CITTA

10TH ANNUAL CONFERENCE
ON PLANNING RESEARCH

PLANNING FOR CLIMATE CHANGE
POLITICAL CLIMATE AND POLICY CHANGES

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THE RESEARCH CENTRE FOR TERRITORY, TRANSPORTS AND ENVIRONMENT

Citta
FEUP UNIVERSITY OF PORTO
FCTUC UNIVERSITY OF COIMBRA

Clássica - Artes Gráficas
1ª Edição
Depósito legal N.º D/L: 442174/18
ISBN: 978-972-752-231-6

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Este trabalho foi financiado por: Projeto POCI-01-0145-FEDER-006775 - CITTA - Centro de Investigação do Território, Transportes e Ambiente - financiado pelo Fundo Europeu de Desenvolvimento Regional (FEDER), através do COMPETE2020 – Programa Operacional Competitividade e Internacionalização (POCI) e por fundos nacionais através da Fundação para a Ciência e a Tecnologia I.P.;
This work was financially supported by: Project POCI-01-0145-FEDER-006775 - CITTA - Research Centre for Territory, Transports and Environment funded by FEDER funds through COMPETE2020 - Programa Operacional Competitividade e Internacionalização (POCI) – and by national funds through FCT - Fundação para a Ciência e a Tecnologia

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Foreword

I'm particularly pleased and honoured to write these introductory lines to this book of proceedings.

Firstly, because it is a wonderful way to celebrate the 10th annual conference organized by our research centre – CITTA. Ten years ago, when we started this journey and organized the first CITTA Conference, I still remember to make the point in the closing speech that more difficult than organizing a first international conference would be to keep its regular organization over the years with the same enthusiasm, rigour and quality standards of the first one. Clearly, this challenge has been successfully met thanks to the collaboration, talent and dedication of all the senior and junior researchers that, over the years, have been contributing to the development and consolidation of our research centre.

Secondly, because the theme of the conference - *Planning for Climate Change* – has long been central to several research projects carried out at CITTA. The subtitle – *Political climate for policy changes* – is an obvious reference to the recent fallacies and denials brought about by the Trump administration to the wider political debate. This new rhetoric is dangerously weakening international long term initiatives that could, if not reverse current trends at least slow down and contain the widespread climatic changes that are occurring on the earth's surface, hitting in particular the poorer and more vulnerable sectors of our societies, specially in the so-called global South.

Thirdly, because for the first time, the organization of the conference was based on an internal call open to all the staff of the research centre, which resulted in the selection of the proposal prepared by Ruben Fernandes and Luísa Batista. To these two CITTA researchers I shall address my deepest thanks and congratulations for the overall success of the conference, which accounted with an excellent choice of keynote speakers, including the Portuguese Ministry for the Environment João Pedro Matos Fernandes, Prof. Filipe Duarte Santos (U Lisbon) and Dr. Vanesa Castan Broto (UC London) and with a most effective and professional organization of the event. In addition, the conference ended with an original round table gathering representatives from five Portuguese Local Authorities – Amarante, Guimarães, Ílhavo, Porto and Viana do Castelo – that, in a vividly and documented way, presented their rich and diversified experiences of implementing adaptation and mitigation strategies at local level to tackle the challenge of climate change.

In the following pages, the reader is going to find a selection of twelve full papers which can be considered a fair sample of the forty oral presentations at the conference

which were initially organised into four thematic tracks, as follows: Climate Change and Territorial Efficiency; Climate Change and Multilevel governance; Climate Change and Transportation Planning; and, finally, Climate Change and Urban Infrastructure.

In comparison to some previous books of proceedings of the CITTA's annual conferences this one is surely much less bulky but, from a research point of view, its contents are no less relevant and the average overall quality still kept at a very high level as the presence of some prominent authors clearly denotes. Enjoy the reading!

Paulo Pinho

Accessibility measures into Portuguese municipal plans

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During the last decades, it has been increasingly noticed the need of the paradigm shift from transport to accessibility-based planning. In fact, reducing the need to travel by providing shorter distances, more choices in travel modes and making it easier and safer for people to access services and facilities, are several ways (amongst others) of reducing transport-related emissions. High accessible conditions are described by low daily distances through appropriate travel times in access to activities enabling urban development towards more sustainable and low carbon strategies. This paper focus accessibility as a core planning concept into municipal plans. Based on a Process of Measurement Conceptual Accessibility (PMAC), elementary contour accessibility measures and performance indicators are used to assess accessibility conditions at the city of Oporto, focused on the access from different basic needs of day-to-day life by public transport and walking modes. The main results highlight the importance of assessing accessibility in land use plans by relating population density before and after accessibility concerns be comprised.

Keywords: Accessibility-based planning; accessibility measures; municipal plans.

1 Introduction

Over the last decades, the concept of accessibility has assumed different practices in urban planning (eg Hull *et al*., 2012; Silva *et al*., 2017; Te Brömmelstroet *et al*., 2016). Moreover, the trend of the paradigm shifts from mobility-based to accessibility-based planning has been increasingly noticed in the scientific debate about the importance of developing strategic planning goals based on the integration of accessibility measures and performance indicators in both transport and land use planning (Bos and Lee, 2012; Cervero, 2005; Envall, 2007; Handy, 2005; Hull *et al*., 2012; Litman, 2008, 2016).

However, it seems that its implementation, related with the urban management, lacks references in the literature, presenting itself as essential for achieving coordination among different planning sectors (and actors). This integration is aimed at compiling adequate financial resources to define common spatial planning objectives and can assist in the decision-making process in transport and land use plans (DGOTDU, 1988).

In Portugal, the understanding of accessibility-based planning has often been through transport plans. As a consequence, the need of adapting Portuguese planning system

remains important, mainly with regard to land use plans. By providing complementary tools to support strategic findings, the path should be focused on a common involvement about the effectiveness of the planning practice through the interaction of accessibility into land use plans.

Moreover, accessibility concerns may vary through each context of planning system regarding operational terms as well as on the needs and priorities of each government. Nevertheless, the practice of accessibility-based planning appears to be difficult to operationalize in urban planning and, as such, understanding its manifold concerns for improving accessibility, is an important task to be undertaken in this paper.

