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EDITED BY LUÍSA BATISTA | MIGUEL LOPES | PAULO PINHO

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Rua Dr. Roberto Frias, 4200-465 Porto

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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 10^{th} 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

Ana Amante, Cecília Silva, Paulo Pinho

CITTA - Research Centre for Territory, Transport and Environment / FEUP - Faculty of Engineering of the University of Porto

ana.amante@fe.up.pt; csilva@fe.up.pt; pcpinho@fe.up.pt

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.

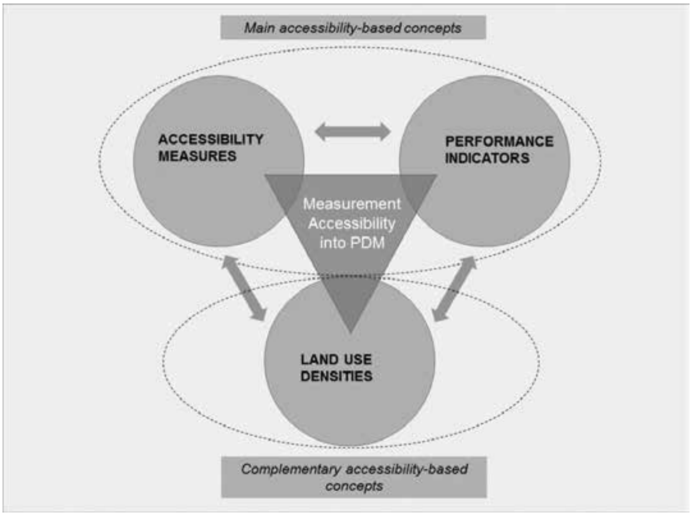

Figure 1. Accessibility-based concepts for measuring accessibility into PDM.

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).

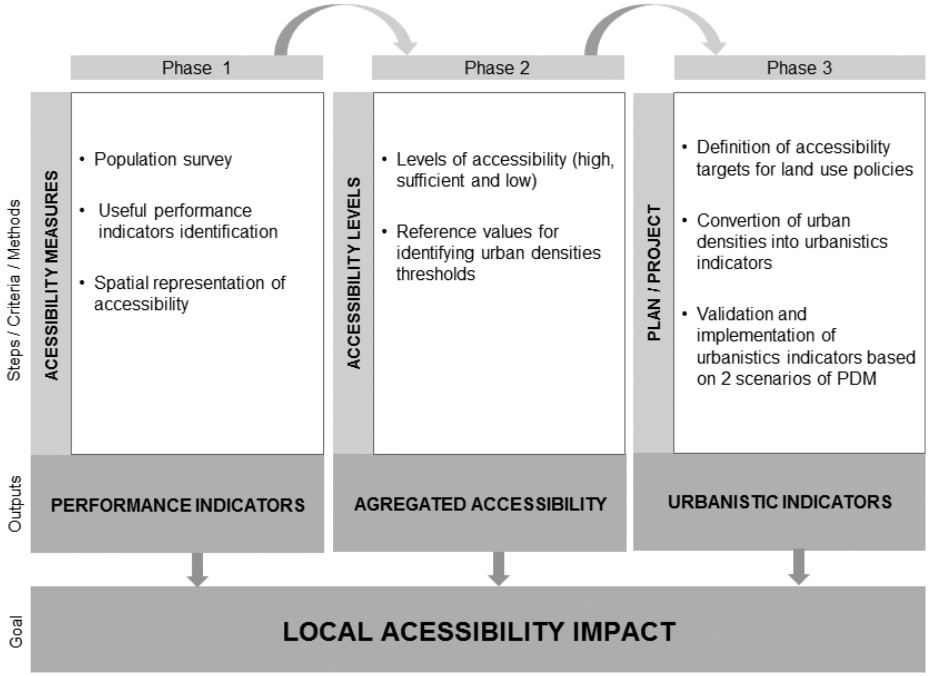

Figure 3. PMAC conceptual framework.

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.

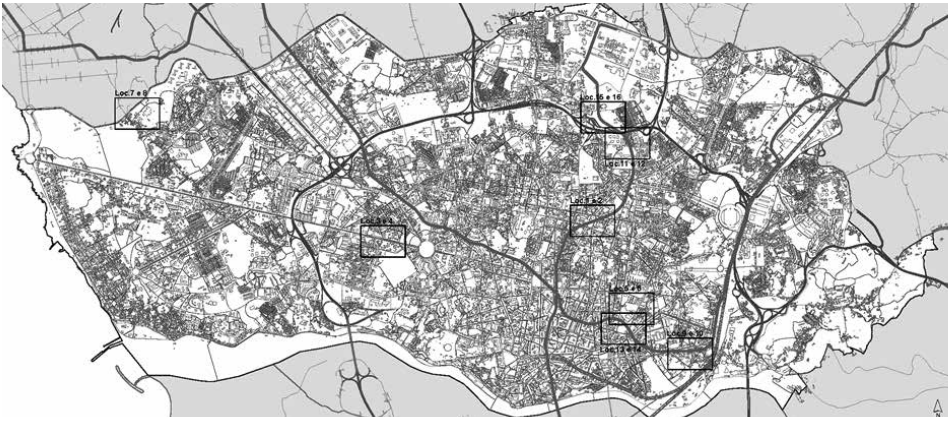

Figure 5. Location of lots in the city of Oporto.

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.

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Evaluation of the environmental sound in the city of Porto

Ana Filipa Silva, Cecília Rocha

DEC - Civil Engineering Department / FEUP - Faculty of Engineering of the University of Porto

ega10054@fe.up.pt; carocha@fe.up.pt

Noise pollution, mainly derived from road traffic, is an increasing threat to the citizens' well-being and public health. Thus, its monitoring and consequent mitigation are crucial. The development of noise maps allows to achieve these goals.
Traditional methods of noise mapping have limitations and measuring equipment is expensive. One solution is the adoption of low-cost technologies. Although they have low reliability, these technologies can be deployed in multiple locations, allowing a high resolution "mapping".
In Porto, one environmental monitoring platform was developed using low-cost sensors: the UrbanSense Platform. This platform is composed by different types of sensors that measure weather conditions, noise and air quality parameters. Each one of these sensors has been installed in areas of influence of major noise and pollution sources as well as in public areas in Porto.
During a period of ten months, the sound information captured by the various noise sensors was analyzed in order to understand which are the main noise sources in the city.
Since these are low-cost sensors, its accuracy isn't as reliable as other certified and calibrated equipment. Thus, to obtain a suitable calibration model for these sensors, were carried out various field measurements using a sound level meter.
The data extracted from UrbanSense Platform were inserted in a geostatistical software, Surfer11, which allowed to obtain a 2D spatial dispersion of noise by the Porto city.
Although the platform had a lack of sound information, it was concluded that the most noise-critical areas are mainly due to road traffic. However, it was not possible to obtain a calibration model.

Keywords: Environmental noise; urbansense platform; low-cost sensors; calibration; noise maps.

1 Introduction

Environmental noise has become one of the most annoying contaminants in modern society directly affecting citizens' quality of life. In cities, there are several noise sources to which the population is exposed, but the most worrying derives from road traffic. In order to minimize the harmful effects of noise exposure and the resultant discomfort, and to preserve the acoustic environment quality, noise mapping is crucial. However, traditional methods of noise mapping have limitations since they are usually confined to a sparse set of locations and, not always with continuous monitoring. Another limitation is associated with some propagation models which extrapolate localized measurements to wider areas that, when the number of measurement points is reduced, may affect the quality of spatial and temporal information (Maisonneuve *et al.,* 2009). One solution to overcome these limitations is the adoption of low-cost technologies – using low-cost sensors – to provide a robust environmental monitoring. These methods tend to produce lower quality data but they can be used in many places allowing a high resolution "mapping" of environmental noise exposure. Thus, the use of this type of sensors provides the granularity, which the traditional method does not reach, reporting which are the noise pollution sources and supporting possible studies on the effects of environmental noise in human health.

The UrbanSense Platform is a monitoring system developed within the European project Future Cities. This project was funded by the FP7 (7th Framework Program for Research and Technological Development) to reverse the negative trend of deterioration in citizens' quality of life by promoting the existence and development of low-cost information and communication technologies, transforming Porto city into a living lab (CCFC, 2012). The UrbanSense Platform is one of the infrastructures created under this project to monitor environmental phenomena using low-cost sensors. It consists of a set of static Data Collecting Units (DCU) in relevant locations in Porto city. Each unit represents a center of sensors that measure atmospheric conditions, noise and parameters related to air quality, installed in areas of influence of large sources of noise and air pollution as well as in public areas of the city. The collected data serves to understand and obtain knowledge of environmental and behavioral phenomena. In this way, they can be used to assess impacts in the city, such as: identifying critical areas and possible damage from urban interventions; for companies, to test their products and models; and, even for research, they can be used in urban planning and transport (traffic and noise measures), in health assessment (relation between asthma and air pollution) and in environment and climate (Calçada, 2015).

From the information gathered during ten months, it was possible to study the noise pollution in several points of the city and to perceive its dynamics during the analysis period. A calibration process of the low-cost sensors was started, through comparing the data extracted from the platform with values obtained from field measurements.

In addition, it was possible to obtain "noise maps" for only two days of the analysis (October 6, 2015 and March 3, 2016), based on the combination of data collected from the platform with geostatistical models, through the software Surfer11.

2 Environmental Noise

Sound is an integral part of our daily life, allowing for interpersonal communication, and it is a sensation caused in the brain due to the uptake by the auditory system of pressure changes that propagate in the air. Too often, in today's society, sound has been the gift of discomfort. Several sounds are unpleasant and undesirable, being called noise (Bruel and Kjaer, 1984). This interpretation implies a judgment of individual value so that the "sound" considered by one individual can be "noise" for another.

The effects caused by noise are classified according to the repercussions they bring to human health. Thus, they can be considered as hearing effects or non-hearing effects. The hearing effects are made visible by hearing loss that can lead to temporary deafness or permanent deafness (partial or total).

Non-auditory effects have repercussions throughout the human body with effects on the physical, mental and emotional levels. Among other effects, noise can result in disturbances in sleep, stress, cardiovascular problems, ringing in the ears and reduction of professional performance, leading to concentration problems and communication difficulties (Carvalho, 2015).

3 State of the Art

3.1 Future Cities Project

Future Cities was a European project led by the Center for Competence for the Cities of the Future of the University of Porto, funded by FP7.

Due to its size, population, infrastructure and a large number of scientists, students, companies and startups, the city of Porto was chosen to be transformed into a "living laboratory", making it possible to experiment on an urban scale and find innovative solutions and develop new products and services. The project was imminently interdisciplinary, bringing together the most varied competences such as ICT (Information and Communication Technologies), psychology, urban planning and civil engineering in order to promote the sharing and active exchange of knowledge and experiences. In addition, it counted with the collaboration of the University of Aveiro and international universities like the Royal Institute of Technology (Stockholm) or the University College London (CCFC, 2012). Within the scope of this project, what is considered as the largest platform of vehicular networks - BusNet - was installed in the city of Porto. It consists in 600 nodes, including more than 400 networked STCP buses which, in addition to providing Wi-Fi for passengers, collect data from the city to reduce energy consumption, environmental impact, and improve road management and public transport.

The SenseMyCity application and the UrbanSense sensor platform were also created. The first is an application to Android smartphones, where the user records their routine with sensors included in their mobile phone and can later upload the data on a web page created for this purpose. By this way, the loaded data can be used for stress analysis of the user and to optimize routes and consumption, as well as to identify people with the same mobility patterns in order to improve car sharing and carpooling systems.

The UrbanSense platform consists of an infrastructure for environmental monitoring in an urban environment, with data communication at a distance, using different sensors that measure atmospheric conditions (temperature, relative humidity, rainfall, wind speed and direction, solar radiation and luminosity), ambient noise and parameters related to air quality (Calçada, 2015; Yunior *et al.*, 2016).

3.2 UrbanSense Platform

The UrbanSense Platform is an urban scale infrastructure for environmental phenomena monitoring using low-cost sensors. By its design and size, it is the only one in the world with these characteristics.

Initially, it consisted of a set of 23 DCU's (Data Collection Unit) located in relevant places in the city. Each unit represents a center of sensors that measure atmospheric conditions – precipitation, solar radiation, wind speed and wind direction - noise and parameters related to air quality – carbon monoxide, ozone, nitrogen dioxide and particulate matter. There are two types of DCUs:

- one contains sensors for noise measuring, air pollution, brightness, temperature and relative humidity;
- and the other type of unit contains the same sensors as the first, adding an anemometer and a sensor for solar radiation.

Figure 1 shows an example of a complete DCU, located in *Rua das Flores*, in which was given a particular aesthetic attention – it was inserted in a flower pot – since this DCU is in a noble area of the city, a world heritage site, in which the equipment is not intended to be very visible.

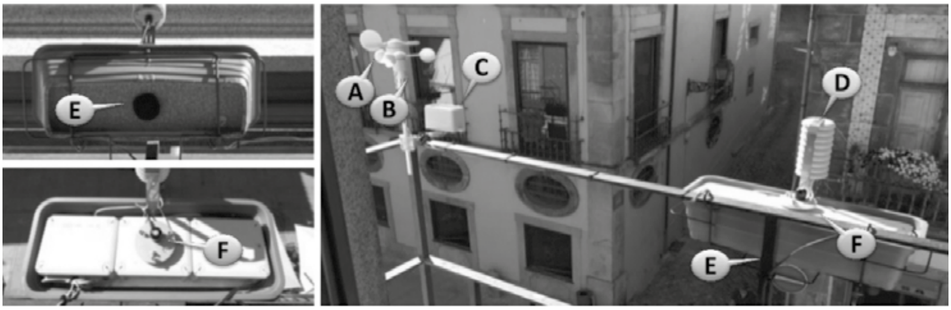

Figure 1. DCU located in a balcony in *Rua das Flores* (adapted from Calçada, 2015). Legend: Sensors for: A – Wind direction; B – Wind speed; C – Pluviometer; D – Temperature and relative humidity; E – Noise; F – Solar radiation.

Each of these units was installed in an area of influence with distinct characteristics in terms of major sources of noise and air pollution as well as public areas, considering the whole city. The selection criteria for the units allocation included streets with high daily road traffic, streets with high road traffic at peak hours, public parks and public areas, squares, pedestrian streets and other streets with different morphologies (width, existence and height of buildings). In Figure 2, the location of these units can be observed.

Two units have been in operation since 2014 (*Rua das Flores* and *Damião de Góis*) while the remaining units went into service from May and September 2015. However, four of the twenty-three units have been removed, two due to damage caused by saltpeter (Rotunda da Cidade de Salvador and Rotunda da Praça Gonçalves Zarco – places near to the beach of Matosinhos) and the others will be moved into most suitable locations. At the moment, the UrbanSense Platform has 19 DCUs.

Figure 2. Location of the UrbanSense Platform DCUs (Light green - noise and air pollution monitoring; Dark green - Noise and air pollution monitoring and weather station; Red - Units to be transferred to other location) obtained from *https: //www.google.com/maps/d/viewer?mid=1AJwFMMi-WZqs44NA7pO_M8OOT-g*

In terms of noise monitoring, the units are, on average, at 3,5 m above ground, except for the existing unit at *Rua das Flores*, which is located on a 8 m high balcony. For these sensors, the information is collected at a frequency of one second while for the other sensors the information collection frequency is one minute (Yunior *et al.*, 2016).

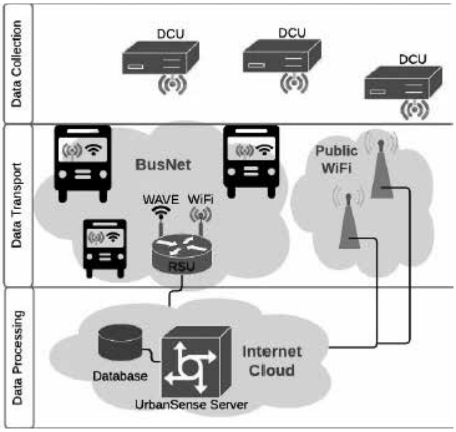

Figure 3. General architecture of the UrbanSense Platform (Yunior *et al.*, 2016).

The UrbanSense Platform is composed of three components: DCUs, a back office for data storage and a communications backbone that collects data from all DCUs to the back office. A global structure of the platform is shown in Figure 3. The transmission of the data collected by the units to the back-office server is made in one of three ways of networks: vehicular delay tolerant network (DTN), as shown in Figure 4, Wi-Fi – both considered low-cost communications – or 3G.

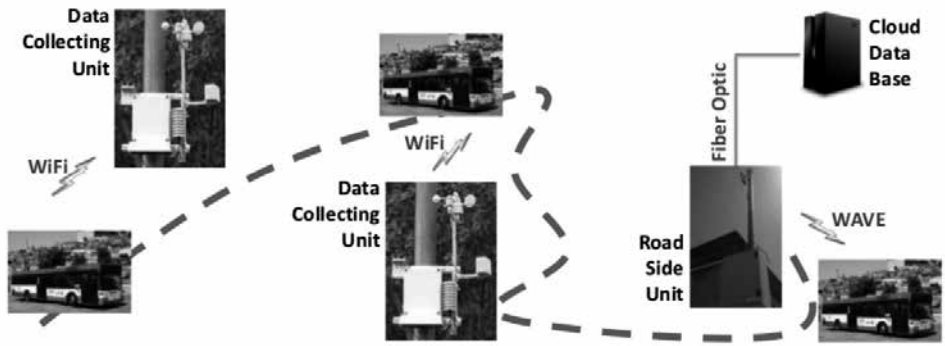

Figure 4. Data communication through vehicular network (Calçada, 2015).

A study conducted in the city of Porto (Yunior *et al.*, 2016) analyzed the ratio of the activity time of each sensor, i.e., analyzed the ratio between the time period in which the sensors provided the collected information and the overall period under analysis, which would correspond - in an expedited way - in the ratio between the amount of data actually collected and the expected amount of data that should have been collected during the test period (6 months). The results obtained in this study reveal that there were 3 significant interruptions of the sensors activity (in terms of duration) caused by damage to the boards and SD cards of DCUs and power failures, as well as other types of incidents. In general, the total operating time of the sensors was about 54%.

The results obtained in the study are shown in Figure 5. In this figure, the ratio of the uptime for each type of sensor is shown in which the horizontal black line represents the operating median, by type of sensor, and the gray bars represent the respective variability of the data obtained, considering the universe of the nineteen sensors that are part of this monitoring network (Yunior *et al.*, 2016).

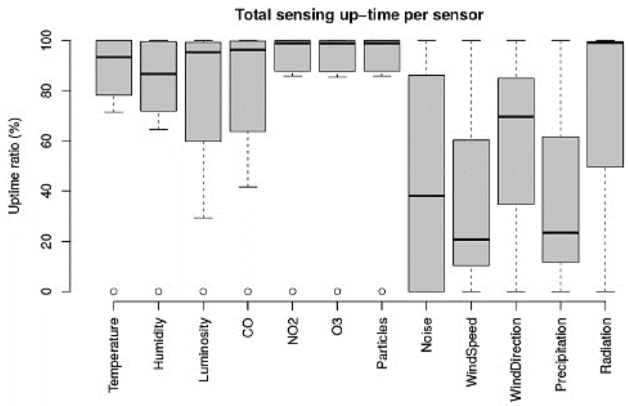

Figure 5. Time-of-activity ratio for the different DCUs constituent sensors (Yunior *et al.*, 2016).

In the case of the noise sensors, the ratio reached was 40%, which shows that there are still significant communication failures in data collection. There are sensors that have never worked (in the case of the *Estádio do Dragão* and the *Cândido dos Reis* sensors) and they are represented by "0". However, there are sensors that have high operating percentages, such as the existing sensor in *Bolhão* (80%). The elongated shape of the gray bar corresponding to the noise sensors, shown in Figure 11, encompasses all existing noise sensors, including those that were not in operation. In addition, the periods of inactivity of the platform are included, which translates into the reduced median presented (40%).

This type of sensor, as well as others that share low operating rates, have the characteristic of being connected to the processor (Raspberry Pi) while the other sensors with better performance (air pollution, temperature, relative humidity and luminosity) are directly incorporated in the processor (Yunior *et al.*, 2016).

The calibration of the platform sensors is performed using a set of high-quality sensors to create calibration models based on linear and non-linear regressions. These are more accurate and therefore more expensive. However, this strategy is not so favorable because the entire procedure has to be repeated for all locations where DCUs are placed and for each time a sensor is installed or replaced. Thus, two reference DCUs for atmospheric pollution sensors calibrated with the high-quality sensors were created. Therefore, for calibration of DCUs in the field, a reference is transported to the proximity of the first to provide comparison values (Yunior *et al.*, 2016).

3.3 Related work

Like the Future Cities Project, there are other organizations/companies around the world that have been developing platforms similar to UrbanSense.

The CITI-SENSE project, also funded by FP7, is distributed in nine cities: Barcelona and Vitoria (Spain), Belgrade (Serbia), Edinburgh (United Kingdom), Haifa (Israel), Ljubljana (Slovenia), Oslo (Norway), Vienna (Austria) and Ostrava (Czech Republic).

The goal of this project is to provide citizens with tools (smartphone applications, widgets, online questionnaires) to "feel" their environment, also serving as a forum for discussion and sharing of ideas. The data is collected through different sensor platforms that monitor air quality and acoustic comfort (CITI-SENSE, 2012).

Under the MESSAGE (Mobile Environmental Sensing System Across Grid Environments) project, the University of Newcastle has developed a set of 50 innovative low-cost sensors that measure noise, carbon monoxide, nitrogen dioxide, temperature, relative humidity and car traffic. These sensors are designed to operate at no cost, with low power and autonomously so they can be implemented in a scattered manner. The use of wireless communications allows the linking of information from sensor to sensor to an end server.

Each sensor provides, in real time, with minute-by-minute measurements, noise data, namely the parameter L_{Aeq} in dB. In addition, validation and the concept of using a sensor array to measure noise in a granular way in urban areas is demonstrated through separate deployments in Leicester (UK) and Palermo (Italy). From the two applications, the results clearly show the potential of these sensors to measure noise levels, improving the understanding of the effect of traffic flow and its characteristics on the different analyzed streets.

The results present a measurement system and a prediction method that offers the potential to explore the most appropriate noise parameters that correlated the human response with traffic noise (Margaret and Fabio, 2012).

The Urban Civics platform presents a program that collects and aggregates data from various urban sources for the understanding of sound phenomena. Thus, it combines data from various urban sensors and participatory sensing, from applications, with data assimilation techniques to generate, collect and process the large amount of data involved (Hachem *et al.*, 2015).

4 Noise in the city of Porto

4.1 Introduction

Of the 23 DCUs of the UrbanSense Platform, only those that contained a noise sensor, a total of 18 units, were analyzed. These units covered areas classified as residential, tourist, traffic, university and parks as described in Table 1.

Table 1. Identification of the DCUs with noise sensor included.

DCUs name	Name code	Type of area
Avenida de França	AF	Traffic and touristic
Bolhão	BO	Traffic
Campo 24 de Agosto	24	Traffic, residential, touristic
Campo Alegre	CA	Traffic, university
Cândido dos Reis	CR	Traffic, touristic
Casa da Música	CM	Traffic, touristic
Combatentes	CO	Traffic, residential
D. Manuel II	DM	Parks, touristic
Damião de Góis	DG	Traffic
Estádio do Dragão	ED	Traffic, touristic
Fundação de Serralves	FS	Residential, parks
Hospital de São João	HSJ	Traffic, university
Praça das Cardosas	PC	Traffic, touristic
Praça da Galiza	PG	Traffic, residential
Praça do Marquês	PM	Traffic, residential, parks
Praça Velasquez	PV	Traffic, residential, parks
Rua das Flores	RF	Touristic
Trindade	TR	Traffic

The data extracted from the platform refers to the months of October, November and December, 2015 and to the months of January, February, March, April, May, June and August, 2016, totalizing a ten-month analysis. Each noise sensor picks up ambient noise values, in fast mode and with weighting curve A, every second.

In order to obtain a concise and easy-to-understand analysis, the following methodology was developed for each month and for each sensor:

- Calculation of the hourly arithmetic average for each day of the ten months of analysis in order to observe the daily and monthly sound behavior;
- Calculation of the hourly arithmetic average of the different days of the week in order to discover the oscillation on the noise in the week days and weekends;
- Calculation of the equivalent continuous sound level, in dB (L_{Aeq}), for each day of the week, monthly and daily, through arithmetic averages;
- Calculation of the day-evening-night equivalent level (L_{den}) noise indicator (logarithmic average) and its constituents, L_{day}, $L_{evening}$ and L_{night}, from the arithmetic mean of the respective hours.

4.2 Results

After each monthly data download, it was observed that not all noise sensors contained all the information, and there were sensors that had not collected any data since the beginning of the data collection. Table 2 shows the monthly percentages of data in each sensor, based on the number of hours per month, as well as the percentage of total data in each month.

Table 2. Monthly percentages of data obtained for the different DCUs, referring to the ambient noise sensor.

	2015			2016						
	October	November	December	January	February	March	April	May	June	August
hours per month	744	720	744	744	696	744	720	744	720	744
AF	98	56,1	0,0	0,0	0,0	43,7	0,0	1,1	0,0	0,3
BO	18,5	0,0	0,0	0,0	0,0	94,4	7,8	4,3	28,2	25,4
24	0,3	0,0	0,0	0,1	0,0	0,3	0,6	0,1	0,1	0,0
CA	0,0	0,0	0,0	0,0	0,0	74,9	7,6	44,9	1,5	2,6
CR	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CM	24,9	0,0	0,0	0,1	1,9	51,6	0,0	0,0	4,9	5,5
CO	22,3	0,0	0,0	1,5	0,0	86,8	0,0	0,0	0,0	9,8
DM	95,6	20,6	0,0	0,0	0,0	76,2	0,0	0,0	0,0	3,5
DG	63,3	0,0	0,0	0,0	0,0	10,9	1,8	0,4	18,5	0,0
ED	48,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0
FS	100	100	100	94,1	78	90,9	89,6	99,9	54,4	8,1

	2015			2016						
	October	November	December	January	February	March	April	May	June	August
HSJ	10,6	0,0	0,0	0,0	0,0	85,3	11,4	30,1	38,3	32,1
PC	28,9	0,0	0,0	0,4	0,0	75,5	0,3	5,4	1,8	3,4
PG	0,0	0,0	0,0	0,1	1,3	1,7	0,0	40,3	4,9	1,1
PM	100	100	39,9	0,0	0,1	87,2	2,4	0,0	0,0	0,0
PV	56,3	0,0	0,0	0,0	0,0	9,4	1,8	3,2	0,7	0,0
RF	55,6	0,0	0,0	0,9	0,0	0,0	0,0	0,3	4,4	1,6
TR	0,0	0,0	0,0	0,0	0,0	87,9	91,9	97,4	24,4	1,7
% data per month	42,5	16,3	8,2	5,7	4,8	51,6	12,7	19,3	10,7	5,6

Observing Table 2, it is noted that there was a great data failure at the end of last year, due to a malfunction of the sensor support computer platform, leading to the highest percentage of data being reached in March, 50%, and to the existing sensor in *Cândido dos Reis* not collecting any data for the entire period of analysis. This lack of data is mainly explained by electronic problems (sensor SD card degradation, power failures, damaged sensor boards) (Yunior *et al.*, 2016).

