* measure, this equidistance line can be measured by Euclidian distances or considering the network infrastructure. From a given origin point, the *isochrone* shows the areas with accessibility by a specific mode within a fixed travel time (or distance), assuming that point as a desirable destination.

There are various possible applications for this measure. An example is mapping an activity type or transport infrastructure (e.g. bus stop) and calculating the area from/to which people can access them within a limit of time (e.g. 15-minute walking), denominated by some authors as service area (Benenson, Martens, Rofé, & Kwartler, 2011). Another common application is to consider a 'hypothetical' origin location, such as the geometric point of each spatial subdivision (census tract). Considering that point as housing locations, we can represent, for example, the accessible area from which people can access available activities within a given travel time and mode.

Bringing it to a practical field, the Isochrones measure can be used to reveal spatial inequalities in the urban territory - land use and/or transport systems -, identifying activities that are not accessible (or accessible by a specific mode of transport) in given travel time or distance. With an easy-to-read representation, this measure can be used to compare the accessible areas of different modes of transport, considering the same travel time, offering a relative assessment between modes. For example, in 15 minutes, the car has generally much greater range than walking and therefore might be considered more competitive for certain people (who has a car). However, considering congestion or time looking for parking place, it might possible that for short trips, the car become less attractive.

The main difference between Distance/Time and Isochrone measures is that while the representation of the first reveals the distance or time in the degree of proximity, the last consider a limit time (or distance and cost) within which all opportunities have access to, and which above this limit have no accessibility at all. Also, while the Distance/Time measure considers the closest way from one location to another, Isochrones considers all possibilities inside the accessible area.

2.1.3.3. Contour (or Cumulative opportunities)

This measure is one of the most common measure in the specific literature, also known as Cumulative Opportunities, as well as Proximity Count or Daily Accessibility, and it counts the number of reachable activities within a given fixed travel time, distance or cost (Geurs & van Wee, 2004). Although most of the studies do not differentiate Isochrones and Contour measures since they consider the latter derived from the first (Silva C. , 2018), for a better understanding and application

it is important to recognise their differences. Derived from the *Isochrones*, the spatial representation of a Contour measure considers not only the accessible area in a fixed travel time and mode, but it counts the number of opportunities in such area.

Studies using the Contour measure are often based on the destination or origin locations. When based on destination, it counts the average population with access to opportunities within the accessible area and, when based on the origin, counts the number of opportunities available to the population in the same area (Silva C. , 2018). A practical example using a Contour measure is to count the number of reachable job opportunities - disaggregated at the census sector level (or another spatial unit of analysis) - from an origin location, in 30 minutes by car. The measure is also often applied to count the number of specific activities (e.g. schools, supermarkets, public spaces, health) from the same origin locations, with another mode and travel time (e.g. 10-minute walking).

Despite being very common in accessible studies, *Distance/Time, Isochrones* and *Contour* measures have some limitations concerning theoretical criteria as highlighted by Geurs and van Wee (2004). First, such basic measures do not take into account distance decay nor competition effects regardless of the demand distribution for an opportunity and capacity limitations of several activities (e.g. schools, hospitals or jobs). Also, *Distance* and *Contour* measures perform arbitrary issues treating all opportunities equally desirable as a result of excluding temporal and individual components. However, these measures are seen as easy tools to operationalise, to interpret and to communicate, which are great advantages in planning practice (Geurs & van Wee, 2004; Silva, 2018).

2.1.3.4. Potential (and Gravity) measure

Potential measures have emerged in accessibility literature aiming to overcome some of the limitations presented in the previous subsection concerning the accuracy on the application of *Distance, Isochrones* and *Contour* measures (Geurs & van Wee, 2004). Derived from a *Contour* measure, this measure counts the number of activities within the accessibility area but considers that the relevance of opportunities increases or decreases depending on the distance from the origin location (Silva, 2018). Therefore, the more distant the activities are from this origin, the lesser the influence on accessibility when compared to closer activities. The formula for this type of measure is the following:

(Equation 1)

$$A_i = \sum_j O_j f(d_{ij})$$

Where, A_i - Origin Accessibility; O_j - Destination Opportunities; $f(d_{ij})$ - Decay function; d_{ij} - Distance, time or cost from i origin and j destination.

Similar to the Contour measure, the *Potential* measure can be based on origin or destination activities' locations. In *Potential* measures, the limit of the area with or without accessibility (represented by Isochrones in Contour measure) is replaced by a residual weight of the opportunities depending on their proximity. Thus, while the Contour measures consider all opportunities equally important within a limit of time/distance or cost, the Potential measure gives a weight to each opportunity proportional to the distance or the size of the activity.

The *Potential* measure is often found in the literature as *Gravity* measure since several authors treat them as the same type of measure. Despite the subtle difference, again, it is important a clear distinction between the two. Both *Potential* and *Gravity* measures count the number of opportunities within a given distance/time, applying different weights to opportunities. The main difference is that in *Potential* measures the weight depends on the proximity of the opportunities, being a distant activity seen as less relevant from a given origin location; while in *Gravity* measures, in addition to the distance decay, it is also applied a weight according to the size or capacity of such opportunities (Silva C. , 2018). Besides the distance decay and competition effect, other additional operational details aimed at overcoming the shortcomings from simple measures might include temporal or individual constraints in Potential and Gravity measures. However, as said, such details increase the complexity and interpretation of accessibility measures.

As so, considering the pros and cons regarding the operationalisation of all the measures to reveal the level of accessibility of a given area, it is believed that the *Contour* measure can potentially characterise local and regional accessibility, while communicating the results properly and easily and, therefore, being the measure applied in this study.

The following Figure 6 presents a conceptual scheme of Isochrones, Contour, Potential and Gravity measures, derived from the simplest Distance/Time measure. In the upper line, Contour measure (right) accounts the number of activities within the accessible area, derived from the simple Isochrone (left). In the line below, Potential (left) measure takes in account a distance decay assuming that, from the origin location, closest activities have more relevance by proximity, and Gravity measure (right) considers, in addition, the competition effect assuming that bigger opportunities are more competitive compared with smaller (or low capacity) activities.

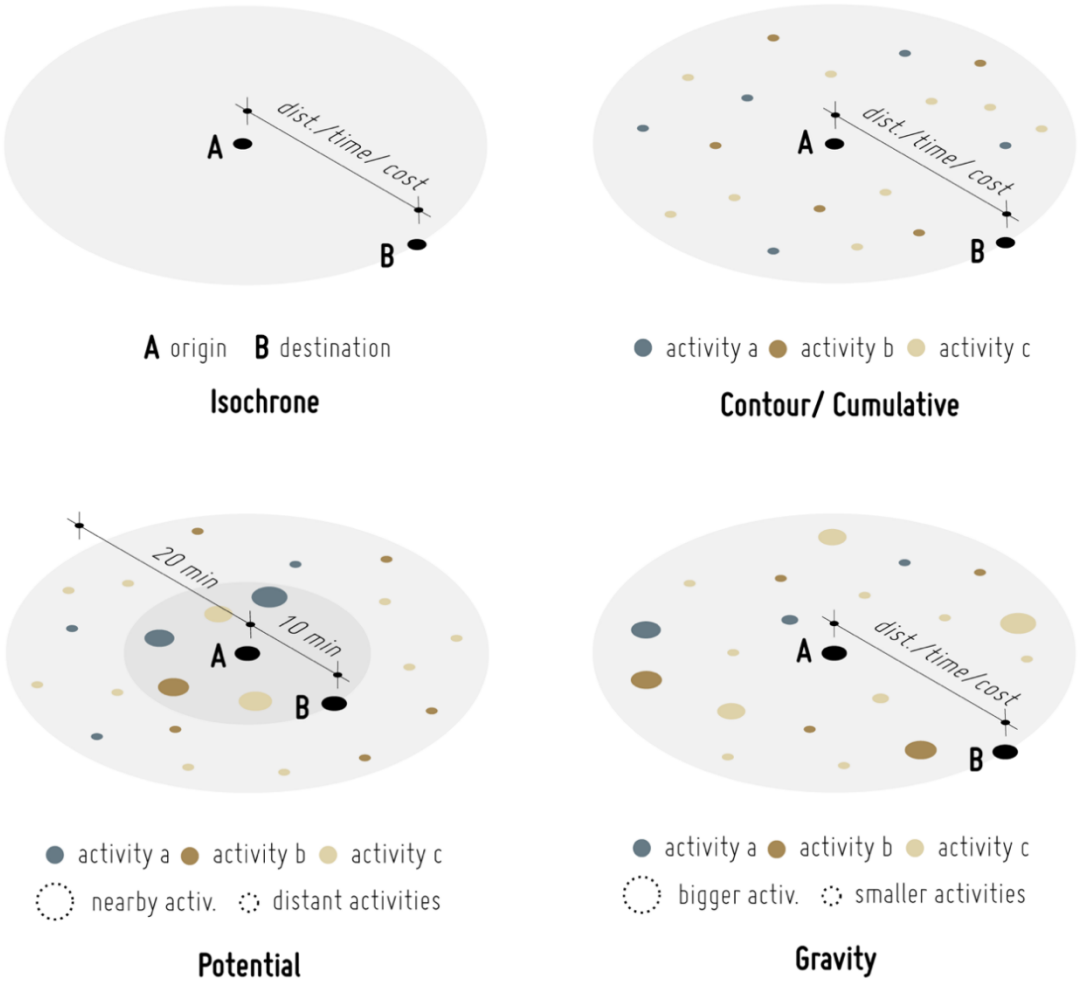


Figure 6 - Conceptual scheme of Isochrone, Contour, Potential and Gravity measures. Based on Silva (2018).

2.1.4. Accessibility Instruments

Accessibility instruments are defined as an operational form of (a set of) accessibility measures aimed at achieving a specific planning objective to supporting integrated land use and transport planning (Bertolini, Hull, Papa, Silva, & Arce-Ruiz, 2019). According to Bertolini et al. (2019), two main goals characterize the usability of the tools: one supports land use developments (where to locate residences, activities and services), while the other focus on managing (encouraging or reduce) the use of specific transport modes. Instruments can tackle one of these goals or both in a multi-disciplinary approach. Generally, the design of accessibility instruments uses not only one, but many accessibility indicators, derived from a combination of types of measures. There are numerous accessibility instruments in the literature, but it is not reasonable presenting all these instruments in-depth here (see Bertolini et al., 2019 for an extensive review).

Table 1 - Accessibility instruments, measures and indicators used.

Instrument	Reference	Type of Measure	Indicator	Description
British Accessibility (ACCALC)	**Department for Transport** (2014)	**Distance - Time**	**Travel Time**	**Average shortest time to reach nearest destination (by mode)**
		Contour/ Potential	Destination	% of users that can access a service within a certain time
		Contour/ Potential	Origin	Number of services available within a certain time
Structural Accessibility Layer (SAL)	Silva & Pinho (2010)	Contour	Diversity of Activity	Number of activity types from a given origin
		Comparative Analysis	Comparative Accessibility	Compare *DivAct* outcomes across all modes considered

This subsection presents the accessibility instruments on which the case study of this investigation is based: the model applied in the British planning system and the Structural Accessibility Layer (SAL), a Portuguese instrument developed by Silva & Pinho (2010). The measures and indicators used in such instrument references are summarised in Table 1, in which fall in the basic measures and types of approaches presented before. This knowledge will be useful to understand how the study case will unfold.

2.1.4.1. British Accessibility Statistics (ACCALC)

ACCALC is an instrument operated by the British Department for Transport which measure the accessibility and connectivity of the population to services considered as essentials. This planning supporting tool is operated by the UK local authorities since 2005 to ensure the access to eight key services: employment centres, primary and secondary schools, higher education institutions, health centres, hospitals, food shops and town centres (Department for Transport, a, 2014). Similarly, the connectivity is based on the easiness to access transport infrastructure as airports and rail stations in addition to the other eight services types.

For each service, accessibility – in their definition *"the extent to which individuals and households can access day to day services"* - is measures based on three types of indicators: *travel time, destination* and *origin indicators.* The first indicator measures the users' average *travel time* needed to reach the nearest service type calculated by transport mode (i.e. public transport/walking, driving and cycling) by their annual National Travel Survey. The destination indicator measures the average population in an area (i.e. LSOA: lower layer output areas or the smaller statistic area) who can access one of these 8 service within a certain time across all modes considered. This indicator can also look for particular social groups "at risk" or exclusion, by measuring for instance the percentage of the target population (e.g. 5-10-year olds) able to access a service (e.g. school) within 15 min across all the modes considered. The origin indicator measures the number of services available

within an area according to selected journey times and mode of transport (for instance, the number of services available within 15 minutes by PT, bicycle or car).

The latest two - destination and origin indicators - are measured in two different ways based on Contour and Potential measures - known as threshold and continuous indicators respectively (Department for Transport, a, 2014). For the first measure, the origin and destination indicators consider a time threshold spent to access the eight key services, while the second measure includes the individual component based on the "sensitivity" of users to choose the closest available service - assuming that closer services are likely to be chosen -, and thus believed to give *"a more complete picture of accessibility"* since distinguishes an area which available service within a time threshold and one *"where the target population will have to travel a greater distance"* (Department for Transport, b, 2014). Table 2 resumes the activities and data applied in this measure.

Table 2 - Lower- and upper-time threshold for the eight key services, and required data.

Activity	Time	Required data in each output area (LSOA)		
	Min - Max	Services' location	Population	'At risk' population
Employment	20 - 40	No. of jobs per LSOA	16-74-year olds	Jobseekers
Primary School	15 - 30	Primary schools	5-10-year old students	Eligible for free school meals
Secondary School	20 – 40	Secondary schools	11-15-year old students	Eligible for free school meals
Further Education	30 - 60	Further education and sixth form colleges/school	16-19-year old students	-
GP (Health Centres)	15 - 30	GP surgeries centres	No. of households	Households without a car
Hospital	30 - 60	Hospitals	No. of households	Households without a car
Food Store	15 - 30	Grocery/supermarkets or convenience stores	No. of households	Households without a car
Town Centre	15 - 30	Town centres	No. of households	Households without a car

2.1.4.2. Structural Accessibility Layer (SAL)

The Structural Accessibility Layer (SAL) is an interesting accessibility-based tool developed by Silva & Pinho (2010) that geographically represents the levels of accessibility by each mode of transport (non-motorised, car and public transport) to different types of services or opportunities, in a comparative way. Developed to measure accessibility at the regional scale - at a high spatial disaggregation level -, the SAL is based on two main indicators: the *DivAct* (diversity of activity index) and the comparative accessibility measure.

The first indicator is a contour measure and counts the number of activity types all origins comprised in the study region (census tract's centroids). The SAL considers 18 types of activities (see the following table) seen as relevant to generate trips given education, leisure, shopping, healthcare,

other activities and employment purposes. The activities are scored by its frequency *F(y)* based on the mobility survey of the Portuguese annual statistics (INE). The time threshold for each transport mode is based on an estimated real average time, namely 45 minutes for public transport, 30 minutes for private car and 20 minutes by non-motorised mode (walking).

The *DivAct* is measured for each transport mode expressing more or less diversity of activities, which ranges from 0 when no accessible activities are found to 1 when all activities considered are accessible, applying the frequency weight of each travel reason. Using the outcome of the *DivAct* measure, the *comparative accessibility* measure develops a relative accessibility analysis across all transport modes considered. This measure defines three classes according to the level of accessibility: class C (low accessibility) from 0 to 0.5, class B from 0.5 to 0.85 (medium accessibility) and class A from 0.85 to 1 (high accessibility). By applying these classes to what the author calls the "benchmark cube" - i.e. combining the accessibility classes (A, B, C) with the 3 'dimensions' of transport, thus, non-motorized (x), public transport (y) and the car (z) - 7 accessibility clusters are defined as a result of combining areas that offer similar levels of accessibility by mode of transport. (for further information see Silva, C, 2008). For instance, cluster III means that an area offers favourable conditions to the use of all modes due to its high accessibility to a range of activities by any mode whereas class VII does only favourable high accessibility levels by the car and thus only offers conditions for car use.

Table 3 - SAL types of activities. Based on Silva (2008).

Travel Purpose	Description	Activity Type	F(y)
Schools	Infant School and Elementary school	1	4
	High School	2	5
	University	3	3
Leisure/ Entertainment	Parks, public gardens, squares	4	8
	Restaurants	5	2
	Cinema	6	2
	Shows/ Theatre	7	1
	Sport	8	8
	Others (e.g. Museums, Libraries, Night Clubs etc)	9	1
Shopping	Food	10	8
	Others	11	2
Healthcare	Pharmacies	12	2
	Hospitals and Clinics	13	2
Other Activities	Public/ Municipal administration offices	14	2
	Postal Office	15	2
	Banks	16	5
	Others (e.g. Insurance, Lawyers, Architects, financial advisers, etc)	17	2
Employment	Employment	18	41
			100

2.2. REGIONAL AND LOCAL ACCESSIBILITY

With the understanding of the main concepts, components, basic measures and relevant instruments on which this study is based, the following section aims to present a literature review on accessibility studies, particularly focused on local and regional scales. This section is organised as follows. The first section presents a definition on regional and local accessibility and related factors affecting each scale; the next section discusses how the traditional transport planning focused at improving [regional] accessibility only by transport means might be inducing accessibility losses at the local scale, and concludes by analysing the studies which use a multiple-scale approach.

2.2.1. DEFINING LOCAL AND REGIONAL ACCESSIBILITY

The investigation on the relationship between local and regional accessibility requires a more comprehensive analysis and a clear distinction between the two concepts. Therefore, local and regional accessibility studies are analysed here upon their (a) *conceptual definitions*, (b) *travel purpose*, (c) *transport mode reliance*. Based on recent studies, some (d) *challenges* are presented concerning the data availability. Such aspects are discussed as follows.

2.2.1.1. Conceptual definitions

With regard to the first aspect, the exploratory analysis of local and regional accessibility studies revealed from the beginning a variety of *concept definitions*. Given the fact that accessibility is already seen as a complex, multi-dimensional and often misunderstood concept by itself (Papa, Silva, Marco, & Hull, 2016), such variation on the concept definitions among studies is seen as a challenge by some authors (Silva, 2020; Iacono et al., 2010).

A recent literature review presented by Silva (2020) shows that local accessibility studies may be found under several names: *Local Accessibility, Micro Accessibility, Neighbourhood Accessibility, Walking Accessibility, Non-motorised Accessibility, and Active Accessibility*. Among other studies, *Pedestrian and Transit Accessibility* are also found in studies focused on a local level (Benenson, Martens, & Rofé, 2010; van Eggermond & A.B. Erath, 2016).

The same exercise is made looking at the reference studies focused on a large scale. Studies focused on a regional geographical scale can be found under names as *Regional Accessibility, Macro Accessibility, Spatial Accessibility, Car Accessibility, Public Transport and Transit Accessibility.* The following Table 4 presents such references organised by scale and conceptual approach.

Table 4 - Local and Regional Accessibility concepts.

Scale	Spatial-based	Reference	Transport-based	Reference
Local	Local Accessibility	(Silva C. , 2020; Handy, 1992),	Non-motorised Accessibility	(Iacono, Krizek, & El-Geneidy, 2010)
	Micro Accessibility	(Mahmoudi & Zhang, 2018)	Pedestrian Accessibility	(van Eggermond & A.B. Erath, 2016)
	Neighbourhood Accessibility	(Saghapour & Moridpour, 2019; Lamíquiz & López-Domínguez, 2015; Barton, Horswell, & Millar, 2012; Witten, Pearce, & Day, 2011)	Transit Accessibility	(Benenson, Martens, & Rofé, 2010; van Eggermond & A.B. Erath, 2016)
Regional	Regional Accessibility	(Kaplan, Burg, & Omer, 2019; Silva & Pinho, 2010; Handy, 1992)	Car Accessibility	(Benenson, Martens, & Rofé, 2010)
	Macro Accessibility	(Mahmoudi & Zhang, 2018)	Public Transport Accessibility	(Kowalski & Wiśniewski, 2019)
	Spatial Accessibility	(Salze, et al., 2011)	Transit Accessibility	(Benenson, Martens, & Rofé, 2010)

A first look under such studies reveals that some authors use terms related to the spatial dimension of the urban environment regardless the scale of analysis (local, micro, regional or macro), while others use terms related to the transport mode favoured for these spatial features (pedestrian, car or public transport). These spatial-based and transport-based tendencies express the main fields of which accessibility studies often come: geography, transport, architecture and urban planning fields (Papa, Silva, Marco, & Hull, 2016). Since accessibility has had its birth in the scope of the transport planning - which traditionally was focused on improving accessibility by mobility means and for a large scale -, studies on “fast transport” are the most commonly found in the literature in comparison to non-motorised modes (Silva, 2020). Even the studies that analyse walking accessibility sometimes consider distances that surpass the 'limit' of the neighbourhood.

The different conceptual approaches are also related to the planning objectives or goals to which the studies are directed. Most studies use accessibility measures based mainly on the land use (spatial) and transport components. In some cases, the spatial and transport components are combined in a multidisciplinary approach, in others, one of these components prevails over the other (Papa, Silva, Marco, & Hull, 2016). Still regarding the conceptual definitions (names) on local and regional accessibility studies, some guesses are made according to the scale of analysis and transport mode considered. Studies focusing on micro scale are related to local and neighbourhood environment with low-speed, individual and active mode of transport, as walking and cycling. On the other side, studies focused on a macro scale relate regional or metropolitan territory with high-speed transport as the car, bus and train. Still, transit accessibility (public transport) was found both for local and regional approaches – by public transport people walk to access the transit stations (Benenson et al, 2010).

Functionally, the concept of **local accessibility** relates to the way people live their daily lives (Barton, Horswell, & Millar, 2012; Handy, 1992), or how close people live from certain activities such as primary schools, health centres and local shop facilities. Studies on local accessibility generally focus on residential mobility to access 'essential' and 'discretionary' activities by an easy walk (Barton, Horswell, & Millar, 2012; Saghapour & Moridpour, 2019), while some relate recreational and utilitarian activities (Witten, Pearce, & Day, 2011) or even "retails to animating walking" (Lamíquiz & López-Domínguez, 2015). Accessibility at the local level is highly related to the **proximity** activities considered essential or complementary to daily needs that people can easily reach by foot or by bike. Such activities potentially induce active mobility playing a role in promoting walkability and liveable communities. In fact, it is recognised that walking and cycling mobility are some of the factors influencing peoples' decisions to live longer in the neighbourhood (Salze, et al., 2011).

Handy (1992) was probably the first to define local accessibility as the analysis of the neighbourhood level and regional accessibility as the analysis of the municipal-metropolitan context. Despite often used indistinctly for microscale contexts, some attention must be given to the *neighbourhood* concept in accessibility perspective. A neighbourhood can be understood as an 'accessible area' that concentrates local activities, where the term 'local' carries a meaning of daily function instead of physical dimension (Barton, Horswell, & Millar, 2012). Neighbourhoods are often defined as areas situated close to transit facilities, allowing for higher density development, and have diversified land uses (Deboosere, El-Geneidy, & M. Levinson, 2018). According to the urban morphology patterns, neighbourhoods are often defined, for example, distinguishing a historical area with characteristics of a small community inside the city from a new urban area with a car-oriented development (Vasconcelos & Farias, 2017). Urban territories are often divided into administrative neighbourhoods with residential, industrial or commercial uses. However, in most studies, neighbourhood refers mainly to residential locations, where accessibility expresses the potential of such areas in promoting active travel for non-work and recreational purposes (Vasconcelos & Farias, 2017; Lamíquiz & López-Domínguez, 2015; Witten, Pearce, & Day, 2011; Krizek, 2003).

The **regional accessibility**, in turn, relates to how connected people are from the surrounding regions (or the other neighbourhoods) and from other activities considered not as "primary needs" such as people and jobs (Kaplan, Burg, & Omer, 2019). These connections between locations are allowed substantially by **mobility**, such as the street network that connect places from the small scale (neighbourhood/community) through the regional or municipal scales (Kaplan, Burg, & Omer, 2019). The connectivity between neighbourhoods, regions and cities depends on the combination of several parameters based on urban development patterns and geographical constraints (e.g. sea-front cities disfavour radial connections) (ITF, 2019), but the transport system plays a crucial role consonant with increased distances.

2.2.1.2. Travel purposes

Among the analysed studies, it is noticed that studies often group travel purposes according to their scale of approach. Most of the local scale studies analyse activities related to daily needs and non-commuting purposes such as *food retail, education, recreation, entertainment and other purposes*. Seen as an essential activity (Barton, Horswell, & Millar, 2012) to promote trips inside the neighbourhood, *food retail* is found in several studies at the local scale (Vasconcelos & Farias, 2017; Barton, Horswell, & Millar, 2012; Witten, Pearce, & Day, 2011; Iacono, Krizek, & El-Geneidy, 2010) as well as at the regional scale (Silva & Pinho, 2010). Activities as super/minimarkets, and other food retails – groceries, bakeries, fruit shops - are considered important to support people's primary needs. *Education* is also considered as an essential activity in Barton's work, and it is one of the most commonly found among studies (Saghapour & Moridpour, 2019; Vasconcelos & Farias, 2017; Barton, Horswell, & Millar, 2012; Witten, Pearce, & Day, 2011; Krizek, 2003). The proximity of schools, especially childcare centres, primary and secondary schools, is a strong factor to promote walking trips due to the parent and child's convenience to access such activities in a short walk. Leisure is also found as a reason to promote walking trips in many local-scale studies (Saghapour & Moridpour, 2019; Barton, Horswell, & Millar, 2012; Witten, Pearce, & Day, 2011; Krizek, 2003). Good access to *recreational* activities, such as city parks, green areas and open spaces, is commonly used as a strong indicator to promote frequent active mobility in neighbourhoods, as well as to promote a healthier lifestyle (Barton, Horswell, & Millar, 2012). Other activities often found among studies are *pharmacies, health centres, general stores and restaurants* (Saghapour & Moridpour, 2019; Vasconcelos & Farias, 2017; Lamíquiz & López-Domínguez, 2015; Krizek, 2003).