The scope of this paper is focused on the integration of accessibility concerns in the Portuguese municipal plan (notably seen as territorial management tools), the so-called *Plano Diretor Municipal* (PDM). Following this problem, the Process of Measurement Conceptual Accessibility (PMAC) was developed and tested in order to fill some of the gaps mentioned earlier.

PMAC is a tool for supporting urban planning based on the use of three accessibility-based concepts: simple accessibility measures, performance indicators and selective urban densities. As a measurement process, PMAC consists of 3 methodological steps considered important to delineate a path towards the introduction of accessibility concerns in PDM by measuring the impact of local accessibility as the ultimate goal. In addition, PMAC is primarily concerned with incorporating part of the accessibility-based planning vision from the assessment of municipal plans and, secondly, in demonstrating the introduction of accessibility concerns into the Portuguese land use plans. PMAC is aimed to enhance local accessibility conditions in the territory by pointing out appropriate strategic planning policies for each category of land uses.

This paper starts with a brief review of the state of the implementation gap of accessibility-based planning across planning practice in Portugal (section 2), followed by the lack of accessibility operational concerns in land use plans (section 3). Section 4 presents the Process of Measurement of Conceptual Accessibility as a tool for assessing accessibility improvements in order to support urban planning. Section 5 summarizes the results of the testedbed selection for improving accessibility by the PMAC. Finally, the main findings are presented in section 6.

2 Implementation gap of accessibility-based planning across Portuguese planning system

Currently, there is still an implementation gap between accessibility concept within urban planning systems (Amante *et al.,* 2013). Several authors of the scientific literature

have been studying the integration of accessibility concerns into several planning instruments, however, the practice of accessibility has been routed to urban policy issues regularly included in the context of transport and mobility planning (Amante *et al.*, 2015; Chapman and Weir, 2008). Despite the efforts of implementing accessibility-based planning in other countries, the tendency for its success seems to fall short of its guiding principles as of its conceptual assumptions. In fact, operational problems and (above all) conceptual assumptions of accessibility continue to be identified as ineffective, making its effectiveness quite complex at territory scale according to the usability of several accessibility instruments (Amante *et al.,* 2013, 2015; Te Brömmelstroet *et al*., 2016).

In general, it is not easy of distinguishing mobility-oriented goals from those of accessibility-based planning (Handy, 2005; Hull *et al.* 2012; Silva, 2013). The first difference between is focused on mobility objectives that distinguish tenuously terms such as "want to" reach a destination or, effectively, "need to" do so.

On the one hand, mobility-based planning gives preference to the transport system efficiency (as infrastructure), not recognizing important factors such as travel choices, travel costs or characteristics of the population or of destinations, for instance. Thus, several authors argue that a high level of mobility may not ensure good accessibility (eg Enval, 2007; Silva 2013). On the other hand, accessibility-based planning enables an integrated approach to land use and transport system by focusing on the person rather than on the infrastructure. Furthermore, Enval (2007) argues that accessibility planning should be based on normative frameworks in order to be identified a set of key indicators establishing actual demand (also referred to by different authors as potential mobility) instead of derived demand. The second difference involves the way both planning reply to changes in the land uses. The difference can be sustained by the short- or long-term effects (Enval, 2007; Levine and Garb, 2002). Strategic changes in land-use patterns may have different effects depending on the practice of both plannings, inasmuch as one intervention may be detrimental to one and beneficial to the other, and these impacts may occur in a reciprocal way (Geurs and Eck, 2001; Halden, 2012; Handy, 2002; Levine and Garb, 2002). Indeed, the urban structure may be a consequence of the territorial expansion process in itself and of the planning practice underlying different urban systems (eg Amante *et al*., 2015).

Likewise, there is a need of adopting accessibility operational concerns, particularly, in Portugal planning system. Over the years, it has been observed a shortage of the ability in operating at the territory, in a more comprehensive way, which has resulted in a number of ineffective planning tools, concerning the integration of land use, mobility and transport policies (Carvalho and Oliveira, 2013; Pinho and Oliveira, 2010). This ineffectiveness has been the result of the inoperability of land use plans, regarded as

still rigid in the current context of uncertainty, not only because of the sectorization of the territory planning areas, but also due to the overlapping of planning technicians' skills and to the many other factors that may induced some of the issues mentioned above. The common interaction between accessibility and urban planning practitioners is still a domain hardly reached by the academic community and among different actors/ stakeholders involved in the planning process (Pinho *et al*., 2012; Silva *et al.,* 2017a, 2017b; Te Brömmelstroet *et al*., 2016).

Though, the inefficiency of the planning process may be a consequence of the legal framework produced by the Portuguese planning system during the last decades. There have been a number of changes in the territory, in particular with the expansion of transport infrastructures and the consequent increase in mobility. In fact, the traditional planning environment has not contributed to the local and sustainable development and the Portuguese planning instruments cannot keep all the changes at once. For instance, both population growth as its shrinkage phenomenon, which have been observed so many European cities (Saraiva *et al*., 2016; Sousa, 2010; Sousa and Pinho, 2015; Wiechmann and Bontje, 2013), have an effect on the housing, employment and on the basic services (eg health, education, culture, etc.). These phenomena have influenced the development of the cities in which planning process should involve joint work of several sectors of decision-making and instruments/tools. It is still clear that these changes will take time to be realized successfully, despite the efforts that have been observed, in recent years, to consolidate urban planning with others European and national policies (through the European Commission funding program designed to Portugal 2020, for instance). In fact, clear approaches are most often related to both legal frameworks from planning systems and to the effectiveness of each plan (Amante *et al.* 2013; DGOTDU, 2011; Ferreira, 1998; Ferreira, 1986; Lobo, 1995; Portas and Domingues, 2001).

As such, there is a need of promoting advances in Portuguese urban planning instruments in order to provide new strategies in the planning system, capable of developing appropriate (and timely) goals that can be monitored and adjusted over time. Hence, it is not important to propose closed and regulatory solutions, but developing common strategic actions that can help decision-making and following-up the objectives of the plans, as referred to earlier.