An individual analysis was performed for each month and for each sensor, applying a color scale dependent on the observed minimum value (the green color), the 50th percentile value obtained (yellow) and the maximum value reached in the month (in red). In this way, it was possible to observe, for the ten-month analysis, the different dynamics existing in the city of Porto. These dynamics are associated to the characteristics of the different zones where the different sensors are located.

The surrounding area of the Serralves Foundation is characterized by the existence of residences and parks, with only one source of main road noise being the Avenida *Marechal Gomes da Costa*. However, the existing sensor in the area is located at the top of the Serralves Museum, reason why it is protected of the activity road and capturing only activities developed in the interior of the Serralves Park in particular when occur high levels of noise as in the case of musical events in the Serralves Gardens.

There are also areas with very characteristic noise dynamics, presenting noise patterns due to traffic at peak hours (*Praça do Marquês, D. Manuel II, Casa da Música, Damião de Góis* and *Avenida de França*) or having a more constant noise pattern (*Rua das Flores, Bolhão* and *Trindade*).

In the area of *Praça do Marquês* there are several basic and secondary schools, which leads to an increase of private or collective vehicles destined to transport students (which also generate noise!). In addition, there are cafes and mini-markets around the square, and even in the square, and the presence of passers-by strolling, socializing and even playing cards is constant. In this way, it can be said that the dynamics of this zone begins very early, in the morning, ending at the beginning of the night. The dynamic that exists in *Praça do Marquês* is repeated in the surrounding areas of the *Rotunda da Boavista* (sensors in *Casa da Música* and *Avenida de França*), adding that there are more tourists in this area due to *Casa da Música* being a famous attraction. The case of the surrounding sensor area on *Rua D. Manuel II* is identical to that of the *Rotunda da Boavista* but due to the influence of the *Palácio de Cristal*, where several cultural activities are developed, namely concerts, involving the emission of very high sound levels, in addition to the presence of numerous people and vehicles.

The surrounding area of *Rua das Flores*, *Bolhão* and *Trindade* have a constant noise pattern but due to different reasons. *Rua das Flores* is a pedestrian area in which there are several businesses of more tourist and social nature like coffee shops, souvenir shops, restaurants, etc. In addition, the presence of street artists is almost always constant, except on rainy days. Frequented also by many tourists this street does not "sleep". In addition to all the hustle and bustle during the day, the "night" also exists in *Rua das Flores*, where students and passers-by take a walk. It should be noted that in June, due to the festivities of São João, this small street can host thousands of people. With regard to the *Bolhão* and *Trindade* areas, the existence of the *Bolhão* market, as well as cafés and shops present in these areas, means that the dynamics of these zones begin in the morning, with the opening of the different businesses, ending at around 8 p.m. In addition, these zones are classified as traffic zones and, in addition, the surrounding streets are covered with cubic pavements, which means that noise levels are higher.

Additionally, in *Trindade* is located the city's main metro station that connects all lines, and also the presence of two car parks, making it one of the main entry and exit points of the city.

5 Initial Validation Procedure

5.1 Introduction

In order to test the reliability of the data collected by the different low-cost noise sensors and to try to validate the results that come from the various sensors spread throughout the city, the data extracted from the low-cost sensors were compared with the values obtained from a precision sound level meter (calibrated and certified device).

In the following points the procedure adopted and the respective equipment will be described.

5.2 Technical description of the equipment

5.2.1 Low-cost Equipment

The acquired low-cost sound equipment corresponds to a SL-814 digital sound level meter (EBay, 2016) and is shown in Figure 6.

Figure 6. Low-cost sound equipment acquired (extracted from EBay, 2016).

According to the available documents, this equipment has, among others, the following specifications:

- Range of measurement: 40 to 130 dB;
- Accuracy: ± 2 dB (under reference condition);
- Weighting filters: A and C;
- Sampling rate: 2 times/second;
- Dynamic feature: FAST (high speed) or SLOW (low speed);
- Work environment:
  - – Temperature: 0 to 40 °C;
  - – Humidity: 10 to 70 % RH;
- Storage environment:
  - – Temperature: 10 to 50 °C;
  - – Humidity: 10 to 80 % RH;
- Power supply: 9-volt alkaline battery.

In terms of actual operating conditions, these devices were deconstructed and their main parts, such as the microphone, preamplifier and control and information collection system, were coupled to the different DCUs, by connection to the Raspberry Pi processor, to form the noise sensor, ensuring not only the power supply (not batteries), but also the possibility of giving instructions to the equipment remotely, as well as the communication of data at a distance, as explained above.

Regarding the operating conditions, the noise sensors are performing the measurements with weighting curve A, in Fast mode and with ambient noise data collection every second.

5.2.2 Precision Equipment

The sound level meter used belongs to the model and brand Brüel and Kjaer 2260 Investigator, shown in Figure 7.

Figure 7. B & K sound level meter used for field measurements.

5.3 Description of the validation process

Before performing the initial process of validation the results collected from the sensors, the following points were defined:

- Which noise sensors to undergo the validation process;
- What parameters to compare;
- What is the time period of each measurement;
- How many measurements to take.

In this way, the following aspects were established:

- Noise sensors undergoing the calibration process:
  – If it is possible, all nineteen sensors used in Chapter 4;
- Parameters to compare:
  – L_{Aeq}
  – L_{Amax}
  – L_{Amin} and
  – Percentiles L_1, L_5, L_{50}, L_{90} and L_{95};
- Time period of each measurement
  – 1 minute;
- Number of measurements to be performed
  – 15 (equivalent to a validation measurement period of 15 minute).

For each sensor location, two tripods were mounted, one to hold the sound level meter and the second to raise the “microphone” at the noise sensor level, except for the existing sensor in *Rua das Flores*, located at 8 meters high on a balcony.

5.4 Results

After collecting the sound information from the sound level meter and the low-cost sensors, it was verified that only the existing sensors in *Bolhão, Praça da Galiza* and *Trindade* captured data related to the measurement times performed by the sound level meter, evidencing, once again, the scarcity of sound information.

Referring to the low-cost sensor in *Bolhão*, it was observed that this sensor recorded values higher than the sound level meter during the measurement period, overvaluing the real noise value in 2 dB(A). Instead, the sensors in *Praça da Galiza* and *Trindade*, captured dB(A) values lower than the ones captures by the sound level meter, presenting a difference of values, on average of 3 dB(A).

A second data collection campaign was then launched.

Before this campaign was carried out, it was sought to know which sensors were actually collecting data and which would then be target of this new monitoring campaign. In this new campaign it was defined that 30 measurements, of 1 minute each, would be recorded instead of the 15 minutes defined in the first collection phase, in order to obtain more records for a possible calibration model. However, after the measurements were taken with the sound level meter, it was verified that no low-cost sensor was in operation at the time of the sound measurements, once again making it impossible to validate the sensor data. It was discovered that they were only measuring between 5 and 6 o'clock in the morning due to a programming error, only detected by the transmission of our information, which had been entered into the system when it was last updated on July 19.

It was a problem that has been solved, but not in time to include this information in the results.

6 The "Wake up" and the "Fall Asleep" in the city of Porto

6.1 Introduction

In this chapter, we intend to give a different use to the results collected by the sensor units. Considering the information gathered in several parts of the city, in an attempt to understand the daily evolution of noise in two particular moments: Autumn of 2015 and Spring of 2016. For these moments, "two-dimensional maps" of the city were created that represented the evolution of the hour-by-hour noise in function of the data provided by the sensors without interference of the topography and the edification: "maps" were created that try to illustrate "the Wake up and the Fall Asleep in the City of Porto" whose process is described in the following points.

6.2 Technical description

In order to obtain the "2D noise maps" from the values coming from the analyzed noise sensors, it was necessary, at first, analyze which months and days were common to all. In Table 2, a great lack of information on the part of the different noise sensors is evidenced. In fact, the months that had more information correspond to October 2015, with 12 sensors in operation, and March 2016, with 13 functional sensors.

The next step was to determine the common day in October and March for the different sensors in operation. It was found that the few data captured by the sensor in *Campo 24 de Agosto*, common to the two months, would had to be discarded due to the incoherence of their values. Thus, 11 sensors were used in October and 12 in March. Next, it was determined which day of the months October and March, common to the 11 and 12 sensors, respectively, concluding that it would be 6 October 2015 (Tuesday) and 3 March 2016 (Thursday) – see Table 3.

Table 3. Noise sensors used in the Surfer11 software.

6 October 2015	3 March 2016
Avenida de França	*Avenida de França*
Bolhão	*Bolhão*
Casa da Música	*Campo Alegre*
Combatentes	*Casa da Música*
D. Manuel II	*Combatentes*
Damião de Góis	*D. Manuel II*
Fundação de Serralves	*Damião de Góis*
Praça das Cardosas	*Fundação de Serralves*
Praça do Marquês	*Hospital São João*
Praça Velasquez	*Praça do Marquês*
Rua das Flores	*Praça Velasquez*
	Trindade

However, it was found that there was not a complete day in common for the noise sensors evaluated on the two days in question. The missing values have been replaced by the hourly average values for the day of the week in question - Monday to October 6 and Thursday to March 3 - or by hourly average values for each month. In this way, the data were obtained for 24 hours and, consequently, for the 4 indicators of discomfort for the two days in question.

The Surfer 11 program then analyzed the spatial distribution of the sound pressure levels: the values obtained for each hour and the discomfort indicator were inserted, as well as the geographical coordinates (latitude and longitude) of each sensor used for each day.

The various contour maps were then generated by the kriging method, also including an image of the georeferenced area of the City of Porto, adjusted to the limits defined in the program.

The color scale used corresponds to that indicated by the APA (APA, 2011). However, on the same scale, the colors for the L_n and L_{den} indicators are added together.

6.3 Results

6.3.1 Preliminary analysis

The "2D noise maps" generated from the sensors fit their location area, which can be seen in Figure 8.

a) b)

Figure 8. a) Base map of the municipality of Porto used for the generation of "2D noise maps"; b) Geographic location of the different noise sensors used, extracted from *https://www.google.com/maps/d/viewer?mid=1AJwFMMi-WZqs44NA7pO_M8OOT-g*.

The different "2D noise maps" created for the 24 hours of the two days of analysis were created in the area of influence of the sensors selected for this simulation.

In an initial analysis, there are some aspects that can be noticed:

- Maps for March – Spring – generally show higher sound level values than those occurring in October (Autumn);
- On the night of October 5 to 6, there was an event in the *Boavista* area that resulted in changes in the sound level at the nearest monitoring stations;
- Still in October, the less touristy areas of Porto and more related to commerce and services (upper part of *Rua de Sá da Bandeira, Rua Fernandes Tomás, Rua de Santa Catarina, Rua do Bolhão*) show that there were lower sound levels in the nocturnal period;
- The *Boavista - Palácio de Cristal – Hospital de Santo António* and *Baixa do Porto* axis show higher sound levels;
- In March, the presence of the monitoring point relative to the São João Hospital revealed that it has a significant influence on the sound panorama of the city;

- As expected, the *Serralves* area is highlighted as the least noisy of all sites monitoring.

Figure 9 represents the “2D noise maps” for the different indicators (L_{day}, $L_{evening}$, L_{night} and L_{den}) for both days in the area of influence of the sensors considered.

6 October 2015	3 March 2016

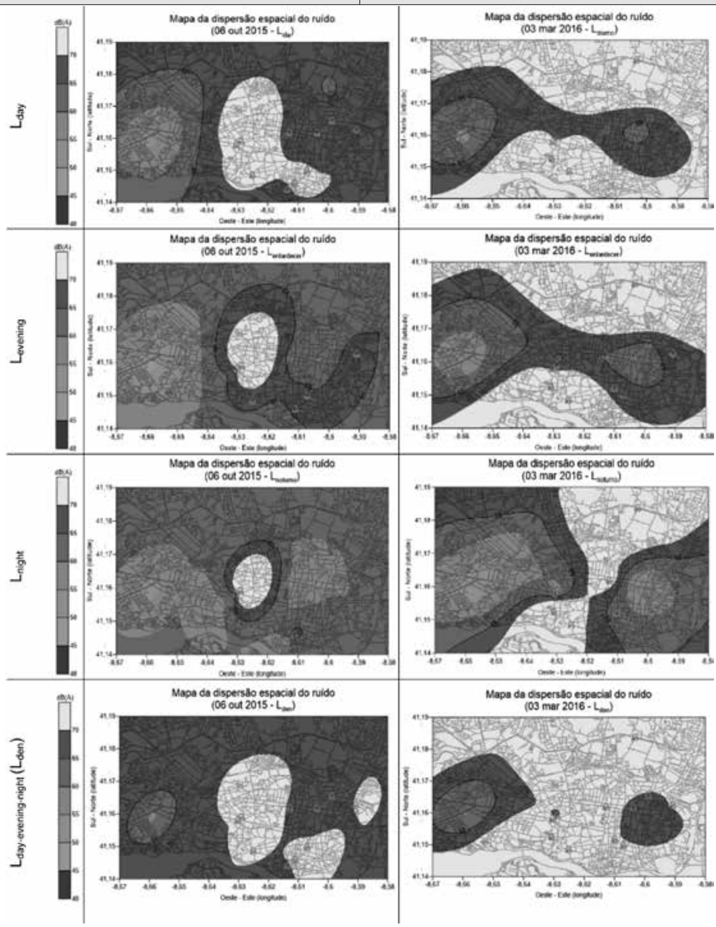

Figure 9. “2D noise maps” obtained for the different indicators (L_d, L_e, L_n and L_{den}) for the days 6 October 2015 and 3 March 2016, respectively.

However, the analysis of Figure 9 shows that it is not possible to directly compare the two “2D maps” obtained by interpolation, since the number and location of sensors is not exactly replicable. The “missing” sensors (*Hospital de São João, Campo Alegre* and *Trindade*) are all associated with traffic situations and, as such, greatly influence the final results.

In particular, the sensor in the *São João* Hospital is undoubtedly fundamental for analyzing the sound pressure levels present in *Estrada da Circunvalação*, the busiest in the area of *São João* Hospital and one of the most important arterial roads in Porto.

Thus, new contour maps were created using only the nine noise sensors common in the two days under analysis: *Avenida de França, Bolhão, Casa da Música, Combatentes, D. Manuel II, Damião de Góis, Fundação de Serralves, Praça do Marquês* and *Praça Velasquez*, whose representation is shown in Figure 10, for the indicators of daytime, evening, night and 24h noise.

6 October 2015	3 March 2016

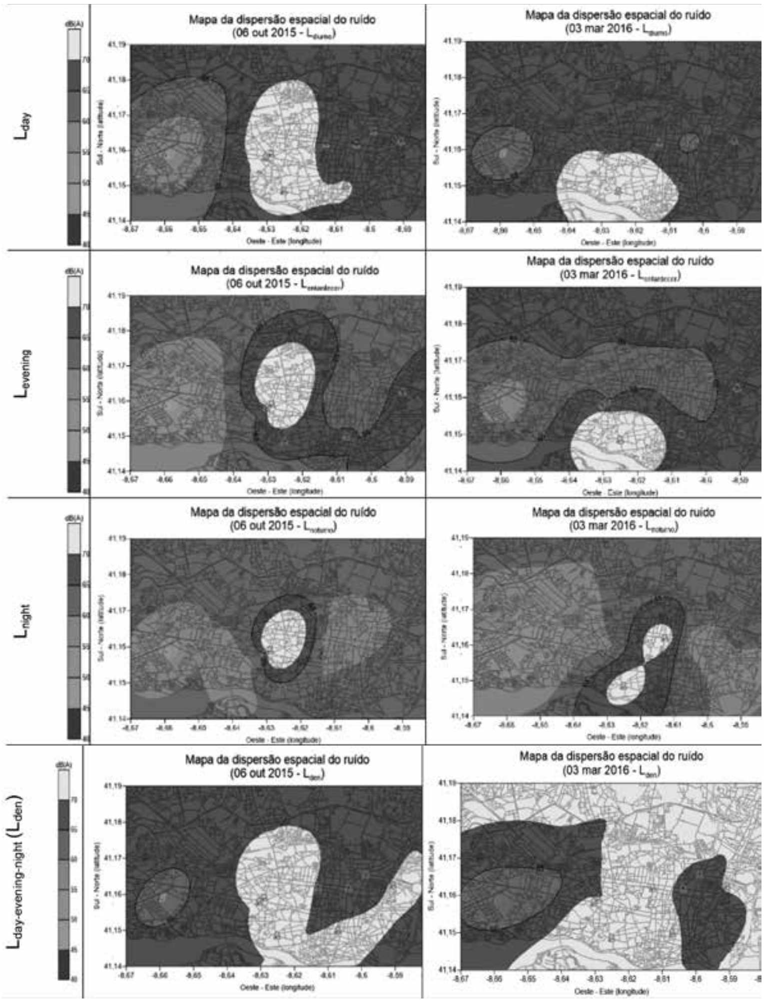

Figure 10. "2D noise maps" obtained for the different indicators (L_d, L_e, L_n and L_{den}) for the days October 6, 2015 and March 3, 2016, respectively, only with sensors common to both days.

Analyzing Figure 10, the difference between the various noise indicators that effectively translate a dynamic in the city of Porto is evident. The daytime noise indicator is the most prominent, showing the great activity that exists in the city between 7 am and 8 pm and its great impact has an impact on the value of the L_{den} noise indicator. It should be noted that, for any of the indicators, the zone surrounding the *Serralves* Foundation sensor is the one that presents lower ambient noise values than in other city areas (on the left of figure 10 with the lightest shade).

It can also be observed the existence of different areas of greater affluence, for the two days of analysis. While on October 6, the area with the highest noise level is located in the center of the municipality (area of the *Rotunda da Boavista*, associated with the magenta color), on March 3 this area is further south, in the surrounding area to the existing sensor in *Rua D. Manuel II* (next to the *Jardins do Palácio de Cristal*).

6.3.2 Porto Noise Map vs generated "2D noise maps"

It should be noted that the maps created from the results of the sensor points do not replace, nor have any pretension to replace, the noise maps elaborated by the Porto City Council, are merely illustrative, do not take into account any kind of attenuation (buildings, barriers, etc.) and are two-dimensional. However, they provide an overview of more critical areas and their area of influence, taking into account the location of DCUs.

In Figure 11 and Figure 12, the noise maps of the city of Porto, corresponding to the L_{den} and Ln indicators, respectively, are represented. The comparison between these two figures and figure 10 (noise indicators) shows that the noisiest areas of the year 2014 continued to persist in the years 2015 and 2016. The most critical areas are: VCI, *Ponte do Freixo, Estrada da Circunvalação*, which represent the areas with the greatest traffic problems.

For October 6, 2015, it is verified that the existing sensor in the *Serralves* Foundation presents an approximate value to the present in the Porto noise map (range: 55 - 60 dB (A)).

Figure 11. Adapted from the Noise Map of the city of Oporto, dated 07/31/2014, related to the Lden indicator (CMPorto, 2014)

Figure 12. Adapted from the Noise Map of the city of Oporto, dated 07/31/2014, related to the Lnight indicator (CMPorto, 2014).

For the L_n indicator, instead of the 2014 map, both test days have indicator values greater than 45 dB (A). The most critical areas highlighted in the 2014 map are maintained throughout the years 2015 and 2016, as is the case for the L_{den} indicator.

6.3.3 Porto city conditioning plan

Figure 13 shows the conditioning plant of the city of Oporto, dated 2012, with the indication of the sensitive and mixed zones, among other parameters, existing in the city.

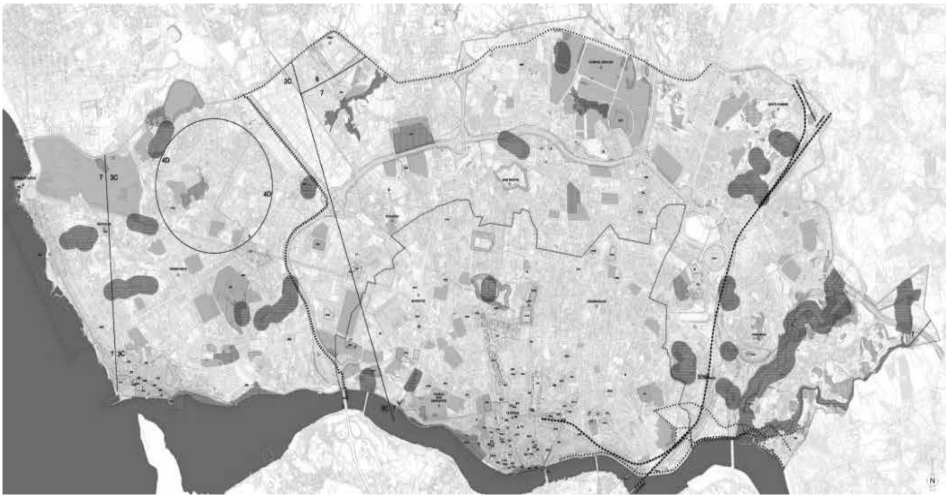

Figure 13. Plant conditioning of the city of Oporto, dated 2012, where the acoustic classification of the municipality is highlighted (CMPorto, 2012).

From the analysis of figure 12 (L_n indicator) and Figure 13, it can be affirmed that in the sensitive zones, for both days of analysis, only the expected value of 45 dB (A) is fulfilled in the *Serralves* Foundation area. In the area of the *São João* Hospital, the limit value is intensely exceeded. For mixed zones, on October 6, 2015, it is possible to verify that the value of the indicator L_n is only fulfilled in the surrounding areas of

Praça do Marquês, Av. dos Combatentes and *Campo Alegre*. On March 3, it is only verified the compliance with the limit value for the area of *Praça do Marquês* and *Campanhã*.

Analyzing figure 11 (L_{den} indicator) and figure 13, it can be stated that, for sensitive areas, the values for March 3 are totally above the legislated. As of October 6th, only a small area surrounding the *Serralves* Foundation meets the limit value of 55 dB (A). For areas classified as mixed, on October 6, the value of 65 dB (A) for the surrounding areas of the *Rotunda da Boavista, D. Manuel II, Trindade* and *Praça Velasquez* is not met. On March 3, only the southwest part of the city and the surrounding areas of the *Praça do Marquês* and *Combatentes* obey the value of the L_{den} indicator.

7 Conclusions

Environmental noise is undoubtedly one of the public health problems that need to be addressed and which is currently taking on a global dimension. The fact that there is a very significant proportion, about 80% of the European population, living in urban areas creates conditions for these people to be exposed to noise levels higher than those recommended by the World Health Organization and the European Union itself.

In this way, the minimization of ambient noise is fundamental to improve the quality of urban life, and in particular of the citizens - both of the inhabitants who live and work there and of the tourists who visit and enjoy it.

So far, in accordance with the European directive on ambient noise (Parliament and European Council, 2002), noise assessment in agglomerations and exposure of inhabitants has been carried out using estimates and noise maps which, although calibrated with measurements, do not represent the 'photographs' of a given moment - in terms of ambient noise - in which the sources of noise originating in traffic, in economic and industrial activities prevail.

These 'more traditional' methods of developing noise maps in cities, whose main weakness is their inertia and the fact that they do not address all sources of noise, shows the advantages of implementing widespread monitoring and, in particular, the implementation of low-cost sensors.

The main advantage of this last method lies in the possibility of being applied in a large scale and of allowing the characterization of the urban environment noise in multiple points, allowing to know in greater detail the particulars of a city and its way of living.

The existence of the UrbanSense platform, framed in the European Future Cities project and unique worldwide, both by the technology used and by its territorial extension, is an added value for the city of Porto, which constitutes a living lab, making possible monitoring the level of ambient noise, various air pollutants and the urban climate.

The analysis performed for the data corresponding to the last 10 months regarding the information coming from the integrated noise sensors of the platform showed that, in fact, there is a dynamic in the city of Porto, different from point to point. Incidentally, as would be expected for any local inhabitant who knows the pace of operation of the city. This situation can be verified not only by the analysis of the numerical data but also by using "geostatistical maps" generated from the Surfer program11 and by the analysis of the noise map of the city of Porto in 2014.

It has been found that noise-critical areas, essentially linked to road traffic, continue to persist.

However, the great news that comes from the analysis of this information is related to the fact that there are places 'without traditional sources of noise' whose environmental noise level is high: pedestrian areas. Due to the great influx of tourists and the aptness of the places for the enjoyment of the new leisure areas, the new pedestrian areas have been registering high levels of noise that are essentially the result of social activities and related economic activities, practically without interference from the noise sources such as road traffic.

The attempt to validate the data that is being collected and the definition of an automatic calibration model for the low-cost sensors of the city of Porto were not achieved due to the lack of data. However, with future optimization of the urban sensor networks, this will be attainable.

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Built Heritage Assessment and urban rehabilitation flexible criteria

Cilísia Ornelas

CITTA - Research Centre for Territory, Transport and Environment / CONSTRUCT - Institute of R&D in Structures and Construction / FEUP - Faculty of Engineering of the University of Porto

cilisia@fe.up.pt

Nowadays, the assessment of built heritage is an important issue in Portugal and throughout Europe, especially due to the aging and degradation of housing stock in diverse urban areas. On the other hand, the discussion of the inadequacy of current regulations to the characteristics of the existing housing stock is pertinent, and is involved with the debate on energy and social vulnerability.