On the other side, studies focused at the regional scale often measure accessibility for commuting purposes (Kaplan, Burg, & Omer, 2019; van Eggermond & A.B. Erath, 2016; Silva & Pinho, 2010; Straatemeier, 2008), although some examples presenting multipurpose analysis. The assessment of employment opportunities and workers' accessibility is seen as a strategy to achieve an environment conducive regional urban development (Deboosere, El-Geneidy, & M. Levinson, 2018).

2.2.1.3. Transport mode reliance

Regional and local accessibility concepts also present great differences on their *reliance on transport modes***.** Because local accessibility deals with smaller areas, this concept is highly related to walking, cycling or other non-motorised modes and little related to the private car. For local or neighbourhood scale, the proximity plays an important role in bringing people, activities, buildings, and public spaces together, with short walking and/or cycling (Silva C. , 2020; Saghapour & Moridpour, 2019). Studies on local accessibility are often found relying on public transport combined with non-motorised modes particularly in the immediate surroundings of the transit stations (Benenson,

Martens, & Rofé, 2010; van Eggermond & A.B. Erath, 2016; Deboosere, El-Geneidy, & M. Levinson, 2018), relating to short-lengths trips made by foot (Handy, 1992; Krizek, 2003; Lamíquiz & López-Domínguez, 2015; Witten, Pearce, & Day, 2011). Considering short trips those that start and conclude inside the neighbourhood (Vasconcelos & Farias, 2017), it might be possible that cycling surpasses such distance in comparison with walking trips leading to some disagreement on the inclusion of such non-motorised mode at the local scale - since people can reach greater distances by cycling compared to same walking travel times (Silva C. , 2020). There are still those that suggest short-length trips (<500m) are likely to be competitive by foot over the car due to fewer constraints (e.g. congestion, parking) (Saghapour & Moridpour, 2019).

In turn, regional accessibility is comprised of bigger areas (allowing the connections between places and people), relying often in high-speed and motorised (car, public transport) modes to access further destinations, such as city centres, peripheral cores, and employment centres (Kaplan, Burg, & Omer, 2019). Regional accessibility studies often relate long-length trips made by the private car or public transport (bus, rail). With regard to the latter, as already said, most of studies combine public transport and non-motorised modes (walking and cycling) due the fact that people need to walk or cycle to access the transit stations (Benenson et al, 2010).

Regarding the time-distance separation, both local and regional studies present different travel times according to the transport mode considered in each study. For a trip defined as “local”, studies use shorter travel times compared to “regional” trips. Generally, walking trips are found using travel times of 20, 15 and 10 minutes. It is common to find some authors that use a distance threshold for local trips instead, varying from 2km to 400 metres – the case of the transit stations’ “catchment areas” (Barton, Horswell, & Millar, 2012). For public transport, studies can consider door-to-door travel times – which includes the time from origin to the transit station, the time inside the transport, and finally the time from the station to the destination, as well as the waiting times (van Eggermond & A.B. Erath, 2016) – or focus only in the time inside the transport (Straatemeier, 2008). Travel times using public transport is about 45 to 60 minutes among the studies (Deboosere, El-Geneidy, & M. Levinson, 2018) (Silva & Pinho, 2010; Straatemeier, 2008). Finally, for the private motorised mode, studies often use travel times in-between walking and public transport travel times. Most of the studies consider about 30 minutes driving as regional trips by car (Straatemeier, 2008; Silva & Pinho, 2010; Deboosere, El-Geneidy, & M. Levinson, 2018). Others prefer to use a distance threshold of about 5km to 25km for regional car-related trips (Kaplan, Burg, & Omer, 2019).

Table 5 – Local and regional accessibility studies.

Accessibility Concepts	Studies	*Land Use Characteristics*		Transport characteristics	
		Related activities	Travel purpose	Transport mode	Travel time-distance
Local	Kaplan et al. (2019)	Core & Periphery centres	Commuting	Car	4km
	Vasconcelos e Farias (2017)	Pharmacies, groceries, bakeries and primary schools	Non-commuting	Walking, car	2km
	Kuzmyak et al. (2006)	Residential, commercial, offices, industries, parks & recreation.	Commuting, residential & recreation	Walking	400 metres
Neighbourhood Accessibility	Saghapour & Moridpour (2019)	Primary/secondary schools, tertiary institutions, medical centres, retail, recreational activities	*"Local and recreational activities"*	Non-motorised (walking and cycling)	1km
	Lamíquiz & López-Domínguez (2015)	Commercial	*"Retails to animating walking"*	Walking	1km
	Barton et al. (2012)	Schools, food shops & pubs, parks, outside areas	*"Essential & discretionary facilities"*	Active Modes (mainly walking)	1,6km (1mile) – 2,4km
	Witten et al. (2011)	Education, transport, recreation, social/cultural, food retail, financial, health, other retails	*"Recreational & utilitarian activities"*	Walking	800m
	Krizek (2003)	Elementary school, small parks, small stores & public facilities	*"Neighbourhood activities"*	Walking	-
Non-motorised Accessibility	Iacomo et al. (2010)	Work, shopping, restaurant & entertainment	Commuting & others	Walking, bicycle	-
Pedestrian Accessibility	van Eggermond & Erath (2016)	Jobs	Commuting	Public transport, walking	1km (from PT stations)
Regional Accessibility	Kaplan et al. (2019)	Core & Periphery centres	Commuting	Car	5km – 25km
	Silva & Pinho (2010)	Employment, schools, hospital, food, general supplies & others	Commuting & other purposes	Car, Public Transport & Walking	30, 45 & 20 min.
	Straatemeier (2008)	Jobs	Commuting	Car, Public transport, Walking & Bicycle	30, 45, 15 & 15 min.
Transit Accessibility	van Eggermond & Erath (2016)	Jobs	Commuting	Public Transport & Walking	1km (from PT stations)
Transport Accessibility	Kowalski & Wiśniewski, (2019)	Business, visit to relatives, friends, and tourism	Commuting & other	Car	20 min.
Car Accessibility	(Deboosere, El-Geneidy, & M. Levinson, 2018)	Jobs and workers	Commuting	Car & Public Transport	20 & 45 min.

2.2.1.4. Challenges on measuring local and regional accessibility

A current challenge highlighted in many local accessibility studies is related to the (d) *data availability* to measure local trips. During the last decades, interest in accessibility at local scale has been growing. Local accessibility studies are often developed using the same models built to assess the performance of motorised transport modes based on transit and road network for regional analysis (van Eggermond & A.B. Erath, 2016). However, to assess local accessibility, related to short length trips made by walking, some attention must be given to the calculation of accessibility at the pedestrian perspective. The need for more accurate and detailed data to measure local accessibility is discussed in several studies on local and neighbourhood accessibility (Silva C. , 2020; van Eggermond & A.B. Erath, 2016; Krizek, 2003). Most of these studies advocate that as much it approximates to a local scale, more complex and detailed data is incorporated into the models. Studies reveal that non-motorised travel is very sensitive to distance and time of travel (Iacono, Krizek, & El-Geneidy, 2010; van Eggermond & A.B. Erath, 2016). For instance, at a street level, pedestrian position characteristics such as the connection of building to the network (entrance interface) and the crosswalk play a relevant role at measuring local accessibility (van Eggermond & A.B. Erath, 2016). Also, road network-based analysis uses the centre line of streets, which might be unfair to assess pedestrian accessibility (Iacono, Krizek, & El-Geneidy, 2010). Differently from car and public transport modes, walking trips must be calculated considering both sides of the sidewalks instead of the street centre line. In addition, more accurate pedestrian network to run the analysis requires more detailed land-use data as well (Silva C. , 2020).

Silva (2020) reinforces this data issue and includes two other difficulties to measure local accessibility, namely the *selection* of *destination* and the relevance of the '*shortest path'*. At the local scale, the most relevant travel purposes are probably related to destinations as daily shopping, recreational activities and small health centres, in opposite to the regional scale, which the purpose of travel is often employment. Also, active modes (walking, cycling, and other non-motorised modes) are less likely to follow the time minimization considered in motorised transport as the impedance factor (time/travel/cost of travel), specially to recreational and physical activities (Barton, Horswell, & Millar, 2012). Walking and cycling travel behaviour are also very sensitive to other built environment characteristics at the local level involving aesthetics, security, safety and comfort features which are likely to influence the chosen route, regardless the distance/time factor (Lamíquiz & López-Domínguez, 2015).

The last challenge presented here derives directly from the points aforementioned and is highly related to the main objective of the present investigation. Since measuring accessibility at the local scale is already a challenge (given the data collection process), the comparability with the regional

scale to quantify the difference between accessibility levels seems tricky because it is based on direct incompatible data sets. As recently recognised by Silva (2020), "*regional accessibility levels will always be higher than local accessibility levels since the former will include the latter"*, thus the comparability between local and regional scales seems to be a challenge by itself.

2.2.2. (REGIONAL) ACCESSIBILITY GAIN OR (LOCAL) ACCESSIBILITY LOSS

The way people live and travel has changed over time. Especially since the mass use of the private car, the manner to which people connect themselves with other places and people has changed significantly. Before that, life was centred in the locality people lived, where work, school, shops and other facilities were available by foot or bicycle, while longer journeys were made only occasionally (Banister D. , 2002). Despite the low speed and reach of non-motorised modes, any activity could be equally accessed anytime by those living in dense, compact and mixed urban centres (Bertolini L. , 2017).

At the end of the nineteenth century, the trains and trams have dramatically increased the speed of travel and allowed people to reach further regions located nearby the stations and served by the railways (Bertolini L. , 2017). Those who could afford a house in residential suburban areas and the daily commute to work, moved to live nearby these transport facilities; others stayed in bad condition houses inside the cities or moved to cheaper and less accessible areas. As explained by Bertolini (2017), cities experienced growth in size and a functional separation took place with the emergency of residential and non-residential areas, while mixed uses were concentrated mainly in the city centres and around transport stations.

The presence of rail stations has transformed place's accessibility levels, increased the land value and changed the cities dynamics in many ways. The mass car ownership brought the next great transformation – started in 1920's in the United States, in 1950's in Europe and later elsewhere (Bertolini L. , 2017). The automobile allows for faster travel than collective rail transport and as a personal transport vehicle it has the potential to be more flexible.

Together with the car massification, cities sprawled (even more) to new zones with few pre-existent land-uses, giving place to new development areas scattered across the road network with increased spatial separation of functions (Bertolini L. , 2017). The phenomenon of suburbanization - or the growth of peripheral areas due to a generalised urban growth - is expressed by the decentralisation of activities, people, and functions in addition to a new expression of spatial configuration (Vasquez, 1992). Among other reasons, new road infrastructure allowed more people to move to small cities

with good accessibility (by car) while the historical city centres have become less dense, but still specialised in jobs and public facilities.

Bertolini (2017) mention two patterns that emerged by these changes in land-use and transport characteristics over time. One is that *spatial separation* is related to increase in *speed* of travel, and conversely to decrease in *diversity* of uses. The other is that reduced *capacity* is related to decrease in built-up *density*. In other words, car-oriented environments tend to have higher spatial separation and less density than those oriented by public transport, which is more scattered but dense at the proximities of transport facilities. On the other side, environments dominated by non-motorised low-speed modes have high density, lower spatial separation of functions and thus, more diversity of uses (see Figure 7).

Contemporary cities' changes in land-use and transport patterns, follow the same tendency as the historical changes aforementioned. It is recognised that the massive use of the private car over the last decades have brought several urban concerns related to traffic congestion, as well as other environmental, public health and social issues.

Traditionally, transport planning has satisfied the demand for transport by the "predict and provide" paradigm, meeting the demand with significant increases in mobility, especially the car-based infrastructure (Silva C. , 2018). The provision of peoples' access to the opportunities spatially dispersed has seen by urban planners as needed and supposed to be met to support the urban development. The traditional transport planning has been satisfied the demand for mobility with increases in transport supply supported by the idea that it was enough to increasing accessibility (Silva C. , 2020). To meet the demand, investments in public transport systems have been made mainly where the density justified the costs, while dispersed zones were increasingly served by the road

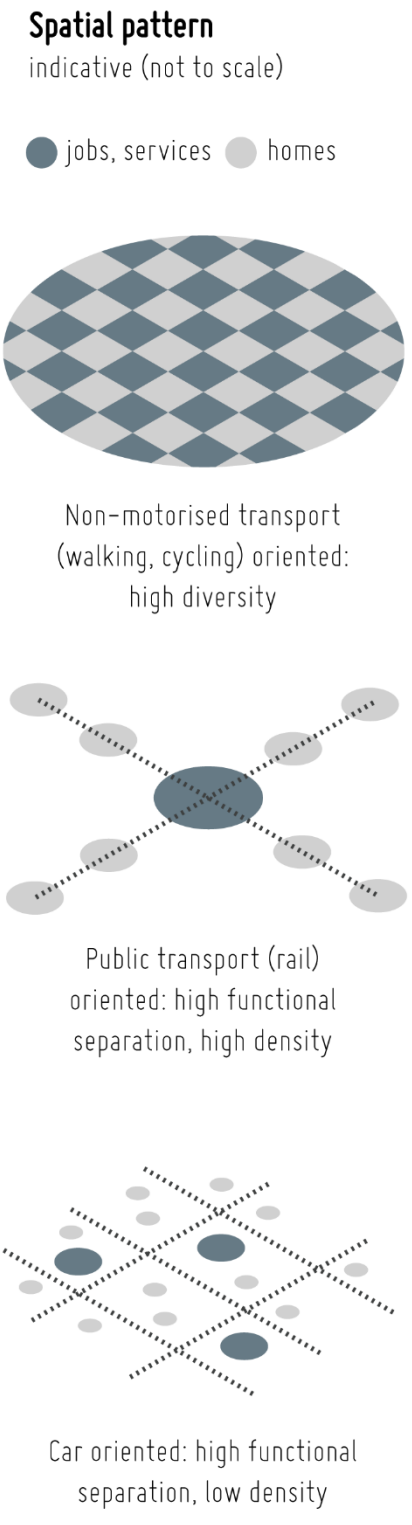


Figure 7 - Spatial patterns and mobility environment. Adapted by the author, based on Bertolini (2017).

network. Construction of highways, provision of parking spaces, and an increase in speed inside and outside the city are some examples of how favouring the car and promotes faster, longer and distant trips over time. For many years, transport planning has been trying to solve congestion problems by estimating traffic growth and building more road space for it (Laad, 2014). However, the new road provision might lead to inducing more demand since more people will start to take their cars generating new trips, known as *induced demand*. In addition, because of the new road capacity and influenced by a "triple convergence", people might change their routes, the time of trips or even transport mode, denominated as *diverted travel*. Both *induced* and *diverted travel* are discussed in detail by Laad (2014).

Recently, it has been recognised the need to shift the focus from mobility to planning for accessibility. The new "*predict and prevent*" paradigm see the demand for transport important but not as the only way to provide accessibility (Silva C. , 2018; Straatemeier, 2008). Travel Demand Management (TDM) emerged in the transport planning field and has been well discussed in many planning documents in Europe and worldwide as an answer to achieve sustainable urban development. Understanding accessibility as an end, it is possible to understand that mobility is only one of the ways to achieve it – when proximity is not an option. Through *environmentally friendlier mobility* (Bertolini, le Clercq, & Kapoen, 2005) urban planners advocate in the direction to reduce the need for travelling (e.g. providing access by information technology remotely), while make the remaining trips more sustainable (walking, cycling, public transport and the use of more efficient/cleaner cars).

Fed by the car massification, mobility patterns have changed as well as the way people consume travel. As we become able to travel faster, **longer length trips (1)** are possible with the same travel time spent. Whether before people have chosen their residence locations by proximity to their jobs and daily commuting, the car democratisation allowed their sprawl generating even longer (and further) trips. As a result, regional commuting trips increased within and outside the city's boundaries (Bertolini L. , 2017).

The second change was the **modal shift (2)**. Car ownership has increased substantially, partially promoted by the automobile industry and by public incentives. By the consumer side, the car might be chosen over other means of transport for several reasons: it is fast, can reach any location and (at least for those who have one) it is available anytime. The private car is also seen as a goods vehicle, statement of status, and is the second item of higher family expenditure after the home (Banister D. , 2002). In fact, the private automobile increased significantly the overall speed of travel if measured door-to-door times, reducing the waiting time spent for the public transport, as well as walking to or from it. The main disadvantage of the car however is its low capacity (at least 10 times lower)

compared to other high-speed modes (Bertolini L. , 2017), which also explain why do we have congestion.

Despite often seen as an enemy by urban planners and environmentalists, it is important to recognise the role of the private car in parallel to the other means of transport. For instance, the car is seen as a fair alternative to dispersed zones where high investments in public transport are not justified (Bertolini L. , 2017). The problem of this anytime-available individual transport is that if people have a car, they do not need many reasons to use it. Together with new routes and extended options on where to go as a result of large investments in roads network over the last decades, **new purposes of travel (3)** have emerged besides the usual commuting trip. Travel become more **complex**, motivated by numerous purposes and even desirable as an experience (Mokhtarian & Salomon, 2001). As a result of all these changes allowed by increased speed of travel, we have witnessing during the last decades an **increased on the overall number of trips (4)** by all transport modes (Bertolini L. , 2017).

But how do these changes indeed affect local and regional accessibility? And precisely, how does the increase in the speed (and thus length) of travel aimed at providing better regional accessibility, bring about local accessibility loss in contemporary cities? Silva (2020) raises this discussion based on the recognition that improvements in accessibility through "mobility gains" generate **changes in land use** occupation. In her words, *"in considering mobility improvement as necessary and even sufficient to enhance accessibility, we have, unwillingly contributed to the loss of accessibility at the local scale, even though accessibility at the regional* [scale] *might be improving".*

Since the traditional transport planning aims to promote accessibility over longer distances (at regional level) by improving the infrastructure capacity mainly based on the private car, new **journey options** become available to people (Silva C. , 2020; European Comission, 2004). With wider journey possibilities, people might change their routes based on travel time (e.g. chosen the faster route even if longer to avoid congestion lanes) or even change their time of travel (e.g. leave the house at different times as the travel time is shorter). Different journeys may give access to different activities located to those who drive by, which might influence their **destination options**. For instance, a person who shops at the supermarket located nearby her/his work journey might change their preference if another option appears along the new journey choice.

Mobility improvements have allowed access to new developing zones of cities – or turned existent dispersed zones more accessible and connected with other regions – which increased the number of available opportunities with great [regional] accessibility for people. Several housing and location attributes influence people's residential location choices related to build environment and individual characteristics (e.g. household size, income, lifestyle). Saghapour & Moridpour (2019) suggest that places where people can walk and cycle create strong and consolidated communities since their

residents are likely to live longer at the same location. On the other hand, car ownership showed negative impact on people's decision on where to live as car users present more "flexibility" to move to farther areas, which are not an option for those who do not have a car.

It is suggested that changes in people's travel behaviour induced by mobility improvements (car-based) and place's accessibility play a role influencing their housing decisions. In the medium term, people might change their **residence location** (Silva C. , 2020; European Comission, 2004). In addition, **bigger activities emerged** allowed by new routes with great accessibility at the regional level, also motivated by other reasons (e.g. land prices, market demand). These locations become very attractive to large shopping centres, office zones and big retail facilities located outside historic city centres. The latter, already pressured by traffic congestion problems due to the limited space and concentration of jobs and public services, are beginning to witness the **closing of local stores** that became less competitive over large regional retail.

Accordingly, two assumptions can be made here. One is that massive investment in road infrastructure has led to the emergence of new developments with great accessibility at regional level favouring the arrival of big stores, shopping centres and global franchises. The other is that local stores have lost their attractivity as a result of the replacement of short trips made by foot to further motorised trips at specific regional locations induced by bigger opportunities. As a result, people might choose to travel farther (by car) to acquire products that could be easily bought at local stores on shorter trips in walkable or cyclable distances. In other words, small and local opportunities lose competitiveness compared to big and regional opportunities; and to access them, short and frequent trips made by foot (or bicycle) are replaced by longer trips made by cars (or transit when available).

These changes in land-use characteristics induced by regional mobility improvements which aimed to respond to the spatial distribution of people/activities, and which in turn, is readjusted to the transport system due to location changes is described by Silva (2020) as '*vicious land use and transport cycle'*. Supported by the concept of *Induced Travel* presented before (Laad, 2014), the cycle is also called '*positive feedback*' which might be explained with an action (mobility improvement) producing a reaction (new mobility and land-use choices) that intensifies the original situation originated by the first action. The result might increase the need to repeat the first action, in turn, intensifies the reaction and so on. Is based on this causal relationship that the hypothesis of the present study is based, inspired on Silva (2020). The following Figure 8 resumes this idea.

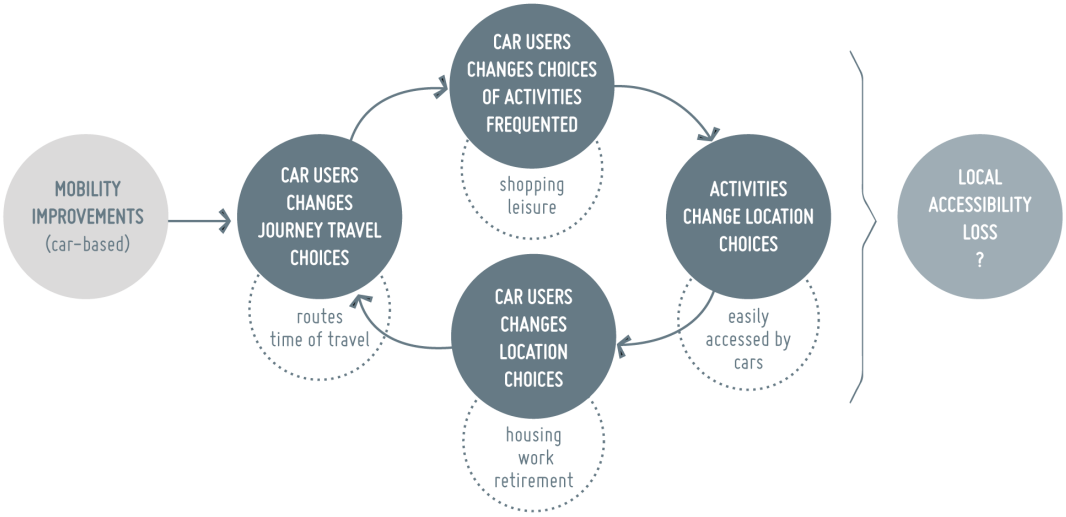


Figure 8 – '*Vicious land use and transport cycle*'.
Adapted by the author, based on *European Commission (2004) Laad (2004)* and Silva (2020).

Great regional accessibility level in cities and metropolitan areas means better connections with the surrounding centralities. These connections imply increased potential mobility and opportunity choices available to people. Regional accessibility's enhancement is strongly related to the economic matter translated as available (and reachable) attracting activities, jobs and wealth for a region (Kaplan, Burg, & Omer, 2019; Kowalski & Wiśniewski, 2019; Straatemeier, 2008). In general, the economic development of cities concentrates in their centralities, where the major number of opportunities are available to the inhabitants, working as an attractor of trips. As such trips are made through the regional urban system, it is likely that the most persistent mobility problems might manifest themselves at a regional scale (Straatemeier, 2008). However, regional economic development might not represent the reality in economics terms in small and disfavoured communities which belong to the region.

There is an assumption on how the centrality benefiting from new opportunities may absorb the economic potential of the surrounding regions, and thus affect local activities (Kowalski & Wiśniewski, 2019). As a result, the main region might concentrate not only the majority of opportunities (e.g. job and services) but also the more relevant regional opportunities, attracting more people (and thus more trips) and by competition from big stores might be contributing to the closure of smaller local stores (Silva C. , 2020).

Other urban concerns related to increase regional accessibility by car-mobility means are: (a) traffic congestion; (b) urban dispersion - inducing the formation of periphery (Kowalski & Wiśniewski, 2019); (c) obesity and sedentary lifestyle - as people will drive more instead of walking (Cervero &

Duncan, 2003); (d) social exclusion - since certain modes are not affordable for everyone (e.g. the car ownership depends on the household income); and (e) environmental issues - associated to carbon emissions (European Comission, 2004).

On the other side, great local accessibility to daily facilities may increase local economy, improve public health, promote social inclusion and environmental sustainability - especially if rely upon active modes. Recent studies associate increased local accessibility with reduced congestion problems, by inducing less car usage while favouring active travel and transit commutes (van Eggermond & A.B. Erath, 2016). Literature has shown that active mobility (walking and cycling) has a role in creating strong communities (Saghapour & Moridpour, 2019). Moreover, improving walkability through pedestrian accessibility is seen as a mean to improve neighbourhood development (Wang & Yang, 2019) and (re)create liveable neighbourhoods (Barton, Horswell, & Millar, 2012).

There is a concern that mobility gains benefiting only regional accessibility affect the land-use patterns of both the region and local communities to which they belong (Handy, 1992). These shifts in land-use occupation resulting from mobility improvements at a regional level probably generate some loss in accessibility level at the local scale (Silva C. , 2020). However, as few studies across scales were found among the literature, the outcomes both in the short and long term remain uncertain.