Currently, the role of local plans is generally focused on the promotion of specific urban development policies. Nevertheless, desirable policies in accessibility-based planning about changing travel behaviours remains far from being achieved insofar as it is necessary to change the paradigm focused on mobility (for accessibility) which is revealed by different access provided by the urban structure and accessibility

conditions comprised in the territory. As such, integrating concerns of this genesis may be an additional approach to current practice in transport and land use planning. By conducting accessibility paradigm within the implementation of municipal plans, there is a tendency to incorporate greater gains in the relationship between the quality of life of citizens and the opportunities of access to certain activities towards more sustainable mobility patterns and low carb strategies.

3 Integration of accessibility concerns in land use plans

As referred to above, there appears to be a number of shortcomings with respect to accessibility operational concerns in urban planning practice as such as with regard to the usability and usefulness of Planning Support Systems across European experiences (eg Te Bröemmelstroet *et al*., 2017; Silva *et al.* 2012, 2017a, 2017b). However, several authors believed that accessibility measures, complemented by the use of performance indicators, are capable of providing a generalized framework for understanding the reciprocal relationships between land use and transport systems (Amante, 2017; Amante *et al*., 2013; Espada and Luk, 2011; Litman, 2013; Te Brömmelstroet *et al*., 2014). With regard to Portugal, Amante *et al.* (2013) have evaluated 18 Portuguese PDM in relation to the integration of accessibility in land use, mobility and transport plans. On the one hand, there is a small influence of the importance of accessibility in those plans and, on the other hand, when specific objectives and measures of accessibility are recognisable, they are disjointed among themselves, in some way. Indeed, the lack of integration between accessibility and land use planning should require a clear definition of local problems and, likely, it should find simple and useful instruments to integrate this issue into cross-cutting planning practices, by clarifying the cooperation and the coordination between different sectors. In fact, the three planning concepts (accessibility, mobility and transport) need to be well simplified along urban management strategies and should be carefully incorporated in practice to minimize the negative effects caused by the disarticulation of these sectors in the decision-making process.

For this happening, several authors claim the importance of introducing accessibility measures in urban planning tools through the definition of appropriate accessibility thresholds for measuring accessibility performance into land use plans (Geurs and Eck, 2001; Handy, 1992; Levine *et al*., 2010; Manaugh and El-Geneidy, 2011; Silva, 2008; Silva *et al.* 2012). On the one hand, the effectiveness of a plan should include a basic or simple accessibility measure (which may be aggregated or disaggregated), in order to simplify the interpretation and understanding of the objectives applied for each plan. On the other hand, the definition of accessibility thresholds lacks a distinction between

the specific objectives and targets within operational measures which are determined according to the concepts of "real" and "potential" mobility in assessing mobility patterns and accessibility levels in planning (eg Pinho and Silva, 2015).

Furthermore, the importance of performance indicators has been included in the accessibility assessment, geared to the performance of the objectives of the plans, particularly in the context of performance planning (eg Litman, 2011, 2013). The interest of applying performance indicators is identifying, essentially, the strategic result in which the effectiveness of the plan and the efficiency of the urban management are oriented.

Additionally, several authors argue that accessibility is positively correlated with urban densities, especially related to the population (eg, Silva, 2013; Cervero, 2011; Ewing and Cervero, 2011). According to Ewing and Cervero (2010), the notion of density is elementary to define urban form by combining several factors related to land use patterns, transport systems and urban design, capable of measuring the degree of compactness of the urban structure (Clark and Moir, 2015).

In this context, this paper can bring added value to the practice of Portuguese urban planning in light of the accessibility conditions comprised of the local plans. Taking into account what has been previously mentioned, it is possible to bring together both planning practices by relating the following complementary components for defining strategic urban policies within land use plans, such as:

Accessibility-based planning:

- Accessibility measures aim to assess the return effects between transport infrastructures and the modal split by equating the urban form and the spatial distribution of the activities and of the population (both in terms of catchment areas and of origin/destination/origin activities). In addition, they can allow the calculation of accessibility levels by combining several variables, such as: land use characteristics, travel purposes, choice of modes of transport, preferences of the individual, competitive effects, travel times, etc (eg. Geurs and Eck, 2001; Silva *et al.*, 2012);
- Performance indicators can provide a simple basis of compliance (or change) based on the desired result. They aim to support the effectiveness of the planning process at all stages (implementation, monitoring, assessment, decision-making, consultation, etc.) towards goals. The selection of these indicators goes through an iterative process among stakeholders and the population, in order to maximize the effectiveness of actions used to improve accessibility (te Brömmelstroet *et al.*, 2014; Litman, 2012, 2013).

Urban planning and territorial instruments (plans):

- Selective densities of land use aim to distinguish the development of urban policies within specific urban areas. According to DGOTDU (2011), the built environment is related to the morphological issue concerning urban densities through a normative system based on urbanistic indexes (Enval, 2007). In addition, they can help to meet accessibility improvements according to several planning goals like, for instance, the viability of transit-oriented development as well as of local proximity services, by encouraging more sustainable mobility patterns (walkability and PT modes). The role of the PDM can promote land use densities in certain areas by producing economic development initiatives in both mobility and transport planning as well as within sectoral programs like education, health, leisure, etc. Hence, urban densities should be operationalized through urbanistic indicators included in land use categories benefiting accessibility towards sustainable planning policies (Cervero *et al.* 2011; Ewing and Cervero, 2011; Pinho and Silva, 2015; Silva and Pinho, 2006; Vale, 2015).

However, the outline of strategic goals should take into account the following issues that can not be overlooked in planning, such as: 1) there are different ways of observing the territory based on accessibility goals and measures; 2) there are different needs for finding the effective way for introducing accessibility measures and performance indicators into Portuguese planning system, and; 3) there are several paths for introducing accessibility concerns in PDM.

4 Process of Measurement Conceptual Accessibility (PMAC)

This section presents a tool for supporting urban planning based on concepts of accessibility, named Process of Measurement Conceptual Accessibility (PMAC). This tool assesses the improvement of accessibility in the scope of municipal land use plans.