This paper points out the need to apply an assessment methodology with patrimonial, technical and social standards to different urban contexts, in order to discuss the application of flexible and differentiated criteria in the urban rehabilitation procedures. The assessment methodology criteria is the result of a vast study, and arises from a comprehensive analysis of building codes and standards that support interventions on built heritage of three Southern European countries with similar cultural approaches: Italy, Spain and Portugal. These general assessment criteria are also the result of technical experts' opinion and inputs at national, regional and municipal levels over urban and building code legislation.

This assessment methodology promotes the debate on the concept of habitability, discusses the existing normative criteria and implements flexibility through an integrating social and environmental response. This discussion recognizes the importance of incorporating flexible criteria on code application, but also that such criteria should be sustained by inventorying and cataloguing processes based on multidisciplinary assessment methodologies.

Moreover, this analysis seeks to achieve the goals of the European Urban Agenda, and improve the quality of life of its residents. These results offer new inputs for the definition and optimization of intervention procedures on built heritage at national, regional and municipal levels, which could be adjusted to the climate change and multilevel governance.

Keywords: Built heritage; housing stock; assessment methodology; building codes; flexible criteria.

1 Introduction

The eminent degradation and aging of a large number of residential buildings stock in different urban areas, in Portugal and throughout Europe, results mostly from the lack of integrated national, regional and local urban policies. This situation also results from the prevalence of fragmented studies, which do not take into consideration holistic analyses involving different problems, contexts, scenarios and scales of analysis.

On the other hand, the inadequacy and incompatibilities of the actual building codes and standards requirements to the particular construction, architectural and material characteristics of existing buildings are widespread. Several scholars are targeting the urgent need to adapt the legislation that regulate the construction sector to allow more flexible and proportional interventions on built heritage (Alonso, 2010; Asensio and Martín, 2012;Casals-Tres *et al.*, 2013; Fianchini and Fontana, 2010; García-Martinez *et al.*, 2010; Rios *et al.*, 2012).

This study shows the relevance of a systematic analysis of the codes and standards involving protection, conservation, rehabilitation and control of interventions on built heritage with similar cultural approaches (e.g. Italy, Spain and Portugal), revealing that significant changes have already been made to some of these regulations (Ornelas *et al.*, 2016a). This debate pointed out that the rehabilitation of residential old buildings should include the re-use and recycle of the existing materials, based on cultural and sustainability issues (Damla and Günçe, 2016; INE and LNEC, 2013). It also emphasizes social issues, concerned with social needs and the expectations of residents (Syed *et al.*, 2016).

It is demonstrated that the discussion around the rehabilitation of built heritage, especially directed to housing stock, converges on the need to build an assessment methodology composed by homogeneous criteria that should include patrimonial, technical and social dimensions. Consequently, the developed assessment methodology referred to as "*Metodologia de Avaliação do Património Edificado Habitado*" – MAPEH (Built Inhabited Heritage Assessment Methodology) -, is concerned to the evaluation of existing residential buildings at any context of analysis. The validation of MAPEH relies on the application of an Assessment Form (AF) to the case study of residential buildings of Porto (Ornelas, 2016).

It is also shown that the application of MAPEH on a broader context with different patterns (e.g. patrimonial/ historic value, age and cost of building construction, state of conservation, safety and housing conditions, population density, energy consumption, basic needs of residents), namely at municipal, regional and national levels, will contribute to a holistic inventory and cataloguing.

Also, this paper aims to show that a comprehensive inventory and cataloguing process of existing buildings is relevant to introduce flexible and proportional criteria on the actual application of regulations and legislation (Ornelas *et al.*, 2016a; 2016b), concerning sustainable urban rehabilitation. Furthermore, this reflection will highlight the need for guidelines that will promote a more efficient territorial cohesion, taking into account laws that are more flexible and the application of new policies, including the discussion of climate changes issues in building interventions.

2 Built heritage assessment methodology

2.1 A systematic analysis of buildings codes

Several scholars are discussing the urgent need to adapt the legislation that regulates the construction sector to allow more flexible and proportional interventions on built heritage (Alonso, 2010; Asensio and Martín, 2012; Rios *et al.*, 2012). The requirements of building codes and regulations are mainly directed to new constructions (Arcas-Abella *et al.*, 2011; Casals-Tres *et al.*, 2010) and its application to existing/old buildings is often constrained by pre-existing conditions that make it difficult to achieve performance levels identical to those of new buildings (Fianchini and Fontana, 2010; García-Martinez *et al.*, 2010). This debate assumes particular relevance when dealing with buildings with patrimonial value, i.e. buildings that demand the preservation of their particular (cultural, architectonic, material, etc.) characteristics and contexts.

A systematic analysis of the building codes and legislation involving protection, conservation, rehabilitation and control of interventions on built heritage of three Southern European countries, with similar cultural, architectonic and climatic approaches (Italy, Spain and Portugal), allows the discussion of both different and common approaches and criteria (Ornelas et. al, 2014a; 2014b) to intervene on built heritage. In the Italian context, the national laws concerning the protection of cultural heritage and the intervention on built heritage promote the creation, at the regional level, of general and uniform guidelines for all regions, with few exceptions. At the municipal level, this approach consents, based on inventory and cataloguing processes, the establishment of clear criteria to classify built heritage and the creation of degrees of intervention adjusted to the different building categories. In the Spanish context, there are national laws concerning the protection of historic heritage, and a building code, which is being adjusted by public institutions to establish proportional and flexible intervention criteria. Each region creates their own laws concerning specific criteria for classification and cataloguing, as well as different measures associated to different levels of building classification to intervene in built heritage, not following a unified process. The housing condition requirements are established at the municipal level and the measures of conservation and rehabilitation are related to criteria stipulated at the regional level. In the Portuguese context, on the other hand, the national laws concerning the protection and classification of cultural heritage are discrete and diffuse and do not promote the establishment of unified databases to classify built heritage, as there are disperse inventory and cataloguing processes established by different entities. Moreover, without regional directives and the lack of guidance from the national building codes and legislation on how to intervene on built heritage (Ornelas *et al.*, 2014b), the intervention procedures are evaluated at the municipal level with national technical/code support (Ornelas *et al.*, 2016a).

This comparative analysis found gaps in the Portuguese legislation and showed the need to create an integrated methodology to define effective intervention guidelines and criteria to adjust the actual buildings codes and standards to the interventions on built heritage. It showed the importance of inventory and cataloguing in this process, as a fundamental tool for establishing levels and measures of intervention. The experts from governmental, municipal and academic institutions in these three countries, when interviewed, underline that the implementation of building codes and regulations has more success when supported by flexible and proportional criteria that take into account the built heritage and its intervention context (Ornelas *et al.*, 2016b). In particular, the comparison of building codes and legislation points out the need for an integrated assessment methodology, i.e. a more holistic knowledge with general criteria that allows evaluating the patrimonial, the technical, but also the social dimensions of built heritage. The evaluation of residents' profile, perception and basic needs is also pointed out by experts as being part of an all-inclusive assessment process of built heritage (Ornelas *et al.*, 2016b).

2.2 A holistic assessment of built heritage

The evaluation of inhabited building stock is important nowadays, as its aging and degradation in diverse urban areas, both in Portugal and throughout Europe, especially in historical centres and central urban areas, is a rather important issue. Several analyses assess the major causes of degradation of built heritage in different contexts and different dimensions (Aitziber, 2015; Vicente *et al.*, 2015; Zabalza *et al.*, 2011). The sustainability of buildings is a multidimensional concept, often focusing solely on environmental indicators, ignoring economic and cultural indicators, as well as the social and patrimonial indicators (Damla and Günçe, 2016; INE and LNEC, 2013; Oleg *et al.*, 2015; Pombo *et al.*, 2016; Ricardo and Bragança, 2011; Tiina *et al.*, 2015; Ulisses and Ghisi, 2016; Zabalza *et al.*, 2011).

Some studies demonstrate that the impact of construction products can be significantly reduced by promoting the use of the best techniques available, replacing the use of finite natural resources for waste generated in other production processes, preferably available locally (Zabalza *et al.*, 2011). Some methodologies compare retrofitting solutions, combining Life Cycle Assessment (LCA) and Life Cycle Cost

(LCC) to evaluate environmental impacts in monetary values (Pombo *et al.*, 2016; Zabalza *et al.*, 2011). In addition, the LCA appears as a renewable approach to assess the environemntal sustainability of different production alternatives (Ricardo and Bragança, 2011; Ulisses and Ghisi, 2016). The social dimension is also included in the LCA analyses. Some authors underline the assessment of health and well-being of residents (Langevin *et al.*, 2013), emphasizing the need to evaluate their behavior in dwellings, especially in buildings with high density, and their perception, through personal interviews of comfort in housing, taking into account their satisfaction and health condition (Casals-Tres *et al.*, 2013; Castellano *et al.*, 2016). This analysis is connected both to energy consumption and social needs; highlighting the social vulnerability of residents associated to low-incomes and low education levels (Langevin *et al.*, 2013).

Recently, energy and thermal comfort in the building stock has become a high-interest topic among scholars. Retrofitting buildings to current energy efficiency and thermal comfort standards is essential for improving sustainability, energy performance and for maintaining the built heritage of historic structures (Häberle *et al.*, 2014; Martínez-Molina *et al.*, 2016).

Additionally, some studies focus on the current concept of habitability in relation to the environmental impact and discuss the importance of redefining it as a social demand. This debate is associated with the need for a more targeted regulation of the housing stock that includes more flexible and pluralistic housing concepts that encompass the urban scale (Arcas-Abella *et al.*, 2011; Casals-Tres *et al.*, 2013). The need to provide adjusted and proportional conditions to the socio-economic requirements of the different resident profiles, following the European agenda, is demanded to reduce energy consumption (Ávila *et al.*, 2013; Castellano *et al.*, 2016; Langevin *et al.*, 2013).

These studies highlight the need to implement an assessment methodology that assess built heritage, taking into account, simultaneously, its patrimonial, technical and social dimensions, and to promote its rehabilitation following adjusted and accurate procedures. Consequently, the creation of MAPEH (Ornelas, 2016) emerge from the need to evaluate different urban housing stock contexts.

3 An assessment methodology for inhabited built heritage

3.1 Presentation of MAPEH

The comparison between buildings codes and legislation concerned with the urban rehabilitation procedures of three Southern European countries (Italy, Spain and Portugal), concerning the protection, classification and intervention on built heritage, highlights the importance to introduce general and homogenous criteria in the assessment and classification of built heritage (Ornelas *et al.*, 2016a). The MAPEH is an integrated methodology that combines the patrimonial, technical and social dimensions (see figure 1). This methodology can be adapted to different urban areas, contributing to identify different problems of the building stock in Portuguese territory, as well as in other countries. These procedures are relevant to create approaches and guidelines directed to regional, inter-municipal and local levels, taking into account multidisciplinary characteristics of different patterns of the building stock (patrimonial value, age and cost of building construction, state of conservation, safety and housing conditions, population density, energy consumption, basic needs of residents). In this way, the MAPEH is a methodology that allows the construction of a holistic view on the buildings condition.

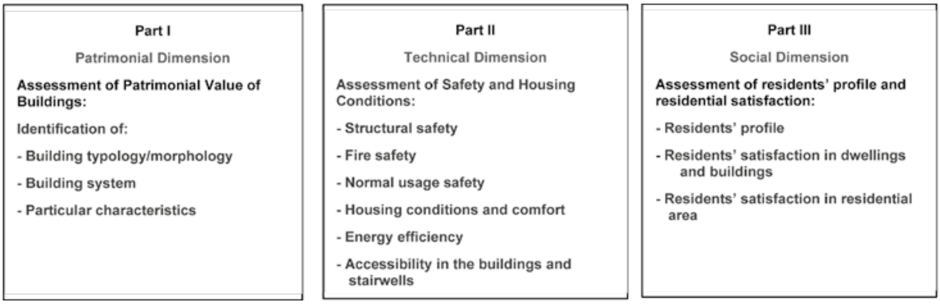

Figure 1. The criteria of patrimonial, technical and social dimensions of MAPEH.

3.2 Operability of MAPEH to old residential buildings of Porto

The application of MAPEH to a specific context is done through an Assessment Form (AF) that converts the general criteria of MAPEH to the criteria of the specific context of analysis. This procedure is supported by the technical and scientific knowledge of experts from the different areas involved (Ornelas *et al.*, 2016b), and by bibliographic research of codes and regulations.

The AF is the main operational tool of MAPEH, and has the same tripartite configuration of MAPEH. Its construction involves the adjustment of the Portuguese regulatory parameters and requirements to the characteristics and features of the old residential buildings of Porto, a process that requires technical knowledge obtained mainly through the support of multidisciplinary teams of experts. The different parts of the AF are composed by quantitative and qualitative parameters/items.

Therefore, the first part of AF evaluates the building's patrimonial value (typology and morphology), constructive systems, material and techniques (stonework, carpentry, stucco, etc.) and the characteristics that add patrimonial value, either from the exterior (volume, facade, skylight, balcony, etc.) or interior (wall lining, flooring, ceiling, stairwell, etc.). The second part is concerned with the assessment of safety (structural, fire and usage) and housing conditions (compartments dimensions, functionality, comfort and accessibility), taking into account the Portuguese building codes and regulations as reference criteria. The third part is related to the social dimension and consists on a questionnaire directed to the representative of each family living in the buildings. It contains questions related to the residents' profile and their residential satisfaction concerning the physical characteristics of the dwellings (see figure 2).

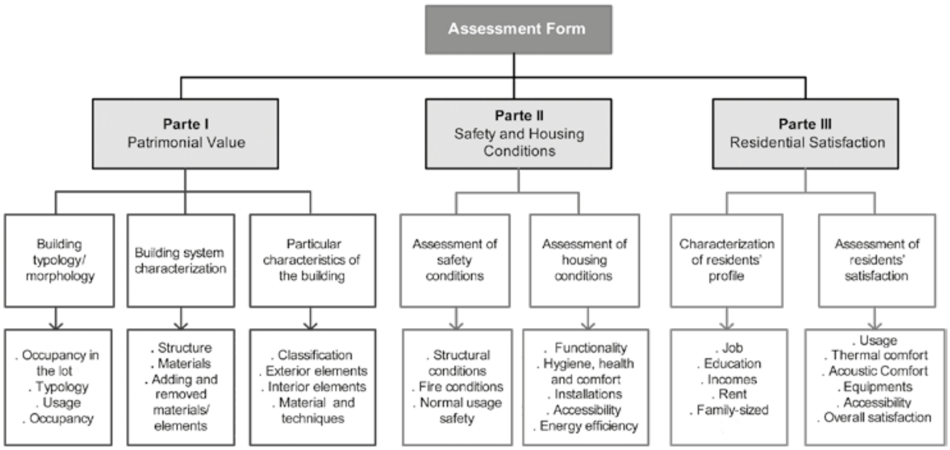

Figure 2. The configuration of AF.

3.3 Validation of MAPEH

To make a comprehensive analysis/diagnosis of the case study, it was first necessary to transform the qualitative data collected by AF into quantitative data.

The quantitative database allows comparing, in percentage, the behaviour of the patrimonial, technical and social dimensions. The data processing enables the identification of the elements with major contributions to the patrimonial value, the most important and common anomalies related to safety and housing conditions, and the most relevant expectations and needs of the residents (see figure 3). In particular, this diagnosis reveals that this built heritage has high patrimonial value, considering its particular exterior (e.g. volumetric, facade and windows frames) and interior elements (e.g. flooring, ceilings and stairs), and its used material and construction techniques (e.g. stonework, carpentry and stucco).

However, water infiltration, especially through the roof, and the material degradation of structural and non-structural walls, roofs and stairs are main anomalies involved in the evaluation of the buildings safety conditions. The addition of interior compartments (e.g. bathrooms and kitchens), the lack of ventilation and the presence of mold and spots resulting from surface condensation are important anomalies that contribute to the poor housing conditions of these buildings.

These aspects are also reflected in the analysis of the social dimension, which reports a negative perception of the residents concerning their housing conditions. In particular, the residents' express negative perception regarding their housing thermal comfort and accessibility, but a positive perception about the patrimonial value of their buildings. Finally, the inquired residents are mostly elderly people who live alone, living in the same dwelling for more than 30 years. These residents also have low incomes and low rents, as well as low education levels (see figure 4).

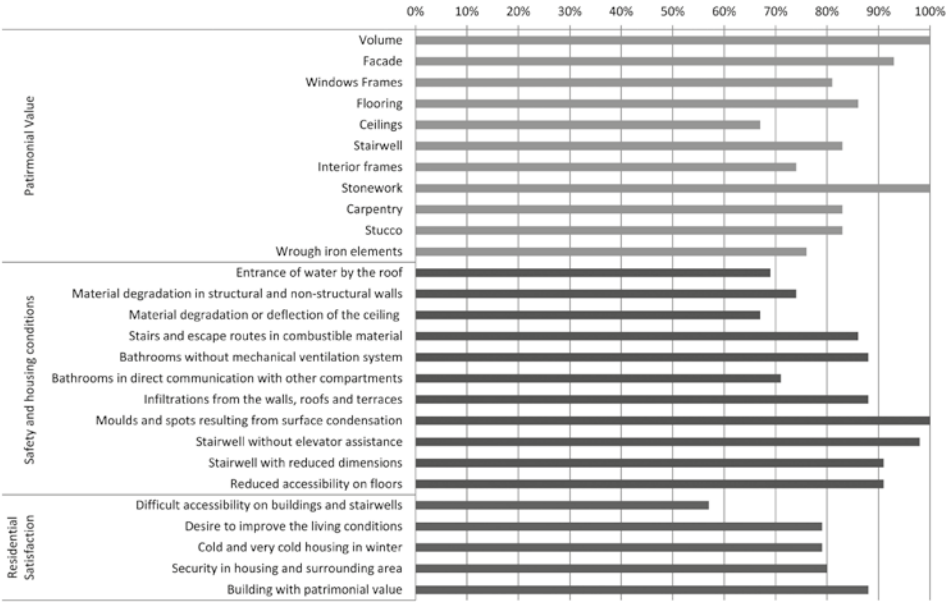

Figure 3. Results of the assessment of the patrimonial, technical and social dimensions of the old residential buildings of Porto.

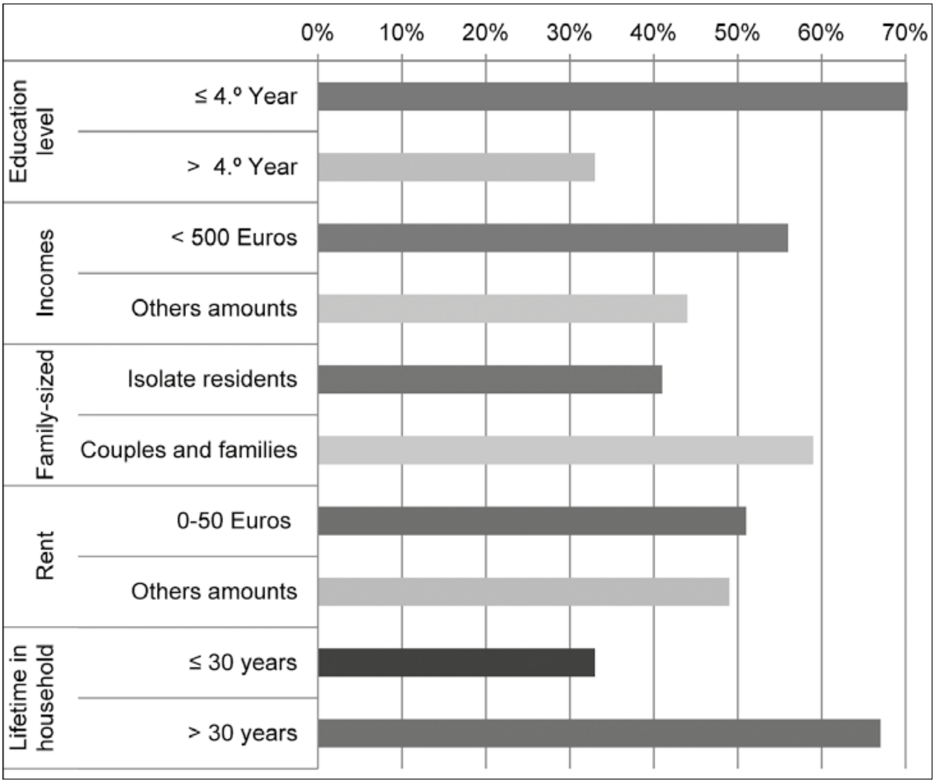

Figure 4. The socioeconomic residents' profile.

The transformation of singular qualitative replies into qualitative values is done by associating binary variables ("0" and "1"), where "1" corresponds to the quality indicator status. It was also necessary to assign weights to each unique parameter, which was accomplished with the support of experts´ opinion. By giving weights between 0 and 3, so that each group of thematic quantitative parameters could be joined in "global variables", namely: patrimonial value, safety conditions and housing conditions, this allowed the characterization of the sample's profile. Through this analysis, a qualitative/quantitative assessment of the patrimonial value and of the safety and housing conditions was also achievable (see table 1) through the division of the interval [0,00; 3,00] into four equal parts. As an example, buildings evaluated between [0,00; 0,75[have low patrimonial and very poor safety and housing conditions. Buildings with values between [1,50; 3,00] have acceptable safety conditions and basic housing conditions.

Table 1. Qualitative and quantitative assessment of case study buildings.

Qualitative/quantitative assessment of case study buildings				
Values of the intervals	[0,00; 0,75[	[0,75; 1,50[	[1,50; 2,25[	[2,25; 3,00]
Patrimonial Value	Low	Medium	High	Very high
Safety Conditions	Not acceptable		Acceptable	
	Very poor	Poor	Reasonable	Good
Housing Conditions	Not Basic		Basic	
	Very poor	Poor	Reasonable	Good

Buildings were also classified in four distinct classes, arranged by decreasing order of patrimonial value, from A to D. In particular, figure 5 shows that there are buildings with quite different safety and housing conditions within each class, meaning that there is no correlation between the patrimonial value of the buildings and their state of conservation. This demonstrates that the high patrimonial value of some buildings did not imply a special attention by the owners or the public entities.

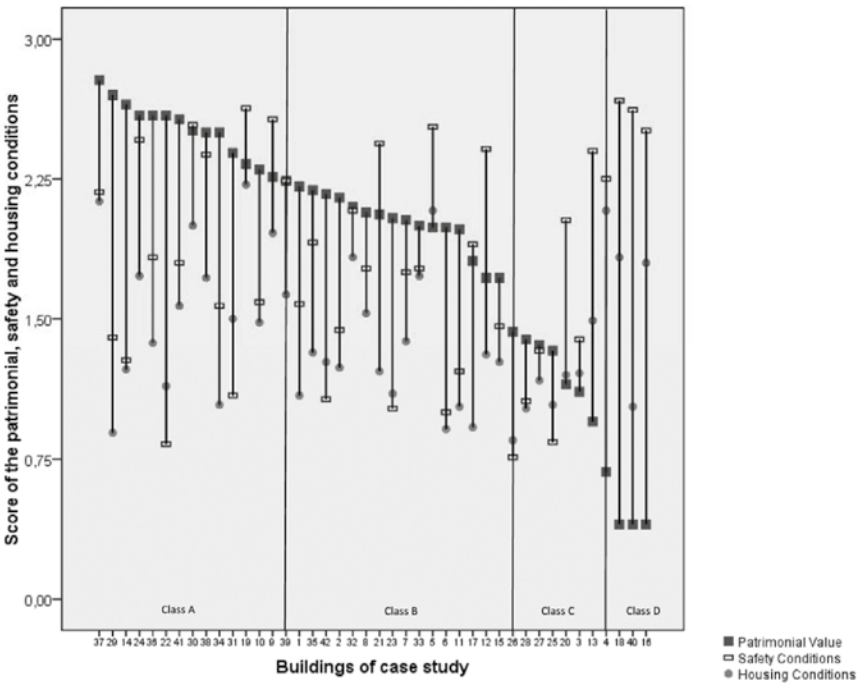

Figure 5. Classification of the old residential buildings of Porto into classes.

The application of MAPEH to the old residential buildings of Porto highlighted the potential of the methodology for collecting detailed and integrated information, which can afterwards be oriented to cataloguing processes. Moreover, the data processing within MAPEH allowed measuring and quantifying the patrimonial value and the safety and housing conditions of these buildings, as well as connecting the residential satisfaction of the residents and their basic needs to the physical characteristics of the dwellings. Moreover, it has shown that there is no correlation between the patrimonial value and safety and housing conditions, as there is a wide variability of these conditions within buildings with similar patrimonial values. This means that buildings with higher patrimonial value do not have a different/ better treatment than buildings with less patrimonial value.

3.4 Levels of interventions

The analysis of the building classes highlights the importance of defining targeted intervention levels directed and adjusted to the patrimonial, technical and social characteristics of the buildings, making MAPEH an essential tool in this process. In Portugal this approach is emerging (Freitas, 2012; LNEC, 1990), but still without the support of a wide inventory and cataloguing process (Ornelas *et al.* 2016a). In other countries (e.g. Italy and Spain) the levels of intervention are supported by current legislation criteria and, hence, by inventory and cataloguing processes (Rios *et al.*, 2012; Rumor and Gonzato, 1989). Considering this, the MAPEH can propose three possible levels of intervention (see figure 6).

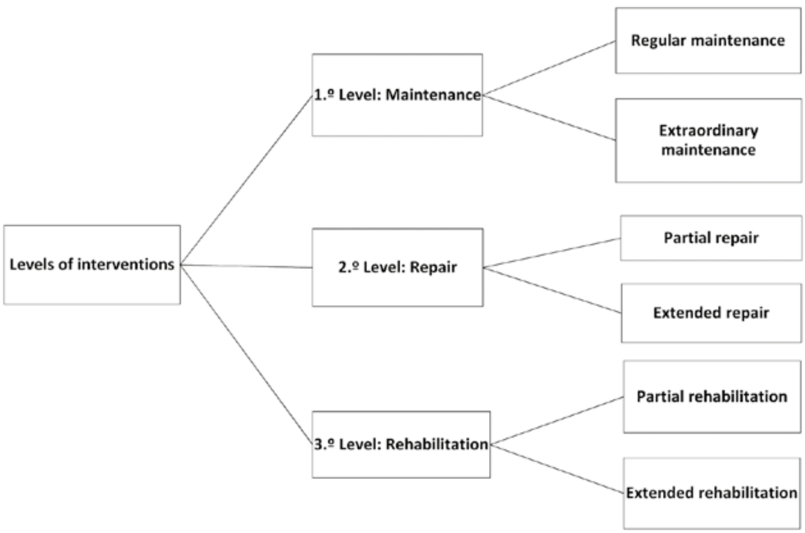

Figure 6. Levels of intervention on built heritage.