In addition, changes in land use and transport are not felt in the same proportion and time (Silva C. , 2020). While improvements in mobility are made in the short term and have quicker effects, changes in land occupation happen gradually over time. In practice, decision-makers assume that faster changes will solve current problems leading to ‘visible’ decisions even unsure about the medium and long-term impacts (Silva C. , 2020). For this reason, practitioners continue to steer actions targeted at the transport system aimed at improving efficiency and capacity of the transport network. Also, it is important to highlight that the management of these two fields (land use and transport) is often carried out separately in cities worldwide. Furthermore, governments tend to change at a rhythm incompatible with land-use changes and, for political reasons, they end up resorting to quicker changes in transport network. These changes focused at improving mobility tend, in the short term, to bring changes in the travel patterns, and in the long run, to new needs in the land use system, as already explained based on the *positive feedback.*

The understanding is that those impacts are felt in the short, medium and long term, but the absence of historical data makes it difficult to distinguish the effects by a period of time. Also, it is likely that both local and regional scales feel those impacts, and thus, change their land-use and transport characteristics. In fact, as the city is a system comprised by many centralities, we cannot assume that

the impacts in long run would be felt only at local scale but a multiscale approach of accessibility levels might be helpful for a better understanding of this concern.

2.2.3. A Multiscale Approach of Accessibility

In order to better understand the relationship between the level of accessibility at regional and local scales, this section presents a review of the literature with a focus on cross-scale accessibility. A few studies have been found analysing accessibility with a multi-scale approach. Although its relevance is highlighted in recent studies (Silva C., 2020; Mahmoudi & Zhang, 2018; Straatemeier, 2008) there are few that actually correlate accessibility levels at local and regional geographic scales. The studies discussed here present varied perspectives, methods and approaches, being important for the understanding of the present research. Such a body of research, while reinforcing the need for additional study using this approach, reveals a current research gap to which this research intends to contribute

Handy (1992) is one of the first raising the concern of a multiscale analysis on local accessibility and regional accessibility. Her study analyses the implications for shopping travel by measuring "both the accessibility to activity within the community [or "local" accessibility] and the accessibility to regional centres of activity from that community [or "regional" accessibility]" (Handy, 1992). Significant relationships were found in her study between the two accessibility levels and shopping travel patterns, revealing that, for shopping purpose, both regional and local accessibility is associated with shorter shopping distances. With some degree of substitutability, the study suggests that accessibility level of each scale is not interdependent, and as a result, high local accessibility in a suburban community can reduce the amount of automobile travel by its residents, particularly for non-work travel, at the regional scale. Her contribution highlights greater importance on LA where the RA is low, while greater importance on RA when LA is low, thus revealing more relevant in communities that have extremes values of accessibility (low local and high regional or vice-versa).

Most recent evidences were found as follows. An interesting approach from regional to local scales given by Straatemeier (2008) measures the potential opportunities by different transport modes (for each scale) revealing disparities in accessibility conditions expressed by land-use and transport systems. Mahmoudi & Zhang (2018) relate travel behaviour theories by examining the link between micro-level (i.e. local or neighbourhood) and macro-level (i.e. regional and county) built environment. Kaplan et al. (2019) presented a comprehensive analysis on the effects of accessibility (as a system) from local up to the regional (as well as national) scales, regarding the characteristics of physical road infrastructure and functional activities. A person-based analysis presented by Chen et al. (2020) investigated, from regional to local contexts, whether accessibility within aged-

communities and neighbouring facilities are considered age-friendly (by promoting more active mobility).

The study presented by Straatemeier (2008) exposes the need for a multiple-scale approach from regional to local accessibility aiming to identify disparities in locations' development potential as a strategy for more effective land use and transport planning policies. Using a cumulative opportunities' accessibility measure, different areas were compared within a region revealing the average population requiring access to reachable regional opportunities by car and public transport. In parallel, a local analysis measured the number of jobs (instead of inhabitants) reachable by car and bicycle. The study points that locations with particular land-use conditions related to high local accessibility (e.g. mixed, diverse and dense) might have low regional accessibility if not well connected to the surrounding regions. Conversely, places with multimodal accessibility (car and public transport) may have excellent regional accessibility given access to distant activities but presenting a lack of local accessibility with no closer local activities. Different travel time thresholds were applied for each mode considered (30 and 45 minutes for car and transit trips at a regional level; 15 minutes for car and cycling trips at a local level). His findings suggest a strategy to assess accessibility in metropolitan areas globally by a combination of local and regional accessibility "layers". Some limitations identified in this analysis consist of exclude walking trips at the local level, as well as do not take into account the distance decay of opportunities. This study reveals significative differences in measuring accessibility at different scales, and support the assumption that a multi-scale approach is needed.

Against the tendency found in the majority of local accessibility studies, which relate the neighbourhood characteristics to walking and cycling trips, and motorised modes measuring regional accessibility, the analysis raised by Mahmoudi & Zhang (2018) presents the role of macrolevel built environment (i.e. Region) in influencing non-motorised travel behaviour. Some might disagree considering this as an accessibility-focused study, but the approach might help to understand the correlation between local and regional environments generating demand for travel. Their findings showed that walking and cycling trips play a role in influencing accessibility at a macroscale through reducing vehicular trips. For instance, characteristics such as block size and connected streets (which can be traduced as the number of blocks of a delimited region) considered at macroscale-built environments favour short-length trips at local scale. Considering the substitutability and *chained*

travel[1], it is assumed that people might shift travel choices from car-oriented to walking-local trips and thus, affect the overall number of regional trips. Some limitations the analysis presented is that it was conducted at the household level, which do not represent the individuals' choices; the cross-sectional analysis captured some correlations but does not allow a full examination of causal relationships; and finally, the analysis did not address the role of *self-selection*[2] on walking trips. Using TAZ (Traffic Analysis Zone) units for the spatial analysis, the study suggests smaller units (as the census tract) and longitudinal data (local-local; regional-regional) for futures investigations.

Conducted from the road-network perspective, the work developed by Kaplan et al. (2019) found significant differences between local and regional spatial-functional systems regarding central urban cores (centralities) and peripheral zones. The study relates locational theories to regional/country scales (economic models incorporated spatial dimension), emphasising that location and size of settlements are affected by proximity to other places by location, distance and size of the neighbouring centres (i.e. relative accessibility). As the mixed-use central core area concentrates a high number of activities and opportunities (jobs, services, commercial clusters) it operates as an attractor of people and trips. The effect generating travel reaches further regions and thus might be observed through different scales (local, regional and national), while peripheral areas with dispersed and low number of activities have an impact essentially at the local scale. The findings on core-periphery correlation highlighted different outcomes from a single scale approach arguing in favour of a comprehensive analysis to characterise different spatial-functional systems. Limitations found in considering a single mode of transport (i.e. private car) which makes the local analysis weak at the pedestrian perspective.

A person-based research handled by Chen et al. (2020) analysed the local and regional scales as different 'steps' of the study. Firstly, the regional approach identified different types of aged communities that revealed inequalities among facilities distributed at the regional level, followed by the local assessment of accessibility regarding facilities located within the neighbourhood addressed to the target-age group. As older adults have weaker mobility, the analysis considered walking trips and focused mainly at leisure activities (grocery, green areas, recreation facilities) and public

[1] Chain travel: when people, on the same trip, make small stops along the route for different reasons. "In the travel chain, people tend to continue to use their private vehicle for the entire chain, since they use the private vehicle for part of the travel chain" (Mahmoudi & Zhang, 2018).

[2] Self-Selection: individual preferences and attitudes when making residential location and travel choices. For example, individuals who prefer to walk or bike may self-select themselves into walkable and bikeable residential locations (Mahmoudi & Zhang, 2018).

transport access. This study is an example on how accessibility measures can identify inequalities in the spatial distribution of certain target groups, by investigating the accessibility disparities at the regional and local scales.

In accordance to the points highlighted in previous sections, those studies present variations with respect to defining local and regional 'dimensions' of analysis, the motivations (or type) of travel and the transport mode considered.

Concerning the study area *dimension definition*, Kaplan et al. (2019) use geographical metric on local and regional context varying from local (4km) to regional (5-25km) – as well as national (>30km) - dimensions; and functionality-based central-core and periphery areas. Some consider the existing boundaries of the neighbourhood defined by the municipality at the TAZ level (Mahmoudi & Zhang, 2018; Chen et al., 2020) which may be context dependent. In relation to the *motivation of travel*, Handy (1992) and Chen et al. (2020) focused on non-commuting trips related to daily-need purposes; Straatemeier (2008) targeted commuting purpose; whereas Kaplan et al. (2019) and Mahmoudi & Zhang (2018) did not distinguish commuting and leisure travel. Regarding the *transport mode's reliance*, some studies focused one specific mode, namely the car (Kaplan, Burg, & Omer, 2019) and walking (Chen, Bouferguene, Shirgaokar, & Al-Hussein, 2020) while others perform different transport mode's accessibility (Mahmoudi & Zhang, 2018) varying in accordance to the scale of analysis. Kaplan et al. (2019) assess car trips using the road network system; Chen et al. (2020) focused on walking trips (justified by the restrictions on aged mobility). Mahmoudi & Zang (2018) considered all modes on regional variables and walking on local variables. Table 6 presents the points mentioned above.

Table 6 - Multiscale approach in accessibility studies.

Reference	Travel purpose/ Related activities		Transport mode	
	Local	Regional	Local	Regional
Handy, S. (1992)	"convenience" activities (supermarkets, drugstores, dry cleaners)	Retail centres, shopping malls or commercial areas	Walking and cycling	Private car
Straatemeier (2008)	Employment	Employment	Car, cycling	Car, public transport
Mahmoudi, J. and Zhang, L (2018)	Employment, population	Employment, population	Walking, public transport, car	Walking, public transport, car
Kaplan et al. (2019)	-	-	Car	Car
Chen, Y. et al. (2019)	Non-commuting	Non-commuting	Walking	Transit

In different ways, these studies support a comprehensive analysis of local and regional accessibility to integrated land-use and transport planning. Cross-scale analysis of accessibility may reveal potential gaps in the urban environment to which planners can better address their policies, and might give a direction of expected effects in short and long-term at both local and regional scale.

To summarize what has been said so far.

- A longitudinal study of local and regional accessibility, that is, local-local and regional-regional, seems to be an interesting strategy to allow comparative analysis using equivalent indicators in each scale, and thus reveal land-use and transport characteristics that have more influence in accessibility levels.
- The character of opportunity might vary from local to regional trips: the size or relevance of activity (e.g. employment, shopping centres) seems to play a bigger role in regional trips, while proximity, variety and number of activities have greater impact on local trips (e.g. local or daily facilities).
- Regional trips are longer and highly related to the private car, while short length trips are more related to local trips, which also imply different travel times for each mode. In addition, for short-length trips, the private car is likely to be not competitive with walking and thus might not be an option (due to congestion and parking demand).
- Some substitution between car-oriented and walking trips might influence the overall of trips – from local to regional level. Whether more people chose to walk for certain purpose, they mean also less people using the car for the same or similar purpose. Chained trips might influence the choice of transport mode. When people choose the car for a certain purpose (e.g. job) they are likely to add other trips along the way, and thus increase the overall share of travel by the private mode.

Inspired by the work developed by Silva (2020), this study aims to investigate whether increases in regional accessibility may be causing some loss in accessibility at a local scale. A multiscale approach of accessibility might be an interesting strategy to investigate whether “live locally” is being replaced by “live regionally connected” and how this affects the overall accessibility in contemporary cities. Differences in accessibility conditions at local and regional scale may give a direction to how policymakers should address land-use and transport planning strategies to increase or reduce these disparities in accessibility.

3

CASE STUDY, METHOD AND DATA

The knowledge presented in the previous chapter allows us to understand the concern on the relationship between regional and local accessibility. In order to answer the research questions, this research uses a case study approach in Matosinhos, Portugal. This section begins by presenting the study area with regard to its spatial conditionings on land use and transport systems; followed by presenting the methodological approach; the indicators used to characterise accessibility at regional and local scales; the last section discusses the process of data collection and manipulation that precedes the application of accessibility measures.

3.1. PRESENTING THE STUDY AREA

Located on the north of Portugal, Matosinhos is one of the 17 contiguous municipalities comprised of the Metropolitan Area of Oporto (AMP), a polycentric region with increasing population growth in which houses about 1,700,000 inhabitants in an area of approximately 2,040 km2 (INE, 2018).

With attention to the context of northern Portugal, Vasquez (1992) discusses three aspects important to understand the decentralization of opportunities (houses, employments, services) from the central area of Oporto as a result of the suburbanization phenomenon – or the growth of peripheral urban areas due to a generalised urban growth. First, the inability in extending the urban area beyond the administrative limits of the city - in addition to the reasons related to the land value – in the central core was no longer responding to the housing demand, especially for the most vulnerable groups. The second aspect, it is the presence of the radial road network towards the neighbouring municipalities. Such mobility system enabling people's displacement between the distribution of opportunities allowed both to absorb the demand for housing and also the emergence of new activities as expected based on the land use and transport cycle. The last aspect is understood as a consequence

of the other two firsts expressed the functional specialisation of the city of Oporto and its surroundings, already since the 1950s: the core associated with administrative management, financial system, and specialised services and trade, while the spatially fragmented surrounding municipalities with predominantly large industrial dimensions in coexistence with residential uses.

It is also important to mention, as already presented in the previous chapter, that it is precisely in this period that the massification of the automobile in the European context is intensified (Bertolini L. , 2017), leading to an increase of car-based infrastructure investments facilitating cities (and people) to spread toward to neighbouring municipalities. In AMP, this spatial dispersion might be expressed by the different urban growth and occupation patterns presented in the last decades between the central city and the surroundings. While the city of Oporto showed a slight population growth and the permanence of its spatial configuration, the adjacent municipalities have shown an accelerated population growth and consequent changes in the spatial configuration to meeting the populational demand increase. As a result, more people moved to live in suburban municipalities. Following a similar logic and also facilitated by improvements in the car infrastructure towards to the small cities, big shopping centres and other large retail stores (e.g. global franchising) have emerged particularly located in the medium sized surrounding cities of AMP.

Benefited by its proximity to the city of Porto and its connectivity (based on car mobility) with other surroundings, Matosinhos was chosen as the case study of the present work. It is intended to investigate how the road system (planned at regional level) affects the accessibility at the local level, based on the patterns of land occupation and distribution of activities.

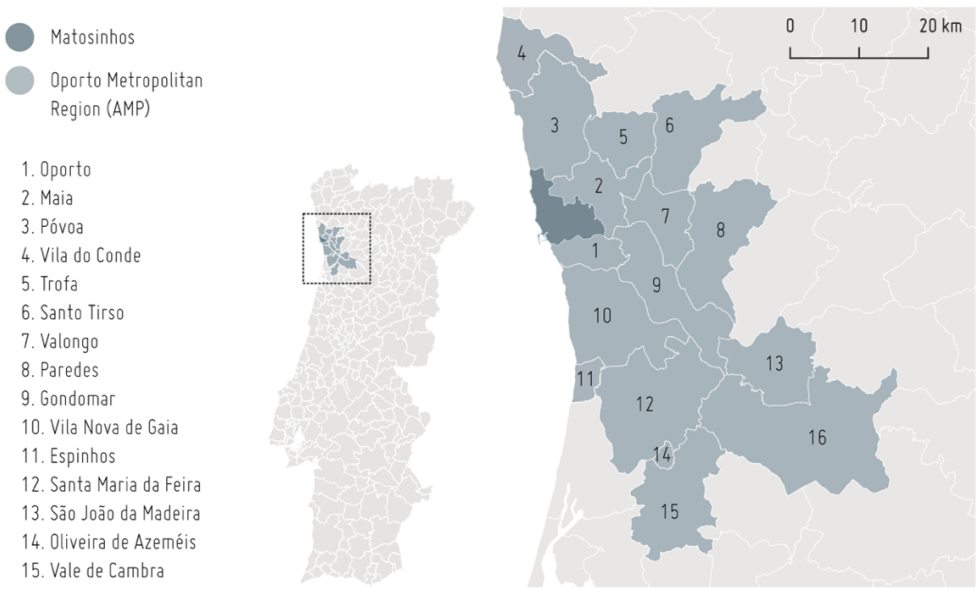


Figure 9 - Metropolitan Area of Oporto.

3.1.1. Housing and Employment Situation in Matosinhos

Regarding the occupational configuration of the territory, Matosinhos presents two distinct land-use patterns: the southern side concentres the majority of the population in the territory assuming a multifunctional dynamic with high density and mixed uses; in contrast, the fragmented northern portion essentially with low density and monofunctional residential uses coexisting with industrial functions (Pinho et al, 2018). Matosinhos resides 175.478 inhabitants (INE, 2011), heterogeneously distributed among 10 parishes[3] (administrative districts shown the left map in Figure 10) namely, (1) Matosinhos, (2) Leça da Palmeira, (3) Perafita, (4) Lavra, (5) Santa Cruz do Bispo, (6) Guifões, (7) Senhora da Hora, (8) Custóias, (9) Leça do Balio, (10) São Mamede de Infesta.

The municipality constitute the 5th municipality with a greater number of jobs in Portugal, employing about 88.394 people, from which 45% (39.968) lives in the municipality (PDMM, 2019). In accordance to the housing, the employment occupation patterns are also heterogeneously distributed. The south side, where it shares a border with the municipality of Oporto, concentrates the majority of employment and activities. Employment in the private sector presents 73,68% of the total of job opportunities in the municipality. The maps below present the spatial distribution of the population (centre) and employment (right) densities in the municipality.

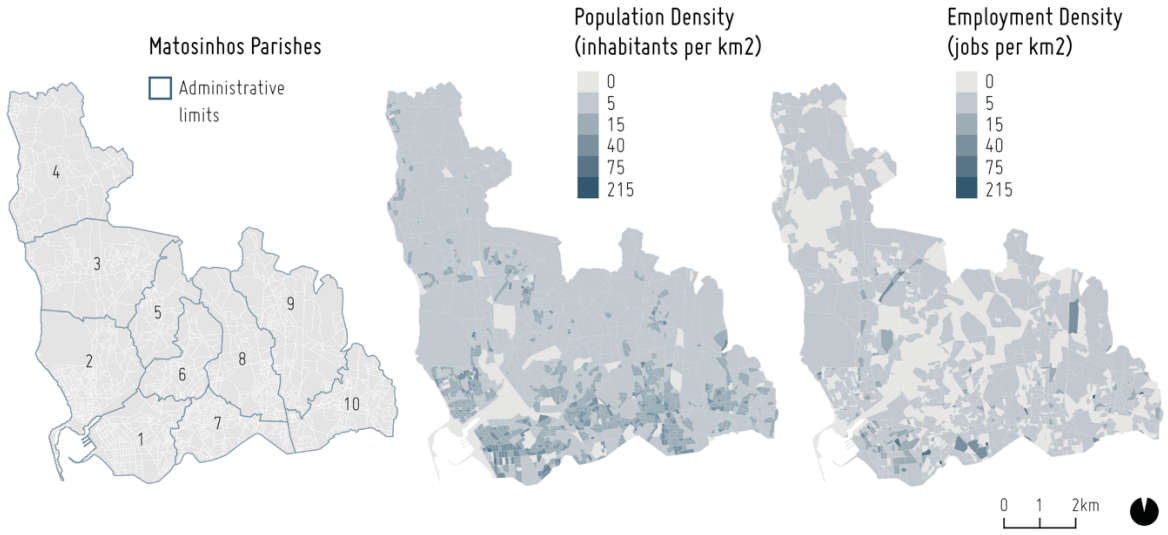


Figure 10 – Matosinhos Parishes, and maps of Population and Employment Density.
Data Source: INE (2011) and GEP (2016).

[3] Since the administrative reorganisation of the parishes in 2013 (DRE, 2013), the territory is divided into 4 parishes by aggregation: Perafita, Lavra and Santa Cruz do Bispo; Custóias, Leça do Balio and Guifões; Matosinhos and Leça da Palmeira; and São Mamede de Infesta and Senhora da Hora.

Regarding the density of opportunities, the parishes with more population per square-kilometre are Senhora da Hora, Matosinhos, São Mamede de Infesta, in contrast with lowest population density found in Lavra, Leça do Balio, Perafita and Santa Cruz do Bispo. The employment density, in turn, reveals to be greater in Senhora da Hora, followed by Matosinhos, Leça da Palmeira, São Mamede de Infesta and Leça do Balio. The lowest values in employment density were found in Lavra, Santa Cruz do Bispo, Guifões and Custóias. Table 7 summarises the population and employment data.

Table 7 – Dimension, population and employment density in Matosinhos.
Based on INE (2011) and GEP (2016).

Parish	Dimension (km2)	Population	Employment	Pop. Density (inhabit/ km2)	Emp. Density (inhabit/ km2)
Matosinhos	4,85	30 984	13 008	6 388	2 682
Leça do Balio	9,11	17 571	11 161	1 928	1 225
Senhora da Hora	3,78	27 747	11 989	7 340	3 171
Perafita	8,48	13 607	7 365	1 604	868
Leça de Palmeira	6,98	18 502	9 453	2 650	1 354
São Mamede de Infesta	5,00	23 122	6 733	4 624	1 346
Guifões	3,69	9 495	1 120	2 573	303
Custóias	6,03	18 650	2 710	3 093	449
Lavra	9,85	10 033	1 054	1 018	103
Santa Cruz do Bispo	3,67	5 767	540	1 571	147
Total Municipality	62,4	175 478	65 133	2 812,3	1 043,8

According to the opportunity's distribution of housing and employment, Pinho et al (2018) classified 16 centralities among the 10 localities of the municipality according to their main functional land use occupation – housing, employment and mixed centralities, as shown in Figure 11 (left). Matosinhos presents bigger relevance as centrality due to its concentration of people, employment and a range of public services, namely the city hall building. The centralities in Leça da Palmeira, Padrão da Légua and São Mamede de Infesta present similar characteristics but in a smaller size. Senhora da Hora presents three centralities (2 housing and 1 employment) although weaker. The rest of the municipality present smaller centralities. The map on the right in Figure 11 highlights other land use characteristics such as the location of places of interest, and the limit of non-urban areas where National Agricultural Reserve is found. In the west of the municipality, the beachfront functions as a coastal geographic barrier.

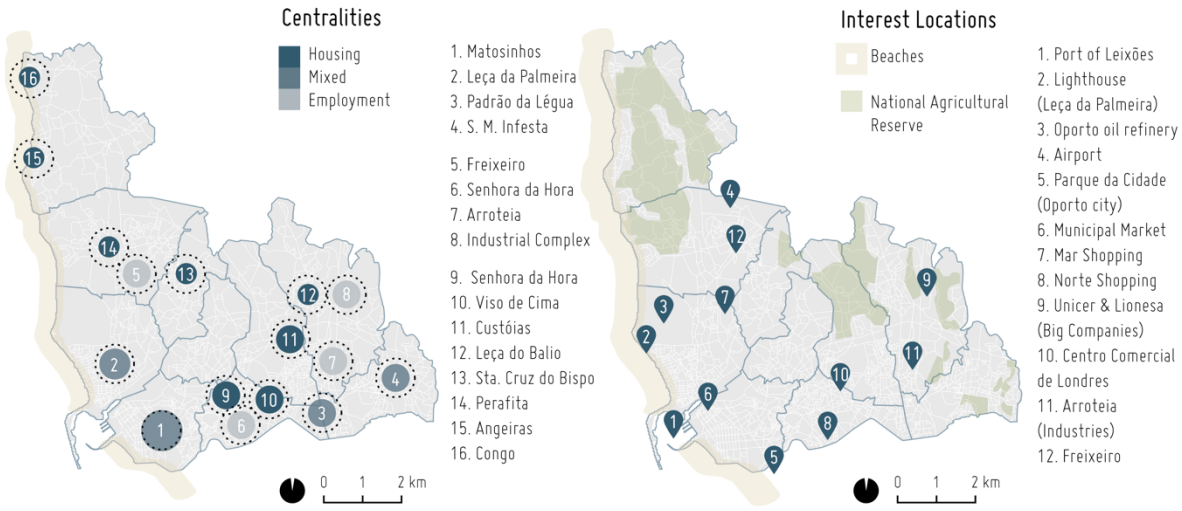


Figure 11 – Centralities and interest locations in Matosinhos. Based on Pinho et al (2018).

3.1.2. Mobility Supply

With regard to the mobility supply, the study area has a set of structural axes, combining road, railway and subway (metro) networks. The railway network is mostly used to logistic purposes due to the presence of the Leixões Port located in the south of Leça de Palmeira. The subway network is provided by the metropolitan operator Metro do Porto with five lines' service (A, B, C, E and F) connecting important locations (e.g. city centre, port, airport). As this study is focused, at the regional scale, on car-based accessibility, it does not deepen the characterisation of the rail and metro networks. At the local scale, we only consider pedestrian trips, and, as so, the bicycle network is not characterised as well. Greater characterisation of the potential mobility by all modes can be found in the Mobility Plan of Matosinhos (Pinho et al. 2018).

The road infrastructure is categorised into three types according the PDM (2019) – fundamental, distributive and local - which vary according to their functions and dimensions. The fundamental roads have the function of linkage to the national and regional roads, cross and connect all the municipalities within the AMP (Pinho et al, 2018). It is the case of the highways A4, A28, VRI, A41, N13/N14. The distributive category is intended to connect the urban centres inside the municipality and between neighbouring municipalities, as well as the distribution of the traffic flow from the highways to the local streets which, in turn, caries the flow inside the neighbourhoods and residential areas. Figure 12 presents the main road-based axes that regionally connect the municipality with its north-south surroundings (A28 and N13/N14) and from the parish of Matosinhos toward the inner continental side (A4), as well as the link between them (A41, VRI). The arrows are named with the municipalities that showed the strongest mobility connections in commuting trips.