PMAC aimed to introduce accessibility concerns into the PDM underpinning four important specific goals in the context of local accessibility by a) promoting the use of simple accessibility measures and performance-based indicators geared to specific planning objectives, b) integrating local accessibility levels based on selective urban densities, c) using urban indicators included in the plans, and; d) measuring the impact of accessibility at municipality scale.

Furthermore, the PMAC proposes a conceptual framework comprising three accessibility-based concepts (Figure 1) related to specific assumptions (Table 1). On the one hand, the use of simple accessibility measures and performance indicators should be clear in operational terms, reflecting the basic needs of the population and their expected accessibility thresholds. On the other hand, the density of urban occupation, as

well as the accessibility levels should integrate accessibility planning targets proposed by the PDM, in identifying their reference values through the changing of urbanistic indicators. From this recognition, the impact of accessibility is the end result of PMAC measured by the adjustment of land use intensities with regard to accessibility concerns.

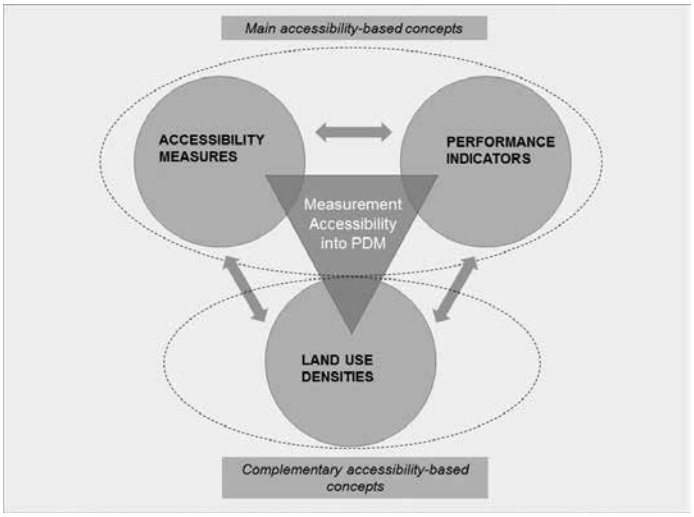

Figure 1. Accessibility-based concepts for measuring accessibility into PDM.

Table 1. PMAC's assumptions from accessibility-based concepts.

Accessibility-based concepts	PMAC assumptions
Accessibility measures	*- Accessibility measure represents the travel time from a particular destination (or the total number of destinations) accessible at a given travel time (Geurs and Eck, 2001);* *- Contour or opportunity-cumulative measures are used, being considered as of simple operationalization and of easy results interpretation.*
Performance indicators	*- Performance indicator represents the percentage of population accessible to an activity (or set of activities) by a particular transport mode and period of time in a given área;* *- Performance indicators provide accessibility to essential basic population services accessible at short distance.*
Land use densities	*- Selective densities comprise the land use intensities in relation to the two population and housing densities, based on the accessibility conditions and by the urban planning indicators of the plan;* *- Selective densification is aimed at improving accessibility based on the accessibility conditions of the urban structure.*

The PMAC is composed by three methodological phases (Phase 1: Performance Indicators, Phase 2: Aggregate Accessibility and Phase 3: Urban Indicators) and is considered as a learning-oriented planning process and decision support tool (Faludi, 2000; Pinho *et al.*, 2012). In fact, the PMAC proposes an approach based on the participation of several stakeholders, intending to be used by technicians of local authorities, planning

professionals and academics, among others. This methodological process is considered important to outline a path towards the introduction of accessibility concerns in the land use plan and each step performed is the result of several criteria methods and actions that precede each phase of the conceptual framework for measuring accessibility.

However, the PMAC is based on seven key principles for its implementation. The first principle states that should be used at the strategic level, exclusively, in the operation of accessibility into land use plans based on the physical and geographical sizes of the cities. The second principle is that should be used a set of accessibility components with at least two of the five components described by Geurs and Eck (2001), specifically transport and land use. The third principle indicates that simple accessibility measures should be easily applied and interpreted. The fourth principle declares to classify an urban territory into accessibility levels through the aggregation of the activities, the distances to public transport and the land use densities (Ewing and Cervero, 2010). The fifth principle asserts its application in urban planning instruments and that may be distinguished by the type of strategy or planning goal to be achieved. The sixth principle uses quantitative variables (through database available at both geographically and statistically levels) and qualitative ones (by conducting population surveys as well as support meetings with different intervenients of the planning process). Finally, the seventh principle is that promote accessibility improvement by changing accessibility indicators into urbanistic indicators under particular land use plan.

4.1 PMAC methodological phases

Phase 1 corresponds to a set of steps in order to find the main components of the performance indicators. Performance indicators are the starting point for assessing accessibility, being able to measure the accessible population based on the most important activities for them as well the appropriate accessibility thresholds for walking and PT accessibility.

This phase establishes two types of distinct approaches: qualitative and quantitative. On the one hand, the qualitative approach is based on the collection of targeted population surveys in order to ascertain the perception of their basic needs regarding the notion of local accessibility and demand requirements for different urban areas. Thus, the first stage of Phase 1 (the implementation of accessibility survey) aims to define the characteristics of performance indicators to use in measuring accessibility. On the other hand, the quantitative approach presents a set of criteria and basic methods for spatially representing accessibility catchment areas (based on isochrones) with the support of Geographic Information Systems (GIS). Thus, the operationalization of accessibility regards the following input and output data:

Input data:

- PMAC considers the area of the municipality;
- PMAC takes into account the location of existing geo-referenced activities (considered as basic needs of the population) based on the results of the accessibility survey;
- PMCA is based on contour / opportunity-cumulative measures and its application requires criteria of average and maximum limits of travel time as well as other assumptions for the calibration of accessibility to modes of transport. Travel times thresholds by mode of transport can be included in the total travel time (eg the waiting time or transhipment time of the PT), also aggregate by type of activity;
- PMAC does not assign weights to activities as it is based on simple accessibility measures (isochrones) rather than on operational complex accessibility measures (for instance, such as gravitational, among others).