The first level includes all maintenance actions, directed to all buildings and that should be applied transversally. It regards actions of regular maintenance, considering all preventive operations, which are actually demanded by current regulations. This first level also includes extraordinary maintenance measures focused on existing installations and equipment. Actions in this category include, for example, fixing small cracks on walls, walls and floor linings.

The second level of intervention includes all repair actions, which are not necessarily included in the maintenance category. These actions are targeted to return the buildings to their previous condition, before the occurrence of such anomalies. It includes measures such as: interventions in flooring, stairwells and infrastructures (e.g. water supply, pluvial drainage, etc.). This category is divided into partial and extended repairs, where it involves less or more than 50% of the building, respectively.

The third and most complex level of intervention - rehabilitation -, assumes the need for deeper actions. According to the criteria and procedures mentioned in the legislation, this type of measures intends to improve safety and habitability conditions, improving the buildings' functionality that suffered from aging or poorly executed interventions. Depending on the buildings conditions and necessary workload, it is possible to have partial or extended rehabilitation interventions. Actions in this category include the replacement of walls, ceilings, flooring, stairwells, sanitary and kitchens facilities, or general infrastructures such as mechanical ventilation systems, exhaust ducts, sewer installations, pipes for water supply and pluvial water drainage.

4 Urban rehabilitation and flexible criteria

4.1 Urban contexts of analysis

Since MAPEH is an assessment methodology concerned with inhabited built heritage, it can be adjusted at any context of analysis. This debate highlights the urgency to evaluate the inhabited housing stock in different urban areas with diverse configurations and problems (e.g. old historic residential buildings, social housing, dwellings of the 70's and 80's, etc.).

The Portuguese national census (INE, 2011; INE, 2012) already provide some insights regarding the overall building condition in national territory (see figure 7 and 8). However, this information is fragmented and scarce to allow a wider debate on the application of normative criteria in urban rehabilitation. In particular, figure 7 shows that there is no direct correlation between population and housing density, as well as the state of conservation of buildings. On the other hand, these results show that there is a strong connection between the age of buildings and their need of repairs (see figure 8).

Figure 7. Population density, buildings density and state of conservation of buildings in Portugal (INE, 2011, p. 19, 66 and 69).

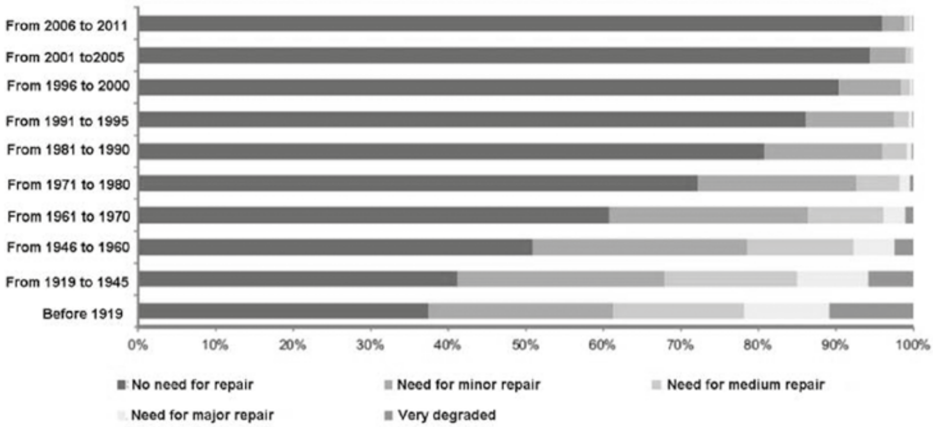

Figure 8. Different building construction periods in Portugal and their need to repair (INE, 2012, p. 34).

In order to complete this characterization, there is a need to identify different housing stock that combine patrimonial, technical and social dimensions. The application of MAPEH should be applied to buildings with different materials, constructive techniques, and to particular characteristics of buildings, different periods of construction and constructive systems (from diverse regions of Portugal). Also, it should include diverse safety (structural, fire and normal usage parameters) and housing conditions (building compartments dimensions, functionality, accessibility and thermal comfort related to the building features), as well as taking into account the population density and different socioeconomic profile of their residents.

4.2 Flexible criteria

The wide-ranging application of MAPEH to different urban contexts, considering diverse scenarios of housing stock will mature a wider discussion and implementation of flexible and differentiated criteria application at urban rehabilitation procedures. This debate is relevant to bring inputs to the Portuguese context, as the actual building codes and regulations in Portugal are mainly concerned with new constructions, discarding the particularities of old buildings, and there is no inventory and cataloguing support for a flexible application of MAPEH. As mentioned before, in other countries (e.g. Italy and Spain) the levels of intervention are already supported by current legislation criteria and, hence, by inventory and cataloguing processes (Rios *et al.*, 2012; Rumor and Gonzato, 1989).

Regarding Spain, it is important to point out two criteria established by the building code - *Código Técnico de la Edificación* - (CTE): proportionality and flexibility. The first criterion aims setting a level of intervention that is reasonable when confronted with the dimension and context of the intervention (repair, renovation, change of use, extension). The criterion of flexibility, on the other hand, exists to overcome code requirements in order to allow higher levels of heritage safeguard, or interventions more suited to the particular characteristics of the constructions and/or to the dimension and context of the intervention (Ornelas *et al.*, 2016a). The figure 9 shows that an intervention should improve the actual conditions of a building, without having necessarily to fully comply with the requirements of codes. While the treatment of such requirements should be homogeneous, the application should be different when applying safety or housing conditions requirements. There are minimum safety requirements that cannot be avoided as they affect the safety of people and their universal rights (Rios *et al.*, 2012).

Actually, an intervention should improve the actual conditions of a building, in particular, codes should include more flexible and proportional criteria, depending on the context of each intervention (Ornelas *et al.*, 2016a). In this regard, MAPEH can also be an important tool to support the creation of those levels, i.e. it can be a tool to support the creation/application of new codes criteria. In addition, such approach implies the establishment of different levels of adequacy depending on the evaluation of the buildings patrimonial, technical and social dimensions, which should be associated to different levels of intervention.

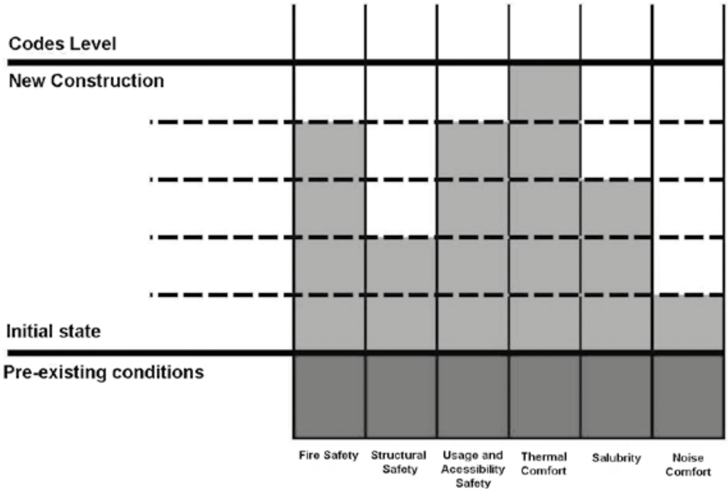

Figure 9. Global scheme of intervention in existing buildings (Rios *et al.*, 2012, p.5).

MAPEH is concerned with the evaluation of housing stock in order to optimize the available resources, while maximizing the outcomes of the intervention in cultural, technical, social and economic terms. Consequently, MAPEH is an assessment methodology that could contribute to close the material cycles, when fostering the reusing of existing materials, while contributing to a natural reduction in energy consumption and greenhouse gas emission (see figure 10).

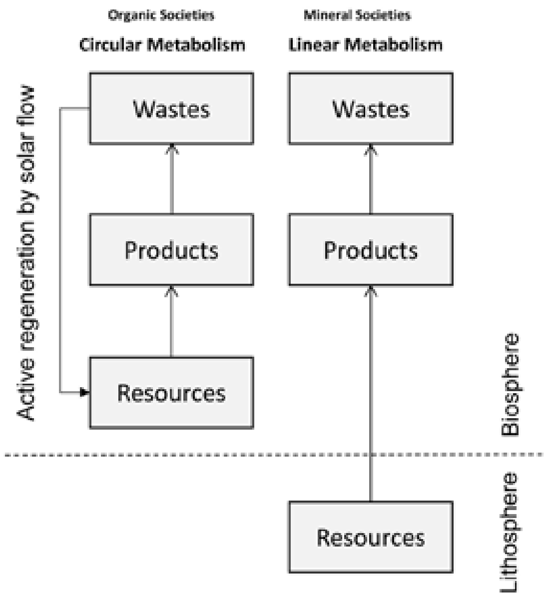

Figure 10. Circular and linear metabolism (Arcas-Abella, 2013, p. 4).

The redefinition of the concept of habitability should be connected with closing material cycles, and consequently, linked to precise resources to be maintained over time (Arcas-Abella *et al.*, 2011). In addition, the built heritage is one of the main components of the urban fabric of older European cities, and consequently any transformation of the model of habitability must be approached from the rehabilitation of its existing stock. In this context, the broad evaluation of housing stock through the MAPEH encourages the debate on the implementation of good rehabilitation practices on housing stock, which will respond to the recent European agenda (2016 and 2017), by improving the quality of housing.

5 Conclusions

The systematic analysis of codes/legislation highlights the importance to introduce general and homogenous criteria to support the assessment of built heritage in general; but also that this should be complemented by approaches and guidelines directed to its regional and local features in order to ensure interventions closer to the built heritage characteristics (patrimonial, technical and social). Therefore, the urgency of this analysis arises from the inadequacy of the current regulations to the characteristics of the existing housing stock. It becomes fundamental to discuss urban rehabilitation criteria at different contexts of analysis.

The application of MAPEH to a broad context of analysis could be a contribution to a complex inventory and cataloguing process of different housing stock at national and regional levels, as well as to the debate on the concept of habitability. The inventory and cataloguing of housing stock will establish a broad and well-founded debate on different normative criteria in the legislation, regulations and building codes, aimed at the rehabilitation of the housing stock. In this process, it will consider different levels of intervention to a well-oriented adaptation of legislation (e.g. climate changes regulations). Governance should increase levels of interventions suitable to the inventoried and catalogued scenarios, and improve the flexible application of legislation and regulation, taking into account other relevant issues such as climate change impacts.

A guide for intervention on built heritage can be developed by MAPEH to prevent further built heritage loss and contribute to a greater territorial efficiency in urban rehabilitation. Each region should, as a consequence, have its own inventory and cataloguing system in order to create well-oriented guidelines adjusted to its built heritage.

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Funding of urban development: the case of tourism

Emília Malcata Rebelo

CITTA - Research Centre for Territory, Transport and Environment / FEUP - Faculty of Engineering of the University of Porto

emalcata@fe.up.pt

The research reported in this article aims at assessing how land capture direct instruments applied at the municipal level can allocate for the social interest the land unearned increments that stem from public decisions concerning the implementation of territorial plans and/or changes in land uses or land use intensities. More specifically, herein are presented the theoretical framework, methodology, results and conclusions of a proposal of a kind of non-negotiable development obligation - applied at the Municipal level - aimed at capturing at least part of the land betterments engendered by plans concerning the allocation of concrete building capacities, objectively computed from the parameters settled in Municipal Master Plans, Urban Development Plans, Detail Plans, parcelling out procedures, or other instruments of territorial management. It is based on an economic assessment method that consists in charging landowners/promoters a 20% fee on land betterment values that result from the assignment by urban plans of specific building capacities to urban interventions especially targeted to tourism uses. The proposed methodology is applied to the Urban Development Plan of the Planning Unit 11 of the municipality of Lagoa, located in the Algarve, Portugal.

These non-negotiable development obligations may be easily applied to other municipalities, within the scope of different kinds of urban plans. They ensure that the betterments they engender are pointed to social purposes. And they further support municipal economic and financial sustainability based on a strategic and integrated planning perspective.

Keywords: Value capture; economic and financial sustainability of urban developments; non-negotiable municipal developer obligations; territorial planning legislation.

1 Theoretical background

Land planning decisions concerning territorial planning development and/or implementation, or changes in urban land uses or intensities of use generally entangle rises in land values, usually termed as unearned increments or betterments (Alterman, 2011; Walters, 2012. The concern for the land social function, which consists of recapturing those unearned increments/betterments, reverting them afterwards to the population´s social interest is longstanding in planning literature (Ingram and Hong, 2007; Netzer, 1998; Rebelo, 2009, 2012; Smolka and Amborski, 2003, 2007). It makes up the core of Land Value Capture (LVC) policies and instruments. These are taxed-based land policies and instruments, which – through returning to communities the land unearned values that accrue from planning decisions and public investments - assure additional income to public administration (Ingram and Hong, 2012), supports welfare redistribution, and controls land prices (namely encouraging the provision of land for urban development (DGOTDU, 2011). However, these policies and instruments have been adopted unevenly around the world´s planning systems, and the narratives of their application point out to divergent reasons for their success or failure. A consistent and coherent body of knowledge, duly supported on practical cases, is still missing.

The overall legislation on land, territorial ordering and urban development was recently reviewed in Portugal – that has culminated in the enforcement of the new Land Planning Act (Lei nº 31/2014) -, in strict coordination with the revision of the juridical regime of Urbanization and Edification (DL nº 136/2014), the juridical regime of Territorial Management Instruments (DL nº 80/2015), the new Cadastral Law, as well as the revision of municipal master plans and respective regulations and of other territorial-based legislation. It was intended to surmount some shortcomings and troubles that have accrued from the application of the previous legislation, that have often revealed contradictions, superposition of regulations on the same territories, and lack of support to the development of integrated inter-municipal policies (www.portugal.gov.pt).

The whole new legislation founds on a completely new approach to planning, adopting the perspective of its proper economic and financial sustainability, thus urban development plans and licenses should only be approved if projects are prone to engender incomes equal or higher that the charges they will involve, what should be duly justified by technical, economic and financial reports.

The proposal herein presented describes in detail a new non-negotiable development obligation designed to support land policies, and applied at the Municipal level, aimed at capturing part of the betterment values accrued from the assignment of concrete building capacities by plans. They are computed from statistical feasible data, and from the parameters settled in territorial plans and other instruments of territorial management.

2 Methodology

To recover at least part of the betterments that accrue from planning decisions or public investments, the following steps were pursued for the studied municipality: (i) identification of concrete building capacities/m^2 enabled by enforced territorial plans in the different municipal territorial areas; (ii) computation of the average infrastructure costs/m^2, construction costs/m^2, and underlying land costs/m^2, according to market trade; (iii) assessment of the municipal land value/m^2 that results from the application of the Real Estate Municipal Tax Code; (iv) computation of the difference between market land costs/m^2 and legal land costs/m^2 according to the two previous values for the different municipal areas, taken as an approach to betterments/m^2; (v) valuation of identified building capacities/m^2 by the previously identified betterments/m^2 of urban buildable land; (vi) computation of 20% of the previous value that represents the potential collectable value that results from the levy of the proposed non-negotiable development obligation to promoters and builders, in order to recover part of the unearned increments that accrue from the building capacities/m^2 assigned by enforced plans (figure 1).

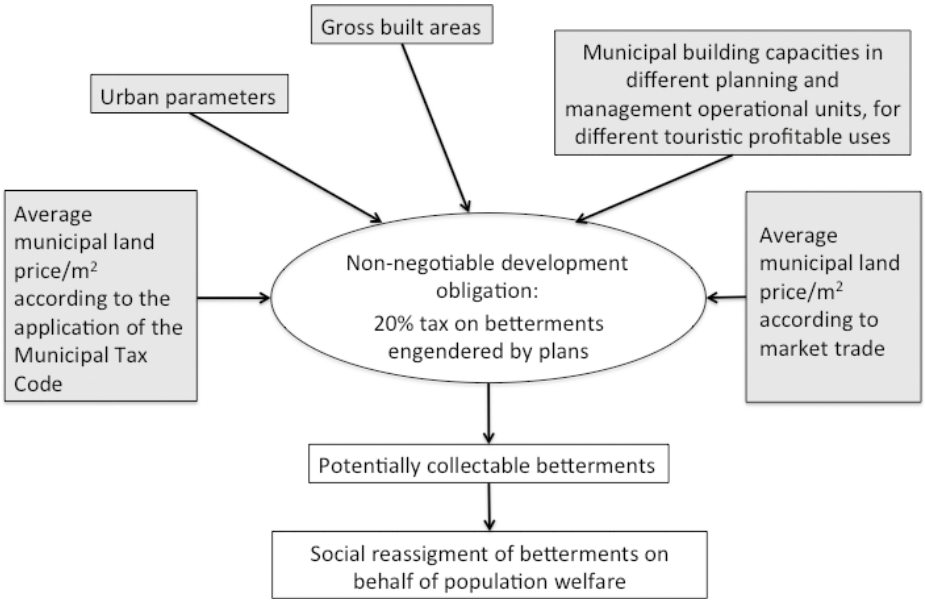

Figure 1. Methodology pursued to compute land collectable betterments/m^2 due to building capacities assigned by plans.

The concrete average building capacity/m^2 means the gross built surface (m^2) licensed by plans in a certain execution unit, intervention area or urban development operation. Its computation results from the product of total gross built surfaces licensed to different kinds of uses by respective occupation and use indexes, weighted by each percentage in the total surface of the execution unit or intervention area, summed up for the all considered municipal areas.

The land price/m^2 based on market transactions is given by the municipal price/m^2 (according to town property trade) net of average infrastructure costs/m^2 and average building costs/m². The proposed approach to betterments/m² is reckoned through the difference between this average municipal land price/m² and the corresponding tributary patrimonial value of buildable land/m² (according to the enforced Real Estate Municipal Tax Code).

The total amount of betterment is, finally, given by the product between these computed betterment values/m² and the concrete building capacities/m² for the anticipated uses of all the plots in the execution unit or urban intervention area.

Finally, the proposed potential capture of betterments – according to this non-negotiable development obligation - amounts to 20% of the previous computed value. A discussion is pursued on the social reassignment of betterments accrued by plans on behalf of the general social interest.

3 Case study

3.1 Territorial Plans enforced in the Municipality of Lagoa

Lagoa Municipality is located in the south of Portugal, in Faro district, by the sea (figure 2). It covers an area of 88,3 km², and lodges a population of about 22 791 inhabitants (INE, 2011). Most of its population work in the tertiary sector, which represents 84,8% of its total employment, whereas its homologous values in the Algarve region amount to 82,5%, and to 65,3% in the continental Portugal (INE, 2012).

Figure 2. View and location of Lagoa Municipality (Algarve) (source: www.google.com).

The plans enforced in the Municipality of Lagoa are: the Municipal Master Plan of Lagoa (RCM nº 29/94, Aviso nº 26197/2008, Aviso nº 3872/2012); the Urban Development Plan of the Planning Unit 1 – UP 1 from Ferragudo to Calvário (RCM nº 126/99, Edital 613/2009); the Urban Development Plan of the Touristic Capacity Area of the Planning Unit 12 - UP 12 (Declaração nº 56/2008); the Urban Development Plan of the Planning Unit 11 - UP 11 (Aviso nº 44845/2008); the Urban Development Plan of the Town of Lagoa (11622/2008); the Ordering Plan of the seashore of Burgau-Vilamoura (RCM nº 33/99); the Regional Plan of Territorial Ordering PROT – Algarve (RCM nº

102/2007; RCM nº 188/2007); the Plan of the Hydrological Basin of the Algarve Streams (DR 12/2002); the Regional Plan of Forest Ordering (PROF) of Algarve (DR nº 17/2006); the Natura 2000 Network (RCM nº 115-A/2008); the Partial suspension of the Regional Forest Ordering Plan (PROF) of Algarve (Portaria nº 78/2013); and the Management Plan of the Hydrological Basins that take part in the Hydrological Basin 8 (RH8) – PGBH of the Algarve Streams (RCM nº 16-E/2013).

The Municipal Master Plan of Lagoa settles the urban developed and developable areas of Lagoa, Estômbar, Porches, Aldeia de Luís Francisco, Ferragudo, Corgos, Bela Vista, Parchal, Mexilhoeira da Carregação, Pateiro, Calvário, Carvoeiro, Poço Partido, Sobral and Torrinha for building purposes. The main goal of this Municipal Master Plan consists in assuring a balanced development, thus promoting rational uses of spaces, as well as the management of resources and heritage preservation so to stand up for its population´s welfare. In line with these concerns, it allows changes in its planning and management operational units - UP 1, UP 2, UP 3, UP 4, UP 8, and UP 9.

This Municipal Master Plan settles planning units UP 7, UP 10, and UP 13 - with current touristic uses as well as the adjacent interstitial tissue - as touristic occupation areas. Furthermore, the Touristic Capacity Areas include the Touristic Development Nuclei - planning and management operational units UP 5, UP 6, UP 11 and UP 12. In these areas are enforced the land use, occupation and transformation regimes settled in ordering plans, restriction plans, and the proper Municipal Master Plan, till the approval of the Touristic Development Nuclei (that are assigned up to 25% of the Touristic Capacity Areas).

Touristic Development Nuclei, by their turn – according to the Municipal Master Plan - must be aimed exclusively at touristic uses (thus excluding incompatible uses), mustn´t include natural parks or reserves, should adopt high standards of quality, and provide leisure facilities. It also should be able to support its own infrastructure costs, and share the costs of municipal infrastructure. Each Nucleus may include different touristic undertakings, provided they are served by a common infrastructure network, and belong to the same Touristic Capacity Area.

The Planning Unit 11 (UP 11) covers 401,6 hectares in the parishes of Lagoa and Carvoeiro, in the municipality of Lagoa. Its intervention area spans from Marinha beach to Cabo Carvoeiro. Its Urban Development Plan defines it as a Touristic Capacity Area (AAT) - that can include one or more Touristic Development Nuclei (NDT) – and sets parameters for land occupation, use and transformation in its intervention areas.

The goals settled for the Touristic Capacity Area of UP 11 convey the implementation of two Touristic Development Nuclei (NDT): East NDT and West NDT (that should both respect landscape natural and cultural values, and the ecological structure). Both of them should cover a total area of 997 737 m^2, that mustn´t exceed 25% the total area of 4 016 158 m^2 of the UP 11 settled in the Municipal Master Plan of Lagoa (thus East NDT was assigned an area of 741 890 m^2 and West NDT an area of 255 847 m^2).

The intervention area of UP 11 includes both urban and rural land. The former includes the developed urban area of Benagil, the touristic-urban area located at Carvalho beach´s north (Clube Atlântico), and two touristic-urban areas located near Alfanzina (which are urban areas outside the Touristic Development Nuclei settled in the Municipal Master Plan). Whenever parcelling out operations are enforced, its license´s guidelines should be pursued. The latter – that conveys land which urban development may be programed - encompasses the new touristic areas inside East and West NDT´s. It mustn´t surpass 30% of the total area of the Touristic Development Nuclei. This urban development land should respect the building regime of respective planning and management operational sub-units, according to the classifications licensed in touristic undertakings. The East Touristic Development Nucleus is implemented through N1 and N2 planning and management operational sub-units, and the West Touristic Development Nucleus through P1 and P2 planning and management operational sub-units.

It is further settled by the Urban Development Plan of UP 11 that the touristic undertakings in each nucleus must conform to four-star or higher touristic lodging categories. The East Touristic Development Nuclei is assigned a maximum of 1 279 beds, whereas the West Touristic Development Nuclei is assigned a maximum of 441, what amounts 1 720 beds.

3.2 Application of the non-negotiable development obligation to the Planning Unit 11 in Lagoa

The annual average of gross built surface (for developed and developable urban land, expressed in m^2) in the municipality of Lagoa was estimated through the product between annual finished buildings[1], the average number of storeys per building, the average number of dwellings per storey, the average number of compartments per dwelling and the average liveable surface per compartment, divided by 0,65 (assuming the liveable surface amounts to about 65% of the gross built surface) (table 1). A four-year period was adopted for the computation, in order to avoid situation fluctuations (INE, 2009, 2010, 2011, 2012).

Table 1. Annual average of gross built surface in the Municipality of Lagoa (for 2008, 2009, 2010 and 2011).

	2008	2009	2010	2011	Total	Average
Total number of finished buildings (1)	228	137	114	64	543	136
Average number of storeys per building (2)	2,7	2,5	2,4	2,2	9,8	2,5
Average number of dwellings per storey (3)	1,2	1,6	0,7	0,5	4,0	1,0
Average number of compartments per building (4)	4,3	4,4	5,5	5,8	20,0	5,0
Average liveable surface per compartment (m^2) (5)	17,3	17,5	19,8	21,6	76,2	19,0
Total gross built surface (m^2) (6)=(1)x(2)x(3)x(4)x(5)/0,65	82.539,8	64.916,9	32.087,0	13.568,8	193.112	48.278

Data collected from the municipal amortization and provision maps concerning public domain´s assets – other construction and urban infrastructure – for 2009, 2010, 2011 and 2012 was used to compute the average annual costs with infrastructure (execution, maintenance and reinforcement). Its value - 705,2 €/m^2 – is approached by the quotient between land property transactions and the previously computed average gross built area (Câmara Municipal de Lagoa, 2009, 2010, 2011, 2012; INE, 2009, 2010, 2011, 2012) (Table 2).

Table 2. Average investment/m^2 in urban infrastructure in Lagoa Municipality.

Investments in urban infrastructures´ execution, maintenance and reinforcement	2009	2010	2011	2012
Annual amortization of urban infraestruture (€)	26.399.063	31.439.028	36.570.644	41.767.542
Annual average investment (€)	34.044.069			
Annual average gross built surface (m^2)	48.278			
Infraestruture´s cost (€/m^2)	705,2			

The buildable land price per m^2 according to market trade is, then, approached by the difference between the transaction value/m^2 and the average costs/m^2 [2]. These costs refer to both urban infrastructures and construction costs/m^2 (table 3)

Table 3. Price of land/m^2 in the municipality of Lagoa, according to market trade (in 2008, 2009, 2010 and 2011).