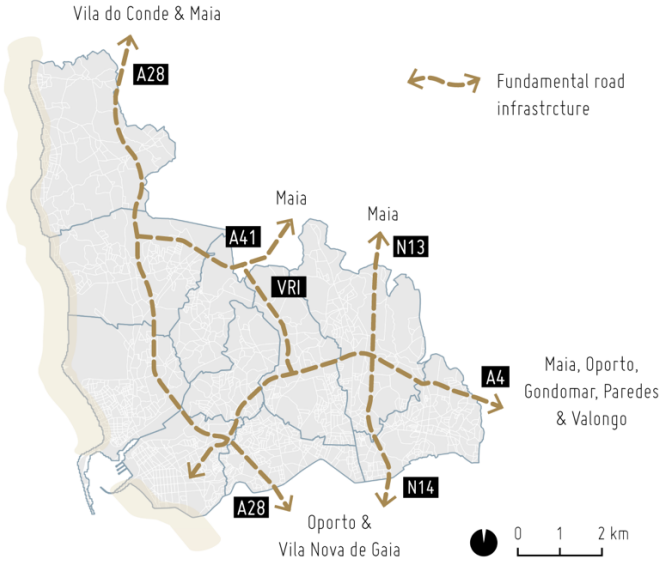


Figure 12 – Fundamental road infrastructure and mobility shares with surrounding municipalities. Data source: Pinho et al (2018) and INE (2018).

The pedestrian network comprises all the areas where people can walk, such as sidewalks, walkways, squares and open spaces (Pinho et al., 2018) allowing the pedestrian to move between desirable locations or acquiring a character of leisure and/or recreational activities (e.g. beaches). In this study we don't focus at the physical characteristics of the pedestrian network. Again, for further characterisation see Pinho et al. (2018).

3.1.3. Mobility Patterns

A survey carried by the National Institute of Statistics of Portugal (INE, 2018) characterises the mobility patterns of the AMP revealing which way the population moves within the territory of Matosinhos and the surroundings municipalities to access the desirable opportunities within the AMP. The survey showed that between the transport options available to people, the automobile is the main chosen transport mode of the residents living in the metropolitan region (67,7%) regardless of the days during the week.

The mobile population is the percentage of the population that travels at least once a day (INE, 2018). During working days, this universe represents about 83% of the total population of the metropolitan region, while during weekends goes to about to 71,2%. Matosinhos has the highest share of mobile population (83%), behind only of Oporto city (85%). The municipality is the third city in the number of trips (359,000) representing 10,6% on a total of 3.4 million trips per day in the entire AMP, while Oporto comprises of 17,6% (419,000).

With respect to the purpose of travel, the survey showed that commuting trips represent 30,3% of the number of trips in the metropolitan region when compared to the other purpose of travel[4] such as shopping (34,6%), accompanying family (20%), leisure (21,5%) and education (15%) reasons. Commuting trips lasting, on average, 21,8 minutes and an average of 2,72 daily trips are performed per day in the AMP. The mobility survey has also shown that within this universe, most job-purpose trips have the origin and destination in the same municipality (about 70%). As expected, Oporto concentrates a higher number of shared flows, being the second or third destination option in eight cities of AMP. Due to the proximity and geographical conditions, Matosinhos presents higher connections with Oporto and Maia, as well as representative flows with municipalities of Vila do Conde and Gondomar.

3.2. PRESENTING THE METHODOLOGICAL APPROACH

This study aims to investigate how regional accessibility affects local accessibility. As discussed in the literature review, studies in this theme use different approaches, and measures of accessibility, which in turn also vary according to the components considered. The two main components seen as essential to allow accessibility assessments - land use and transport– are often combined with other aspects reflecting the temporal dimension and individual choices (Geurs & van Wee, 2004). This study focuses only on the land use and transport components, which express the spatial distribution of opportunities, and the transport system allowing population's access. These two components are considered adequate to a comprehensive investigation of spatial aspects at different scales in the city (Silva & Pinho, 2010). The integration of these two urban systems resorts to accessibility measures based on the location of opportunities (location-based measures), where opportunities can represent activities and people.

It is also understood that the population has different socioeconomic characteristics accordingly to age, income or level of education, and that accessibility may reveal differently for distinct groups of people (e.g. a location with good car-accessibility is not well addressed for low-income groups). However, as the definition of a target population does not correspond to a concrete objective in this study, it was decided not to make any distinction between these groups, and thus the resident population in the study area is considered in absolute terms.

Another important decision was not to incorporate a time series study, as commonly found in the accessibility literature focused on representing the differences in accessibility over time (e.g. measure

[4] Shopping and leisure trips are computed in non-week days. Employment, education and familiar accompanying in weak days. Data source: INE (2018).

the accessibility improvements allowed by a new scenario of transport provision). In the absence of temporal data that explicitly express the changes in the land use system induced by improvements in the transport system in the last decades, the approach focuses instead on the static representation of accessibility levels, at the regional and local scales, in order to investigate factors in the two components – land use and transport - that can reveal accessibility disparities.

Based on the definitions explored in the literature review, the concept of "regional" accessibility refers to the potential for interaction between people and opportunities, in longer distance and trips, related to motorised modes, particularly the private car[5]. The concept of "local" accessibility, on the other hand, is defined as the potential of people to access activities related to daily needs, in a short walk. Thus, the present case study focuses its attention precisely on the mobility potential of the road (car) and pedestrian systems.

As suggested by Mahmoudi & Zhang (2018), a cross-scale approach is a potential way to reveal accessibility disparities between different scales. The approach consists of measuring regional and local accessibility independently, considering each the scale *impedance* (by mode and travel time), and (indirectly) comparing the results regarding the differences on the level of accessibility. Thus, in this study, regional and local accessibility are measured and analysed from different perspectives: transport mode and transport travel times (30min by car and 10min by walking, respectively).

Given these points, the research's methodological approach consists of indirectly comparing Regional Accessibility (RA) and Local Accessibility (LA) by measuring the potential activities in each scale according to its indicators. The analysis unfolds in four steps presented in Figure 13.

(1) Measuring RA using a Contour measure: within 30 minutes driving, accounting for population and employment in Matosinhos and its metropolitan region (AMP);

(2) Measuring LA using Contour measure: within 10 minutes walking, accounting for population and employment in the context of Matosinhos;

(3) LA indicators also account for local activities[6] related to daily needs such as food supply, education, recreation, social activities, and other stores within the same time threshold.

(4) Comparing[7] (spatially and statistically) the values of RA and LA.

[5] Due to time constraints, a choice was made not to incorporate public transport as a motorized mode in the analysis, and bicycles as a non-motorized mode. Thus, the analysis focuses only on car and pedestrian mobility.

[6] As these are local support activities, this step was limited to local analysis.

[7] An indirect analysis of the LA and RA values for each statistical subsection (census tract).

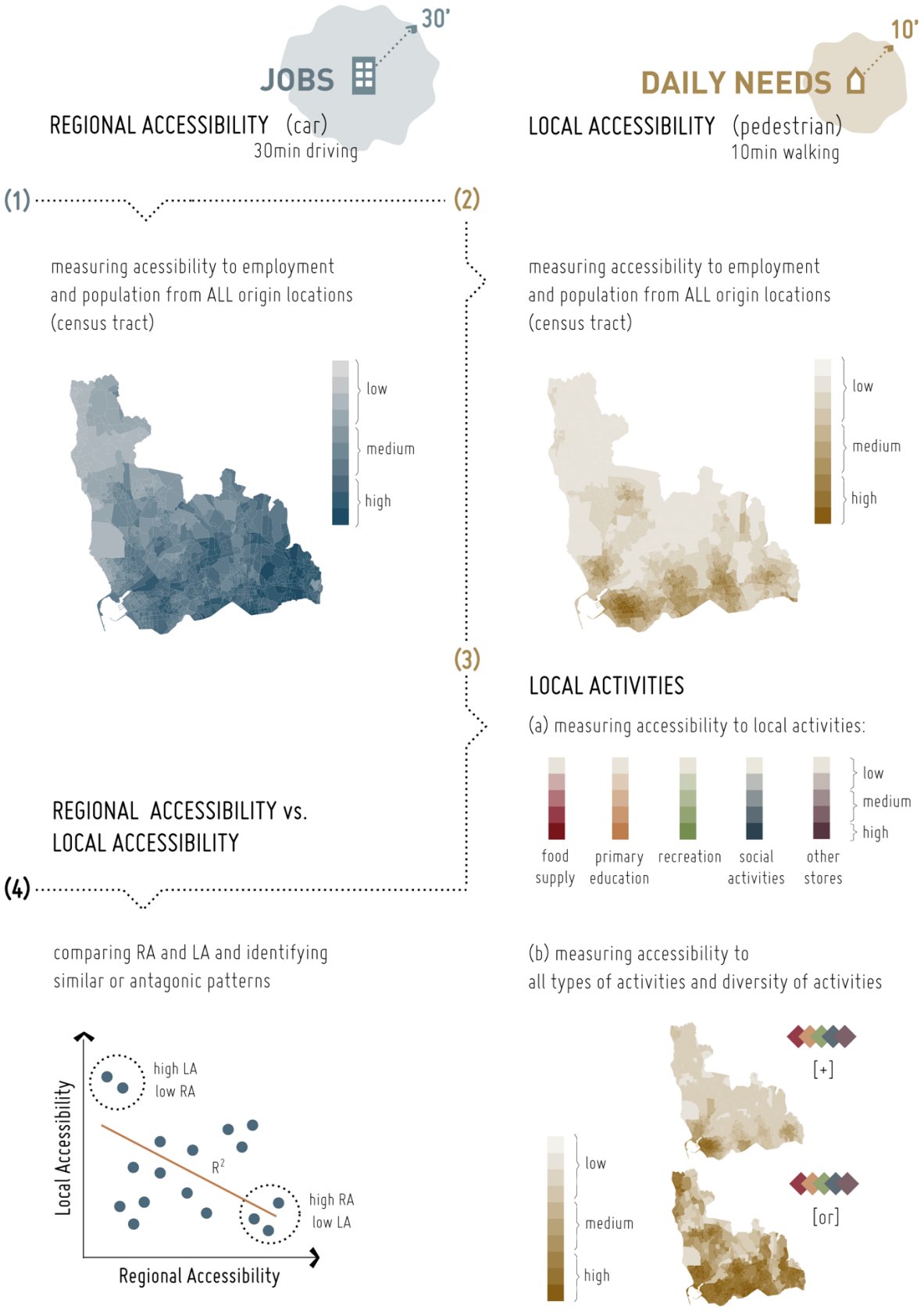


Figure 13 - Resume of the methodological approach.

In the first three steps, RA and LA are empirically analysed in qualitative and quantitative terms using accessibility maps. The full characterisation of regional and local accessibility levels allows investigating the spatial patterns related to the access to opportunities by the motorised (car) and non-motorised (walking) perspectives.

The comparison between the regional and local accessibility levels comprises of both spatial analysis (side-by-side maps) and basic statistic methods. Known that the regional analysis favours the access of individuals to a greater number of opportunities – that is RA is naturally higher than LA -, the values of RA and LA are analysed for each statistical subsection in order to be able to assess whether there are similar or antagonistic patterns without ever directly compare RA and LA.

A complementary spatial analysis is made including the 16 housing, employment and mixed centralities to comparatively analyse RA and LA in more detail. Defining a 500m radius from the central point, each centrality is classified in low, medium and high accessibility level at regional and local scales. The class are empirically defined based on the accessibility level (below, above or in the average) and the distribution of the subsections (census tract) within the defined radius.

Statistically, the relationship between RA and LA relates the numerical data of each of 1586 census tracts in Matosinhos is paired with their respective RA and LA values in a linear analysis. Using basic statistic methods, LA values of population, employment, local activities and diversity of activities are defined as dependent variables in the axis-charts, and RA values as the independent variables. The matrix plots give us information on the form (i.e. linear, non-linear), the direction, (i.e. if such relationships are positive or negative) and the strength of the relationship. Holding the hypothesis that car-based accessibility is affecting accessibility at the local level, the expected results is a negative relationship, where the level of LA decrease as much RA values become higher.

3.2.1. Defining RA and LA Indicators

Inspired by the British planning system (DfT, a, b, 2014), the indicators considered in this study are defined as origin and destination-based, counting the number of reachable activities (origin-based) and the population (destination-based) with access to such activities, given the regional and local travel times and modes. Another fundamental inspiration was given by the Structural Accessibility Layer (SAL) designed by Silva and Pinho (2010), both for the activities' choice and particularly with relation the Diversity of Activity (*DivAct*) indicator which assesses the degree of mix uses in a certain urban environment.

Table 8 summarises the accessibility indicators used to characterise the level of accessibility at regional and local scales. Aiming to respond to the research objectives established in the introductory chapter, the indicators are organised as follows.

Table 8 – Research question, objectives, correspondent indicators and expected outcomes.

Question	Objectives	Measuring Accessibility	Indicator	Outcomes
How Regional Accessibility (RA) affects Accessibility at the local level (LA)?	1) Characterise Regional Accessibility (RA): based on 30 minutes driving trips.	Accessibility to employment and population.	Population Accessibility;	1 map
			Employment Accessibility;	1 map
			Sum of both opportunities	1 map
	2) Characterise Local Accessibility (LA): based on 10 minutes walking trips.	Accessibility to employment and population.	Population Accessibility;	1 map
			Employment Accessibility;	1 map
			Sum of both opportunities	1 map
		Accessibility to local activities and diversity (mix uses).	Accessibility to 9 Activities;	9 maps
			Sum of Activities;	1 map
			Diversity of Activity	2 maps
	3) Relationship of RA and LA values	Spatial analysis of RA and LA by accessibility maps	RA and LA values and centralities	RA vs. LA Index
		Statistical analysis of RA and LA by axis-charts.	RA and LA values	Axis-charts

3.2.2. Accessibility to Population and Employment

The first three indicators – population, employment and sum of population and employment - are measured both for regional and local scales. Population indicator counts the number of people living within the accessible area, measured from all origin locations (centroids of each census tract unity) of Matosinhos. Similarly, employment indicator accounting the number of job opportunities available in the same accessible area. The third indicator sums the accessible population and employment opportunities aggregating the data from the previous two indicators. This aggregated indicator is used by Pinho et al. (2008) to measure, for example, the number of trips with more than one destination (e.g. job and study purposes).

The legend of the population and employment indicators are standardised to the maximum values of the accessible population, while the sum of opportunities' indicator considers its maximum value. The method to classify the accessibility values based on Jenks' natural breaks[8] with nine classes clustered in three groups defined as low (lowest 3 values), medium and high (highest 3 values).

[8] Jenks natural breaks seeks to reduce the variance with classes and maximize the variance between classes.

3.2.3. Accessibility to Local Activities

3.2.3.1. Essential and Complementary Activities (one destination)

Particularly for the local scale, in addition to population, job opportunities, and aggregated indicator summing both opportunities, nine activities[9] are considered important to support people's daily needs at the neighbourhood level by a short walk. In accordance to several studies on LA, this indicator measures accessibility to nine local activity: supermarket and small food shop; nursery and primary schools; public spaces; cafe and restaurant; pharmacy and general store. The activities are grouped into two categories of essential and complementary local activities described in the following table.

Table 9 - Local Activities considered in LA.

	Category	Activities	Description	Total no. of activities*	Data Source
Essential	Food Supply	1. Food Retail	Super/ Minimarkets	109	GEP
		2. Food Shops	Bakery, fruit, meat, fish stores	174	GEP
	Education	3. Nursery School	Kindergarten (children until 5-6 years old)	87	GEP
		4. Primary School	Basic school	13	GEP
		5. Public Spaces	Parks, squares, living spaces	24	CITTA
	Recreation	Beaches	Points located every 500 metres along the coast	28	CITTA
Complementary	Social Activities	6. Cafes	Cafes, tea houses	363	GEP
		7. Restaurants	-	526	GEP
	Other Stores	8. Pharmacies	-	72	GEP
		9. General stores	Clothes, shoes, bookstores, stationary, 1-euro store, other retails	462	GEP

*Within the municipality and the immediate surroundings.

Activities considered essential to support frequent daily needs often related to the families' routine account for food supply, education and recreation purposes, found in almost all studies related to local accessibility or active travel. Those related to *food supply* includes super/minimarkets, and specialised food retail as bakeries, butchers, fishmongers and fruit shops. As *educational* activities,

[9] The logic for choosing activities was based on people's need for services or activities in daily life. Although the importance and need for accessibility to health services is recognized - above all in the current context of the Covid-19 pandemic - it was decided not to include health equipment – such as hospitals and health centres - in the analysis.

this study considered kindergarten and public primary schools[10]. The *recreational* activities included public spaces, squares, city parks, green areas and open spaces in Matosinhos and its surroundings. Due to its geographic factor, the recreational activities also included the beaches. Complementary activities include *social* activities as cafes and restaurants; and *general stores* accounts for pharmacies and specialised stores as clothes, shoes, and other retails. Complementary activities are likely to occur less frequently during the week, for social and non-essential purposes.

To estimate the accessibility to local activities, instead of estimating the number of [population and employment] opportunities disaggregated at the census tract level, each opportunity is considered as a point according to its real location. In the case of the beaches, the points were located along the coast-line every 500m. As in the previous indicators, the activities are counted only if located within the accessible area comprised of the isochrone reference of 10-minute walking, and then disaggregated at the census tract level. To measuring LA levels, each activity type was measured as a single destination to Local Activities' indicators and as an aggregated indicator summing all activity types.

3.2.3.2. Sum of Local Activities (nine destination types)

Similar to the sum of population and employment, this aggregated indicator sums all essential and complementary local activity types measured previously separately. The LA level will be high when more activities are found within the accessible area, and low when less activities are available, regardless of the type of activity.

3.2.3.3. Diversity of Activities (aggregated)

Regarding the Diversity of Activities indicator, a different logic is applied. According to Silva & Pinho's (2010) work, the *DivAct* measure accounts for the diversity of activities instead of quantifying the number of reachable opportunities. In this case, it does not matter how many schools, supermarkets or restaurants are found within the accessible area, but the way the accessible activities are combined promoting a mix of land uses concerning everyday needs. Therefore, the nine activity types are scored ranging from 0 (when no activity type is found) to 1 (when at least one destination of each activity type is found).

It was decided not to apply any weight to the activities. Instead, the analysis consisted of two stages: one considering only the essential activities, and the other including all nine local activities, whether

[10] Activities such as large institutions of higher education, high schools and secondary schools were not considered in the analysis due to the fact that their dimensions exceed the "local" character. In addition, such bigger activities are usually served by public transport - modal which was not considered in the case study.

essential or complementary. In the first case, the indicator reveals whether none or all five essential activities are available in a 10-minute walk. In the second case, the level of local accessibility can vary from 0 to 9 different activities, revealing low (0 to 3), average (4 to 6) or high (7 to 9) mix of uses. As the amount of activities is essentially higher to complementary activities due to the great number of cafes, restaurants and general stores, the two analysis allows for more detail with regard to the diversity of uses. For instance, an area with medium LA to this indicator (all activity types) might not respond to the essential needs although served by several complementary activities.

3.3. DATA COLLECTION AND MANIPULATION

3.3.1. DATA COLLECTION

With the definition of the RA and LA indicators, comes the data collection and preparation stage. The analysis on RA and LA is performed using Geographical Information System (GIS) software – ArcMap 10.7.1 and QGIS 3.0 – which allows the combination of spatial and network data enabling an examination for the entire municipality of Matosinhos.

Land use data on population, employment opportunities and local activities were disaggregated at the census tract level - the Portuguese smallest spatial unit of analysis - which corresponds to city blocks or parts of locations existing in rural areas.

The transport data comprises street and pedestrian networks.

Regarding the source of data, the distribution of population was obtained by the National Statistical Institute of Portugal (INE) of the latest Census in 2011. The data on the employment distribution was obtained from GEP (Strategy and Planning Office – or *Gabinete de Estratégia e Planeamento*, in Portuguese) comprises only the private-sector[11] (2016). Local activities' data is based on INE's Economic Activities Catalogue (CAE), which classifies the types of activities in Portugal. The GIS-based transport data (road and pedestrian network) was based on Open Street Maps (2020). Table 10 summarises the dataset used in this study.

[11] Only the municipalities with available data to employment opportunities were considered: Gondomar, Maia, Matosinhos, Porto, Póvoa do Varzim, Trofa, Valongo, Vila do Conde, Vila Nova de Gaia. Population data were also limited to these municipalities.

Table 10 - GIS dataset, unity, source and year of data.

GIS Dataset	Unity of Data	Description	Source	Year
Census Tract	Km2	Spatial unity of analysis (km2)	INE	2011
Population	Inhabitants	Resident population per spatial unity of analysis	INE	2011
Employment	Workers	Employments per spatial unity of analysis	GEP	2016
Activities' Location	Unity, km2	Selected activities' location	GEP	2020
Road Network	Km	Road network	Open Street Maps	2019
Pedestrian Network	Km	Pedestrian network (based on the centred line road network)	Open Street Maps	2020

3.3.2. Manipulation and Preparation

Additional information is needed to allow the manipulation of the collected GIS-based dataset. This process of data preparation is fundamental to make the performance of RA and LA not only possible but reliable.

The calibration of the road network used on the RA analysis considered the normal and peak hours average velocities[12], by type and restrictions (direction) of the streets. For the road network inside Porto (main city of the metropolitan area), located at south of Matosinhos, speeds from 20km/h to 35km/h, and outside from 35km/h to 75km/h, considering local streets and highways respectively. As 30-minute trips form a larger accessible area, some attention was given to avoid operational errors such as 'barrier effect', by making sure that the network database covers an area with a safety margin from the limits of Matosinhos.

The pedestrian network, derived from the street network, was 'adjusted' to the person's perspective assuming 5km/h velocity, no "one-way restrictions", and removing non-walkable routes. The walking paths are based on the street centred lines derived from the road network. The need for more precision is recognised from the perspective of pedestrians, reflecting, for example, both sides of the streets. However, as the objective is to investigate whether there is a relationship between the levels of RA and LA, there is no reason to justify increased rigour. In addition, accurate data consumes more time in collection and execution, as well as requiring greater computational capacity.

[12] These represent the road average velocity in a scenario before the Covid-19 pandemic, during which urban movements have abruptly decreased, and thus would not represent a normal congestion scenario.

4

REGIONAL AND LOCAL ACCESSIBILITY

Designed as a case study in Matosinhos, the present investigation intended to answer the research question on how regional accessibility affects local accessibility. In the introductory chapter, three main objectives were defined: i) to characterise regional accessibility; ii) to characterise local accessibility; iii) finally, to spatially and statistically analyse the relationship between regional and local accessibility levels. Accordingly, this chapter presents results of RA and LA analysis, in addition to discusses such results face to the theoretical knowledge provided by the literature review.

4.1. REGIONAL ACCESSIBILITY LEVELS

4.1.1. POPULATION AND EMPLOYMENT

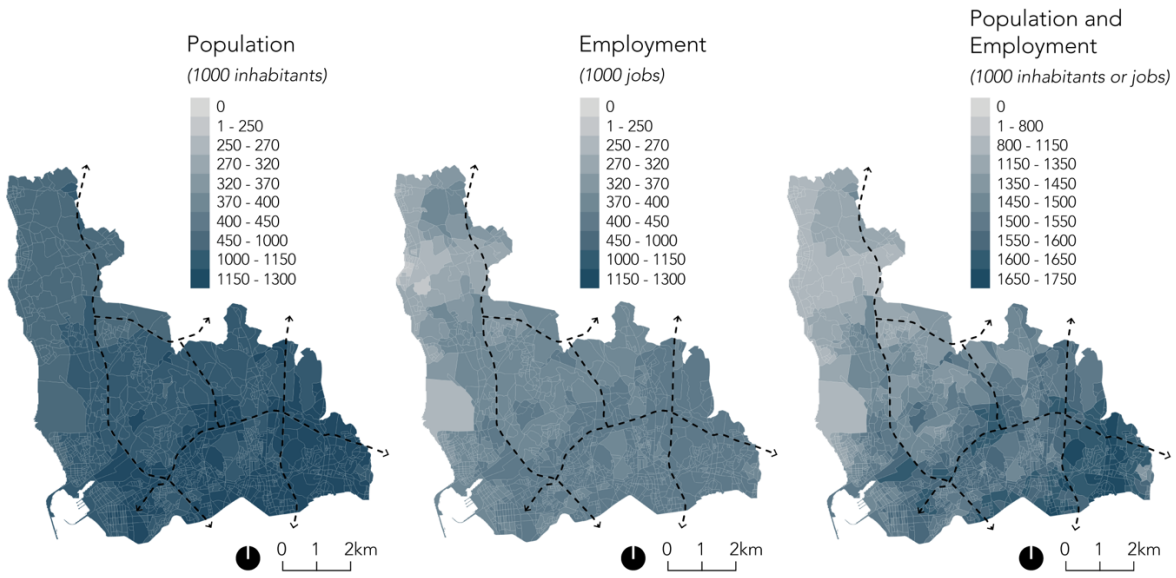


Figure 14 - RA Levels to Population, Employment and Sum of Population and Employment.

The analysis to population (left map in Figure 14) showed that, regionally, the level of accessibility is homogenously high for the entire municipality. The highest values were found in the south portion, in the parishes of Matosinhos, Senhora da Hora and São Mamede de Infesta, the locations bordering Oporto limits. While the municipality houses about 10% of the AMP population, these high RA areas allow about 1.3 million people living in the broader urban area[13] to have access – assuming them as desirable destinations.