Output data:

- PMAC assumes accessibility measurement based on activities (destiny)' catchment areas (disaggregated or aggregated);
- PMAC defines the population ratio with access to certain activities by walking and PT transport modes.

Phase 2 represents the state of the methodology in which accessibility levels are evaluated representing the integration of urban structure on accessibility, based on threefold (Cervero, 2011; Pinho and Silva, 2015; Silva *et al.*, 2014): 1) distance or travel time to PT[1]; 2) access to destinations; and; 3) diversity of activities (or mix or utilisation density)[2]. The result of this phase is called Aggregate Accessibility.

Aggregate Accessibility allows the definition of three classes of accessibility in order to perceive how accessibility is distributed in the territory or in a certain urban area, such as:

- **High level**: corresponds to high accessibility conditions (or maximum accessibility) with access to a greater number of activities and transport modes (walking and PT) in short travel time;
- **Medium Level**: corresponds to medium accessibility conditions with access to certain activities and transport modes (walking and PT) in adequate travel time;
- **Low Level:** corresponds to low accessibility conditions with access to a few (or single or none) activities and transport modes (walking and PT) in long travel time.

Additionally, the aggregate accessibility allows the characterization of urban areas, not only the definition of the type of strategy to adopt in terms of the integration of land use and transport policies, but also the outline of specific objectives set in the plan. The PMAC also proposes to reconcile the levels of accessibility through urban densities referred to in its based concepts (the population quotients are defined from 0 to 1, matching from low to high accessibility levels). Through these, the densities reference values are found by relating them to each level of accessibility, as a basis for verifying the strategy (or strategies) to be adopted on PDM.

Phase 3 is the last one to be carried out of the Conceptual Framework of PMAC. Accessibility concerns are introduced into the plan through the conversion of urbanistic indicators. For this, PMAC establishes two basic principles for defining strategies, such as:

- **High level**: a) (re) locating population to near areas with good accessibility conditions in order to reduce the use of car and for promoting non-motorized modes; b) maximizing the intensity of people to high capacity of transport systems whose terms of urban planning may allow it and where there is space for maneuver in terms of building capacity; c) developing high density areas;
- **Low level**: a) restraining densities in underserved areas by high-capacity transport systems and within highly congested urban areas facing widespread environmental and operational problems; b) restricting land use occupation in areas with low accessibility conditions.

In short, the strategies to be adopted in PMAC are as follows: 1) increasing densities in high accessibility level; and 2) decreasing densities in the low level of accessibility.

In order to convert the benchmarks defined for the densities into urbanistic indicators, the PMAC focus exclusively on the constructive indicators being able of guiding the building capacity and the strategic development of the territory. Moreover, the PMAC suggests the use of the constructive index (or similar indicator) as the common urbanistic indicator to all Portuguese PDMs. The options are related to the implementation of each plan, leaving the decision to the stakeholders as to the planning objectives to be achieved.

The potential impact of accessibility aims to measure accessibility improvements by assessing its performance in the PDM. Finally, the variation of the potential impact of accessibility results from the difference between the total potential population found in the plan after accessibility concerns compared to the baseline situation, according to the accessibility levels comprised at the local scale (Figure 2).

$$Potential\ Accessibility\ Impact = \frac{Variation\ of the\ Accessible\ Population}{Variation\ of\ the\ Total\ Population}$$

Figure 2. Measurement of accessibility impact.

In sum, the PMAC proposes a conceptual framework for the measurement of accessibility drawing a path towards the introduction of accessibility concerns into PDM (Figure 3).

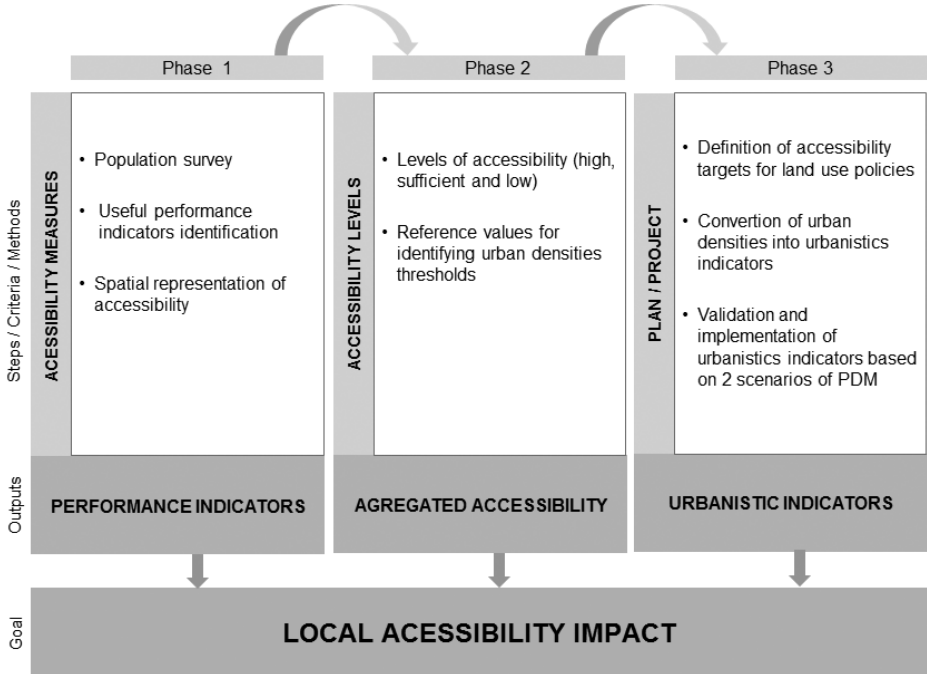

Figure 3. PMAC conceptual framework.

5 Testbed selection

The municipality of Oporto has been chosen as a case study for the application of PMAC. Oporto is the main urban and densified city into Metropolitan Area of Porto. It is characterized by compact urban form with a maximum urbanization rate, containing 237 591 inhabitants. In short, the city of Oporto represents 48% of the population of the North region covered by 2 041.3 Km^2.