	2008	2009	2010	2011
Total value of town property trade (€) (1)	101.687.923	92.541.438	93.778.000	103.169.000
Gross built surface (m^2) (2)	82.539,8	64.916,9	32.087,0	13.568,8
Transaction value/m^2 (€/m^2) (3)=(1)/(2)	1.232,0	1.425,5	2.922,6	7.603,4
Construction costs/m^2 (4)	482,4			
Urban infrastructure costs/m^2 (5)	705,2			
Price of buildable land/m^2 of construction (€/m^2) (6)=(3)-(4)-(5)	44,4	237,9	1.735,0	6.415,8

Considering the contribution of each planning and management sub-operational unit and each type of use predicted in the Planning Unit 11 is proportional to its licensed gross built areas aimed at profitable uses, the average municipal buildable land/m² based on town property trade is reckoned as the weighted sum of these different land prices/m².

The product between the price of buildable land/m² and respective net land use index/m² was computed after the identification of the gross built surface assigned to profitable uses (m²) in each area of Lagoa Municipality (where different plans and urban parameters are enforced). Then the percentage that each area represents in the average land price/m² each year is identified, in relation to the maximum licensed built area in the total build and buildable municipal areas. The sum of these parcels is, afterwards, extended to all the areas, thus the municipal land price reaches the value of 721,9 euros/m², on average, per year.

In order to estimate the betterment value/m², it is now necessary to compute the value of the buildable land/m² based on the application of the formula and parameters settled in the Real Estate Municipal Tax Code for each identified area in Lagoa Municipality. An average annual tributary patrimonial value of 56,1 euros/m² was found out (based on corresponding values for 2008, 2009, 2010 and 2011).

The betterment values/m² corresponding to each planning and management operational sub-unit and profitable touristic uses were assessed through the product between its licensed gross build surface and the difference between the annual land price/m² based on market trade (721,9 €/m²) and the homologous price that resulted from the application of the Real Estate Municipal Tax Code to Lagoa municipality (56,1 €/m²) (table 4).

It is finally computed the 20% tax for social purposes what, for this specific Development Plan, amounts to 12 764 718 € (table 4).

Table 4. Average betterment values and potential collectable values for all the planning and management operational sub-units and respective touristic uses in the Planning Unit 11 of Lagoa.

<table>
<tr><th colspan="3">Touristic undertakings</th><th rowspan="2">Land surface (m²)</th><th rowspan="2">Gross built surface (m²) (1)</th><th rowspan="2">Surplus values (€) (2)=(1)*665,8</th><th rowspan="2">20% of surplus values (€) (3)=0,2x(2)</th></tr>
<tr><th colspan="2">Planning and management operational sub-units</th><th>Classification</th></tr>
<tr><td rowspan="4">Planning and management operational sub-unit East NDT</td><td>N.1</td><td>Lodging establishments (Hotels)</td><td>30.000</td><td>15.000</td><td>9.987.000</td><td>1.997.400</td></tr>
<tr><td rowspan="2">N.2</td><td>Lodging establishments (Hotels, Serviced Flats ou Inns)</td><td rowspan="2">191.050</td><td rowspan="2">56.210</td><td rowspan="2">37.424.618</td><td rowspan="2">7.484.924</td></tr>
<tr><td>Lodging complementary means (Holiday Villages)</td></tr>
<tr><td colspan="2">Total (East NDT)</td><td>221.050</td><td>71.210</td><td>47.411.618</td><td>9.482.324</td></tr>
<tr><td rowspan="4">Planning and management operational sub-unit West NDT</td><td>P.1</td><td>Lodging establishments (Hotels)</td><td>10.000</td><td>5.000</td><td>3.329.000</td><td>665.800</td></tr>
<tr><td rowspan="2">P.2</td><td>Lodging establishments (Hotels, Serviced Flats ou Inns)</td><td rowspan="2">66.754</td><td rowspan="2">19.650</td><td rowspan="2">13.082.970</td><td rowspan="2">2.616.594</td></tr>
<tr><td>Lodging complementary means (Holiday Villages)</td></tr>
<tr><td colspan="2">Total (West NDT)</td><td>76.754</td><td>24.650</td><td>16.411.970</td><td>3.282.394</td></tr>
<tr><td colspan="3">Total values in the Planning Unit 11 (UP 11)</td><td>297.804</td><td>95.860</td><td>63.823.588</td><td>12.764.718</td></tr>
</table>

4 Conclusions, reflections and applicability

This article settles and justifies a methodology to compute 20% of betterment values resulting from plans and planning decisions (Rebelo, 2013) that municipalities are potentially able to recover from the application of the proposed non-negotiable development obligation. It is applied to the development Plan of The Planning Unit 11, in Lagoa (Portugal).

Through a clear identification of urban development funds´ origins and applications, and an objective quantification of betterments that accrue from municipal planning decisions and urban operations, this new instrument strengthens the economic and financial sustainability of municipalities. It subsequently contributes to a more balanced distribution of urban development costs and benefits throughout the whole population, private stakeholders and decision makers within a certain municipality (Smolka and Amborski, 2003). It doesn´t neither entangle a fiscal aggravation for most population, nor a rise in building costs (Smolka and Amborski, 2007; Hong, 1998). Besides, it ensures that betterments accrued by plans are used on behalf of the general social interest.

This proposed methodology and instrument can be applied to other municipalities and intervention areas of Municipal Master Plans, Urban Development Plans or Detail Plans, because it founds on inter-municipal comparable data and methodologies. And the funds thus collected can be used to promote the general social welfare.

This new instrument clearly fits the scope and goals of the new Portuguese Land Planning Act and complementary legislation, especially as far as the economic and financial sustainability of plans and urban interventions are concerned, promoting equity and social cohesion. Thus it will make a significant contribution to urban development and to municipal populations´ welfare.

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Endnotes

1 It corresponds to the sum of new buildings, and buildings´ enlargement, changes and/or reconstruction.

2 These costs are issued in the governmental orders that render applicable the article 39th of the Real Estate Municipal Tax Code enforced in 2008, 2009, 2010 and 2011 (Portaria nº 16-A/2008; Portaria nº 1545/2008; Portaria nº 1456/2009; and Portaria nº 1330/2010, respectively).

Planning for adaptation: Synergies of urban planning and climate change. Mumbai case study

Gonçalo Martins
URBE - Núcleos Urbanos de Pesquisa e Intervenção
goncalo.a.martins@gmail.com

The integration of climate change issues into urban planning practices are becoming a target of debate by different authorities due to the impacts and losses caused by different types of disasters in cities. One of the considerations is whether the synergies from the connection between these two fields can influence the city preparedness to disasters and its development. Through an emphasis on the benefits of planning for adaptation and the analysis of flooding risk in cities, the city of Mumbai was used as a case study. The research explores the approaches that authorities delineated in their urban and disaster plans to face the impacts of climate change. Further, the research sought the level of integration of urban planning and disaster management in the city and if planning for adaptation is a known method by authorities. The research shows that Mumbai displays different causes for its floods and the urban and disaster plans develops a mitigation strategy with a focus on the improvement of physical infrastructures and lower connection between urban planning and climate change fields. Although the current literature recommends an integration of climate change issues into urban planning practices, Mumbai urban and disaster plans are developing the first steps for this connection. Planning for adaptation it is an unfamiliar approach to Mumbai authorities and therefore adaptation measures are not a priority to urban development, leading to an incomplete planning and disaster analysis and approach.

Keywords: Urban planning; climate change; planning for adaptation; disaster management; mumbai.

1 Introduction

Nowadays climate change has become a widespread issue to international organisations and for governments and authorities in different countries owing to its risks, impacts and damages into social, economic and environmental characteristics. A recent report by the United Nations Office for Disaster Risk Reduction (UNISDR) indicates that in the last 30 years the reported natural disasters has doubled, increasing the human losses and economic impacts worldwide (UNISDR, 2014). As a result, this leads to the debate of how climate change and cities are interlinked.

Therefore, different stakeholders started to establish links between climate change and urban planning practices. This starts to gain more interest due to the existing vulnerabilities in cities and the challenges of facing different types of natural disasters that have a direct or indirect impact on urban development (Wamsler, 2008). The current plans, policies and practices in the frame of urban planning needs to be reviewed, with the purpose to give a proactive intervention and reduce risks to cities and its inhabitants. Thus, it became essential to integrate new methodologies into urban planning.

Debating, among other approaches, the effects of climate change on cities, several international reports were published in recent years. In 2005, the UNISDR presented the Hyogo Framework for Action 2005-2015, where strategies and approaches to reduce vulnerabilities, risks and hazards were discussed. Later on, in 2010 the World Bank publishes the report called Cities and Climate Change where it was discussed, for instance, the opportunity brought by climate change to cities to become more resilient and the role of policies in changing behaviours. In the same year, the Organisation for Economic Co-Operation and Development (OECD) publishes the report Cities and Climate Change, covering the important role that cities can play at response efficiently and effectively to climate change impacts. All these concerns about the effects of climate change in cities, leads to new challenges on the traditional urban planning practices, where the topics about disaster management and disaster risk begin to be addressed on city development.

From the synergies of these two fields with the requirement of adapt the current urban planning practices, it emerges the field of Planning for Adaptation. With the debate about the integration of climate change into urban planning practices, adaptation strategy arises as a possible approach to link these two fields. On the current literature, this type of approach is referred as planning for adaptation for encompassing all the different risks and climate impacts in urban planning practices (Wamsler *et al.*, 2013). Thus, planning for adaptation is an approach that focuses on the adaptation of strategies and measures as an act of anticipation from climate change impacts (Bicknell *et al.*, 2009; Preston *et al.*, 2011; Satterthwaite *et al.*, 2007). One of the motivations that leads city authorities to develop planning for adaptation is due to previous events and experiences of natural disasters (Carmin *et al.*, 2013), which increases the perception of city vulnerabilities. In this process, local communities and civil society organisations are described as important actors to be involved (Bicknell *et al.*, 2009). Therefore, adaptation emerges as a different approach to the traditional planning practices, with important aspects that can contribute to planning city development through a look of climate change themes.

In order to integrate adaptation into the urban planning field, Wamsler (2014) suggests six strategies to be implemented (separately or combined) by local authorities which may contribute and provide a change in institutional frameworks:

i) implementation of programs aiming to reduce risk, which are not part of the implementing body sectors;
ii) modification of sector-specific plan to maximise its potential for risk reduction;
iii) modification of the organisational management, structure, policy and legislation;
iv) modification of an organisation way of operating and internal policies;
v) promotion of cooperation between different urban actors;
vi) shift in the philosophy of professional and educational sectors.

Given the fact that the research topic to analyse and explore covers a large range of subjects about urban planning and climate change, it was necessary to scrutinise in detail the urban planning system and the disaster management system of a vulnerable city. Moreover, it was also essential to focus on a specific climate disaster with the purpose to understand how the current urban and disaster plans are outlined to response, the type of adopted approach for a certain type of disaster and the existing connectivity of these two fields. For this purpose, the city of Mumbai was chosen as a case study with an emphasis on flooding risk. In order to developing the topics previously stated, the research was divided in four parts: Section 1 provides a description of the methodology used; section 2 contains the findings; section 3 delivers an analysis; and the last part is reserved for conclusions.

2 Methodology

2.1 Research method

Having defined the research topic, it was necessary to choose a suitable method that helped on its development. The adopted method is known in social sciences as qualitative research, which is based on methods of analysis, explanation and argument aimed to produce rounded and contextual understandings on the basis of rich, nuanced and detailed data (Mason, 2002). Through the different types of approaches to assemble qualitative data (e.g. interviews; focus groups; ethnography; observation; and case studies (Berg, 2001), it was considered that the appropriate method to develop the research was by choosing a case study as a source of analysis. This method allows the exploration of information and data about a specific theme and is a useful tool to analyse new processes and its outcomes (Rivera and Wamsler, 2014). Thus, the city of Mumbai emerged as a case study. The option for not using quantitative data was due to incapacity of establish contact with the Mumbai authorities.

The methodology adopted for this research is categorise in three phases of development with different scales of action. The initial step, defined as *data collection*, was the moment of information gathering about the topics of urban planning and climate change. Therefore, it was necessary to divide the information collected in different categories such as: adaptation; climate change; international organisations; resilience; urban risk; urban planning and Mumbai. Each category includes articles, reports and books about each theme. This division contributed to an effective analysis of each document and for its consultation during the research process.

The next phase, *findings*, it was the readings and analysis of each document, in order to select the key aspects about the different subjects related to urban planning and climate change. This part of the work contributed to contextualise the research topic on the current debates, to increase the knowledge about it and to establish contact with the context of the case study.

Finally, on the third phase, *analysis*, the focus was on the understanding of how urban planning and climate change are addressed in Mumbai through the analysis of the current urban and disaster plans. Thus, the data collected about Mumbai and the background information about the research topic, helped in the process of relating theory with practice. The research methodology began with a holistic view and it was gradually focusing in a more detailed analysis.

During the process of collecting data about the research topic, it was used different Internet search engines. The initial search was by using the Westminster Library by selecting terms such as: urban planning; cities; climate change; adaptation; resilience; disaster risk; vulnerability; floods; coastal cities; climate measures; and Mumbai. Then, it was considered necessary to collect material about international organisations in order to comprehend the current practices, debates and challenges worldwide.

Thus, the other instruments used were the World Bank Library and the OECD Library, by using part of the terms mentioned above. These Internet search engines were chosen due to its credibility on collecting the required information. Regarding to Mumbai urban planning and climate change plans, reports and policies, it was consulted government institutions websites, such as: the Government of India; the Government of Maharashtra; the Mumbai Metropolitan Region Development Authority (MMRDA); and the Municipal Corporation of Greater Mumbai (MCGM). It was considered the government websites as the most credible sources to collect the necessary documents.

2.2 Data analysis and references classification

Through the collection of different documents, it was made an initially content analysis to facilitate the identification of chapters and sections related to the aspects of climate change and urban planning in Mumbai. The initial researches showed that the Indian authorities characterises climate change related topics in the field of disaster management. Under those circumstances, it was adopted the same name in this research for a better comprehension. The topic about urban planning it is referred as planning, town planning and as urban development. In this case, it was not necessary to adjust the name of this field.

At this stage, the research pointed its focus on two categories: disaster management and urban planning. Then, each category was divided into two sub-categories, i.e. policies, plans and reports, to facilitate the organisation of each category and its documents.

After analysing the collected information, it was chosen for both categories the most appropriate plans to be analysed the connections between disaster management and urban planning and its concerns about flooding risk. To finding these connections, the analysis was based on the plan sections that express information about the opposite category. In other words, on the selected plan from disaster management it was analysed the sections that contained information about adaptation, floods and urban planning. On the urban plan the focus was on disaster management and floods. The last step of references analysis was to do a review of all the documents collected in each category by using keywords as codes (figure 1). Then, when a section of the document contained the searching keyword, it was classified according to one of the three codes:

– **DM:** Section with disaster management codes;
– **UP:** Section with urban planning codes;
– **DMUP:** Section with codes that show links between DM and UP.

Through this process there were only considered the words that establish a true connection with the two categories, otherwise the number of the words identified would be higher and meaningless. Due to the importance of the words *adaptation* and *foods* on the disaster management category, the documents from this category were reviewed under its own code through those two words.

Further, the collected data was converted into values from 0 (zero) to *X* (infinite), representing the number of codes found in each document. This procedure enables a systematic exploration of the references collected, allowing a perception about the level of integration of the subjects related to disaster management and urban planning.

The outcome obtained from this process, are considered the primary data of this research since it is produced through the analysis of each document and therefore used for critically analysis. The data represents a complement to the information contained in the urban and disaster plans, contributing for a more detailed analysis of Mumbai approaches.

Figure 1. Keywords in each category.

3 Findings

3.1 References classification

Concerning to Mumbai references, there were identified 14 relevant documents under the categories of disaster management and urban planning (table 1) elaborated by the Government of India, the State of Maharashtra, the Mumbai Metropolitan Region Development Authority (MMRDA) and the Municipal Corporation of Greater Mumbai (MCGM).

In the disaster management category, the list of documents reflects the evolution about perception of climate change impacts within the Indian context. As a matter of fact, one of the policies identified, the Disaster Management Act 2005**,** was created after a disaster event in 2004, leading to the improvement of the appropriate preparedness and capacity building measures in the whole country to any type of disaster (MCGM, 2010). Thus, the discussion about climate change issues may effectively stared through this policy. After this year, it was found several documents regarding this issue. However, they may exist other relevant documents before the 2005 policy but they were not found throughout the research.

Regarding to urban planning category, the oldest reference collected is a State Government policy from 1966 (table 1). In contrast to the previous category, the topic about urban planning is in discussion for a long time in India. The documents from this category, reflects the evolution of planning system in India, with the definition of the tasks of its planning authorities and commissions and the type of urban development desired to the country, states and cities.

The two selected plans chosen for analysis, one from each category, are the *Greater Mumbai Disaster Management Action Plan* (GMDMAP) and the *Greater Mumbai Draft Development Plan 2034* (DP 2034). Each document was considered the most appropriate and significant in its category, giving the perception of the current approaches in development by Mumbai authorities.

Table 1. Found codes by category and references (at bold the two selected plans)

Category	Year	References	CODES		
			DM	**UP**	**DMUP**
Disaster Management	2005	The Disaster Management Act 2005	0	1	1
	2007	Greater Mumbai Disaster Management Action Plan	18	9	1
	2008	The National Action Plan on Climate Change	30	4	1
	2010	Disaster Risk Management Master Plan: Legal and Institutional Arrangements	9	27	2
	2010	Disaster Risk Management Master Plan: Emergency Operations Plan	0	0	0
	2010	Disaster Risk Mitigation in Mumbai City	6	4	1
	2011	Disaster Risk Management Master Plan: Handbook	5	5	1
		TOTAL	**68**	**50**	**7**
Urban Planning	1985	National Capital Region Planning Board Act 1985	0		0
	1999	Regional Plan for Mumbai Metropolitan Region 1996-2011	10		1
	2005	Report of Mumbai City Development Plan 2005-2025	20		4
	2007	Maharashtra Regional and Town Planning Act 1966	2		0
	2013	Twelfth Five Year Plan 2012-2017	156		6
	2014	Maharashtra State Development Report	7		0
	2015	Greater Mumbai Draft Development Plan 2034	31		1
		TOTAL	**226**		**12**

3.2 Context of Disaster Management and Urban Planning in Mumbai

The Government of India has published in 2005 the Disaster Management Act, which brought important features for acting against the climatic change impacts through three main territorial authorities. The National Disaster Management Authority is responsible for the conception of policies on disaster management, to prevent and mitigate the effects from disasters events (Government of India, 2005). Further, it was allocated the responsibility of elaborate the National Plan for the Disaster Management for the whole country.

Second, the State Disaster Management Authority is responsible for the elaboration of the State Disaster Management Plan that include, for instance, the vulnerabilities of different parts of the State and the methods to integrate the mitigation measures into development plans (Government of India, 2005).

Lastly, the District Authority has the responsibility of elaborate the District Plan that must include, for instance, the vulnerable areas to different forms of disasters, the measures to be adopted by the different departments and the response plans and procedures in case of a disaster occurrence (Government of India, 2005). Due to its scale of intervention, the plan should be reviewed and updated annually. The District Authority is also responsible for establishing the guidelines for the integration of mitigation measures into development plans and projects (Government of India, 2005). In the case study under analysis, the responsible authority is the MCGM through the disaster management unit.

With regard to urban planning, the structural document is the Maharashtra Regional and Town Planning Act of 1966 (last legal amended in 2007) published by the State Government of Maharashtra. This act provides the guidelines for land use planning and development in the different State regions according to three different planning levels and plans.

The first planning tool introduced by the act is the Regional Plan, which should be elaborated by a Regional Planning Board. The plan should include in its proposals the important subjects to the region development, including the proposals for land development, network of communications and transport and conversion and development of natural resources. The act recommends that its revision or modification should not occur earlier than ten years (Government of Maharashtra, 2007b).

The second plan of the hierarchy is the development plan, whose preparation is from Planning Authorities' responsibility. The development plan should include, among other subjects, the proposals for land use - e.g. residential, industrial, commercial, agricultural and recreational -, and proposals for flood control and prevention of river pollution (Government of Maharashtra, 2007b). In the case of Mumbai, this is an important subject to be developed by its planning authorities. The revision of the development plan should occur at least once in 20 years (Government of Maharashtra, 2007b). Within this type of plan, the planning authorities may also elaborate local plans for areas of comprehensive development, i.e. areas that requires to be developed or redeveloped as a whole (Government of Maharashtra, 2007b).

3.3 Disaster Management category: Greater Mumbai Disaster Management Action Plan

Elaborated in 2007 by the Government of Maharashtra, the GMDMAP is an important reference to Mumbai preparedness to different type of climate disasters. The 15 chapters of the plan gives a holistic view about Mumbai through a brief review of the urban fabric characteristics, followed by an emphasis on the subjects of disaster management and strategies and measures to be adopted in city.

Table 2. GMDMAP contents.

1. Introduction;	9. Standard operating procedure: Functions of various department of MCGM;
2. Risk assessment and vulnerability analysis;	10. Automatic weather station network;
3. Mitigation strategy;	11. JCB & Dumpers
4. Disaster Management Act - Summary;	12. Non-Governmental Organisations and voluntary agencies;
5. Mitigation measures for Greater Mumbai;	13. Reporting formats;
6. Need for co-ordination mechanisms;	14. Plan dissemination through community education;
7. Institutional arrangements	15. Ward level response plan.
8. Standard operating procedure	

The GMDMAP has its focus on development of preventive measures and a mitigation strategy for Mumbai, where these two solutions are described as the appropriated approaches to reduce the city vulnerabilities. In order to clarify these two categories, the authorities discuss the difference between preparedness and mitigation, asserting that preparedness focuses on plans to respond to a disaster threat or occurrence, and disaster mitigation focuses on the hazard that causes the disaster and tries to eliminate or drastically reduce its direct effects (Government of Maharashtra, 2007a).

According to the plan, the disaster mitigation approach should include structural and non-structural measures, where for this last group of measures is mentioned, among others, the regulation of land use and building codes (Government of Maharashtra, 2007a). This short sentence is the first link founded that attempts to establish a connection between disaster management and urban planning. Although, in the mitigation strategy goals it is not suggested the necessity of linking these two fields, focusing only on the reduction of the risks of loss of life, economics costs and the increasing the public awareness about disaster risk (Government of Maharashtra, 2007a).

Further, the GMDMAP establishes three main fields for incorporation of mitigations measures: infrastructure improvement; communication and public information systems; and land use policies and planning. In each category, it is developed subcategories with a focus on different subjects (e.g. transport infrastructure and emergency operation centre) where it is possible to found some codes related to urban planning and flooding risk. Regarding to urban planning, the third category of mitigation measures mentions the Regional Plan for the MMR as the basis framework about the course of planning and land use to be followed. Therefore, the GMDMAP sets five priorities for the land use policies and planning under a mitigation strategy.

Table 3. GMDMAP land use and planning priorities.

Priorities	Objectives
Safe siting	Analysis of the existing settlements in terms of typology of vulnerability to facilitate the preparation of a master plan for safe siting of such vulnerable settlements.
Improvement and protection of landfill sites	Reduce the current practice of crude dumping and the proliferation of informal settlements;
Control on land reclamation	Development of control rules to protect water bodies and storm water holding ponds
Shifting of storages and hazardous units from residential areas	Reduce the number of hazard units within residential areas through incentives from actions at micro-level
Decongestion	Shift employment opportunities from the major commercial activities (port, agriculture, steel and other wholesale markets) to outside the city

Relating to flooding, it is mentioned the need of infrastructure improvement, where the SWD system is included. The major focus is to augment its capacity and dissociate it from the sewer system in order to improve the system function and reduce the coastal pollution. Furthermore, it is proposed the arrangement of 77 pumps across Mumbai and the installation of 26 automatic weather stations with rain gauge to monitoring rain intensity in order to facilitate the early warnings. The implementation of these measures requires the involvement of MMRDA, MCGM, Mumbai Port Trust and the department of Sewerage Operation (Government of Maharashtra, 2007a). The urban planning department or other related unit is not mentioned. In addition to these measures, the GMDMAP also contains a Standard Operating Procedures (SOP) for responding to monsoon related flooding in Mumbai. The SOP analyses the flooding risk in Mumbai as a long-term and annual disaster that requires different types of mitigation measures. The SOP indicates a list of public agencies that are required to respond to this type of climate event and the three main authorities to coordinate and supervise the response mechanism (figure 3). On the rest of the contents of

GMDMAP, there are developed related subjects to disaster management but does not encompasses information about urban planning and floods. Nonetheless, the plan recognises that some of the measures are beyond the SOP scope.

Table 4. GMDMAP long-term measures to mitigate floods.

Broadening and deepening of rivers	Repair/reconstruction of dilapidated building
Upgrading and cleaning of storm water drains	Improvement of solid-waste management and transport infrastructure and services
Construction of anti-landslide retainer walls	Rainfall monitoring stations
Relocation of vulnerable settlements	

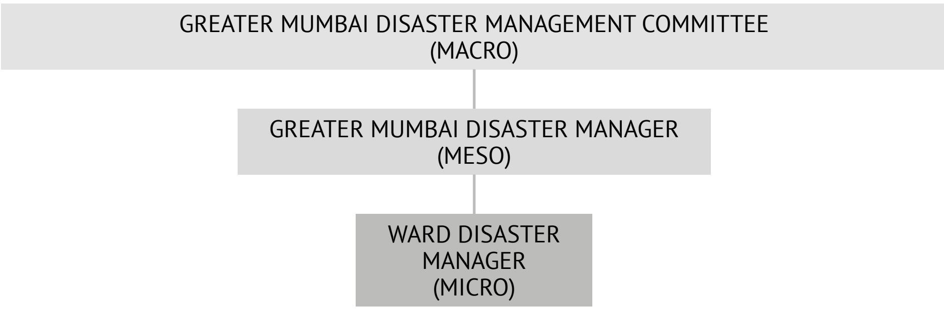

Figure 3. Institutional mechanism of flooding response (adapted from Government of Maharashtra, 2007a).