To employment opportunities, the map (centre) present essentially average values, with a few areas with low accessibility conditions. As a result of the standardisation of the legend to the population indicator, its maximum values around 450.000 people and also showed the highest values in the south of the municipality. The areas that presented high RA (not highest) values for population, in this case, showed low employment accessibility conditions, observed in Lavra (in the proximity of a housing centrality) and in Leça da Palmeira (oil refinery). Comparatively to the rest of the municipality, these results revealed that, from these areas, fewer employment opportunities are available for the population within 30 minutes driving. Although low values, it is still possible to reach a maximum of 250 000 job opportunities among the surrounding municipalities.

To population and employment, the map (right) shows more heterogeneous values in comparison with the other previous two indicators. The highest RA values are still found generally in the south portion as a result of the previous indicators, but also revealed some areas with low and medium RA while summing both opportunities. Assuming that the number of people is always higher than employment, the best conditions of accessibility for this composite indicator presents when both population and employment are high. Medium and low RA values are presented where less people and/or less jobs are found. The south of Matosinhos presents average values where before presented essentially high accessibility, revealing areas with different people or job occupation patterns.

It is possible to notice in these maps a trend (although discrete) in the shape of high values' areas drawn by the highspeed road infrastructure as in the A28 highway. The closer we get to the northern portion of the municipality the RA levels gradually decrease, but it is still possible to recognise high levels along a great part of such road infrastructure.

4.1.2. DISCUSSION

Characterised from the point of view of long-length trips, the regional analysis showed that the potential mobility has a great reach face to the population living in the surrounding regions,

[13] Gondomar, Maia, Matosinhos, Porto, Póvoa do Varzim, Trofa, Valongo, Vila do Conde, Vila Nova de Gaia.

reinforcing the relevance of the municipality face to its metropolitan region. Such potential, as mentioned by Kaplan et al (2019), allows the connection of people and places from local neighbourhoods to regional urban centres, where more activities and opportunities are concentrated. Thus, we can say that Matosinhos benefits from a privileged location to the north of the municipality of Oporto, the main urban centre of AMP -, revealed by the three maps. The empirical analysis suggests an influence of the presence of high-speed road infrastructures for the regional integration of the municipality.

With regard to employment accessibility, the results have shown more differentiation and variation in the levels of accessibility, presented by the lowest values in the northern portion of the municipality in contrast to high RA in the southern portion. Together with the population indicator, the employment indicator highlighted the differences between labour supply and workers demand (population), considering car-based mobility. Supported by the concept of *derived demand* from Kockelman (2014), it can be said that this space-time difference between the supply and demand for opportunities has a great role in the generation of regional trips in Matosinhos. To exemplify such variation in the supply and demand for work between the north and the south of the municipality, we recall the numbers of the last mobility survey (INE, 2018) which shows that of the 30% of trips made for work reasons, 70% have origin and destination within Matosinhos.

When summing the employment and population opportunities of the previous indicators, the results revealed where the areas with the best accessibility conditions are located, and highlighted the less-favoured areas, either due to the low levels of accessibility to work or population. The medium-high RA values following the high-speed road infrastructure A28 (in the right map in Figure 14), highlights the decrease in RA values toward the northern side. Such accessibility conditions, characterised by their low densities and great spatial separation (facilitated by the road network) are quite favourable for the car use, called by Bertolini (2017) of "car-oriented environment".

4.2. LOCAL ACCESSIBILITY LEVEL

4.2.1. POPULATION AND EMPLOYMENT

Accounting for short-length trips, the analysis at the local scale reveals greater differentiation in the spatial patterns, allowing further investigation at the pedestrian perspective. From this point of view, it is possible to analyse the accessibility conditions with regard to the housing, employment and mixed centralities defined by Pinho et al, (2018), as well as interest points found in Matosinhos.

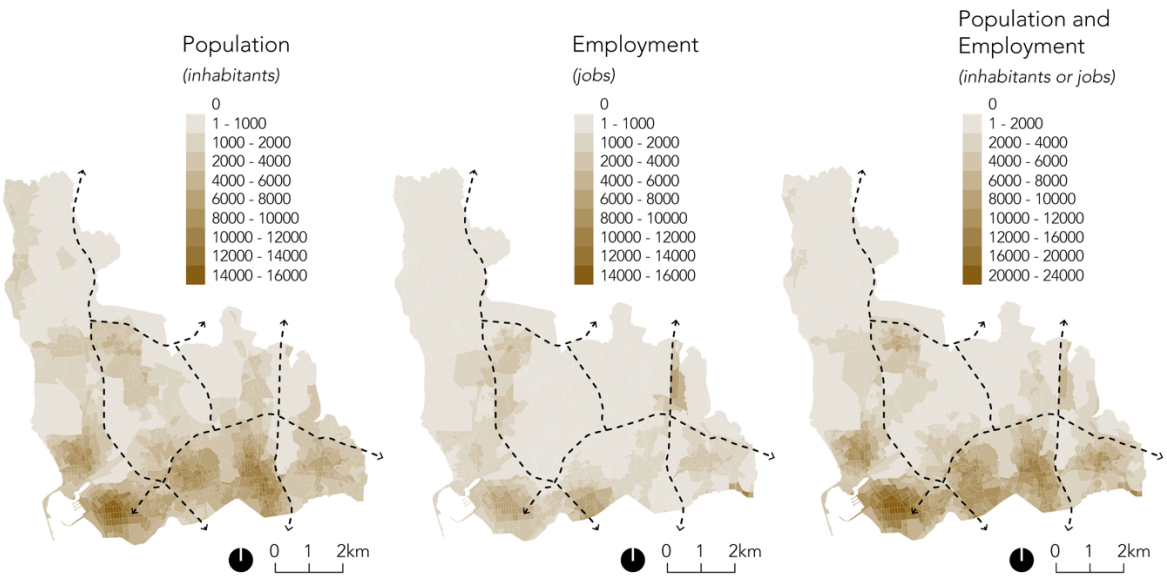


Figure 15 - LA level to Population, Employment and Sum of Population and Employment.

With regard to population accessibility (left map in Figure 15), best accessibility conditions were found in the proximities of the mixed centralities of Matosinhos, Leça da Palmeira, Padrão da Légua and São Mamede de Infesta, as well as housing centralities of Senhora da Hora. Some of the areas can give access to about to 9,18% of the population living in the surroundings in a short walk. The other housing centralities are located in medium values of LA while a great part of the municipality presents low LA for this indicator. Lowest LA values appear near employment centralities as Leça do Balio and Freixeiro (close to Mar Shopping).

When we bring into attention the employment (centre) map, it is clear that great part of the municipality has low LA while the best values are presented in specific locations where employment opportunities are more concentrated. The areas with highest LA are found in Matosinhos, in the proximity of Norte Shopping and the Industrial Complex in Leça do Balio. The south of Sao Mamede de Infesta bordering Oporto is highlighted as well in this map revealing areas where up to 10 000 jobs are reachable in 10 minutes walking. The industrial complex of Unicer and Lionesa, as well as the proximity of Norte Shopping, are some of the areas that in the population map were with the low and medium LA level, in this indicator presented the best conditions. In the south of São Mamede de Infesta, bordering Oporto limits, the LA values are highlighted as well.

To population and employment accessibility, the (right) map seems very similar to the population indicator in the south portion of the municipality, and to the employment conditions revealed in the previous indicator. Predominately high values in the south followed by medium LA found in the north while low LA is found in the rest of the urban territory. The parish of Matosinhos shown the highest value of LA where concentres accessible blocks for up to 12 000 opportunities of population

and jobs. Leça da Palmeira, Senhora da Hora (Norte shopping) and São Mamede de Infesta were also found to have high LA, in addition to the proximities of the industrial complex in Leça do Balio. The area surrounding Mar Shopping in Perafita, while having a concentration of employment (shown in the employment map), few people live closely and thus in the aggregated map it gets low values.

4.3.2. LOCAL ACTIVITIES

The evaluation of accessibility to the nine local activity types analysed the access (or not) of opportunities according to its distribution, and the potential population that can reach activities in a 10-minute walk. The results of all local activities – supermarket, food store, nursery and primary schools, recreation, cafes, restaurants, pharmacy and general stores - are presented in the maps in the following Figure 16 (see original maps in Appendix).

The maps showed interesting results in relation to accessibility to the local opportunities in the study area. When analysed all together, it is easy to identify areas with a lack of accessibility for certain activity types in great part of the study area, highlighted by the maps of supermarket[14], education, recreational activities and pharmacies. As such activities are in a lower number than other activities (e.g. restaurants and general stores), they do not cover the entire territory (at least by a short walk) and tend to concentrate in specific locations. High density areas in the southern side of the municipality concentres the best accessibility conditions to local activities, following the pattern found in the population indicator. The downtown Matosinhos showed the maximum values of LA to almost all local activities - except to primary schools. Leça da Palmeira and Senhora da Hora presented medium LA, but there is no lack of accessibility to any indicator. Another location that concentres medium LA is the centrality of São Mamede de Infesta, although revealed low accessibility to restaurants and no access recreation activities. Low LA values was found in the housing centralities of Lavra (Corgo, Angeiras), although enable access to all local activities – except primary schools. Some similarity can be identified in the map of general stores with relation to the employment indicator, which showed the best LA conditions in the centralities of Matosinhos, Senhora da Hora (Norte Shopping) and Freixeiro (Mar Shopping). An exception was found in the location of large Unicer & Lionesa companies, which revealed low accessibility for all indicators of essential activities.

[14] Hypermarkets located in Mar and Norte Shopping were not counted due to their dimensions surpass the local character.

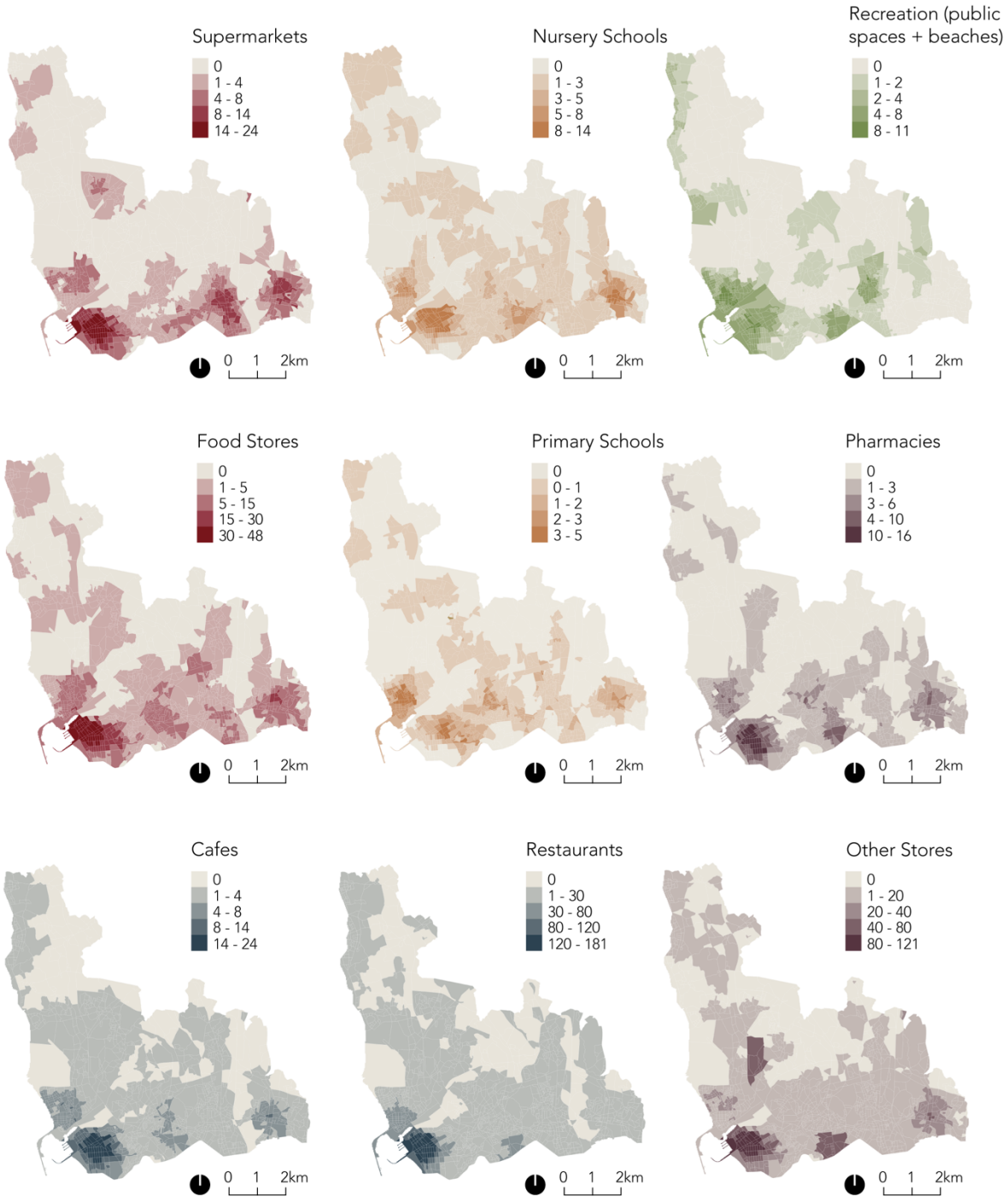


Figure 16 - LA levels to Local Activities.

In the supermarket map, an insight that the analysis provides is the identification of a "gap" between the eastern side of Senhora da Hora and the centrality of São Mamede de Infesta, although presented both medium-high accessibility and proximity in between. Contrary to what is found to the west of the centrality of Senhora da Hora, where the values of LA decrease gradually as it usually appears on accessibility maps, the rupture found to the east of this centrality seems to be whether due to the presence of the N13/N14 highway between these two centralities, or to the lack of a pedestrian or local infrastructure. This pattern is also found in the food store, nursery school, cafe and restaurant indicators, which the gap follows the entire N13/N14 route. An exception to this pattern shown in the general stores' map, where no gap is found. This finding leads to the understanding that the accessibility conditions is rather to the presence of this type of activity than to the lack of pedestrian structure.

Beyond the (visually clear) spatial disparities in local activities among the territory, the analysis allowed a closer investigation on the coverage of population and employment opportunities by such local activities (Table 11). Restaurants and cafes revealed to be the most benefiting activities covering 97,7% and 91,9% of the population respectively, followed by general stores (87,8%), nursery schools (85,4%), food stores (84,5%) and supermarkets (80,3%). In the case of employment coverage, the activity that revealed more relevance was the general stores (85,6%), followed by cafes and restaurant (about 80%). Food supplies and primary education covered about 70% of population.

Although education and recreational activities (i.e. public spaces and beaches) showed to be more related to the location of people than to employment opportunities, the accessibility conditions to these types of activities revealed big constraints particularly to recreation activities (53,2%). With regard to this activity, the analysis have shown that although the territory benefits geographically from the sea coast, there are breaks in the continuity of the beaches due to the presence of large facilities with logistic and industrial use (Leixões port and the refinery). In addition, as most of those areas have low population density (south of Matosinhos is the exception), the beaches showed a very discreet influence on the levels of accessibility to leisure activities covering less than 15% of the population. Overall, the results showed limited conditions of accessibility to recreational activities showing a good part of the population without access by short-walking trips (43%).

With regard to the primary schools the analysis expresses low local coverage (70,7%), even in areas with high density of population. In fact, in recent years, the implementation of a municipal policy has led to the closure of small primary schools by clustering them into larger primary schools (CMM, 2006). This map is a clear result of such strategy.

Table 11 summarises the coverage of population and jobs in the municipality by the local activities, in addition to highlighting the best and worst scenarios of LA levels found in the centralities.

Matosinhos was found as the location with the best accessibility conditions to local activities. The worst scenarios were found mostly in the employment or industrial areas, as in Complexo Industrial (Unicer & Lionesa) and Arrotéia, where present no LA conditions except to restaurant, pharmacies and general stores (still with low LA values).

Table 11 - Best conditions of local activities to the municipality and centralities.

	Entire Municipality				Centralities		
Activities	Pop.	(%)	Jobs	(%)	Best Scenario		Worst Scenario*
Supermarket	140 890	80,3	46 767	71,8	14-24	Matosinhos	Complexo Industrial (Unicer&Lionesa), Leça do Balio, Custóias, Sta. Cruz do Bispo, Perafita, Corgo
Food Shops	148 344	84,5	46 572	71,5	30-48	Matosinhos	Complexo Industrial, Arrotéia, Angeiras
Nursery School	149 818	85,4	43 919	67,4	8-14	Matosinhos, São Mamede de Infesta	Complexo Industrial, Freixeiro (Mar Shopping)
Primary School	124 118	70,7	31 262	48,0	2	Senhora da Hora	Complexo Industrial, Arrotéia, Padrão da Légua, Freixeiro, Sta. Cruz do Bispo, Perafita, Angeiras, Corgo
Public Spaces	89 417	50,9	-	-	-	Matosinhos, Leça da Palmeira, Norte Shopping (S. Hora)	S. M. de Infesta, Leça do Balio, Complexo Industrial, Arrotéia, Freixeiro (Mar Shopping), Senhora da Hora
Beaches	24 949	14,2	-	-	-		
	97 730	57,0	34 682	53,2	8-11		
Cafes	161 402	91,9	52 648	80,8	30-97	Matosinhos, São Mamede de Infesta	Complexo Industrial, Arrotéia
Restaurants	162 762	92,7	52 187	80,1	80-181	Matosinhos	Arrotéia
Pharmacies	123 729	70,5	44 565	68,4	10-16	Matosinhos, Norte Shopping, Guifões**, S. M. Infesta	Sta. Cruz do Bispo, Perafita, Angeiras, Arrotéia
General Stores	145 025	87,8	55 800	85,6	80-121	Matosinhos, Norte Shopping, Freixeiro (Mar Shopping), S. M. Infesta	Sta. Cruz do Bispo

*no accessible activities

**not defined as a centrality by Pinho et al. (2018)

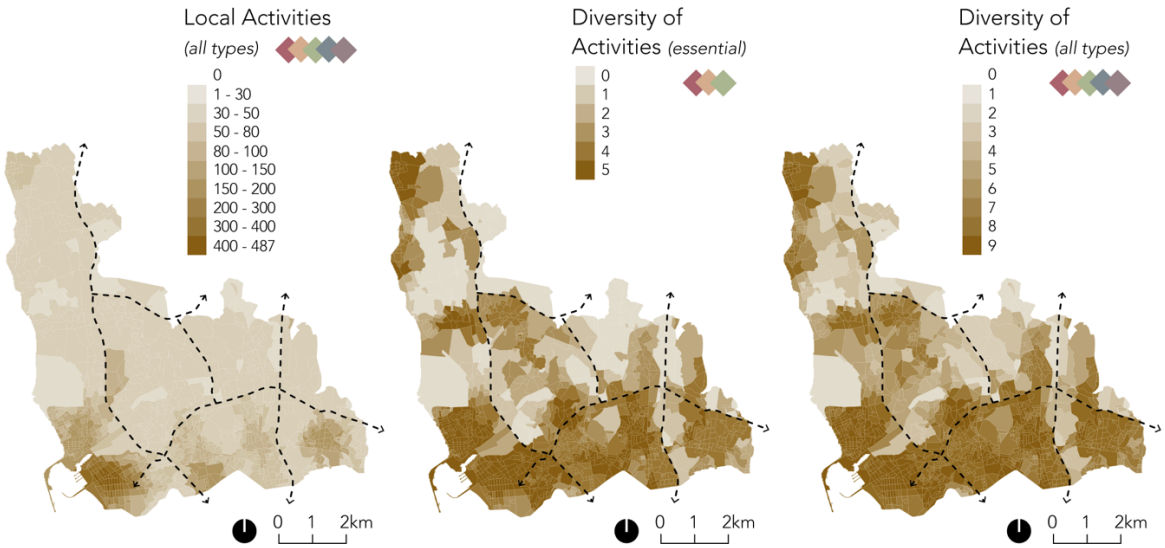


Figure 17 - LA level to all Local Activities and Diversity of Activities.

By aggregating the all types of activities in the left map in Figure 17, it becomes clear that the study area has very few locations without access to any of the selected activities. These locations may correspond to non-urban land or large areas where pedestrians do not have access (the example of the oil refinery), with low population density housing 1,52% of population (Table 12). Generally, the territory has homogeneously low values of LA, with the exceptions in the south portion where concentres great part of activities. Matosinhos, Leça da Palmeira, Senhora da Hora (Norte Shopping), Perafita (Mar Shopping) and São Mamede de Infesta were found the highest values of LA.

Table 12 - Population with access to all local activities.

Population with access to more than 100 activities	…more than 50 local activities	…more than 30 local activities	…up to 30 local activities	…less than 10 local activities	Population with no access to local activities
32 731	64 269	102 883	69 914	19 360	2 681
18,7%	36,5%	58,6%	39,8%	11,0%	1,52%

In contrast with the maps that represent the accessibility to conditions on activities in quantitative way, the other two maps (centre and right in Figure 17) present the variation of accessible activity types from (all) the destination locations in Matosinhos, or in other words, the diversity of activities. If before we analysed accessibility regarding the number of options available to people in 10-minute walking, now we analyse how many different types of activities each location provides access to. The centre map presents the access to the activities seen as essential needs (food supply, education and recreational destinations), followed by the map of diversity of all activity types (right).

Again, as a result of the previous maps, the diversity of activities' maps (both) reveal generally the highest LA values in the south portion of the municipality, showing great potential to diversity of activities. 38,4% of the population has the best conditions of LA for essential activities' diversity, nearly Matosinhos, Leça da Palmeira, Senhora da Hora and in the south of Guifões.

A great part of its surroundings presents also high LA values (access to up to 4 activities), covering 32,2% of the population. Although often shown low values in previous maps, the housing centralities of Lavra presented high values for this indicator as well. 12,2% of the population lives in areas where it is possible to reach 3 types of essential activities and those who can access up to 2 activities sum 12,5% of the total population. 4,7% of the population has no access to any activity considered as essential for this study. Such examples are found in the non-urban areas and some surrounding zones along the highways N13/N14 and A28.

The right map (all activities) presents similar results with respect to highest values of LA, although "minimised" some low value areas in the previous map – justified by the access of cafes, restaurants, pharmacies or general stores. Abruptly low values along the N14/N13 highway were also found as a result of the lack of accessibility to both essential and complementary activities. Regarding all local activities, 14,6% of population has access from 4 to 6 types of destinations, more than 76,1% has access to at least 7 and about 62,8% are covered by 8 different types of activities. In the entire territory, 32,4% of the population has access to 9 different types of destinations within 10-minute walk. Such values are shown in Table 13.

Table 13 - Population with access to different types of destinations – diversity of uses.

Essential Activities	No activity	1	2	3	4	5
	8 233	8 915	12 675	21 287	56 266	65 202
	4,7%	5,2%	7,3%	12,2%	32,2%	38,4%
Essential + Complementary Activities	No activity	1-3	4-6	7-9	8-9	9 (max)
	2 749	13 713	25 608	133 476	110 165	56 934
	1,5%	7,8%	14,6%	76,1%	62,8%	32,4%

4.3.3. DISCUSSION

In the local analysis, the assessment took into account short-length trips made by foot. The literature suggests that local trips are shorter, more frequent and motivated by activities that are essential and complementary to the daily needs of the population. Thus, the analysis of accessibility conditions to population, employment opportunities, and a set of nine local activities - for the purpose of food supply, primary education, recreation, social interactions and other stores - showed to characterise in detail the potential for walking mobility in Matosinhos. On a local scale, the analysis revealed very

clearly its relationship with the proximity of land uses. In 10 minutes of walking, a person reaches around 800 meters (considering 5km/h speed), which implies a very limited accessible-area, especially when compared to 30 minutes driving. Thus, at the local scale, the assessment of accessibility proved to be more related to proximity than to mobility, as advocates Silva (2018).

Considering the greater importance of the proximity in the characterisation of accessibility at the local scale, the current analysis also revealed a strong relationship with the density of land uses, both for population and for employment. The mixed centralities of Matosinhos, Leça Da Palmeira and São Mamede de Infesta stood out as the best conditions for local accessibility to the population, and the centralities of Senhora da Hora (Norte Shopping) and the Unicer & Leonesa industrial complex for employment. Such centralities are good examples for understanding the differences in supply and demand in the land use system which active mobility would be unlikely to respond by themselves (unless people are willing to walk further). As a result, this demand is probably being answered in other ways.

Bringing attention to the assessment of accessibility to the nine types of local activities, restaurants and cafes revealed to be the activities with the best accessibility conditions, followed by general stores, nursery schools, food stores and supermarkets. Such activities, as shown in the literature (discussed in the section 2.2.1.2), are potential generators of walking trips and important to meet the "proximity" needs of the population. In the case of employment coverage, the activity that revealed more relevance was the general stores, followed by cafes and restaurant, as well as food supplies. In other words, while general stores are more related to employment occupational patterns, cafes and restaurants revealed to promote better local accessibility conditions to residential uses.