5.1 Results for improving accessibility by the PMAC

In order to facilitate the definition of the performance indicators included in Phase 1 of the PMAC, the activities were grouped into nine categories, setting up thirty-two performance indicators obtained from the population survey (Table 2). On the one

hand, the walking accessibility was calculated by using two accessibility thresholds (travel time set at 5 and 10 minutes) regarding PT access points (392 STCP/Bus stops, 25 Metro stations and 3 Train stations) The basic activities found include Public Basic Schools (Total=62), Public Secondary Schools (Total=13), Public Universities (Total=24), Cinemas and Theaters (Total=8), Health Centers (Total=25), Pharmacies (Total=108), Public Hospitals (Total=12), Food stores (Total=59), Gardens and Green Parks (Total=42), Public Security (Total=25) and Sport Fields (Total=22). On the other hand, the accessibility by PT was defined in a maximum travel time of 20 minutes (from door to door and being complementary with pedestrian mode)[3] for the Basic Schools Secondary Schools, Universities and Hospitals. The measurement of accessibility comprised the accessible population ratio (Table 3).

Table 2. Main activities and thresholds accessibility.

Activities/Travel time	Walking Accessibility (5 minutes)	Walking Accessibility (10 minutes)	PT Accessibility (20 minutes)
ID1	STCP (ID1.1)	STCP (ID1.2)	
	Metro (ID1.3)	Metro (ID1.4)	
	Train (ID1.5)	Train (ID1.6)	
ID2	Basic Schools (ID2.1)	Basic Schools (ID2.2)	Basic Schools (ID2.3)
	Secondary Schools (ID2.4)	Secondary Schools (ID2.5)	Secondary Schools (ID2.6)
ID3	Faculties (ID3.1)	Faculties (ID3.2)	Faculties (ID3.3)
ID4	Cinema/Theatre (ID4.1)	Cinema/Theatre (ID4.2)	
ID5	Heath Centre (ID5.1)	Heath Centre (ID5.2)	
	Pharmacy (ID5.3)	Pharmacy (ID5.4)	
	Hospital (ID5.5)	Hospital (ID5.6)	Hospital (ID5.7)
ID6	Food Store (ID6.1)	Food Store (ID6.2)	
ID7	Gardens/Parks (ID7.1)	Gardens/Parks (ID7.2)	
ID8	Public Security (ID8.1)	Public Security (ID8.2)	
ID9	Sport Fields (ID9.1)	Sport Fields (ID9.2)	

Based on Phase 2 of the PMAC, Aggregated Accessibility was found resulting from the overlap of the 32 performance indicators described earlier. The accessibility classes were assigned in relation to the number of times the same activity is achieved in the same travel time, ie, the greater the number of areas of influence of performance indicators contained in an urban area, the higher their level accessibility. The Aggregated Accessibility aimed to find accessible population included in each level of accessibility in order to ascertain the selective population densities, thus depending on the accessibility conditions (Figure 4).

Table 3. Accessible Population ratios by performance indicators.

PI code	Performance Indicators (PI)	Population ratio
ID.1.1	Percentage of population accessible to bus stations (STCP) in 5 minutes by walking.	**51%**
ID.1.2	Percentage of population accessible to bus stations (STCP), in 10 minutes by walking.	**80%**
ID.1.3	Percentage of population accessible to metro stations, in 5 minutes by walking.	**12%**
ID.1.4	Percentage of population accessible to metro stations, in 5 minutes by walking.	**35%**
ID.1.5	Percentage of population accessible to train stations, in 5 minutes by walking.	**1%**
ID.1.6	Percentage of population accessible to train stations, in 10 minutes by walking.	**5%**
ID.2.1	Percentage of population accessible to Basic Schools, in 5 minutes by walking.	**31%**
ID.2.2	Percentage of population accessible to Basic Schools, in 10 minutes by walking.	**76%**
ID.2.3	Percentage of population accessible to Basic Schools, in 20 minutos by public transport.	**87%**
ID.2.4	Percentage of population accessible to Secondary Schools, in 5 minutes by walking.	**8%**
ID.2.5	Percentage of population accessible to Secondary Schools, in 10 minutes by walking.	**27%**
ID.2.6	Percentage of population accessible to Secondary Schools, in 20 minutos by public transport.	**50%**
ID.3.1	Percentage of population accessible to Universities, in 5 minutes by walking.	**0%**
ID.3.2	Percentage of population accessible to Universities, in 10 minutes by walking.	**26%**
ID.3.3	Percentage of population accessible to Universities, in 20 minutes by public transport.	**48%**
ID.4.1	Percentage of population accessible to Cinemas and Theaters, in 5 minutes by walking.	**2%**
ID.4.2	Percentage of population accessible to Cinemas and Theaters, in 10 minutes by walking.	**8%**
ID.5.1	Percentage of population accessible to Health Centers, in 5 minutes by walking.	**16%**
ID.5.2	Percentage of population accessible to Health Centers, in 10 minutes by walking.	**47%**
ID.5.3	Percentage of population accessible to Pharmacies, in 5 minutes by walking.	**47%**
ID.5.4	Percentage of population accessible to Pharmacies, in 10 minutes by walking.	**79%**
ID.5.5	Percentage of population accessible to Hospitals, in 5 minutes by walking.	**2%**
ID.5.6	Percentage of population accessible to Hospitals, in 10 minutes by walking.	**10%**
ID.5.7	Percentage of population accessible to Hospitals, in 20 minutes by public transport.	**34%**
ID.6.1	Percentage of population accessible to Food Stores, in 5 minutes by walking.	**36%**
ID.6.2	Percentage of population accessible to Food Stores, in 10 minutes by walking.	**70%**
ID.7.1	Percentage of population accessible to gardens and green parks, in 5 minutes by walking.	**16%**
ID.7.2	Percentage of population accessible to gardens and green parks, in 10 minutes by walking.	**43%**
ID.8.1	Percentage of population accessible to PSP, GNR and Firefighters, in 5 minutes by walking.	**10%**
ID.8.3	Percentage of population accessible to PSP, GNR and Firefighters, in 10 minutes by walking.	**32%**
ID.9.1	Percentage of population accessible to Sports Fields and Pools, in 5 minutes by walking.	**7%**
ID.9.2	Percentage of population accessible to Sports Fields and Pools, in 10 minutes by walking.	**35%**

Figure 4. Aggregate Accessibility in Oporto (darkest colors represent high accessibility and the lightest, the lowest one).