3.4 Urban Planning category: Greater Mumbai Development Plan 2034

The MCGM prepared the DP 2034 for Mumbai as the structural planning document for city development. The plan was developed under the guidelines of the Maharashtra Region and Town Planning Act and from the experience of the previous development plans of 1967 and 1991 (MCGM, 2015). The document is divided in three parts: context and challenges; visualising the future; and proposals. As a common planning method in the development of a master plan to any city, the basic characteristics, such as demography, economy, transport and environment, were analysed by the authorities. The goal of DP 2034 is to lead Mumbai into a more competitive, inclusive and sustainable city, keeping the city economic primacy as a central factor to its success (MCGM, 2015). The proposed spatial development strategy for Mumbai has its bases on a polycentric growth, transit-oriented development, anticipatory programming for future needs and preservation of its natural areas (MCGM, 2015). The plan also describes the development strategies to follow in order to achieve the city objectives: competiveness; inclusivity; and environmental sustainability (MCGM, 2015).

Table 5. DP 2014 contents.

1. Background for preparation of DP 2034	9. Environment	17. FSI: A tool for managing physical development
2. The Regional context	10. FSI and density	18. Land for public purpose
3. Existing land use	11. Obtaining land for public purpose	19. Transportation and road network
4. Population	12. Growth scenarios	20. Environment
5. Economy	13. Vision and objectives	21. Development control regulations
6. Transport and communication	14. Approach to the formulation of development plan	22. Local area plans
7. Physical infrastructure	15. Spatial development structure	23. Financing implementation of the development plan
8. Social infrastructure	16. Land use zoning	24. Monitoring and evaluation

The references about disaster management and floods on DP 2034 started on the chapter seven through the analysis of the existing physical infrastructure. In this section, it is analysed the current SWD system. Owing to the annual monsoon rainfall in Mumbai, the drainage system is considered a central aspect for one of the proposed planning goals: sustainability. The DP 2034 mentioned that the previous plans proposed pumps of high capacity to overcome the storm water during monsoon and sluice gates for the flooding brought from high tides. However, the challenge for a better SWD continues, where it is pointed the system age, the rainwater holding capacity and the open spaces with inadequate holding capacities as the main negative points (MCGM, 2015).

In the chapter related to the environment, the DP 2034 identifies the most prone areas to flooding in Mumbai, referring the main causes that contributes to this event: geography, its estuarine setting, the increase surface runoff and the low lying coastal edges (MCGM, 2015). Still in the part I of the plan, it is dedicated a trivial reference to climate change by mentioning the increase intensity of climatic events (e.g. rainfall; floods; unseasonal rain or drought; intense heat; sea level rise; cyclonic storm surges; and increasing outbreaks of tropical diseases and epidemics) in Mumbai and the existence of a distinct SWD sectorial plan. Further, the DP 2034 sets a strategy called *green the grey*, which is related to the development of a green infrastructure to mitigate climate change vulnerabilities (by proposing natural areas (table 6)). In fact, this is one of the few times that the expression 'climate change' is used on the plan.

On the last part of the document, where it is described the proposals about environmental sustainability, it is referred the category of disaster management by mentioning that floods and landslides are the two disasters with higher impacts in city. However, the plan indicates the GMDMAP as the document where the issues 'climate change' and 'disasters' are studied in more detail and in a holistic perspective. Therefore, the DP 2034 suggests following the mitigation strategies defined in GMDMAP (table 4). The only strategy suggested is the formation of a green-blue web through the development of buffer zones along rivers and creeks. This measure will contribute to reduce flooding risks by permitting water bodies to flood their banks without affecting people. This recommendation of a strategy for flooding prevention, it the last reference in DP 2034 regarding to the category of disaster management.

Table 6. Allocated areas for land use zones.

ZONES	MUMBAI (ha)
Commercial - Residential	14,448
Residential - Commercial	11,775
Industrial	4,027
Natural Areas	11,289

4 Analysis

4.1 Disaster Management

In India, the discussion about the impacts of climate change and the emerging of the field of disaster management has happened recently. The low integration of disaster management plans and urban planning it may be justified due to the lack of experience in the disaster field and for being a new topic of discussion among authorities. The National Action Plan on Climate Change emerges as the document with more of these keywords (30 in total) where the term adaptation it is used at least in 22 times. In fact, the plan document is the unique reference that introduces the term of adaptation as a possible approach to act against the different climate events. The remaining references have a strong focus on mitigation measures and plans. Regarding to floods, the GMDMAP has at least 18 citations. For being a city scale plan, it is not surprising that the document has more quotes about this type of disaster. In contrast, the Disaster Management Act 2005 and the Disaster Risk Management Master Plan Legal and Institutional Arrangements have no sections related to floods and adaptation.

Regarding to the sections with urban planning codes, the findings show that six of the seven documents contains sections or words related to this field. The document with more codes identified was the Disaster Risk Management Master Plan Legal and Institutional Arrangements, with 27 sections. In this document, it was also identified the majority of links between disaster management and urban planning. This Mumbai framework tries to integrate urban planning as an important component of the mitigation strategy through, for instance, the improvement and protection of landfill sites, control on land reclamation and monitoring local land use changes. The other two most relevant documents with links to urban planning was the GMDMAP (with nine links) and the Disaster Risk Management Master Plan Handbook, with five sections identified. For a second time, the Disaster Risk Management Master Plan Emergency Operations Plan does not take into consideration the urban planning field in its contents.

Concerning to the links between disaster management and urban planning, all the references contains few links between these fields. This may indicate that disaster management authorities are acting as an independent body of action, focusing only on climate change subjects. However, it is necessary to understand that this field needs to be integrated with other areas, where their actions affect directly and indirectly the territory, the environment and the population.

Focusing on the GMDMAP, there were identified eighteen sections related to disaster management, nine to urban planning and only one strong evidence of linkage between disaster management and urban planning (table 1). As mentioned before, this connection was found during the description of the mitigation strategy, where it is stated that land use policies and urban planning are an important component for mitigation. In a global analysis of the GMDMAP and looking at the subjects of floods, adaptation and urban planning, there are pros and cons to argue.

Regards to floods, the local authorities were capable to identify this type of disaster as one of the city vulnerabilities to the effects of climate change, either natural or manmade. In the analysis of the city plan, it is notable that the current major concern is the improvement of the SWD system.

To proceed to its renewal, a great economic investment would be necessary to this physical infrastructure, characterising this solution as a long-term measure. The proposed actions referred in the table 4 shows an exclusive focus on the development of physical measures. Therefore, it lacks for the inexistence of social measures to Mumbai population, since they are the most vulnerable group during floods. However, the plans set mitigation flood measures in different fields of action, which is considered appropriate based on the current city context:

- **Territorial:** Anti-landslide walls; river intervention;
- **Physical:** Building intervention; water and waste systems;
- **Technical:** Rainfall stations.

Another positive aspect, is the planned disaster structure at three levels (figure 3) which may contribute for a better organisation between authorities and therefore for a better planning response and management of disasters.

Regarding to adaptation, the constant focus on mitigation approach developed on GMDMAP, anticipates the lack of attention in adaptation measures by Mumbai authorities. In fact, the term adaptation it is not mentioned even once in the entire plan. This reflects the authority and political will on addressing disasters through mitigation, i.e. long-term physical actions to eliminate the climate effects (direct approach) without a balance with short-term and local measures (indirect approach). Another possible justification for not including an adaptation approach, it may due to authorities' inexperience on the adaptation field, since it is often confused with disaster risk reduction owing to it is closely links (Wamsler, 2014). This may be a result from the lack of sharing knowledge between educational institutions and authorities, creating a constraint to a full disaster approach.

Finally, yet importantly, the GMDMAP dedicates an entire section to land use policies and urban planning. Even that section only occupy one page, the authorities had the concern to integrate urban planning as part of its mitigation strategy. The reference used by authorities was the Regional Plan for MMR, where through its guidelines they provide five fields of planning mitigation action. This was considered the only effective evidence about the connection between disaster management and urban planning.

In conclusion, the GMDMAP appears as a pioneer disaster tool for Mumbai, which will need to be taken under consideration for future disaster plans, through the analysis of its implementation process, its strengths and weaknesses. The coming plans should be open to a higher range of measures and approaches, and a balance between mitigation and adaptation.

4.2 Urban Planning

The urban planning practice in India had officially and legally beginning in 1985 with the National Capital Region Planning Board Act. Older than the disaster management act, this reference reflects the concerns of its time, where the subjects related to climate change were not discussed in terms of city planning, its sustainability, vulnerability or resilience. The findings show zero connections with the codes of DM and DMUP. Bearing in mind that the first official document of disaster management was in 2005, the results from this reference were not a surprise.

In a different position, the Indian Twelfth Five Year Plan 2012-2017 contains the majority of codes related to disaster management. Under the different keywords, climate change emerges as a new concern and a challenge for the country. In twenty-eight years, it is possible to observe a paradigm shift in India regarding to its officials and legal plans: the Twelfth Five Year Plan (2013) contrasts with the National Act (1985) about the focus on climate change related subjects. Therefore, it is a signal of an adaptation to the country challenges, either urban or climatic. This document is the only reference that contains at least one keyword of each keyword searched. Other important evidence is the constant presence of DM codes in the urban planning references along the years, with a visible trend on the keywords used.

Nevertheless, the findings indicate that the tendency it is not reflected in the connections between disaster management and urban planning. The National Capital Region Planning Board Act 1985 and the Maharashtra State Development Report contains zero sections in this code. The document with the most number of links is, once more, the Twelfth Five Year Plan with six keywords. Taking into account these outcomes, we concluded that the current urban planning documents are looking for a method to mainstreaming the disaster management, adaptation and mitigation into their practices. However, the findings indicate that in upcoming policies and plans the number of sections about disaster management may increase.

Regarding to the DP 2034, it contains 31 DM codes, although it was identified only one connection between disaster management and urban planning. The keyword 'floods' is used on the plan with more relevance (15) followed by vulnerability (8), climate change (5) and disaster management (3). The surprise was the non-appearance of the keyword adaptation and resilience in the entire plan. The only connection identified between the two fields was the section dedicated to the disaster management, where it is mentioned the GMDMAP as an important reference to be linked with it. Therefore, the DP 2034 represents an important master plan for Mumbai, which encompasses the climate change effects as one of the urban challenges for the city development. Notwithstanding that, there are some considerations to argue.

The DP 2034 contains several sections discussing the flooding risk in Mumbai. During the environmental analysis, the development plan refers the need of improvement of the current SWD system. Further, the plan "encourages" the implementation of only two measures: green the grey and a green-blue web. As an urban plan that outlines the city development, it was expected to find some methods or mechanisms for a better land use in flooding prone areas. The DP 2034 does not develop constraints for urban development in these areas and do not provide additional measures to be implemented. In fact, the last part of the document where it is settled the proposals for Mumbai, the plan indicates to follow the mitigation strategy outlined in the GMDMAP concerning to flooding risk. This was considered the only link between these fields, although the authorities do not suggest the integration of the mitigation measures into the development plan, or additional recommendations for new measures in different fields of action. Looking for the strategies developed by Wamsler (2014), in this circumstance, of a mitigation approach, it is not visible any efforts to incorporate these two fields for a common objective: reduce the flooding risk.

Another important aspect was the four land uses defined to Mumbai where the two measures mentioned above are incorporated in the natural areas. However, the allocated area for natural areas is approximately 11.289 ha and the total area for urban development (which include the other three zones (table 6)) is about 30.250 ha. According to this, the natural areas that are an important component for flooding prevention only occupies 37.3% of the proposal spatial development. The natural areas could play a key role for the development of an adaptation and mitigation strategy and further be implemented in the GMDMAP. The classification of areas for land use are a notable opportunity for establish a tie with disaster management.

Thereby, the DP 2034 reflects that planning for adaptation in Mumbai are not a priority for authorities, despite of the recognition of climate change impacts. The perception in that the GMDMAP acts as a constraint to the DP 2034, since develops its own proposals for disaster management. In other words, through the existence of a plan that deals with the disaster management subjects, the Mumbai authorities sees that the DP 2034 has no obligation to further develop the subject. Overall, the current planning structure and related operational instruments seems not to be prepared to integrate climate change measures. There is an independent mitigation strategy in development, but lacks for not having adaptation measures, reflecting the absence of a planning adaptation approach in Mumbai.

5 Conclusions

The research tried to demonstrate the current positions and views about urban planning and climate change, the complexity and challenges of disasters in cities, the synergies resulted from the fusion of urban planning and climate change and the actual context of planning for adaptation in planning and disasters practices.

The synergies from the equation *urban planning* + *climate change* = *planning for adaptation*, results in a more prepared and resilient city to face disaster events. Based on the current literature and the case study, the research showed that synergies might be related to: appropriate frameworks; plans and policies in urban planning and disaster management; urban infrastructures adapted with the correct capacity; population prepared to face climate events; individual and political behaviour changes; urban development practices adapted to face new challenges; and a deeper understanding of climate change in urban planning practices. Therefore, the establishment of strong connections between urban planning and climate change still need to be addressed in city scale, where other type of synergies may emerge from new experiments and researches. The research tried to show the different ways of how urban planning and climate change are connected, the current strategies for link these fields and the benefits that each field could gain.

Despite of years debating the effects of climate change, their connection to cities and its recognition by authorities as a key aspect are growing gradually. Planning for adaptation is giving the first steps as an alternative approach to act against climate change. City authorities need to address their plans and policies for urban planning and disaster management through a more holistic and integrated approach. In fact, the current literature argues about the inevitable connection and integration of climate change in urban planning practices, through an adaptation of the current policies, frameworks, plans and the urban fabric and its sectors.

The research intended to show that adaptation may be a possible and solid solution to authorities prepare their territories and policies for a better response against different disasters. With the purpose of mainstreaming adaptation into urban planning field, it will require cooperation between different urban actors and a change of political will. The reason for this is the increasing reported disasters worldwide along these years. The most vulnerable cities will need to elaborate suitable policies and plans to address their most common disasters. For this, planning for adaptation is seen as an emergent and potential field of innovation for cities, demanding a constant exploration of new data. As a result, the research indicates that planning for adaptation is a realm that requires further investigation and debates. Therefore, the traditional planning needs to be open to new challenges, either territorial or climatic. Adaptation provides the capacities to transform the urban fabric into a more prepared and resilient city.

Although, as demonstrated in the case study, planning for adaptation is currently viewed as a new field of action to authorities, where they were unable to proceed to a balance approach of measures and strategies. This was an important finding since for a proper disaster management strategy is required a balance between adaptation, risk reduction and mitigation. In this case, Mumbai is missing an adaptation approach and, therefore, its integration into urban planning practices. The unfamiliarity of the analysed plans with this topic has led to another finding. Planning for adaptation may be difficult to explain and demonstrate to professionals within and outside of this field, due to its different understandings in city context, its links with disaster risk reduction and the immediate costs of adaptation measures. Changing behaviours and practices in organisational structures represents a challenge not only for adaptation but also for mainstreaming climate change related topics.

This study of Mumbai allowed to demonstrate how authorities prepare their urban and disaster plans and how the concerns about climate change are addressed into urban development. In this case, it was privileged a mitigation strategy without solid evidences of connection with urban planning. The focus and inflexibility about the mitigation strategy and the separate implementation of its measures without urban planning appears to be the most significant gaps of the GMDMAP. The city of Mumbai and its inhabitants would benefit from the synergies created by this integration. However, it is recognised the influence of political will in climate change policies. As mentioned before, it requires a change on current organisations functions, structures, practices, behaviours and cooperation between urban stakeholders.

The detail analysis of flooding risk in the case study showed that the measures proposed has its focus on the improvement of city physical infrastructures. The SWD system is a shared concern between GMDMAP and DP 2034. Nevertheless, this cannot be the only evidence that Mumbai authorities may use to link urban planning with disaster management. Adaptation needs to occur at different levels. It was surprising to find that it was not included in the mitigation strategy any potential measures to involve the population knowledge into local mitigation measures against floods. The focus on physical measures was evident in both plans. Owing to the current circumstances of Mumbai, it is acceptable that the major concern is the improvement of the drainage system capacity.

Although, if urban development continues to growth without restrictions, the city will enter on a non-going cycle of mitigate measures to reduce vulnerabilities caused by the lack of integration of planning and disaster policies and plans. Each city should have on its planning procedures the elaboration of a disaster framework, i.e. a disaster nexus, through the identification of the most prone areas and common disasters. The urban actors should be responsible for its elaboration in order to address the climate change issues. Then, the integration of climate change into urban planning requires a full integration of adaptation (measures and strategies) into social, environmental and urban planning policies and plans. The contribution of other urban actors with empirical research would be an important aspect.

With all this process rooted into structures, process and plans, the point is to find the most suitable approach to each situation. The question is to *adapt* the city response to the disaster that has occurred through *adaptive* mechanisms and procedures that city had done previously. This in an important finding since it helps on the initial analysis of city disasters, in the integration of climate change into the urban planning context and indicates that adaptation needs to be seen as a continuing cycle/process of preparation, response and revision. This allows the existence of different mechanisms and possibilities for disaster response.

The information and analysis from this research is an attempt to contribute to the discussion about planning for adaptation, reiterating the necessity of integrate climate change issues into urban planning practices. Through the investigation of the actual disaster approach made by Mumbai authorities, it was possible to address theory into practice with the analysis of the levels of integration between planning and disasters. Adaptation, vulnerability and resilience started to become expressions applied in cities to explain its functions and interactions in the field of climate change. Overall, it was interesting to do a research about planning for adaptation as a new area of intervention in cities development. Being urban planning a dynamic process, it has the capacity and potential to integrate parallel fields to improving welfare of citizens and cities. Planning for adaptation may provide a complementary understanding of planning the cities under the challenges of climate change, where new visions and solutions may arise to achieve sustainable and resilient cities.

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School Mobility Management case study: German College of Porto (Deutsche Schule zu Porto)

João Filipe Teixeira[1], Cecília Silva[2], João Valente Neves[3]

[1] Research Fellow (CITTA/FEUP).
[2] Associate Professor (CITTA/FEUP)
[3] Head of the Mobility Management and Traffic Municipal Division (Porto City Council)
joaoteixeira@fe.up.pt; ccsilva@fe.up.pt; joaoneves@cm-porto.pt

Recently we have witnessed a sharp rise in the percentage of students using individual car as the dominant mode of transportation on home/school trips. It is in this sense that falls this present study, whose main objective is the evaluation of soft measures of School Mobility Management within the student community in a particular case - the German College of Porto. The implementation of these measures aims to increase the levels of sustainable mobility. The results analysis showed that although it cannot be stated that there was effectively a change in the student's mobility patterns due to the implemented measures, there was a high degree of awareness. In addition, there was a high receptivity by the school and the students themselves about the importance of the theme, strengthening the role of such measures in increasing sustainable mobility within the student community.

Keywords: Sustainable mobility, school mobility management, soft measures, German College of Porto.

1 Introduction

In recent decades we have witnessed a sharp decline in the student's percentage traveling on foot or bike to school. Data shows that in the US in 1969, 40.7% of students used to walk or bike to school, declining to only 12.9% in 2001. At the same time, the proportion of children being taken to school by their parents by car increased from less than 20% to 55% (McDonald, 2007; McDonald and Aalborg, 2009).

The situation is rather similar in Europe, where for example in the United Kingdom, the proportion of children using the car as the mode of travel to school increased form 16% in 1985/86 to 28% in 1999/2001 (Cairns, *et al.*, 2004). This phenomenon is particularly worrying since this type of traffic (home/school) can represent up to 20% of peak traffic in urban areas, which can result in 4 additional trips per day (KonSULT, 2014).

The justifications for this modal shift lie on the increasing home/school distance (which makes walking or cycling infeasible), as well as in the fact that parents are afraid of allowing their children to walk or cycle because of the traffic risk. This fear creates a vicious cycle of increasing traffic and sense of insecurity, as more and more parents take their children to school, the risk of accidents for all other students increases, exacerbating the feeling of insecurity (KonSULT, 2014; McLaren and Parusel, 2011).

Additionally, we need to consider the fact that there has been a general increase in car ownership and use, particularly regarding the ownership of a second car in the household (Pontefract, *et al.*, 1999). Another effect of this modal shift relates to the children's own health as they stop exercising during their trip to school (KonSULT, 2014).

The Schools Mobility Management presents itself as an important tool in order to change this scenario. It consists in a set of measures that aim at changing the behaviour of the school community in their home/school trips, mainly through the reduction in the car use (including all the effects of this situation: less CO_2 emissions, less traffic congestion problems and road accidents, lower mobility costs, etc.), while promoting the use of more sustainable modes of transportation. At the heart of school mobility management are soft measures (based on voluntary travel behaviour change) like information and communication services, as well as awareness campaigns promoting sustainable mobility (KonSULT, 2014).

It is within this framework that the present study was developed, whose main objective was to assess how the promotion and implementation of soft mobility management measures can influence the mobility patterns of pre-university students.

To accomplish that, we assessed the impact of a 5 measures package implemented by the German College of Porto (Portugal):

1. Carpooling;
2. Park and Stride;
3. School Route Map;
4. Safe Parking Banners;
5. Tree of Life Contest.

These measures were selected by the school from a set of soft measures presented to them at the beginning of this study (for more details see chapter 3) and were implemented between the 2nd and 31th of May, 2016.

2 State of the art

2.1 Framework

The School Mobility Management can be implemented at different scales and scopes, ranging from a single measure for a single school to a measures package for all the schools in a city, region or even in a whole country (KonSULT, 2014).

The initiative can come from the authorities (local, regional, national, etc.), from schools or even from teachers or parent associations, being common and desirable the integration of the whole school community in the process of defining and implementing the measures (KonSULT, 2014).

There is a wide range of mobility management measures implemented mainly in North America (USA and Canada) and Western Europe (mainly in the United Kingdom, Germany, the Netherlands, Belgium and Austria) (Cairns, *et al.*, 2004; Hinckson, *et al.*, 2011; KonSULT, 2014; McDonald, *et al.*, 2013).

In terms of specific measures, the measures implemented in the school will be highlighted in more detail next.

2.2 Carpooling

According to Arbour-Nicitopoulos *et al.* (2012), in the context of home/school trips, carpooling can be defined as "a parent/caregiver using their car to drive a child(ren) from their own household and a child(ren) from one or more other households to/from school". This measure aims to optimize the car use by increasing its occupancy rate, eliminating trips and allowing gains in terms of environmental impact as well as in the students' own safety by reducing traffic around the school.

Arbour-Nicitopoulos *et al.* (2012) explored the use of carpooling in schools in the Toronto and Hamilton areas, where they interviewed 1001 parents about their school mobility options, noting that only 1.7% used carpooling, although 33.8% used the car as the mode of school transportation. However, 25% of them had participated at least once in carpooling schemes with friends or neighbours. These authors concluded that this is an underutilized measure and that it should be promoted among the parents who use the car.

In the United Kingdom, this measure is common across the country with, for example, the websites of Devon, Durham and Luton counties having dedicated webpages on how to implement and promote this measure in a school (Devon County Council, n/d; Durham County Council, n/d; Luton Borough Council, 2016).

Another example is the Safe Routes to School (SRTS)[1] program in which carpooling is one of the incentivised measures (Safe Routes to School Online Guide, 2015). For example, in Marin County, California, the assessment of the program's implementation, conducted between 2000 and 2002 in 15 schools and involving 4665 students, revealed a 91% increase in carpooling and a 39% decrease in the number of children arriving

[1] The SRTS is an American program created in 2005 that aims to enable and encourage children to walk and bicycle to school and to make these transportation alternatives safer and more appealing. In 2010, it was implemented in all the 50 states, covering more than 10 400 schools across the country (McDonald, *et al.*, 2013; National Center for Safe Routes to School, 2011).

by private car carrying only one student (Staunton, *et al.*, 2003). Several of the largest US metropolitan areas have programs that assist in the formation of carpools, having recently been adapted to include school trips. For example, the SchoolPool program is a service that matches parents with pupils attending the same school so they can organize carpools, or walk or bike together (Safe Routes to School Online Guide, 2015).

2.3 Park and stride

The park and stride scheme (or park and walk), inspired by the park and ride, consists in parking the car carrying children to school at 5 or 10 minutes away from it, making the remaining journey on foot. It is therefore a measure suitable for parents and students who live too far from school to do the whole trip on foot. This type of measure helps reducing traffic around the school gate and encourages active mobility (Safe Routes to School Online Guide, 2015; Walk to School Living Streets, n/d).

Several schools in the UK are currently operating this type of scheme successfully, many of which are supported and promoted by associations such as Living Streets[2] . It is one of the most popular initiatives because of the limited amount of work required for its implementation, compared with some of the other initiatives to encourage walking, with application examples in the cities of Durham and Brighton-Hove (Brighton & Hove City Council, n/d; Durham County Council, n/d; Walk to School Living Streets, n/d).

It is also important to highlight that this is one of the measures presented in the American program SRTS, having a special emphasis on its website (Safe Routes to School Online Guide, 2015).

2.4 School Route Map

A school route map consists on developing and disseminating a map containing the most accessible and convenient routes for walking and cycling to and from school, as well as the areas to avoid due to high traffic volume or lack of pedestrian infrastructures. The justification for this measure relates to the fact that one of the major barriers for students to walk or to bike to school is the perception of unsafety due to car traffic near the school premises. By defining the routes with the best conditions for this type of mobility, there is a reduction of the associated risk, with an increase in the number of students walking or cycling (National Center for Safe Routes to School, n/d) (Safe Routes to School Online Guide, 2015).

This measure is recommended by the SRTS (USA), which advises that the map should be defined by the school and the local traffic officials, and contain the streets

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[2] Non-profit organization financed by the British Government, responsible for the dissemination of sustainable mobility measures (Living Streets, 2016).

around the school, the school itself, the traffic control devices, pedestrian routes and crosswalks (National Center for Safe Routes to School, n/d; Safe Routes to School Online Guide, 2015).

2.5 Safe Parking Banners

One of the problems common to many schools relates to parents parking illegally near its perimeter, endangering students' safety. One way to raise awareness about this problem is by placing banners warning about the dangers in parking unsafely and inconsiderately outside the school gate (Buckinghamshire County Council, 2016). Although this measure does not directly promote an increase in sustainable mobility, by reducing the sense of insecurity perceived by the school community, the use of more sustainable transportation modes like walking and cycling becomes more attractive.

The banners work in a 3-colour system, with each subsequent colour having a stronger message (Buckinghamshire County Council, 2016):

- Green – "If you care about children's safety, don't park here"
- Yellow – "Parking here is selfish and dangerous"
- Red – "What part of SCHOOL – KEEP CLEAR don't you understand?"