The analysis revealed that the biggest constraints in the urban territory for local trips are for primary education purposes and outdoor leisure activities (i.e. public spaces and beaches). With relation to the later, the analysis of the accessibility to outdoor leisure activities have shown that although the territory benefits geographically from the sea coast, there are breaks in the continuity of the beaches due to the presence of large facilities with logistic and industrial use (Leixões port and the refinery), which may disregard radial connections as points the International Transport Forum (ITF, 2019). In addition, as most of those areas have low population density (with exception of Matosinhos), the beaches showed a very discreet influence on the levels of accessibility to leisure activities covering only 15% of the population. On the other hand, the best accessibility conditions for this indicator was found in locations benefiting of proximity to city centres, good pedestrian network (walkways) and proximity to relevant public spaces (e.g. Parque da Cidade, located in the border of Matosinhos and Oporto). As argue Barton et al. (2012), the importance of leisure activities is related to reasons of health, well-being and social life, in addition to being mentioned as a good indicator of more active

mobility neighbourhoods. The overall limited conditions of accessibility to recreational activities (public spaces and beaches), let a good part of the population in the municipality without access to this type of activity in a short walk (43%). The same concern revealed to LA conditions to educational purposes. As a reflex of recent clustering of primary schools by municipal policies (CMM, 2006), primary schools are fewer in number which limit the reach of residents in their vicinity. Given that primary education students are still not independent on their trips (they depend on their responsible to drive to schools), this is another indicator that shows the limited conditions on local accessibility may be contributing to more cars trips, more congestion, more trips in the overall. Such patterns might reveal an unsustainability of the transport system.

Regarding the indicator of the sum of local activities, the analysis showed that only a small portion of the municipality has no access to any local activities in short-length journeys. The most beneficial areas for this indicator were found in mixed centralities (Matosinhos, Leça Da Palmeira and São Mamede de Infesta) and close to shopping centres (Norte and Mar Shopping), where up to 100 options of activities were found. As these locations concentrate a high number of activities and opportunities (jobs, services, commercial clusters) it operates as an attractor of people and trips both locally and regionally. This result is in agreement with the thought of Kaplan et al (2019) that the proximity, size and relevance of activities play a role in accessibility conditions. Since such accessibility condition, which presented a regional potential, is available (by local trips) only to 18% of the population, it is likely that these settlements act as an attractor of long-length trips (by car).

The results obtained with the analysis of the diversity of activities showed that the southern portion of the municipality benefits from better accessibility conditions (e.g. Matosinhos, Leça da Palmeira and São Mamede de Infesta, as well as in the vicinity of residential and employment centralities in Senhora da Hora). With high density and mixed uses, these centralities have great potential to induce short trips on foot, thus configuring non-motorised environments as suggests Bertolini (2017). Still in the south of the municipality, the analysis showed a rupture in accessibility conditions between the mixed centralities of Padrão da Légua and São Mamede de Infesta, which can be explained by the presence of the N13/N14 highway (as a result of low accessibility for all local activities, except for general stores). A similar “break” was found along the A28 highway in the analysis of diversity of essential local activities (i.e. food supply, primary education and recreation). This result, although empirical, reinforces Silva's assumption (2020) that accessibility at the local scale is affected by regional accessibility based on car mobility.

4.3. COMPARING RA AND LA

4.3.1. SPATIAL ANALYSIS

The spatial analysis highlights clear differences both in quantity and distribution of activities according to RA and LA conditions. Comparatively, the population maps reveal that although the municipality has homogeneous high levels of car accessibility, at the pedestrian perspective the accessibility conditions express great differentiation in the urban territory. In both scales, the results revealed better conditions in the south portion bordered to Oporto, with a substantial decrease towards the north of Matosinhos. However, such differences are only clearly revealed through the local analysis, allowing for more detailed regard to the study area.

Based on the housing and employment centralities defined by Pinho et al (2018), the RA and LA levels were classified in high (++), medium (+) and low (-) accessibility conditions, considering the accessibility levels found within an area comprised by a 500-metre radius from the centre of each centrality (Figure 18). This approach allows therefore analysing antagonist centralities characterised with high accessibility at the regional scale which presents low LA in a neighbourhood level.

As RA to population presented essentially high values, the attention turned to the lowest values of LA in the same indicator. Industrial uses presented the lowest LA levels of population accessibility, namely Arrotéia and the industrial complex Unicer & Lionesa. Looking at the employment LA, the industrial complex revealed more relevance than Arrotéia, showing high LA due to greater concentration of job opportunities.

With regard to both population and employment, the regional analysis presented the best conditions in São Mamede de Infesta and part of the Arrotéia centrality. However, in the local analysis, Arrotéia presented the lowest LA conditions. Centralities with average RA conditions revealed lowest LA values in Leça do Balio, Santa Cruz do Bispo, Perafita and Freixeiro. Also presenting average RA values, Matosinhos revealed to be the most favourable centrality in terms of population and jobs, at the local scale. While the potential population and employment opportunities of Matosinhos favours LA, at the regional scale, when we compare to the best-condition centralities in the inner side of the municipality, the analysis suggests this centrality has some features which constraints RA levels. In other words, it is possible that the geographic (coast board-line) and transport (e.g. congestion, parking) characteristics play a role in accessibility conditions at the regional level.

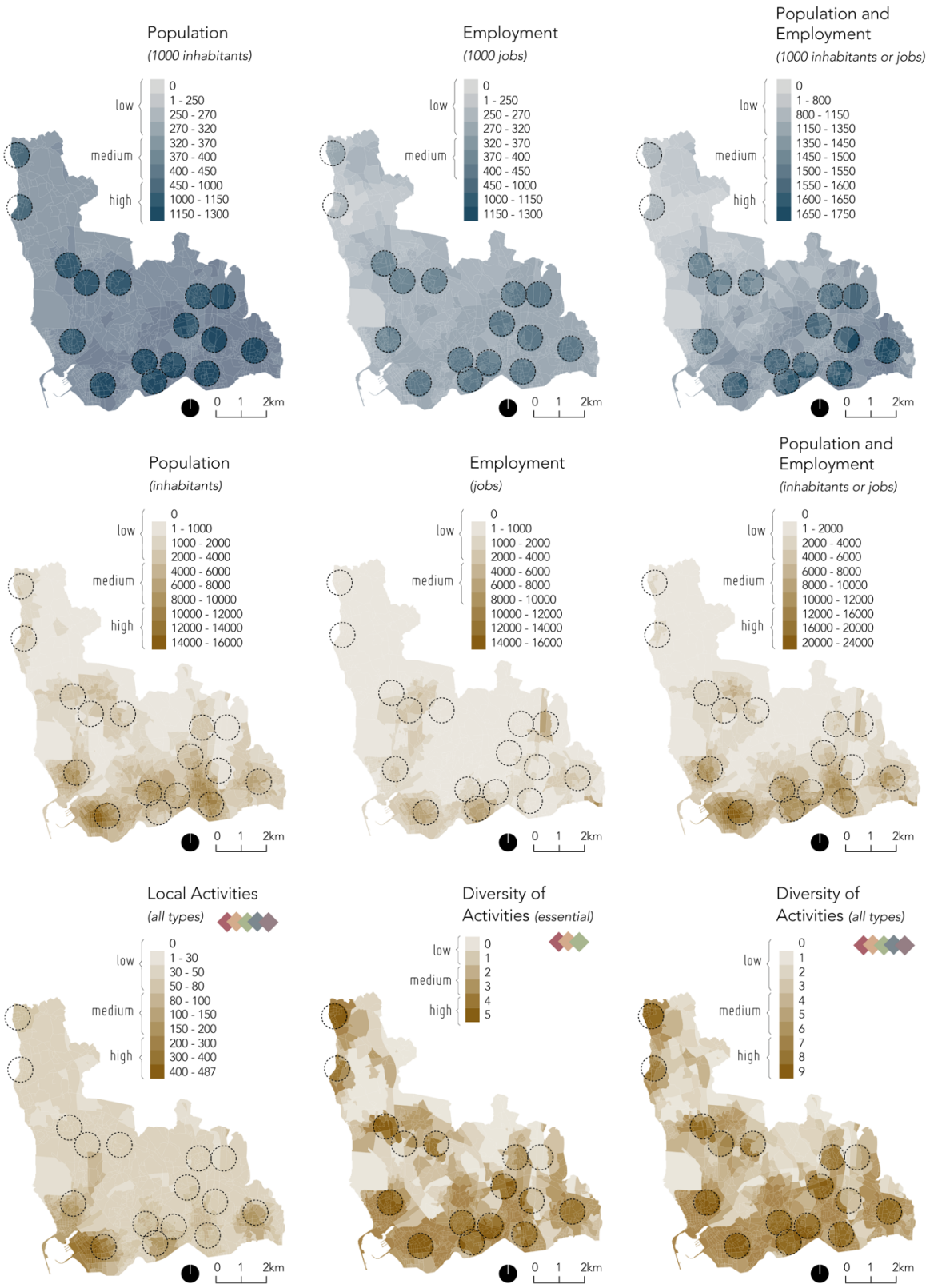


Figure 18 - Centralities and classes of RA and LA.

Speaking in transport characteristics, the aggregated map of populations and employment LA highlights the 'void' found just below the industrial complex in the perimeter of the N13/N14 highway. This location, although surrounded by a great number of jobs by the industrial uses, it is not favourable to promote walking trips due to the existence of the fast-speed road structure or the lack of local infrastructure. On the contrary, these locations on the regional map present high or at least average values of RA. A similar pattern of low LA versus high RA is also found along the perimeter of A28 highway despite less intense in the north portion of the municipality. Although empirically, these are interesting evidences on how regional accessibility might be affecting local accessibility.

Analysing the potential to local activities, the territory has homogeneously low values of LA, with a few exceptions where concentres great number of local activities, namely Matosinhos, Leça da Palmeira, Senhora da Hora (Norte Shopping), Freixeiro (Mar Shopping) and São Mamede de Infesta, were found good LA conditions. On the other hand, great part of the centralities revealed low values for LA. With regard to diversity of activities, although the limited conditions of accessibility to local activities, in diversity of uses, the major part of centralities present high values. Exceptions found in Santa Cruz do Bispo, Angeiras (medium LA), Arrotéia and industrial complex (low LA). This table presents an Index of RA and LA results of each centrality.

Table 14 - Accessibility Index RA and LA.

		Regional Accessibility			Local Accessibility				
	Centrality	Pop	Emp	Sum	Pop	Emp	Sum	Local Act	Div Act
Housing	Perafita	++	+	+	-	-	-	-	++
	Custoias*	++	+	+	+	-	-	-	++
	Leça do Balio	++	+	+	-	-	-	-	++
	St. Cruz do Bispo	++	+	+	-	-	-	-	+
	Corgo (Lavra)	++	-	-	-	-	-	-	++
	Angeiras (Lavra)	++	-	-	-	-	-	-	+
	Senhora da Hora*	++	+	+	++	-	+	-	++
	Viso de Cima* (S. Hora)	++	+	+	+	-	-	-	++
Employment	Norte Shopping*	++	+	+	+	+	+	+	++
	Freixeiro (Perafita)*	++	+	+	-	+	+	+	+
	Arroteia* (L. Balio)	++	+	++	-	-	-	-	-
	Industrial complex* (Leça do Balio)	++	+	+	-	+	+	-	-
Mixed	Matosinhos**	++	+	+	++	+	++	++	++
	Leça da Palmeira*	++	+	+	++	-	+	+	++
	Padrão da Légua*	++	+	+	++	-	++	-	++
	São Mamede de Infesta*	++	+	++	+	-	+	+	++

Accessibility classes: (++) high; (+) medium; (-) low
Size of centrality: (**) big; (*) medium; ( ) small

At the regional scale, all centralities showed high car accessibility to population, and the major part of the centralities presented medium RA to employment and sum. Exceptions were found in Corgo and Angeiras with low RA and LA values for all the other indicators. The best RA conditions to sum (of people and jobs) showed in Arrotéia and São Mamede de Infesta, but for the local scale, they present accessibility loses in terms of local activities and job opportunities, especially in Arrotéia where low LA for the others indicators at the local scale were found.

Matosinhos, Leça da Palmeira, Padrão da Légua and Senhora da Hora present medium RA and high LA to population. From these, only Leça da Palmeira showed favourable to local activities. With great potential to access local destinations, population and jobs, Matosinhos was found as the centrality with more potential for promoting walking trips at the local level. It is likely that this area attracts people from further localities, even for those that do not live in the municipality, assuming a regional character. Therefore, the centrality showed average regional conditions coexisting to the best LA values due to its concentration of activities (density) and the proximity with specific destinations (City centre, Oporto, Beaches, Parque da Cidade). Monofunctional centralities with the same level of RA showed lack of LA (Norte Shopping is an exception).

Figure 19 presents examples of the centralities with antagonistic classes of accessibility conditions. Angeiras and Congo presented low RA and high LA to the diversity of activities. Senhora da Hora, Viso de Cima and Padrão da Légua showed high RA and low level of LA to employment opportunities. Finally, Complexo Industrial and Arrotéia with high RA and low LA conditions to population and employment, although present medium LA in a few blocks (correspondent to high employment density areas).

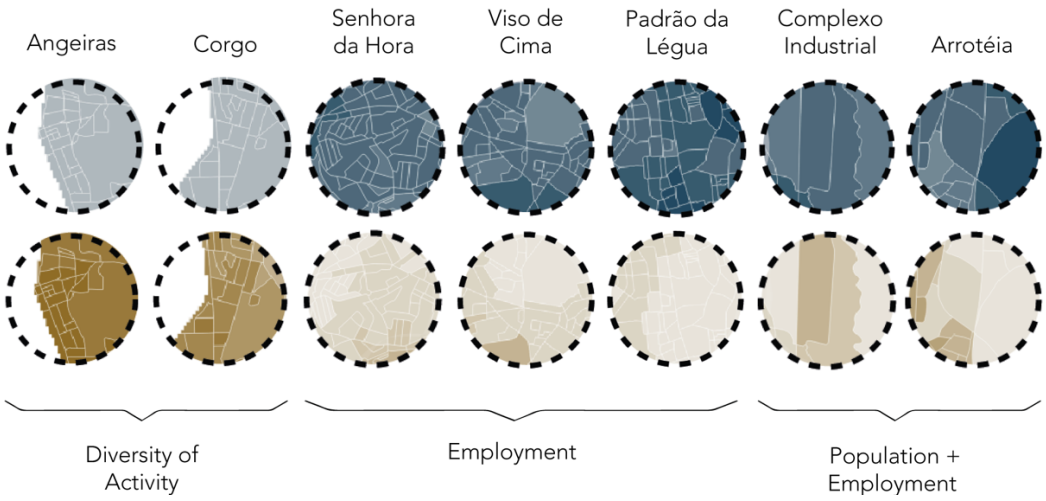


Figure 19 – Antagonist values on RA (population and employment) and LA (to employment, sum of population and employment, and diversity of activities).

4.3.2. Statistical Analysis

To assess the relationship between RA and LA levels, without directly comparing regional and local values – assuming that the former will be always higher than the latter - a statistical analysis is conducted paring the 1584 census tract values with a simple linear analysis. In the following charts, the values of population and employment RA are assumed as the independent variable (x-axis), while the dependent variables (y-axis) are tested with LA values of population, employment, sum of population and employment opportunities, sum of local activities and diversity of activities.

The values of population RA range from 600 000 to about 1 280 000 inhabitants, the employment RA goes from about 250K to around 430K, and the sum of population and employment range from 800K to 1700K people and/or jobs.

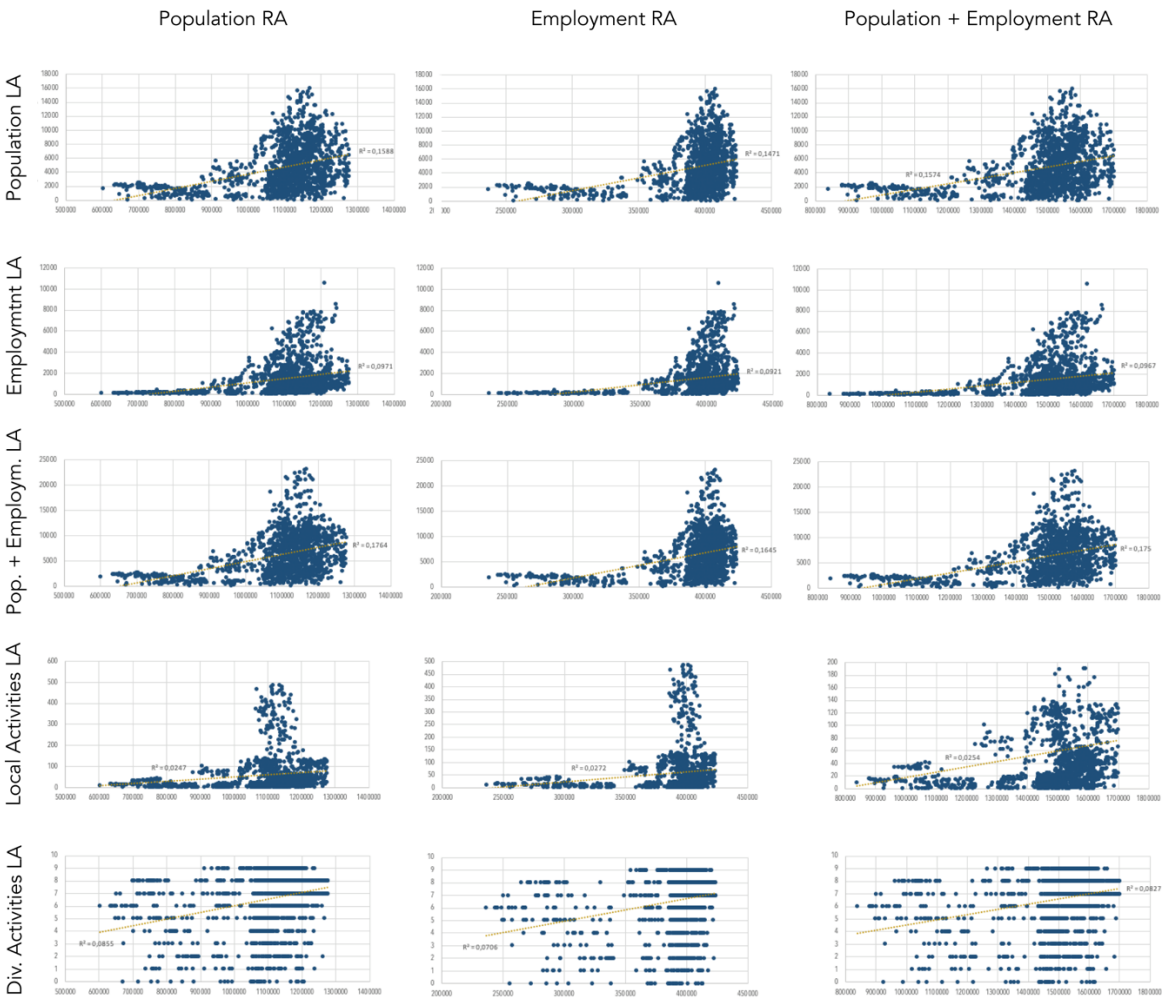


Figure 20 - Linear analysis of RA and LA variables.

With regard to population and sum of population and employment charts combined with all RA indicators, the charts express a non-linear ascendant trend (shape of dots). The analysis of population RA to these indicators allows us to make some considerations:

- The dots found in the left side of the graphs indicates areas, varying from low to medium RA conditions, where present no accessibility at the local level;
- The concentration of dots in the right side indicates that a considerable part of the areas with medium-high RA (1100K - 1200K) present LA values below the average;
- The best RA conditions (1200K – 1300K) are found between medium-low values of LA, but never with the best LA conditions;
- The best LA conditions (12K - 16K) appears in lower quantity and more dispersed in the graph when medium-high RA values are found;
- From these best LA values, accessibility conditions tend to be worse as RA increases. In other words, after the best conditions of LA are established, the relationship with RA tends to become negative.

The employment LA chart presents a more linear relationship with population RA represented by the bottom values of the chart following the trend line. The concentration of dots with medium-high RA is still noticeable, where low values of LA presented, but there is a great dispersion in the results. Highest values reveal that although the best values of RA show low LA, some points with high values of LA (8K) was found where RA (1100K – 1200K) present medium (although still high) values.

In the population and sum graphs, the dots appear concentrated mainly in the range of 400K regional jobs or people. The lowest RA values do not reach zero in the two graphs, as in the employment graphs. Similar conclusions drawn here are the extreme values, expressing that to a certain value of RA, the relationship with LA is positive and, after a certain value of RA (400K), the relation becomes negative.

Analysing the relationship between population RA and employment RA with the number of local activities, it is noted that the best LA values are where the level of RA is medium-high. Most of the observations with RA below 400K accessible jobs have access to up to 150 local activities. However, when RA is higher, accessible local activities can be as high as 500, despite the high degree of dispersion.

The results of the relationship between jobs and population RA with the number of local activities (LA) showed high dispersion and it is difficult to draw any conclusion on the graph format. The concentration of dots continues at the average values of RA, but below the trend-line and therefore,

at values below the LA expected results. The same occurs with the diversity of activities (LA). The best diversity conditions are found between mid-high RA values, ranging from 1400K to 1600K employment and population.

The diversity of activities chart revealed a great variability and little/ no association with RA, certainly due to the ordinal local values combined with values extremely high to the regional indicators. Thus, little conclusions can be made from these charts. However, the graphs shows how high values of RA can present either a diverse or specialised local environment.

In all charts, after reaching high (but not highest) RA values, LA tends to reduce from medium to low values as found in some indicators in the empirical analysis. Due to the large sample size and the great variation in the accessibility levels, our case study revealed that the relationship between RA and LA is essentially weak, explained by the low (below 0,5) R-squared coefficient[15] (Table 15). Therefore, the statistical analysis and requires further investigation to draw robust conclusions.

Table 15 - R^2 values of RA and LA indicators.

LA vs. RA indicators (R^2)	RA Population Accessibility	RA Employment Accessibility	RA Sum of Population and Employment
LA Population Accessibility	0,1588	0,1471	0,1574
LA Employment Accessibility	0,0971	0,0921	0,0967
LA Sum of Population and Employment	0,1764	0,1645	0,175
LA Sum of Local Activities	0,0247	0,0272	0,0254
LA Diversity of Activities	0,0855	0,0706	0,0827

4.3.3. DISCUSSION

Analysed both in isolation and at an aggregated level (quantity and diversity of activities), the conditions of the population, employment, and nine local activities, elementary to allow the subsequently spatial and statistical analysis, showed its importance on the understanding of regional and local accessibility conditions of Matosinhos in detail. Although presents essentially high RA conditions, at the local scale the analysis expressed great differentiation in the urban territory. The assessment of local accessibility clearly revealed the disparities (or imbalance on population and opportunities' demand) in the land use system, especially in the northern portion of the municipality.

[15] Known as Pearson's coefficient, R-squared (R^2) reveals the strength of a correlation relationship in statistical analysis. R^2 is 1 when a perfect correlation is found, strong if range from 0,75 to 1, moderate from 0,5 to 0,75 and weak from 0,25 to 0,5, regardless if the relation is positive or negative.

Looking at the centralities, those with the greatest RA (and therefore more potential mobility for the car) are located in the inner part of the municipality, close to the N13/N14 highways, in particular Arrotéia and São Mamede de Infesta. A closer look at the two centralities revealed that such conditions facilitated by car (high RA) can reveal both low LA conditions (Arrotéia) as well as medium-high LA conditions (S.M. Infesta). Such spatial pattern is identified in the statistical analysis, expressed by the great variation of LA when RA presents the maximum values.

Matosinhos was the centrality that presented the best levels of LA. With average RA values and proximity to interest locations, Matosinhos has a great potential to attract regional trips. However, it is possible that spatial factors (speed of the streets, traffic congestion or the coast barrier) may be conditioning the level of accessibility by car, when compared with other inner side centralities. By Kaplan et al (2019), the urban structure along the coast disfavour radial connections which might be this case. In the statistical analysis, Matosinhos can be represented by the most scattered points at the top of the graph, with high LA and medium RA. In other words, these results reveal that the best conditions of LA can coexist with good (not the highest) conditions of RA, especially when there is a combination of people and jobs (mixed centralities).

As this example, medium RA values was also presented in other monofunctional and residential contexts but revealed not favourable LA conditions when offer a low number of jobs and/or local activities closely (e.g. Padrão da Legua). The employment centralities with big shopping malls (Norte Shopping e Freixeiro) although present the same potential of local activities differ in the mix of uses and density of population. In the case of Norte Shopping, the centrality benefits of high density and proximity with other housing centralities, while Freixeiro presents low-density residential uses. The analysis showed breaks in LA conditions which can be explained by the fast-speed road infrastructure (A28) that gives access to the Mar Shopping surroundings. In the graphs, the lack of accessibility is expressed by the dots in the left side of the graphs, especially with regard to employment LA.

In general, the results revealed that excessive increases in RA (shown by the decay of LA in all charts after LA maximum values) may be constraining local accessibility conditions whether due to the smaller number of jobs or local activities found (as in Arrotéia and S.M. Infesta). Such findings partly support the hypothesis that RA (based on car-based mobility) is affecting LA.

If we understand the characterisation of RA as a reflex of segregated planning of transport and land use in the last decades in Matosinhos and the metropolitan region - aimed at achieving accessibility with more mobility and speed – decreases in LA can be read as accessible losses at the local scale. Reminding the “land use and transport cycle” from Silva (2020) and the “positive feedback” from Laad (2014), which explain that the changes in one or more systems induces changes in people's travel behaviour and may change their routes, their choice for activities, as well as influences

activities' location (as explained in Figure 8). However, the analysis reveals not enough to explain how this phenomenon occurs: if there are fewer local activities or people, or if the small businesses end up benefiting from large anchor stores etc. Without a temporal record of accessibility conditions in the study area, little conclusion in relation to the loss of local accessibility can be made.