Accessibility levels revealed a number of interesting aspects in the urban context of Oporto based on specific conditions of the territory concerned. In general, the method used helped to define three accessibility levels in a diagnostic phase, lying to two positive accessibilities conditions (high and medium levels) and a negative one (low level). The results allowed to observe the differences in accessibility in the city as a whole (Table 4) indicating that about 57% of the population is allocated to low accessibility and only 11% (approximately) has access to good accessibility conditions.

Table 4. Accessibility indexes by levels of acessibility.

Acessibility Levels	Population	Acessibility Index
High	10,51%	[0,60 – 0,84]
Medium	32,73%	[0,40 – 0,59]
Low	56,76%	[0 – 0,39]

Nevertheless, it became important to compare the effective population densities in the three levels of accessibility with the densities of urban occupation in the municipality. This evaluation was carried out based on the calculation of percentiles of urban occupation densities. This observation shown that both (accessibility and urban) planning practice do not go together, not checking a direct relationship of its integration, especially concerning the average values of the population densities at the maximum and minimum levels of accessibility (the high level of accessibility covers 95 inhabitants/hectare; medium level has 105 inhabitants /hectare and low level comprises 91 inhabitants/hectare) (Table 5).

Table 5. Average percentiles of population densities according to accessibility levels.

Percentis (average)	High accessibility	Medium accessibility	Low accessibility	Oporto Municipality
Population density (Inhabitants/Hectare)	95	105	91	96

According to the assumptions of the PMAC, new reference values for the population densities have been found for the PDM (currently nonexistent) according to levels of accessibility with the purpose of defining the strategic goals of accessibility for the development of urban policies (Table 6). In fact, this stage of PMAC made it possible to find the trend contrary to the current practice of urban planning. The reference values of the population densities showed a favourable contribution to urban development according to the context of urban settlement of the city. Table 5 indicates that for improved accessibility these reference values of densities should increasing about 15% at the high accessibility level and decreasing of approximately 45% at the minimum level of accessibility.

Table 6. Population densities into PDM according to accessibility levels of Oporto.

Accessibility levels	Efective Population density (average)	Population density (reference values)
High	95 Inhabitants/Hectare	**110 Inhabitants/Hectare (minimum reference value)**
Medium	105 Inhabitants/Hectare	**[50 – 110] Inhabitants/Hectare**
Low	91 Inhabitants/Hectare	**50 Inhabitants/Hectare (maximum reference value)**

The selective population densities were adapted through the following urbanistic indicators in order to implement and assess the accessibility improvements in the plan (Phase 3 of PMAC), by using: a) Number of floors; b) Gross Floor Area (GFA); c) Constructive Index (CI), and; d) Waterproofing Areas. The assessment of the indicators resulted in the simulation of two scenarios of PDM. The first scenario was considered without accessibility concerns (designated as Current PDM) and the second was presented has comprising accessibility concerns (designated as Modified PDM).

Through the detailed reading of the plan, the key limit indicator of the increase (or decrease) constructive capacity across land use categories, was the CI. Although this indicator is dependent on the GFA and on the Plot Area, the decision ends up to increase (or decrease) 10% of the constructive capacity for both levels of accessibility (high and low), while maintaining a reasonable (but not excessive) rationality of the statutory coherence of the plan. In addition, the conversion of urbanistic indicators fell

in the Areas of Consolidated Urban Front, Areas of Continuous Consolidation Urban Front, Areas of Single Family Type Housing and Areas of Isolated Construction with Prevalence of Collective Housing[4], although the PDM of Oporto includes nine categories of Urbanized Land Uses[5].

On the one hand, from the changing of CI, it was possible to input positive contributions at the Current PDM, by affording a set of construction indexes composed of minimum values (although the current PDM only defines maximum values)[6]. On the other hand, the number of floor indicator was more difficult of quantifying due to lack of specific building data. As such, the indicator was altered in relation to "add a floor" and "reduce a floor" in the classes of High and Low accessibility, respectively, compared to those defined by the current PDM (being attached only to maximum values per category of land use).

The implementation of the urbanistic indicators was carried out in the simulation of sixteen urban intervention proposals[7] in the city of Porto, mainly based on the development of new building projects[8] (Figure 5), according to the current PDM regulations.

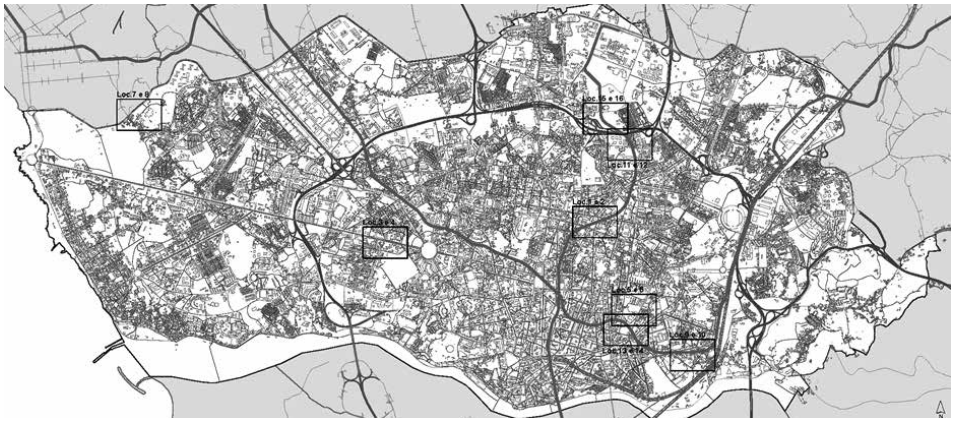

Figure 5. Location of lots in the city of Oporto.