Schools should start the campaign with the green banner and, if it has no effect, they should replace it with the yellow banner, until reaching the red one (Buckinghamshire County Council, 2016).

Regarding practical application cases the UK stands out, with examples from the city of Brighton & Hove and from the Buckinghamshire county (Brighton & Hove City Council, n/d; Buckinghamshire County Council, 2016).

2.6 Tree of Life Contest

The Tree of Life is a contest that allows a visual representation of how sustainable the school trips are. Over a period of time, students are asked how they travelled to school. On the day of the survey, each student receives a leaf shaped paper to colour in (Luton Borough Council, 2010):

- If they have walked or cycled they colour it is dark green;
- If they travelled by public transport or used a park and stride scheme, they colour it light green;
- If they shared their car with other students (carpooling), they colour it yellow;
- If they travelled by individual car, they colour it brown.

The students then glue the leaves in a tree-like structure. At the end of the period, the greener the tree, the "healthier" it is, thus instilling the cause/effect relation between the modes of transportation and the environment. The idea is that throughout the contest students will change their mobility patterns according to the tree's "health" (Luton Borough Council, 2010).

There are several options on how to implement this concept: from a large tree in the school hall to all students and a dedicated meeting once a month/quarter to discuss the tree's health; a tree for each school year in the hall to encourage competitiveness between each year; or even one tree per classroom, introducing a competitive element between the classes, in which the most sustainable one receives a prize (that will serve as an additional incentive for behaviour change) (Luton Borough Council, 2010).

In terms of application, this measure is part of the Luton's school travel plan (UK), suffering from a lack of available information on implementation results. However, there are several other types of contests with the same purpose as the Tree of Life (i.e., increasing sustainable mobility among students) with positive results, for example the Traffic Snake Game[3] showed an increase between 8 and 14% in the sustainable trips (Canters, *et al.*, 2010; Intelligent Energy Europe, 2011; Mobiel 21, n/d), so it is expected that the contest impacts will be similar.

3 Methodology

The methodology contemplated the implementation of 5 soft measures of school mobility management at the German College of Porto (see previous points), and the evaluation of its effects in the school community mobility patterns, specifically the students and their parents responsible for their transportation.

Data collection was conducted through two types of instruments - surveys on student mobility and in-situ measurements on traffic conditions during the students' main entry and exit times - and in two periods: before and at the end of the implementation of the mobility management measures.

3.1 The German College of Porto

The German College of Porto (*Deutsche Schule zu Porto*) is a private educational institution founded in 1901 (Figure 1), currently having 116 employees and 652 students. The students are divided by (according to the Portuguese education system):

- Pre-primary education (covering children until 5 years old) with 151 students;
- 1º cycle of basic education (4 years of schooling) with 181 students;

[3] Competition created to encourage sustainable trips to and from school. Throughout the game's duration, students place small individual stickers on a larger class dot each time they travel to school in a sustainable way. Once the class dot has been filled, it is then attached to the Traffic Snake Game banner, with the students winning prizes (Canters, *et al.*, 2010; KonSULT, 2014).

- 2º cycle of basic education (2 years of schooling) with 82 students;
- 3º cycle of basic education (3 years of schooling) with 135 students;
- Secondary education (3 years of schooling) with 103 students.

Figure 1. German College of Porto facilities.

The college is located in Porto (Portugal's 2nd largest city) in the *Guerra Junqueiro* Street (Figure 2). The street is approximately 700 meters long and connects *Campo Alegre* Street to *Boavista* Avenue (two major city arteries). It is a one-way street (South - North) inserted in an urban area and is characterized by having two traffic lanes and longitudinal parking on both sides (Ferreira and Carvalho, 2015). Another street of interest for the present study is the *António Nobre* Street that intersects the *Guerra Junqueiro* Street near the school, being therefore an important source of school traffic.

Figure 2. Location of the German College of Porto in the city of Porto (Google Maps, 2016).

The German College also suffers from the same mobility problems mentioned above, with much of the school community using the individual car as their mode of transport.

In this sense, in 2015, the Porto City Council conducted an analysis of the *Guerra Junqueiro* Street. After the diagnosis of the existing situation, the Porto City Council proposed an integrated solution to the problem, which considered 2 types of measures:

1. Implementation of structural measures for traffic management and signalling, namely:
    a. Enhancement of the school zone traffic signs;
    b. Installation of bollards near the crosswalks and intersections;
    c. Creation of student drop-off and pick-up zones near the schools.
2. Awareness-raising measures to be implemented by the schools.

This latter type of measures were the focus of this article, specifically with the pilot project implemented in the German School of Porto.

It should be noted that the structural interventions in the *Guerra Junqueiro* Street carried out by the Porto City Council coincided with the analysis period of this study. As such, they may have had effects on the impact analysis results of the measures implemented in the German College of Porto, especially regarding the in-situ measurements (since the structural interventions aimed at changing the traffic behaviour).

3.2 Implementation of the mobility management measures

Based on the existing literature, a list of school mobility management measures was presented to the school, who then selected 5 to be implemented:

1. Carpooling;
2. Park and Stride;
3. School Route Map;
4. Safe Parking Banners;
5. Tree of Life Contest.

The official period in which the measures were implemented took place between 2 and 31 of May 2016. Table 1 briefly describes the main implementation stages.

Table 1. Summary of each measure implementation.

Measure	Main stages	Date
Carpooling[4]	Promotion (guide sent via email to the parents).	April 15th
	Discovering potential users (through a survey).	15 to 21 April

Measure	Main stages	Date
Park and Stride	Identification of parking areas within 1 km of the school.	11 to 15 April
	Mapping the identified areas (with the distances and pedestrian routes to school).	16 to 27 April
	Promotion (the map and a guide were sent to the parents).	May 2nd
School Route Map[5]	Organization of the groups (consisting of 11th grade students and teachers).	11 to 15 April
	Assessment of the school surroundings in order to identify the school walking routes.	19th, 20th and 23rd May
Safe Parking Banners	Creating the banners.	11 to 28 April
	Display of the 1st Banner (Yellow) at the school gate.	April 29th
	Displaying the 2nd Banner (Orange[6]) at the school gate.	May 9th
	Duplication of the 2nd Banner with a version in German.	May 16th
Tree of Life Contest	Definition of the contest rules (by classes with 472 students participating, survey of students once a week).	21 to 27 April
	Informing the teachers and providing the necessary materials.	May 2nd
	Contest (and display of the trees in the school atrium to identify the most sustainable).	2 to 31 May

3.3 School mobility surveys

In order to assess any changes in the student's mobility patterns, two online surveys were carried out, before and at the end of the implementation of the mobility management measures referred above.

The surveys were made available to the parents through email and was requested that the parents needed to answer the surveys together with their children, therefore the target population was the school students (652 students) and their parents.

3.3.1 Pre-implementation survey

The first survey was conducted between 8 and 29 of March 2016 and contained 13 questions. These were divided into 3 sections:

1. Sample characteristics, such as students' age and education cycles, municipality of residence and an estimated home/school distance;
2. Sample behaviour: student's school entrance and exit times;

4 It was not possible to fulfil the original plan that consisted in proposing carpool circuits to the potential users.

5 It was not possible to develop the map and spread it through the community. However, the map developed in the park and stride measure fulfils part of the objectives as it indicates the pedestrian routes between the parking areas and the college, as well as the area cartography, like sidewalks, crosswalks and existing traffic signals.

6 We chose to use a yellow, orange and red colour system instead of the original (green, yellow, red) mentioned above, since the green colour could had send the wrong message as it is normally associated with something positive.

3. Modal choice, with the respondents who selected the car as their main transportation mode also being questioned about sharing it.

3.3.2 Post-implementation survey

The second survey was conducted between 19 and 31 of May 2016, and contained 25 questions, divided into 3 sections.

The first and second sections were a repetition of the first survey in order to assess the behaviour change in a global way and contained 9 questions.

The third section aimed at assessing the impact of the mobility management measures implemented in changing modal behaviours. Firstly, we assessed the dissemination level of each measure among the respondents, then, and for the respondents who stated that they had had knowledge of the measures, the perceived impact itself (on a scale of 0 to 5, where 0 means that they were not influenced at all and 5 that they were greatly influenced).

3.4 In situ measurements

One of the ways to evaluate the measures' effects in terms of modal change is by observing the traffic behaviour near the school. To this end, we defined two periods of in-situ measurements: one before the implementation of the mobility management measures and another at the end of their implementation.

3.4.1 Pre-implementation measurements

In order to evaluate the car traffic near the school, on-site measurements were carried out on March 8th 2016, which were divided into 3 groups.

The first measurement group consisted in counting the number of cars who dropped off and/or picked up students, covering the beginning of *Guerra Junqueiro* Street up to the intersection with *Dr. José de Figueiredo* Street, as well as the *António Nobre* Street.

The second group focused on traffic counts from *Guerra Junqueiro* and *António Nobre* streets.

Finally, we proceeded to assess the transit queues by counting the number of vehicles existing in each section every two minutes. The sections analysed consisted in the beginning of *Guerra Junqueiro* Street up to the intersection with *Dr. José de Figueiredo* Street, as well as the *António Nobre* Street.

The periods of analysis were 3 and covered the periods of more traffic near the German College, which were identified by the school itself and reinforced by the mobility survey results, with each period of analysis lasting 30 minutes:

- Morning period, between 8:00 a.m. and 8:30 a.m.;
- Lunch period, between 1:15 p.m. and 1:45 p.m.;
- Afternoon period between 3:50 p.m. and 4:20 p.m.

Figure 3 shows the areas covered by the in-situ measurements.

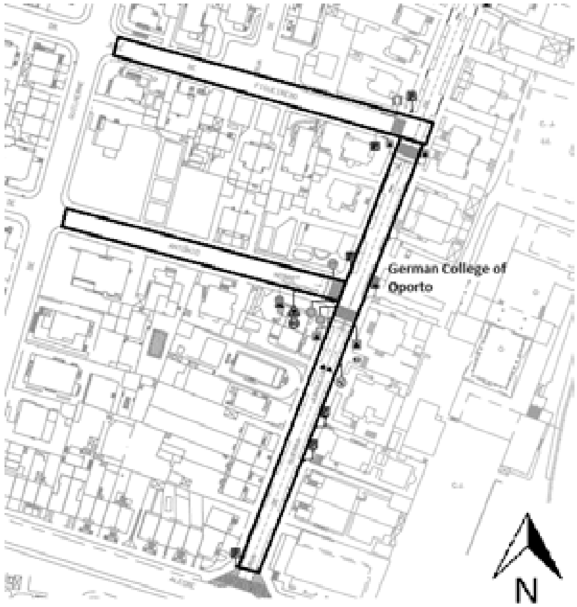

Figure 3. Areas covered by the in-situ measurements (Scale 1: 1000).

3.4.2 Post-implementation measurements

The in-situ measurements at the end of the measures' implementation were carried out on May 17th.

Regarding the park and stride areas we identified 3 parking areas (Figure 4) in which we monitor the number of vehicles that parked in the designated areas carrying students from the German College.

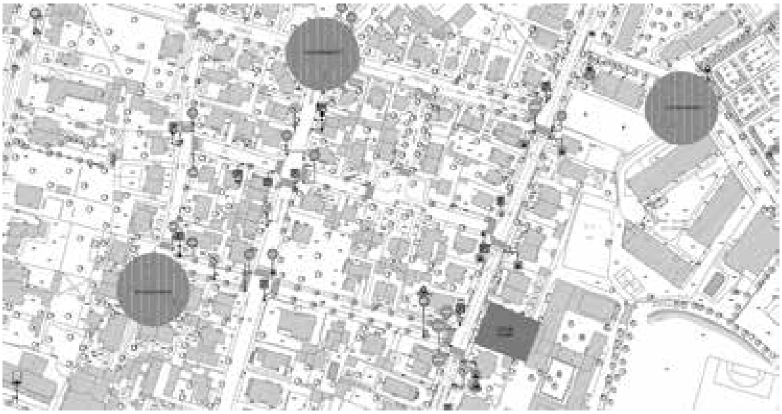

Figure 4. Parking areas proposed to the parents (circles) near the German College (rectangle).

4 Impact assessment of the measures package

To evaluate the behaviour of the target population the results were divided into two sub-chapters:

- Results that reveal the behaviour of the target population (revealed preference), which were obtained by comparing the surveys carried out before and at the end of the measures' implementation and the in-situ measurements carried out near the school;
- Results that reflect the respondents' opinions on how they were influenced (stated preference), which are obtained through questioning the respondents about their perception in relation to the implemented mobility management measures (second survey).

4.1 Revealed preference

4.1.1 Comparison between the school mobility surveys

As mentioned earlier, two surveys were conducted (one before and one at the end of the implementation of the mobility management measures) in order to assess possible changes in the students' mobility patterns.

In the first survey we obtained 285 responses in a universe of 652 students, which shows a response rate of 43.7%. In the second survey, 145 answers were obtained in a universe of 652 students, leading to a response rate of 22.2%[7].

Regarding the sample characteristics, Figure 5 represents the distribution of the respondents by the several educational cycles of the German College obtained in the first and second surveys.

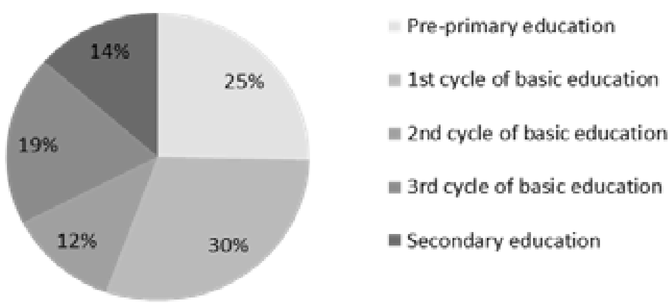

Figure 5. Distribution by educational cycles (average of the two surveys, N=430).

[7] The drop in the response rate may be related to the respondents' saturation as they received several emails about the project. In this sense, it should be noted that the changes that occurred might result from sample biases and not in fact behavioural changes due to the implemented measures.

We can see that the individuals are divided mainly between pre-primary education and the 1st cycle of education (55%), which implies that this is the group with fewer mobility options available due to the inherent age limitations. On the opposite side, we have the cycles of education referring to older students with more mobility options.

Figure 6 shows the home/school distances. We can observe that due to the considerable home/school distances verified for most students, walking on the whole trip is quite limited (we cannot expect the students to walk more than 1 km on each trip), leading to the fact that, and with regard to sustainable mobility, cycling, public transportation, school transportation, or other modes such as carpooling or park and stride, are potentially more suitable for the majority of the respondents (87%).

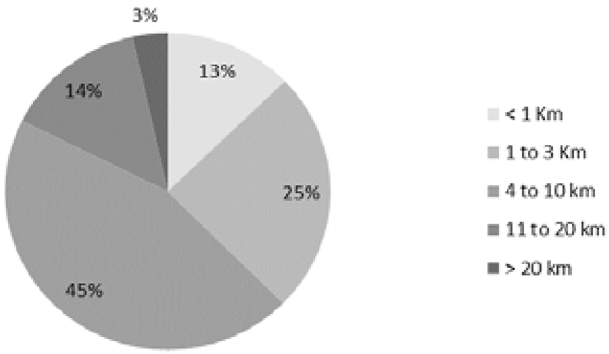

Figure 6. Home/school distances (average of the two surveys, N=430).

The main modes of transportation used by students on the home/school trips are shown in Figure 7, divided between the car and more sustainable modes (walking, cycling and public transport).

The results show an overwhelming dominance of the car (close to 90%). Pedestrian trips are reduced, as well as the demand for public transport that is residual, despite the offer of bus lines in the area (this may be related to the social stratum who attends a private school).

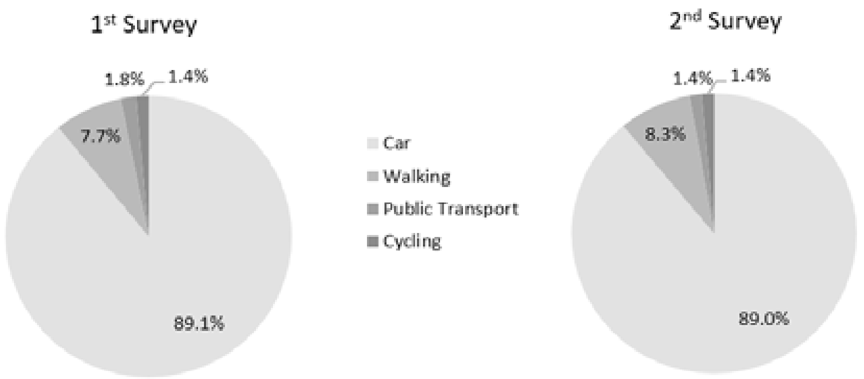

Figure 7. Modal distribution: 1st survey on the left (N = 285), 2nd survey on the right (N = 145).

Comparing the results before and at the end of the measures implementation, we can note that the modal shift was residual, with a slight decrease in car use (0.1%) and a 0.6% increase in walking, however this was minimized by the loss of public transport modal share. Regarding the cycling modal share, its residual value is expected since the area surrounding the school presents a lack of cycling infrastructure such as bike lanes to encourage bicycling.

Thus, broadly speaking, sustainable modes of transport represented 10.9% of the modal choice in the 1st survey versus 11% in the 2nd survey.

Additionally, we analysed the relation between the home/school distances and the modes of transportation used (Figure 8 and Figure 9).

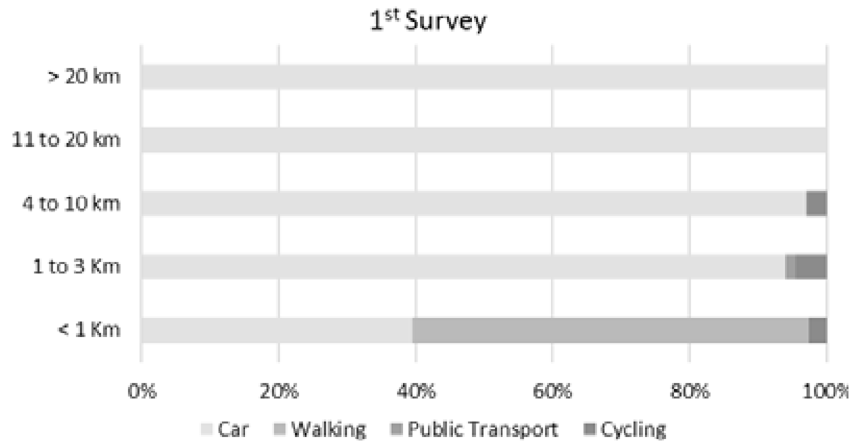

Figure 8. Relation between home/school distances and mode of transportation, 1st survey (N= 285).

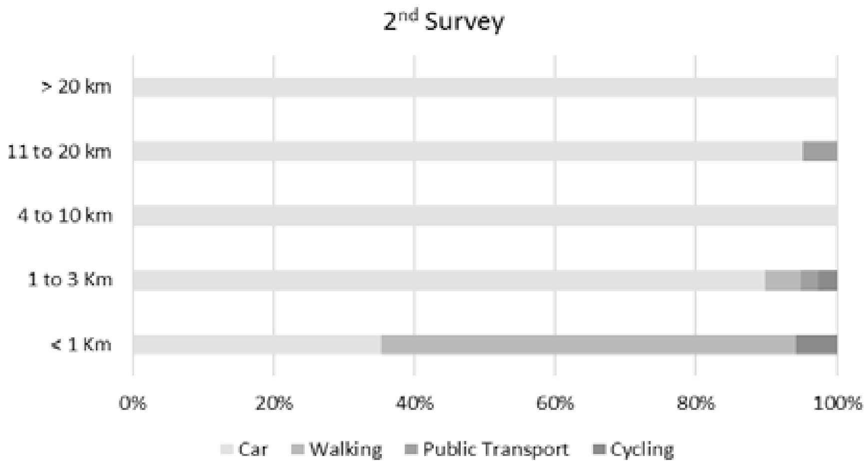

Figure 9. Relation between home/school distances and mode of transportation, 2nd survey (N=145).

Comparing the figures above, we find that for distances up to 1 km car use has decreased nearly 5%, with an increase in the walking and cycling modes. For the distances between 1 and 3 km, there was also a slight decrease (4%) in the use of the car.

For the remaining distances, the almost exclusive dominance of the car has remained (although the use of public transport over distances between 11 and 20 km has appeared, these 5% represent only 1 respondent).

Another way to minimize the car's environmental impacts is by sharing it with others, in order to eliminate the need for additional trips. Figure 10 shows the percentage of students who share the car with people that also have the German College of Porto as destination (colleagues, parents or siblings).

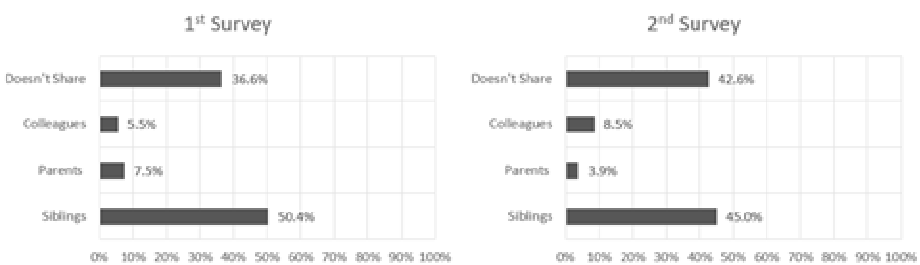

Figure 10. Percentage of students who share the car (with colleagues, parents or siblings that have the German College as the destination): 1st survey on the left (N=254) and 2nd survey on the right (N=129).

The figure above shows that most of the people with whom the occupant shares the car (having the same destination) are siblings (50.4% in the 1st survey and 45% in the 2nd survey).

We can also infer the percentage of respondents who use carpooling, corresponding to those who share the car with colleagues, in this way, we observed an increase in its use from 5.5% to 8.5% (in the universe of students who use the car).

4.1.2 In situ measurements

As already mentioned, a series of in-situ measurements were carried out before and at the end of the measures implementation period in order to evaluate changes in the traffic behaviour near the school.

Figure 11 shows the variation on the number of vehicles that dropped off and/or picked up students between the two measurement periods for each street and the two streets total.

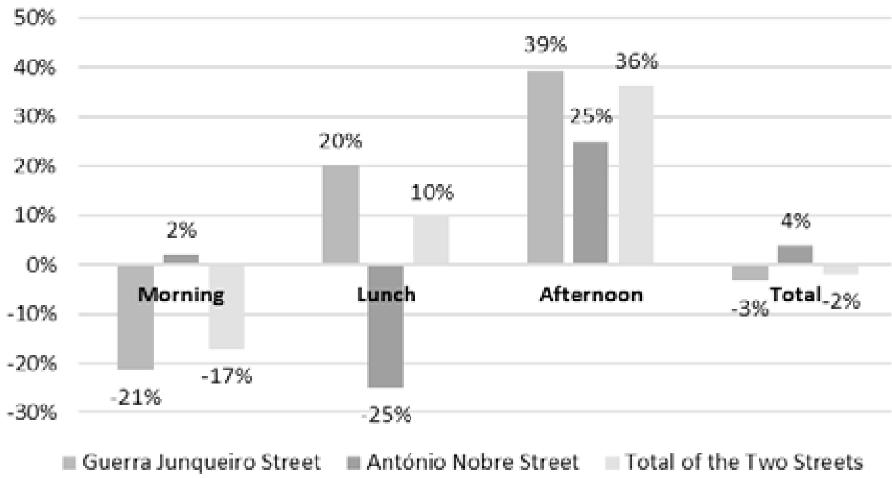

Figure 11. Variation on the number of vehicles who dropped off and/or picked up students between the two measurement periods (Note: the variation relates to the total number of vehicles in each street).

We can notice a decrease in the number of vehicles who dropped off and/or picked up students in the *Guerra Junqueiro* Street, precisely in the morning period with a 21% reduction, however this reduction is counterbalanced by an increase in both streets in the afternoon period, leading to only a 2% overall decrease.

This vehicle decrease, especially in the morning, may be related to the structural interventions carried out by the Porto City Council aimed at managing the traffic flow, making more difficult to park near the school (especially the bollards placed near the crosswalks and intersections).

As previously mentioned, home/school trips can represent a considerable percentage of the rush hour traffic. In this context, Figure 12 shows the traffic percentage that had the German College as destination (vehicles that dropped off and/or picked up students divided by the total number of existing vehicles on the street) before and at the end of the measures' implementation.

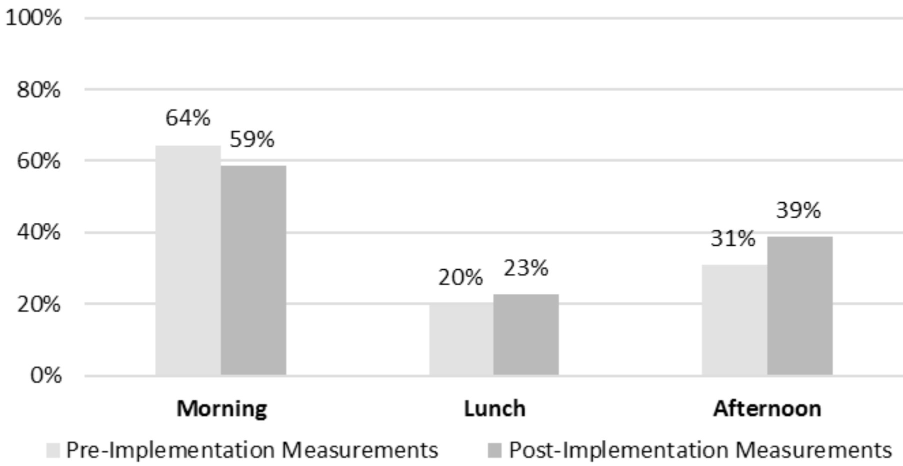

Figure 12. Percentage of the existing traffic that had the German College as destination.

Analysing the figure above, we can see that in the morning period most of the traffic in *Guerra Junqueiro* Street (64% in the pre-implementation and 59% in the post-implementation measurements) had as destination the German College, leading to the inference that home/school trips play indeed an important role in the traffic behaviour. In the lunch and afternoon periods this percentage was much smaller, in line with the fact that in those periods there was a lower turnout of vehicles dropping off and/or picking up students.

Regarding the variation between the two measurements, there was a 5% reduction in the vehicle percentage in the morning period, but there was also an increase in the remaining periods, especially in the afternoon, with an 8% increase.