In general, the statistical analysis on the relationship between RA and LA showed essentially positive, but only until a certain extent. In all graphs, after reaching the best RA values, LA tends to reduce. This finding, although not entirely conclusive nor enough to completely answer the research question, in part, support the assumption that local accessibility is affected by regional accessibility levels. The statistical analysis gives insights concerning the local accessibility loss by the regional accessibility levels and supports some of the results found in the spatial analysis. Due to the great variations in the accessibility values of each scale, the statistical analysis revealed a weak relationship between RA and LA and requires further investigation.

With a focus on proximity and active mobility, the real means of promoting more quality of life, the debate on local accessibility has gained strength in recent years. Planners advocate in favour of that Silva (2018) calls the "predict and prevent" paradigm, managing the demand for travel. For instance, residents of the mixed centrality in the centre of Matosinhos are very well covered by proximity services for which the car becomes less competitive. An *environmentally friendlier mobility* as say Bertolini et al. (2005), with high density, good diversity and proximity to certain destinations (shopping, education, recreation, restaurants) has a great potential to generate local active mobility, thus to reduce "excess" regional travel made by car.

Comprehensive and transversal planning must be aimed at taking advantage of the regional mobility conditions (based on the car) existing in low-density regions in order to induce more robust urban occupation patterns (e.g. residential centralities of Lavra). At the same time, it should take advantage of the good conditions of local accessibility (e.g. Matosinhos, Senhora da Hora) to induce more sustainable mobility patterns, for example, with the implementation of policies that discourage the use of the car (reduce parking, areas limited to pedestrians) while motivate travel by active modes.

5
CONCLUSION

5.1. FINAL CONSIDERATIONS

The present study aimed to investigate how regional accessibility (RA) affects local accessibility (LA). Applying a case study in Matosinhos, Portugal, the research unfolded to the accomplishment of three specific objectives, namely the characterisation of (1) RA and (2) LA with attention to the distribution of activities and the system that facilitates car and walking trips, and the (3) analysis on the relationship between the two.

Applying a *Contour* measure, the characterisation of accessibility in 30-minute trips by car proved to be quite applicable for the regional context due to its comprehensiveness in relation to the metropolitan region. As so the 10-minute walking trips to the local environment. Analysed both in isolation and at an aggregated level (quantity and diversity of activities), the conditions of the population, employment, and nine local activities (supermarkets, small food stores, kindergarten, primary schools, public spaces, cafes, restaurants, pharmacies and general stores), elementary to achieve the subsequently spatial and statistical analysis, showed its importance on the understanding of regional and local accessibility in detail.

The spatial analysis evaluated similar and antagonistic accessibility patterns of the two scales under investigation, disaggregated at the census tract level. With attention turned to the main centralities of the municipality, opposing patterns of high RA and low LA found in the housing and employment centralities, particularly in the proximities of highways and large commercial establishments (shopping centres).

With regard to the statistical analysis, the study revealed interesting results, although with great variations in the accessibility values of each scale which highlights the need for further investigation. The relationship between RA and LA was essentially positive, but there seems to be a (quite high) value of RA from which the LA starts to fall. In summary, all graphs revealed that, after the best

conditions of LA are established, the relationship with RA tends to become negative. This finding, although not entirely conclusive nor enough to completely answer the research question, in part, support the assumption that local accessibility is affected by regional accessibility levels.

Justifying some of the opposing patterns found in the spatial analysis, this trend suggests that the levels of local accessibility are partly affected by regional accessibility by facilitating car trips whether due the presence of highways or the large commercial establishments (shopping centres) with regional reach. More studies would need to be developed including other spatial factors, and assisted by a variety of statistical tests to further corroborate these findings. For instance, a statistical analysis focused precisely on medium-high values for RA and low values for LA could draw more robust answers about the relationship of accessibility levels between the two scales.

An important reflection that remains is how these big activities (shopping centres), which concentrate a large number of activities (and jobs), are affecting small stores' location at the local scale. Do such establishments encourage the appearance of nearby activities functioning as anchors? Or, on the contrary, are they leading to closure due to competition effects and therefore affecting LA conditions? Future research that incorporates data from the next demographic census in a temporal approach (from 2011 to 2021) could reveal further insights.

5.2. CONTRIBUTIONS

This study adds a methodological contribution to the knowledge by a comprehensive accessibility approach at different geographic scales and reinforces what has been said in recent studies. By combining RA and LA analysis, it was possible to identify spatial patterns that, on an exclusively regional scale, would not be able to provide. On the other hand, an exclusive emphasis on walking on a local scale would not characterise the county's reach at the regional scale in relation to neighbouring municipalities (employment and population accessibility). The work contributes to a better understanding of the relative accessibility in a cross-scale analysis, as well as walking and car potential mobility.

It is important to note, with respect to the replicability of this study as well the generalisation of the results, that the case-study can have specific conditionings untransferable to other contexts. The application of the proposed approach larger urban contexts it might require more time and improved computational capacity. Bigger cities mean more data to manipulate and processing on GIS software, which in turn will require more time and computational resources, especially for car-based regional accessibility. In turn, a similar analysis of local accessibility conditions in a larger urban context (such as Brazilian cities, for example) would take a long time to collect and correctly manipulate data on the local activities involved. In other words, local-scale analysis consumes more time in the

preparation to perform accessibility measures, while regional accessibility is more time consuming while running such measures thus requiring a greater computational apparatus.

5.3. POLICY IMPLICATIONS

Through the cross-scale methodological approach, it is possible to evaluate how land-use and transport policies are responding to RA and LA needs. While regionally the municipality has the potential to answer quite well the car-oriented commuting demand, it is at the local analysis that the biggest constraints appeared. The analysis provides an understanding of LA conditions which may orient planning decisions. For instance, the centralities with the best LA conditions (e.g. Matosinhos) can stimulate its residents to enjoy the proximity activities providing appropriate pedestrian conditions and parallelly discouraging car use or the need to travel further. Furthermore, land-use policies can steer strategies to improve accessibility conditions in the areas where presented low LA: whether by increasing population density in the employment centralities with good potential of local accessibility (e.g. Freixeiro) or even inducing more mix and commercial uses in residential centralities (e.g. Corgo, Custóias) providing increased local job opportunities.

The concept of accessibility gained strength in recent years, showing increasing concerns in analyse accessibility at the local scale. The present study represents one more effort in this direction. Recently, the world has forcibly witnessed what it is [return to] living without major regional movements in the face of the COVID-19 pandemic, bringing important reflections on the importance of local and neighbourhood accessibility. After years [or even decades] of urban theory advocating toward "*walkable neighbourhoods"* and need of "*proximity services*" (food supply, recreational activities, restaurants) in the daily lives of the population, today it can be said that - in the absence of other alternatives - we are [finally] learning from practice.

6
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APPENDIX

The original accessibility maps produced for the present dissertation are organised as follows:

Regional scale (RA):

Accessibility to population, employment and sum of both (3 maps)

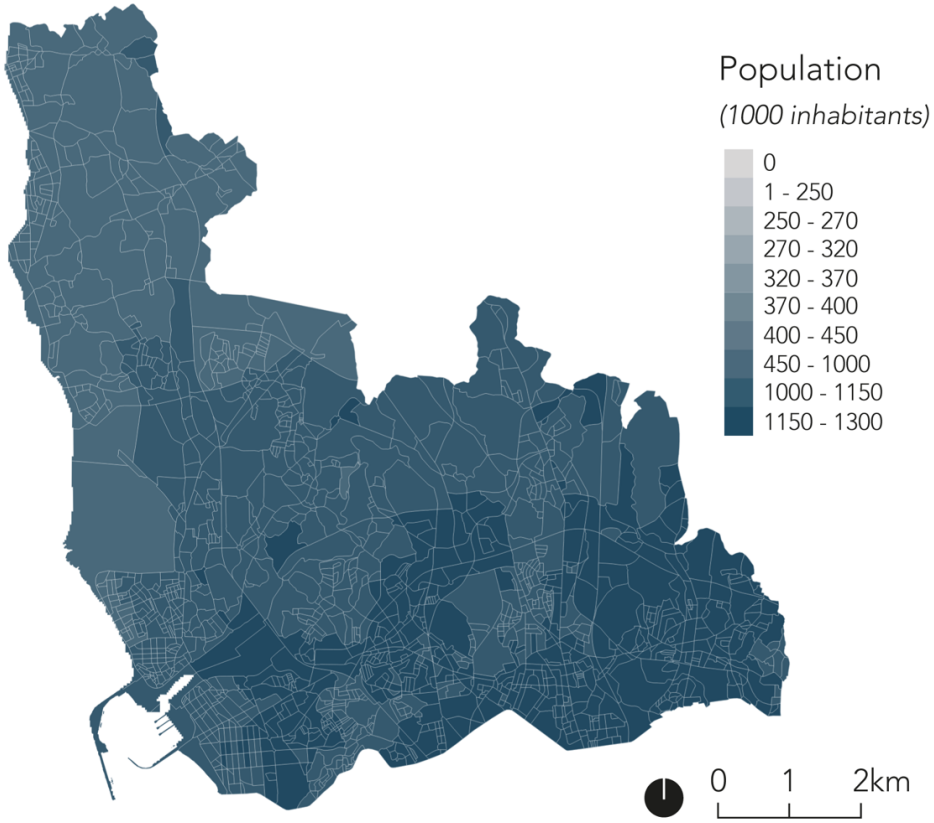
Local scale (LA):

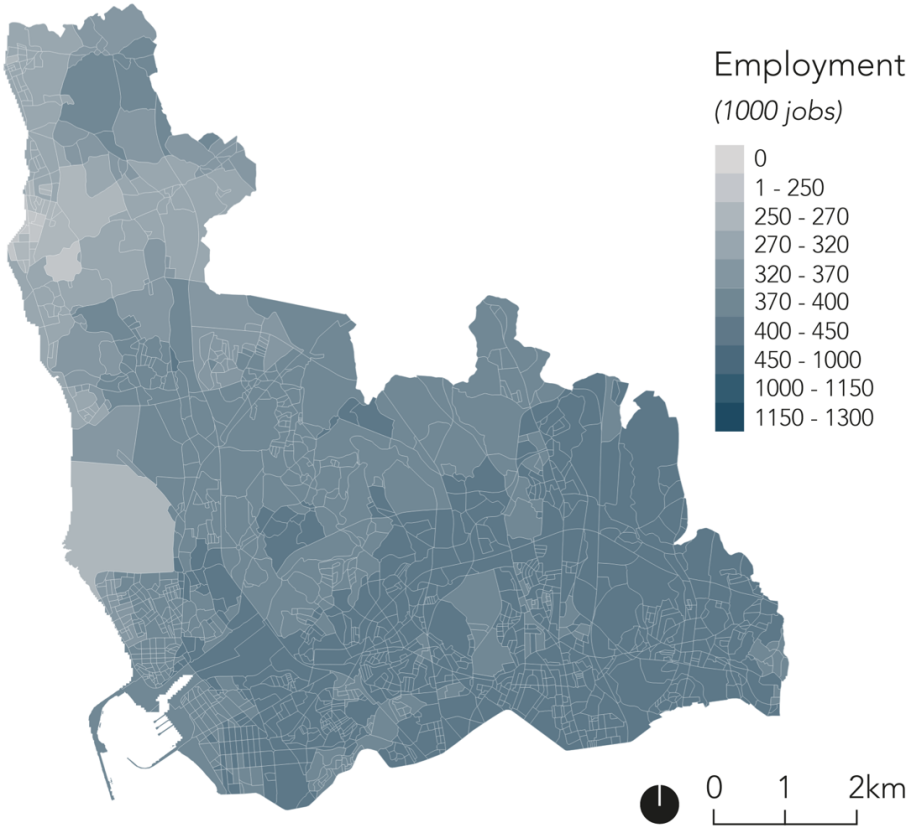
Accessibility to population, employment and sum of both (3 maps)

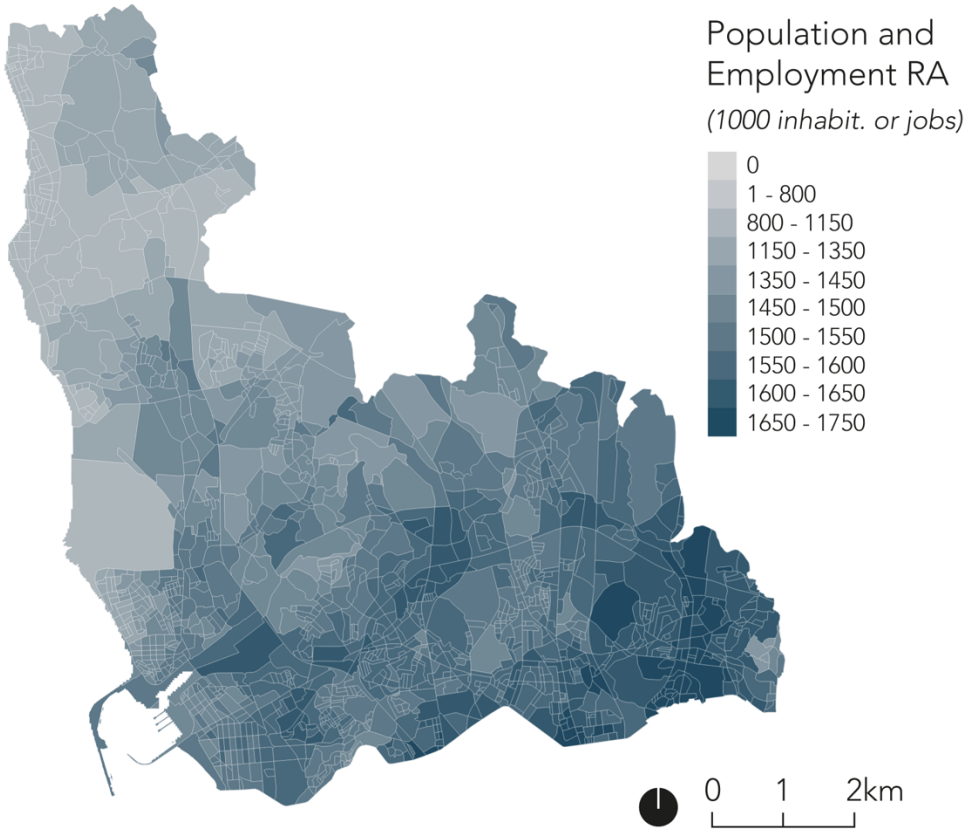
Accessibility to local activities (9 maps)

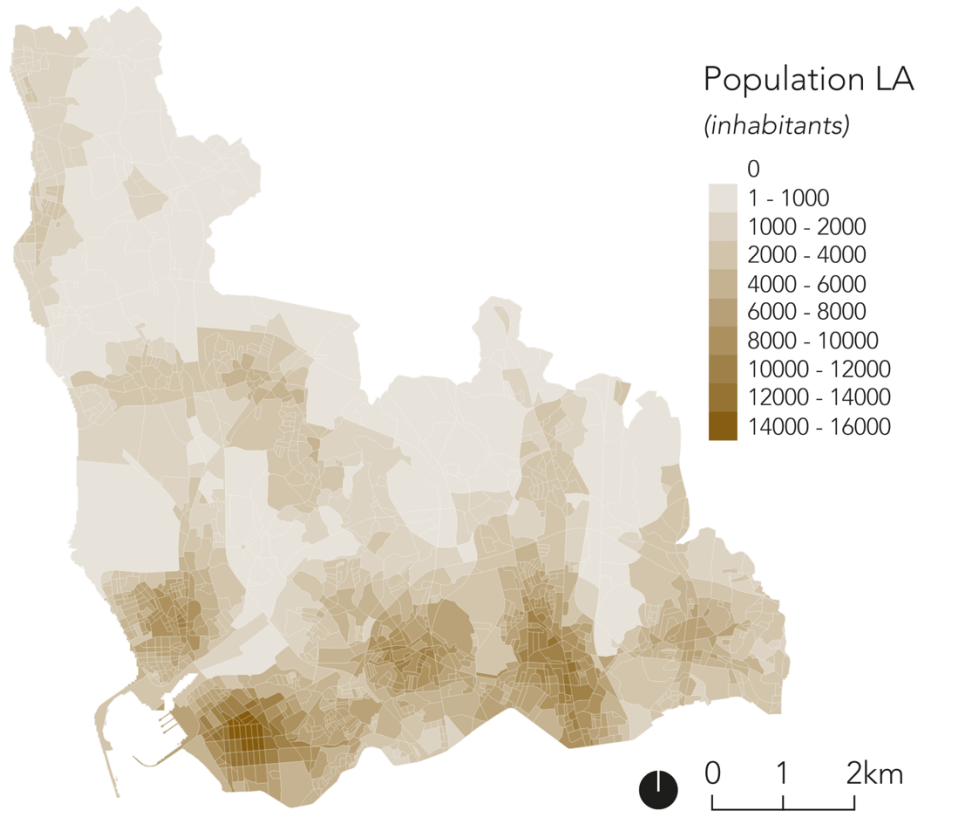
Sum of local activities (1 map)

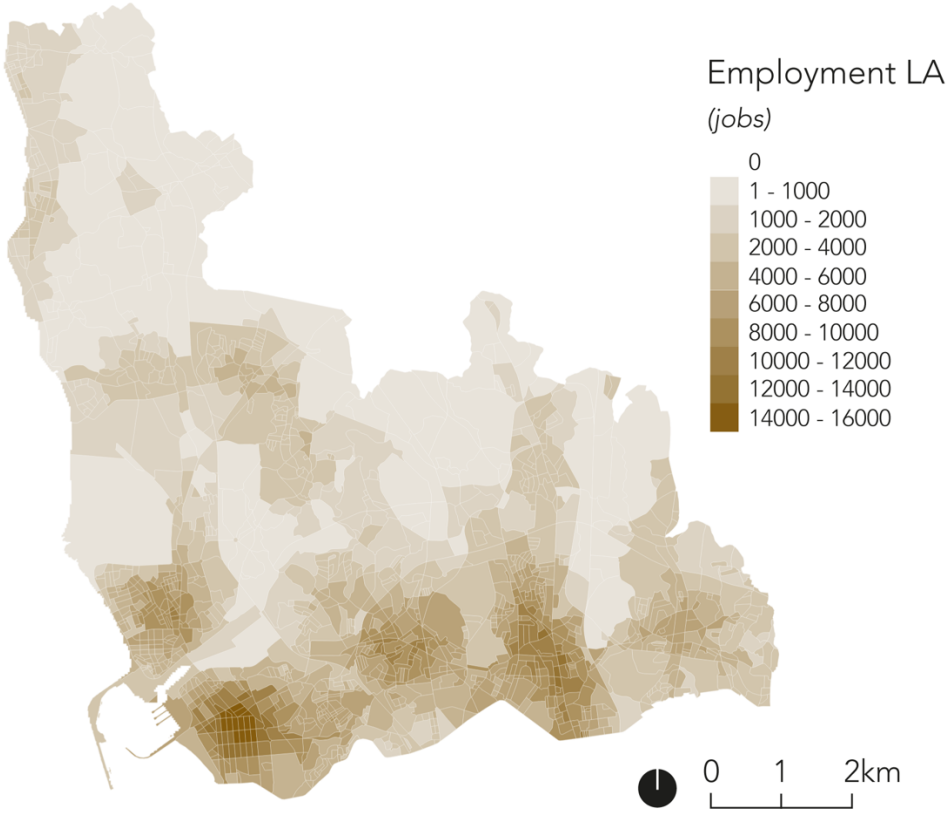
Diversity of activities – essential and all activities (2 maps)

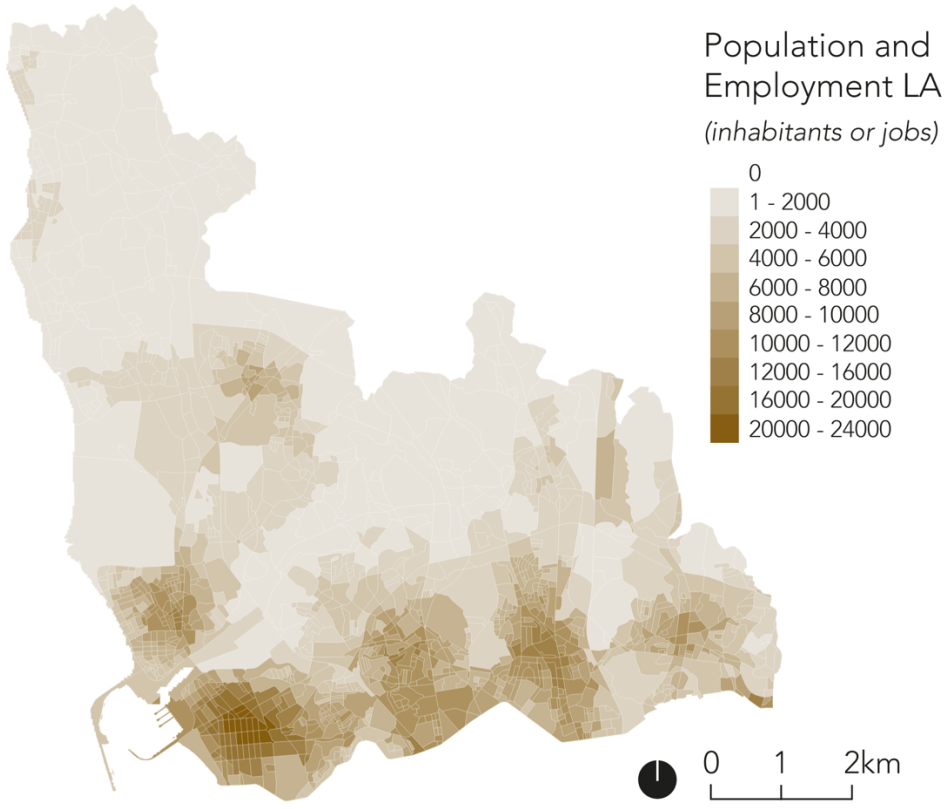

Population
(1000 inhabitants)
0
1 - 250
250 - 270
270 - 320
320 - 370
370 - 400
400 - 450
450 - 1000
1000 - 1150
1150 - 1300
0 1 2km

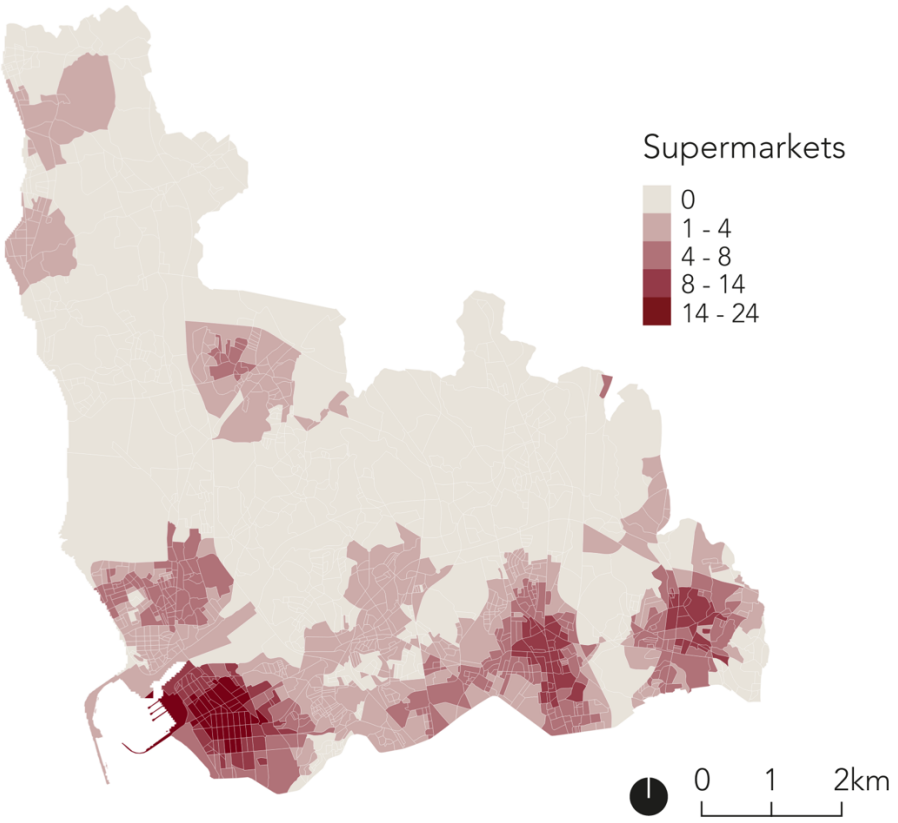

Employment
(1000 jobs)
0
1 - 250
250 - 270
270 - 320
320 - 370
370 - 400
400 - 450
450 - 1000
1000 - 1150
1150 - 1300
0 1 2km


Population and
Employment RA
(1000 inhabit. or jobs)
0
1 - 800
800 - 1150
1150 - 1350
1350 - 1450
1450 - 1500
1500 - 1550
1550 - 1600
1600 - 1650
1650 - 1750
0 1 2km