The evaluation of the expected population has resulted from the maximum and minimum values of the population allowed for both accessibility levels, representing the total population of the sample. In general, there was an overall impact of population gains for both levels of accessibility resulting from its improvements in performance indicators (10% for high accessibility and -27% for low accessibility). Although negative percentages were observed at the low level of accessibility, it has revealed an increase of accessibility, insofar as the planning strategy defined for the low level aimed at reducing urban densities in these areas (Table 7).

Table 7. Overall impact of improving accessibility.

Accessibility Levels	Performance Indicators (overall impact)
High	10 %
Low	- 27 %

6 Main findings

Despite the Portuguese planning system does not (currently) establish the concept of accessibility in its planning practice, this paper showed a positive trend in the integration of both urban and accessibility planning by implementing the PMAC. It is believed that PDM should not include every sector of planning within its competence (in fact, there are other non-regulatory plans or programs designated for), however, it is important to consider accessibility in spatial planning at the strategic level taking into account the possibilities and the potential of urban areas through the introduction of accessibility concerns in land use plans. Thus, the PMAC proposes a conceptual framework for the measurement of accessibility based on methodological phases considered important to outline a path towards the introduction of accessibility concerns in PDM. The PMAC intends to point out alternatives of how to "work" the territory, motivated by the implicit planning instrument and by the three accessibility-based concepts.

In general, the results allowed to observe the variation of accessibility based on the effects caused by the improvement of accessibility, based on two scenarios of the PDM. In fact, the impacts revealed that is possible to obtain positive accessibility improvements along different land use policies through PMAC. On the one hand, the use of simple accessibility measures and performance indicators should be clear in operational terms, reflecting the basic needs of the population and the expected travel time thresholds. On the other hand, the accessibility levels and consequent definition of selective urban densities should be able to incorporate accessibility planning goals in the PDM. Based on this planning support tool, the impact of accessibility was the end result attained according to accessibility concerns.

Nevertheless, like any other methodology of diagnosis and evaluation, the implementation of PMAC may have pros and cons. Since the PMAC does not include criteria for assessing the diversity of uses (unlike the Transit-Oriented Development policies, for instance), the exploitation of the relocation of activities was here excluded for measuring the improvement of accessibility. Thereby, densities were studied to determine the extent of the effect at the municipality scale. Effectively, it is not clear that the relocation of activities leads to increase accessibility, as it can also influence mobility planning strategies through the relocation of activities (near the high-capacity roads) leading to increased regional accessibility (rather than local) beyond urban centres.

Effectively, the debate on the relocation of activities under the PDM assumes strategic accessibility conditions relating the proximity of the basic needs of the population at the local scale. Here, the improvement of accessibility was found based on the enhancement of urban densities focused on the PDM regulatory management. Despite this research did not address this question, the debate on the relocation of activities at municipal and inter-municipal level is relevant for improving accessibility and further research is required on these topics.

In short, this research highlights the importance of considering accessibility concerns into land use plans, through the operationalization of significant accessibility-based concepts, for the accomplishment of land use policies based on accessibility conditions given by urban structure.

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Endnotes

1 Proximity to PT stops is one of the six variables of the built environment mentioned by Ewing and Cervero (2010) in reducing of the energy consumption as well as CO2 emissions. These variables are included in the group of "D" elements related to the reduction of travel time to the activities and with the lower consumption of urban space used by car. Although these variables are essentially focused on the concept of Transit Oriented Development (TOD), it is believed that its implementation is an important factor for improving accessibility. The authors

consider as comfortable accessibility distance threshold of 500 meters or 5 minutes walking to a PT stop as travel time threshold.

2 Utilisation Density is based on the principle indicating that the greater the diversity of activities in an urban area, the better the land use (Jaeger and Schwick, 2014). Cervero *et al.* (2011) have also related the diversity of activities and local services linked to pedestrian mode (and delimited by a certain distance), arguing that these conditions reduce considerably the demand for car mobility.

3 However, the accessibility to these activities may be calculated for travel times of more than 20 minutes if it is relevant at intermunicipal level, depending on the urban structure of each city. It should be noted that the high capacity of PT corresponds to bus lines in which frequency is less than 10 minutes (inclusive), seen in this research as high frequency service.

4 The remaining classes were not included in the assessment, due to the fact that they did not provide any reference information on urban indicators thus increasing the complexity of the adaptation of urban indicators and the definition of land use development policies under the PDM.

5 According to the PDM of Porto in force, the categories of urbanized land uses are characterised as Historic Area, Consolidated Urban Area, Consolidated Urban Area, Consolidated Housing Area, Isolated Building Area with Prevalence of Collective Housing, Special Urbanization Area, Business Area, Existing Equipment Area, Proposed Equipment Area and Movement System and Mobility.

6 CI indicator was changed exclusively in the Class of Building Area with Prevalence of Collective Housing, since it is only mentioned in this land use category in the PDM concerned. On the one hand, based on the formula indicated in this paper, and by replacing the population density with the minimum reference value at High level of Accessibility (> 110 Inhabitants/Hectare), the minimum value of 0.45 for CI was found. On the other hand, the maximum CI found was of 1.1, being the result of the increased constructive capacity by 10% over the maximum CI found in the current PDM (CImax <1). At the low level of Accessibility, CI was based on the maximum reference value of the population density (<50 Inhabitants/Hectare), resulting in a second CI (also maximum) of 0.21 compared to the first CI defined by the decrease of 10 % of the constructive capacity (CImax <0.9, whereas the current maximum is 1).

7 Taking into account that the measurement of accessibility performance in PMAC should cover a period of ten years (which is similar to the time period for the treatment of Census statistical data in Portugal), this stage of PMAC comprised a theoretical application since it was not possible to comply with this period of analysis.

8 The location of the lots is characterized by being empty lots or lots with empty buildings or in need of significant renovation works, corresponding to the designation of "new construction" in Oporto's PDM. The selection of lots was random, but had underlying the need to be included in both high and low levels of accessibility as well as in the four classes of land uses, in order to be evaluated.

Acknowledgements

This paper was developed under the PhD research entitled "Accessibility measures in the Portuguese urban planning system" financed by the Portuguese Foundation for Science and for Technology (Project Reference: SFRH/BD/77650/2011).