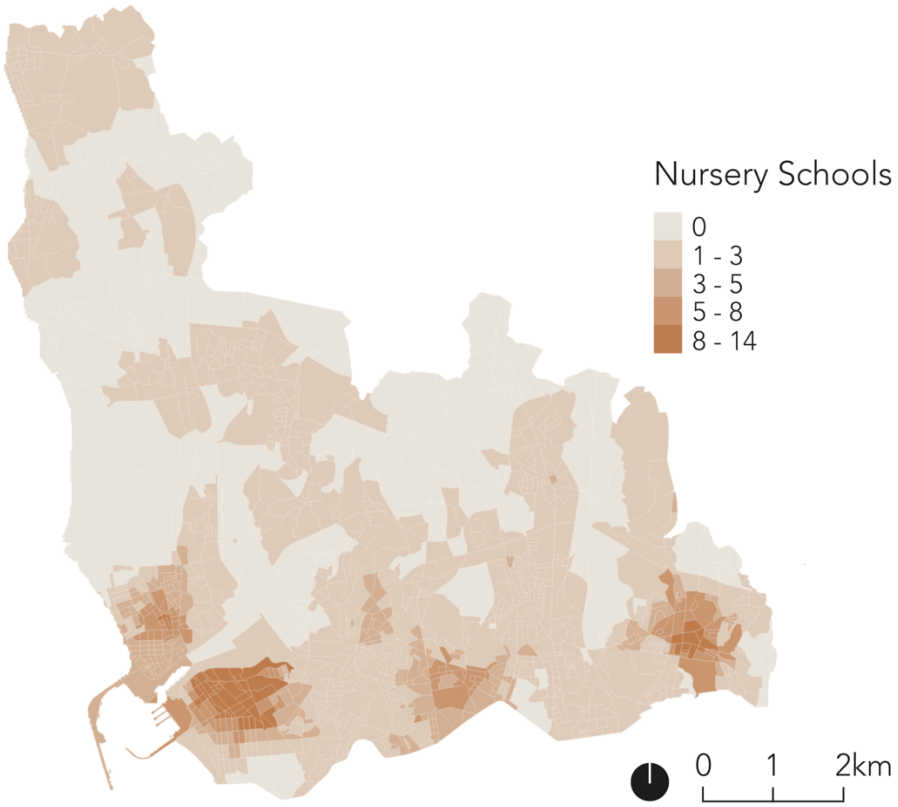

Population LA
(inhabitants)
0
1 - 1000
1000 - 2000
2000 - 4000
4000 - 6000
6000 - 8000
8000 - 10000
10000 - 12000
12000 - 14000
14000 - 16000
0 1 2km

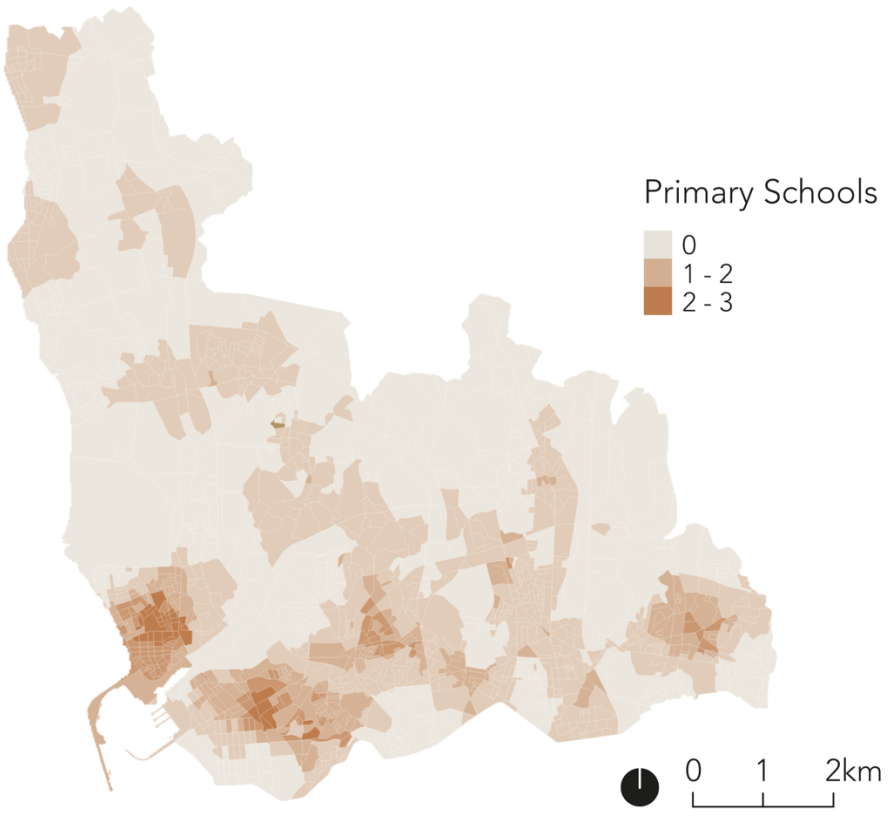

Employment LA
(jobs)
0
1 - 1000
1000 - 2000
2000 - 4000
4000 - 6000
6000 - 8000
8000 - 10000
10000 - 12000
12000 - 14000
14000 - 16000
0 1 2km

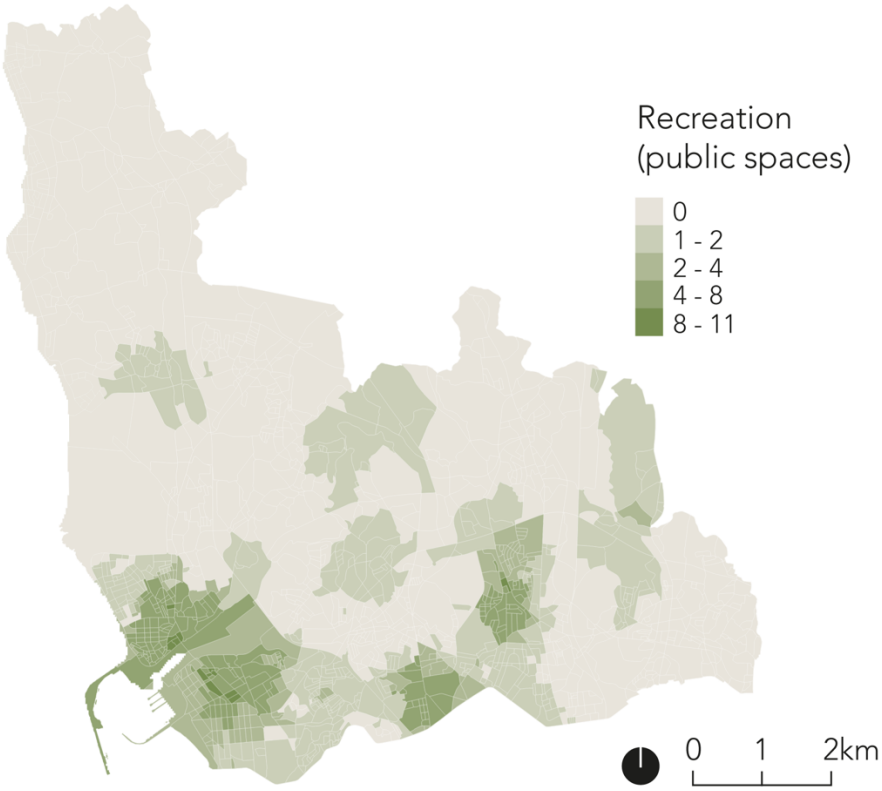

Population and
Employment LA
(inhabitants or jobs)
0
1 - 2000
2000 - 4000
4000 - 6000
6000 - 8000
8000 - 10000
10000 - 12000
12000 - 16000
16000 - 20000
20000 - 24000
0 1 2km

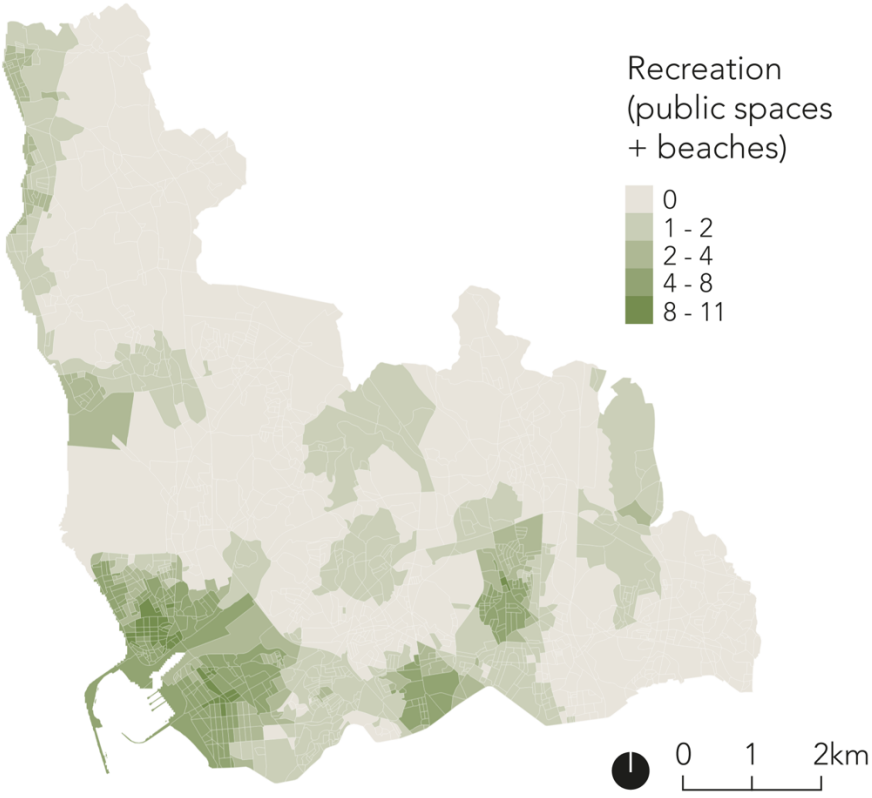

Supermarkets
0
1 - 4
4 - 8
8 - 14
14 - 24
0 1 2km

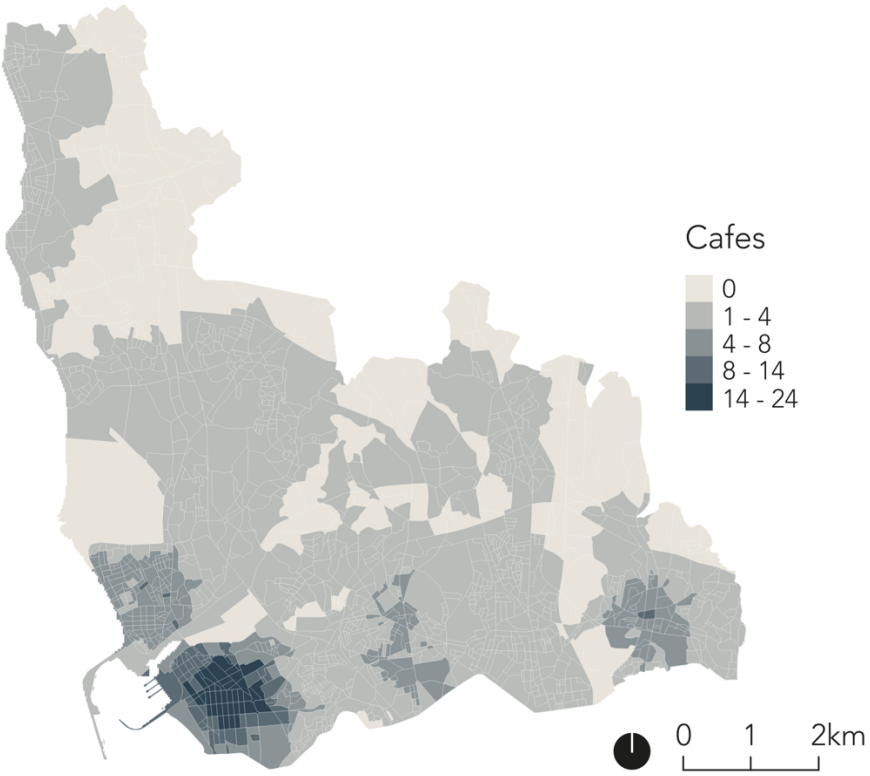

Food Stores
0
1 - 5
5 - 15
15 - 30
30 - 48
0 1 2km

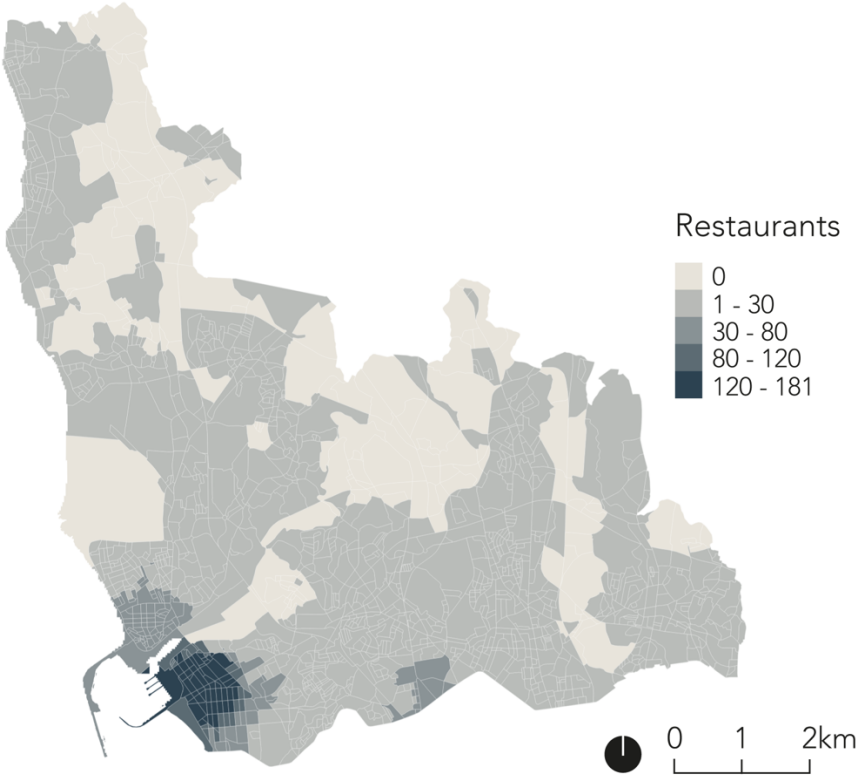

Nursery Schools
0
1 - 3
3 - 5
5 - 8
8 - 14
0 1 2km

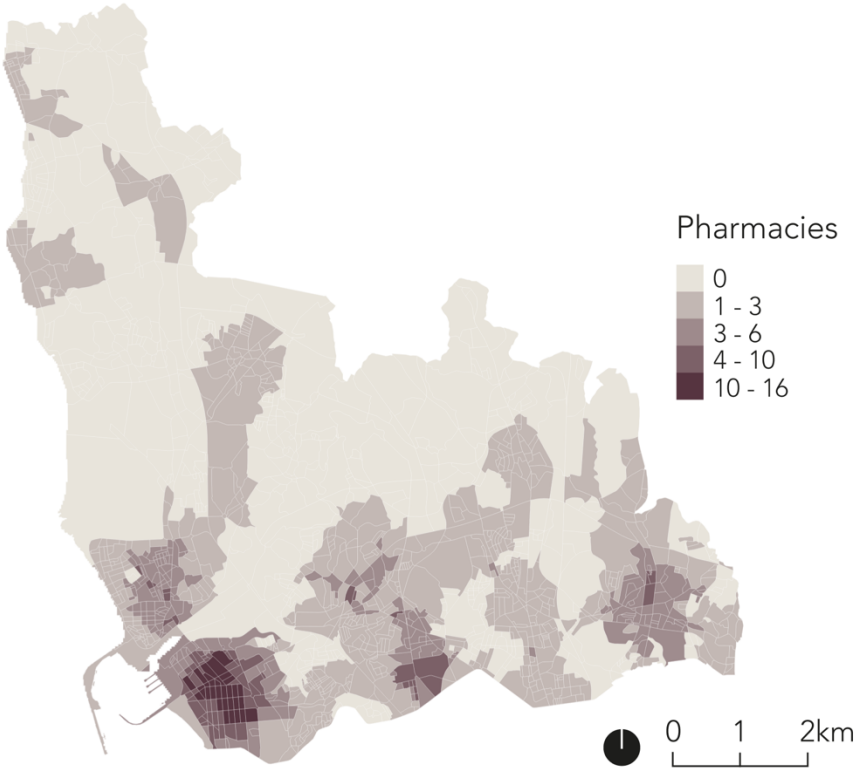

Primary Schools
0
1 - 2
2 - 3
0 1 2km

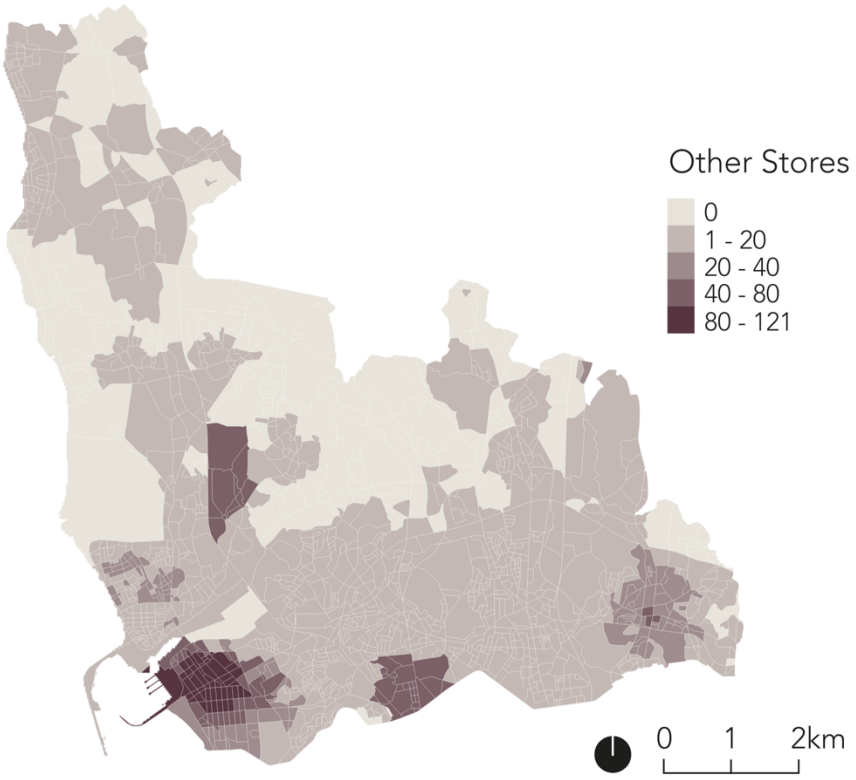

Recreation
(public spaces)
0
1 - 2
2 - 4
4 - 8
8 - 11
0 1 2km

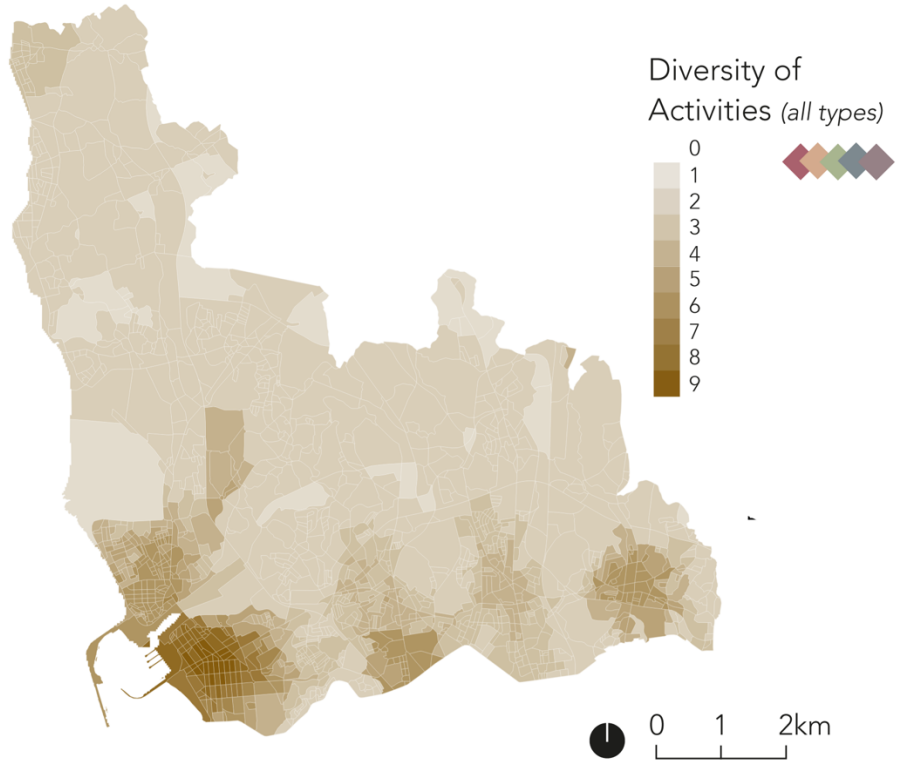

Recreation
(public spaces
+ beaches)
0
1 - 2
2 - 4
4 - 8
8 - 11
0 1 2km

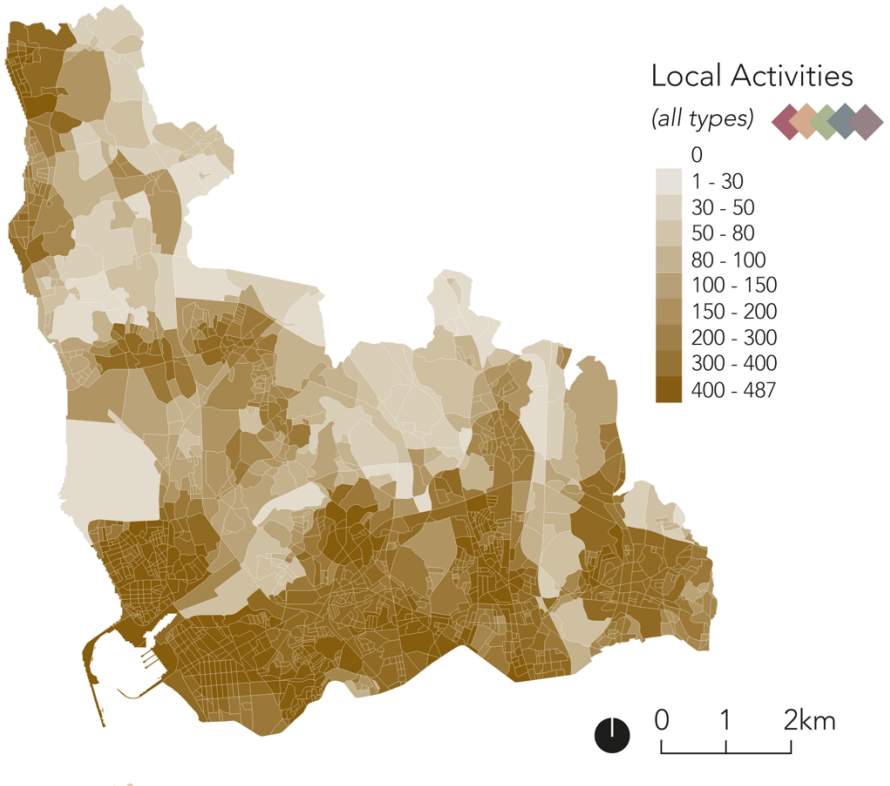

Cafes
0
1 - 4
4 - 8
8 - 14
14 - 24
0 1 2km

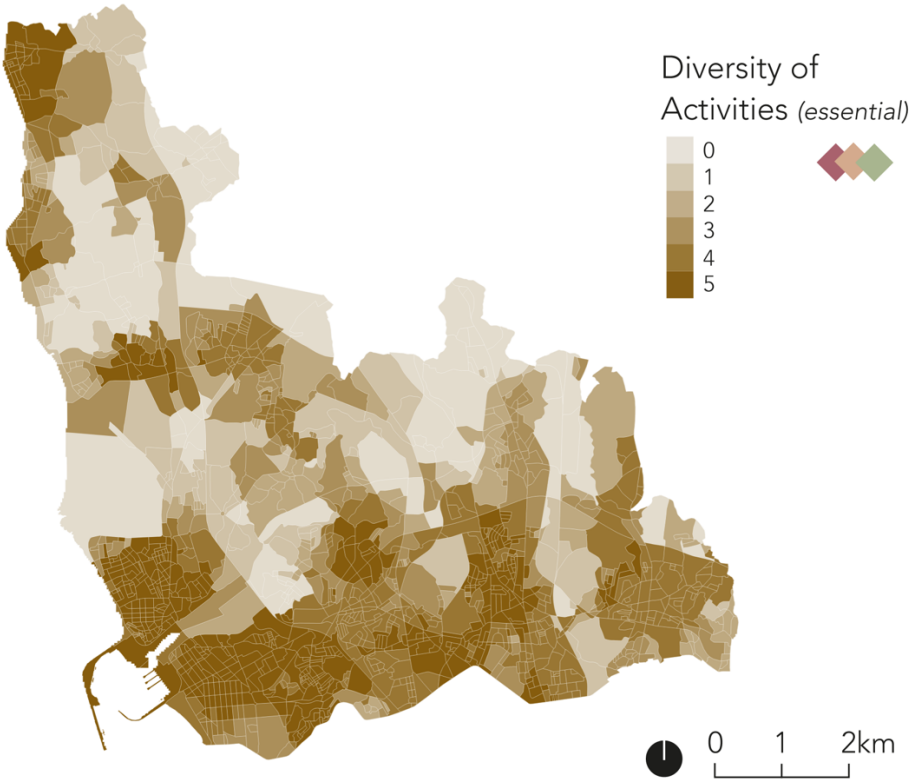

Restaurants
0
1 - 30
30 - 80
80 - 120
120 - 181
0 1 2km


Pharmacies
0
1 - 3
3 - 6
4 - 10
10 - 16
0 1 2km


Other Stores
0
1 - 20
20 - 40
40 - 80
80 - 121
0 1 2km


Diversity of
Activities (all types)
0
1
2
3
4
5
6
7
8
9
0 1 2km


Local Activities
(all types)
0
1 - 30
30 - 50
50 - 80
80 - 100
100 - 150
150 - 200
200 - 300
300 - 400
400 - 487
0 1 2km


Diversity of
Activities (essential)
0
1
2
3
4
5
0
1
2km