Regarding traffic queues, Figure 13 shows the variation in the average number of queued vehicles before and at the end of the measures' implementation.

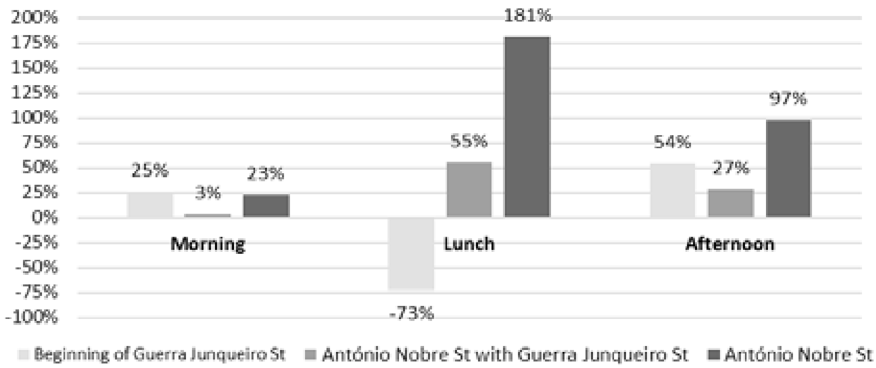

Figure 13. Variation of the transit queues size before and at the end of the measures implementation.

With the exception of the lunchtime at the beginning of *Guerra Junqueiro* Street, there was a generalized increase in the number of queue vehicles, especially in *António Nobre* Street.

This increase can be explained by the structural measures implemented, especially the bollards placed near the crosswalks and intersections, which makes changing lanes harder. Bearing in mind the fact that a significant number of vehicles that stop at the school do so in the parking bay and in the right lane, this leads to more traffic jams.

Finally, the last measurement consisted in monitoring the 3 parking areas recommended for park and stride (with the measurement taking place on May 17th). Taking into account the large number of students using the car, there was a poor adherence to the indicated parking areas, with only 4 users.

4.2 Stated preference

4.2.1 Dissemination degree of the measures

For each measure, we inquired whether the student (and/or the parent) was aware of each measure implementation, the results of which are expressed in Figure 14 and Figure 15.

Figure 14. Respondents percentage who reported being aware or not of the carpooling, park and stride and Tree of Life contest implementation (N=145).

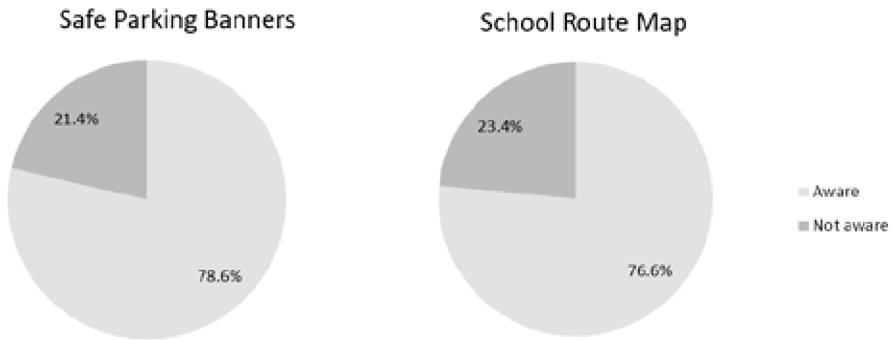

Figure 15. Respondents percentage who reported being aware or not of the safe parking banners and the school route map implementation (N=145).

From the figures above, we can see that for all the measures, more than half of the respondents were aware of their implementation, reaching levels above 90% in carpooling and park and stride.

The measure with a lower level of awareness turned out to be the Tree of Life contest (64.8%), which indicates that some parents gave their opinion in the survey instead of the children, since, with the exception of the 12th grade students, every school year participated in the contest (and thus were aware of the measure). Another lesson that can be drawn is that the students themselves were not excited enough with the contest to share it with their parents, resulting in the low awareness level measured in the survey.

Finally, given that the school route map, as mentioned in the previous chapter, turned out to not be disseminated in the school, with only a small group of students having knowledge of it, it is surprising the measure's high awareness level (with 76.6% claiming to be aware). This can be explained with a possible confusion with the park and stride measure, since this involved sending a map with parking areas and walking routes from them to the school.

4.2.2 Influence perception of the measures on mobility patterns

For the respondents who stated that were aware of the measures, they were asked to declare on a scale from 0 to 5 how much each measure had influenced their mobility patterns. The results are presented in Figure 16.

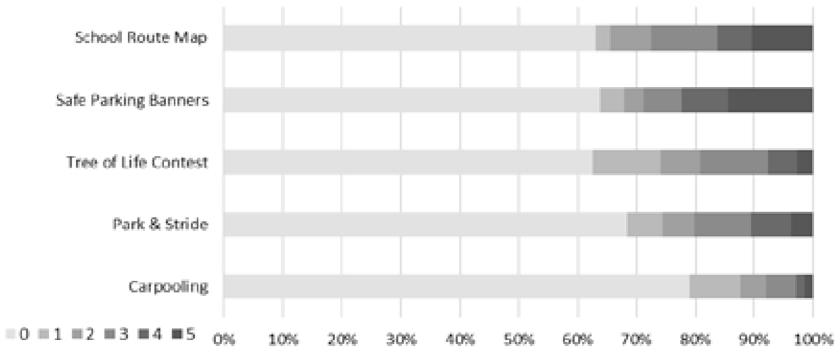

Figure 16. Influence of each measure on the respondents' mobility patterns on a scale from 0 to 5.

The Figure 16 analysis makes it possible to ascertain immediately that all measures had little impact, with more than 60% of respondents stating that they did not felt influenced at all by any of the measures.

The measure with the most impact turned out to be the safe parking banners, with 14% of the respondents choosing the highest level on the scale. That can be explained by this being one of the measures more visible for the parents as it is located near the school gate, and as there are indications that part of the answers had the parents' opinion instead of the students this caused the measure to stand out.

On the opposite side, we have carpooling, with 79% of respondents saying that it had no influence on their mobility patterns. This can be explained by the fact that the measure was not entirely implemented, compromising its effectiveness, since initially the idea would be to form carpool circuits.

Regarding the other measures, the Tree of Life contest results were disappointing, with only 3% of those surveyed stating that the measure had a significant impact on their mobility patterns and with 63% saying that they felt no influence at all. Possible reasons for this poor performance relates to, as already mentioned, some of the parents giving their opinion instead of the children, and also by the fact that in many of the classes the students have only pointed out once how they travelled to school, which means that they did not had the opportunity to see the tree's "health" evolving as a consequence of their mobility choices. Furthermore, this contest, contrary to other similar competitions studied in the literature, did not use prizes as an incentive factor which may also have had a role in the low awareness generated by it.

Finally, we also specifically questioned what kind of impacts were perceived. Starting with carpooling, 21.2% of the respondents indicated that they had started considering carpooling, with also 10.2% stating that they were already carpooling before the promotion of the measure. These results indicate that if the measure had effectively been fully implemented, the results could have been better. In concrete terms of adherence only 2.2% of the respondents stated they started to participate in a carpool scheme. Moving to the park and stride measure, 10.6% stated that they would consider parking in the indicated areas and 15.9% reported using the indicated areas. Finally, in relation to the Tree of Life contest, only 11.6% of the respondents stated that they have started to use more sustainable modes of transport in result of the contest.

5 Conclusions

Regarding the main objective of increasing the sustainability of the student community mobility, the comparison between the surveys carried out before and at the end of the measures' implementation showed that the modal shift was residual, with only a 0.1% increase in the use of sustainable modes of transport, representing only 11% of the modal split. In addition to the more usual sustainable modes of transport, another way of minimizing the environmental impact is carpooling, in which we observed a 3% increase within the universe of students using the car.

Specifically, the respondents' own perception of each measure's influence on their mobility patterns was also evaluated, in which the safe parking banners turned to be the measure with a greater perceived impact, possibly due to being exposed near the school gates causing a greater visual impact. It is important to remember that this measure is not intended to encourage more sustainable modal choices, but merely aimed at alerting drivers about the safety problems associated with abusive parking. Therefore, this measure was not expected to cause changes in the modal choice, only to change the parents' behaviour when dropping their children at school.

One of the justifications for the low impact on the students' mobility is explained by the relatively short period in which the measures were in place and by the difficulty in fulfilling all the implementation plans, compromising the measures' effectiveness. It may also be relevant to note the lack of a clear objective guiding the measures selected in this package. In fact, the measures have very different goals (modal shift to more sustainable modes, car use reduction, safety, health) limiting the ability to complement each other and to generate synergistic effects. In addition, there is also evidence that in the surveys some parents provided their opinion instead of the children, partially distorting the results.

Given the difficulty in causing a significant change in the mobility patterns in the short-term, another way is to raise awareness about the problem in order to influence modal changes in the medium/long term. In this sense, in terms of presenting the measures and their importance to the target audience, this was relatively a success since for all the measures more than half of the respondents stated knowing about their promotion, even surpassing 90% in some cases (carpooling and park and stride).

Finally, the research results suggest that the initiative for the implementation of this type of measures has to pass through the schools since they are effectively the ones with more chances of influencing the students' mobility patterns, nevertheless they should be supported by specialized entities when preparing their school mobility plans (through technical and financial support). In addition, the very implementation of a large number of mobility management measures implied a great mobilization of human resources that was a hindrance. *A posteriori* this leads to, and given that for many of the measures it was not possible to fully comply with the original plans, the option for a smaller number of measures and with complementary objectives could have had better operational results.

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The governmentality of urban land in tropical climates: addressing the root causes of socioecological conflict

José Barbedo

CEAU - Center for Studies in Architecture and Urbanism / FAUP - Faculty of Architecture of the University of Porto

jbarbedo@arq.up.pt

This study questions why issues of urban land supply are not being properly considered in the design of policies of adaptation to climate change, particularly in territories where fast urban growth is at the root of socioecological conflicts and related climate vulnerabilities. The paper theoretically explores the Foucaultian concept of governmentality in discussing how urban land demand and supply chains are subject to the influence of economic, political and societal logics of production of the urban space. The analytical framework used in the study departures from a micro analysis of urban politics and land-use change dynamics at the local scale, in order to discuss core elements of state practices, economic interests and social demands that altogether condition the actual distribution and reproduction of climate-related risks. The paper concludes that there is no way of talking about human adaptation to global warming without an effective policy capable of assuring the necessary flows of urban land for the poor in fast-growing cities of tropical regions, as well as effectively safeguarding important life-support systems on which the climate resilience of urban communities depends.

Keywords: Governmentality; adaptation; socioecological conflict; urban resilience; climate vulnerability.

1 Introduction

While the consequences of global warming are particularly alarming in tropical climates, many countries located in the megathermal coastal zone signed political compromises to develop climate change adaptation and mitigation policies. Among these, Brazil joined the coalition of countries seeking ambitious goals at the Paris Climate Conference (COP 21), but the crucial question of how to operationalize adaptation in matters of spatial planning remains largely unanswered. The dilemma lies between the need to adjust the systems of production of the urban space, and the lack of political will to rethink fundamental questions of urban land reform in the context of climate change. This disconnect evinces the gap between normative and practical realities, while socioecological conflicts are continuously reproduced at a fast pace. As a primary step to address this gordian knot of climate policy, this study displaces the axis of discussion on global risks to old problems of environmental justice, focusing on the problems of access to urban land by the poor. These problems are particularly visible where the concentration of land resources in large holdings remains a structural characteristic inherited from patrimonialism. Brazil for example, is characterized by very contrasting realities between land abundance and land scarcity in the same geographical space, while historically the poor never had access to land for housing in adequate locations (Baldez, 2003). Central to this debate is the concept of "urban environment transition" (McGranahan *et al.*, 2001), referring to the underpinning problems that arise from rapid urban growth. Within this wider context of change, the lack of access to urban land by the poor can be described as an "adaptation deficit" (Burton, 2004; Burton and May, 2004; Quan and Dyer, 2008; Parry *et al.,* 2009), which leads to a higher exposure to natural hazards.

A clear sign of the contradictions concerning the commitment of the Brazilian government to establish adaptation measures is that the policy areas of natural disasters and cities have been excluded from the National Policy on Climate Change as originally defined by Government decision in 2009. Another example of the lack of commitment with previously established international agreements is the discontinuation by the Secretariat of Strategic Affairs of a major study on the expected impacts of climate change on Brazil, called "Brazil 2040"- this study aimed to assess possible impacts of climate change on water resources, power generation, agriculture, health, and infrastructure. After the first commitments assumed by the Brazilian Government over two decades ago for promoting sustainable patterns of urban growth, these fundamental goals have not yet been solidly linked to national adaptation policies. Indeed, the most difficult policies to be implemented within this broader framework are related to urban land matters, where strong economic interests encapsulate past legacies and ad-hoc arrangements that together shape the dynamics of land-use-change. These forces at play are so ubiquitous in decision-making processes that may explain why land speculation practices are not totally inconvenienced by the State. In between the process of social change, and the pressures exerted by economic forces for the speculation of land markets, the State is permanently tensioned between the growing needs for urban land (at its weakest side) and the imperatives of capital accumulation (at its strongest), lending an ambivalent role to government institutions that affect their own working. Discussions on reflexive governance take account of these unintended consequences (VOß *et al.*, 2006; VOß and Kemp unpublished manuscript), highlighting the endogenous nature of steering political actors (Rip, 2006), ultimately jeopardizing the regulation of key aspects of land governance.

The conflicting interests that contribute to the inaction of the state in key areas of public policy, is claimed to constitute a "governability dilemma" (Bruera, 2013). Governability is often used as a buzzword by mainstream politicians, for explaining why some of the most sensitive issues are set aside from the political agenda. In land matters this dilemma has to do, on one hand, with the domination of economic interests within the conditions imposed on political parties by the mechanics of electoral cycles; and, on the other hand, with the permanent need of the State to ease up social pressures and demands by chasing after the process of illegal occupation of land. However, the notion of governability does not provide satisfactory conceptual tools for envisioning political change. And it does not explain its oxymoron, where the need for establishing political compromises among the various forces contributes itself to the political gridlocks that are meant to be avoided through political negotiation. Moreover, the political and academic discourse on governability may have very sweeping implications on the interpretation of adaptation theories from a conformist standpoint. This standpoint contributes to the belief that the critical problems of urban land that have been chronically set aside have limited scope for practical application.

The present study enlarges the scope of this discussion from the perspective of the Foucaultian concept of governmentality. By exploring the validity of this concept for analyzing critical problems of urban policy, some of the causes that are at the root of hydrological risks are identified, but also the reasons why these causes have been chronically set aside by policy makers. Foucault's notion of political rationality and the concept of governmentality seem particularly useful for explaining these dilemmas, allowing to focus on the procedures, tools, and techniques by which the power relations take place (Foucault, 2007). The concept of governmentality allows to better understand how the State combines, arranges, and fixes existing micro relations of power, which are then codified, consolidated, and institutionalized (Jessop, 2007), highlighting certain rationalities of government institutions (Walters and Haarh, 2005), and its interactions with the logics of economic agents and societal actors.

Departing from these theoretical considerations, the overlapping logics of appropriation and speculation of land resources will be identified in this paper as "the elephant in the room" at the juncture of urban governance and climate policy. Seen from the analytical angle that will be therefore described, the reproduction of socioecological risks is explained as a social construction resulting from a complex warp of political disputes, through which power asymmetries have an imprint on climate vulnerabilities.

2 Methodology

This study seeks an analytical balance between the analysis of physical and sociopolitical aspects discerned between the spatial analysis and the stakeholder analysis. The spatial analysis focuses on land use change dynamics within the territory under study, and is part of a doctoral thesis which involves the hydrological modelling of the water basins where the city of Paraty is located (Barbedo, 2016; Barbedo *et al.*, 2014). Due to the limits and focus of this paper on the politics of land-use change, the results and methods of the hydrodynamic model are not hereby described and its results are only very briefly illustrated, considering 3 of the 44 scenarios modeled for this case-study. The future scenarios consider also climate change impacts considering a rainfall increase of 10% and an increase in mean sea level of 15 cm for the year 2040. The criteria for the adoption of these changes in rainfall and boundary conditions of the basin are based on a regional report of COPPETEC (Rosman, 2015), and the hydrological study was based and developed from the preliminary model of Marins (2013). The analysis of land-use change dynamics in the Municipality of Paraty, consider quantitative and qualitative information about urban growth and land use change within the study territory. Eighteen sample areas were selected, capturing the most significant territorial transformations occurring between 2001 and 2012. The analysis of satellite images collected from the platform Google Earth Pro made it possible to quantify the number of urban operations, the increase of converted areas for commercial and residential use, and the increase in the number of urban clusters.

Qualitative information was based in direct contact with the decision making process in Paraty and by conducting interviews with a wide range of stakeholders. The stakeholder analysis focuses on the internal stakes (i.e. the interests of the actors) that influence and condition land use change dynamics at the micro-level of decision making. Direct observations of deliberation processes, semistructured interviews and focus groups held in the Municipality of Paraty, allowed to identify conflicts of interest regarding land use decisions. Participation of the author in a workgroup for discussing the Master Plan of Paraty between February 2013 and July 2014, yielded a relevant inside perspective on related decision-making processes and highlighted the relevance of the various issues under analysis.

Key actors were interviewed following a snowball approach, starting at public hearings where they were represented. This made it possible to identify stakeholders in the early stages of the research and subsequently to identify a broader range of actors with influence on land-use decisions. A desk-based study of official reports provided inputs for the preparation of the interview questions and broadened the scope of the data collection exercise. A guideline with a set of interview questions addressed the different ways parties perceive how land should be used according to each interviewee, grasping causal relationships regarding dysfunctions and conflicts on land uses. Interviews were semi-structured in order to allow for exploration of other topics that emerged during the course of the questioning. The data collected from interviews were triangulated through focus groups with representatives of the main sectors involved (housing market and construction businesses, tourism industry entities, environmental organizations and technical experts). Interviewing stakeholders and observing deliberation processes enabled to deconstruct to some extent, how individuals, social groups, and political forces exert their influence over land-use decisions. The identification of key constitutive relationships between each group of agents allowed to unfold the actual process side of politics where individual and collective actors interact. In total, 29 semi-structured interviews were held involving a wide range of actors and anonymity was guaranteed to all participants. These actors included three officeholders at the State level, three municipal officers, one former secretary of the environment, two representatives of NGOs, five residents affected by flooding, four real estate developers, two large land owners, four medium-size land owners, three local politicians, and two leaders of local associations. Besides these, many informal conversations were carried out with people interested in urban development, local economy, and urban governance. These people range from professionals of the construction sector to engineers, architects, low grade officers in government offices, petty property brokers, shop owners and traders, construction contractors, members and volunteers of political parties, municipality staff, lower rank police officers and landowners.

The findings of the stakeholder analysis focus on how the various actors operate, whether they are property owners, real-estate agents, construction business professionals or government officials. Particular attention has been paid to the identification of conflicting interests concerning land uses and the actual process side of politics where individual interests and government actors interact. Insights from these narratives helped to pin-point questions for subsequent interviews to government officials and private investors, which proved to be useful for understanding the modes of regulation and de-regulation of real estate and construction businesses. The stories narrated by the interviewees were haphazard and anecdotal, often highlighting the unruly and hidden factors shaping formal and informal processes of land-use change. Observing the distinct and common aspects of these stories allowed to make sense of the various reported episodes, helping to bind the loose threads together and place these in a broader discussion regarding the macro regulatory context of urban policy, unpacking the relationships between formal and informal processes of land-use change.

3 Results

In order to make an analysis of the land-use change dynamics in the Municipality of Paraty, 18 sample areas were selected, capturing the most significant territorial transformations occurring between 2001 and 2012. Figure 1 shows the number of urban operations, the increase of converted areas for commercial and residential use, and the increase in the number of urban clusters.

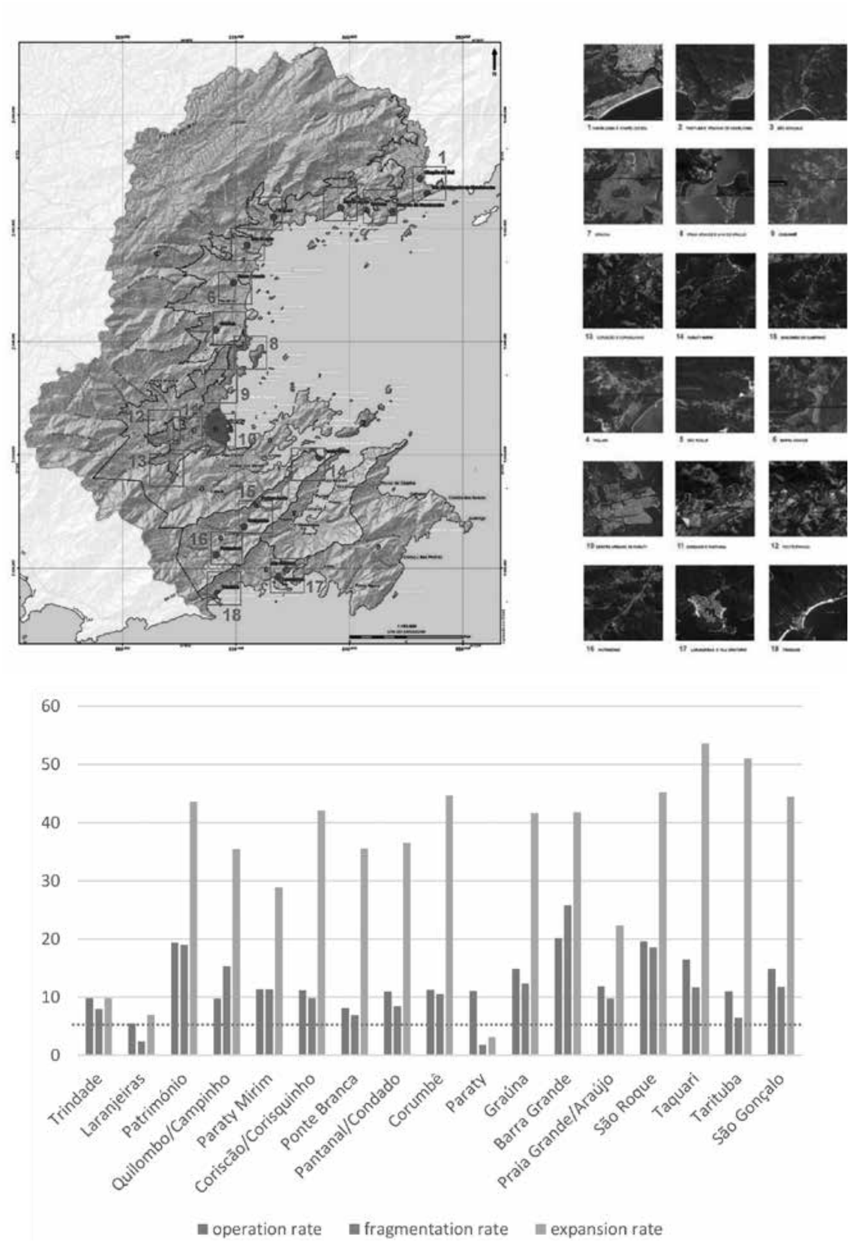

Figure1. Location of the sample areas in the Municipality of Paraty and results of the comparative analysis of the rate of land-use change operations, the number of clusters (fragmentation rate) and expansion rate.

The above figure sums-up the results of the analysis of land-use change in the most populated areas of the Municipality of Paraty. The rates were obtained from calculating the rate of land-use change operations, the number of clusters (fragmentation rate) and an estimate of the expansion rate, all presented in annual percentage of growth. What stands out from this analysis are the low values of expansion rate and fragmentation rate found in the city of Paraty, while the number of urban operations was approximately equal to average values found in other sample areas. This is explained by the size of the original settlement, since the expansion areas are proportionally small compared to the urbanized areas registered in 2001. It is noteworthy that Laranjeiras is the urban settlement that presents expansion and fragmentation values closer to the low rates of Paraty. This may indicate a high level of exclusion in the city of Paraty, although there is still a considerable portion of its area that is not yet developed.

Even without reliable information about land provision and demand, it is clear that present regulations regarding land subdivision within the urban perimeter are not adjusted to the demand and possibilities of low-income groups, where the largest housing deficit exist. The absence of urban policies and land tenure arrangements for the provision of adequate sites at affordable prices results in the emergence of illegal plot divisions and informal housing in upstream areas, which are currently leading to furthering environmental degradation and the aggravation of flood risks. This fragmented pattern of urban expansion in the periphery of Paraty is contributing to the deepening of spatial segregation and social exclusion problems in the municipality, as well as aggravating flood risks in downstream urban areas. Due to the lack of affordable alternatives and the absence of targeted schemes for low cost housing, the poor cannot afford to buy, build, or rent secure housing in safe areas, while lands of higher value are occupied by better-off urban residents. This explains why the city of Paraty presents the lower population increase when comparing to other areas in the municipality. According to Census data from IBGE from 2000 and 2010, the population in the Municipality of Paraty had an increase of 2.44%/year. The Master Plan of Paraty of 2010 (not approved) estimated population values based on population data from 2007 for each Macrozone, as is shown in the table below.

Table 1. Population data for the period 2000-2010.

	ha	MA	2000	2010	2015	2020	2025	2030	2035	%/year
Trindade										
Laranjeiras	1971	MA9	1065	1600	1925	2316	2787	3354	4035	3.77
Património										
Quilombo/Campinho										
Paraty Mirim	5132	MA6	1610	1242	1350	1448	1576	1685	1789	1.20
Coriscão/Corisquinho										
Ponte Branca										
Pantanal/Condado	2412	MA2	3979	7324	9665	12754	16830	22209	29306	5.70
Corumbê										
Paraty	594	MA3	13957	16426	17688	19048	20511	22088	23785	1.49
Graúna										
Barra Grande	4088									
Praia Grande/Araújo	2140									
São Roque		MA1	5497	6636	7229	7875	8579	9345	10181	1.73
Taquari										
Tarituba	1.551									
São Gonçalo										
		MUN.	26108	33228	37486	42290	47709	53823	60720	2.44

Considering the above estimates of population growth, and in order to understand the effects of the possible consequences of different land-use change scenarios on a more detailed level, 44 scenarios of urbanization considering also different climate variables and time periods were modeled in Barbedo (2016).

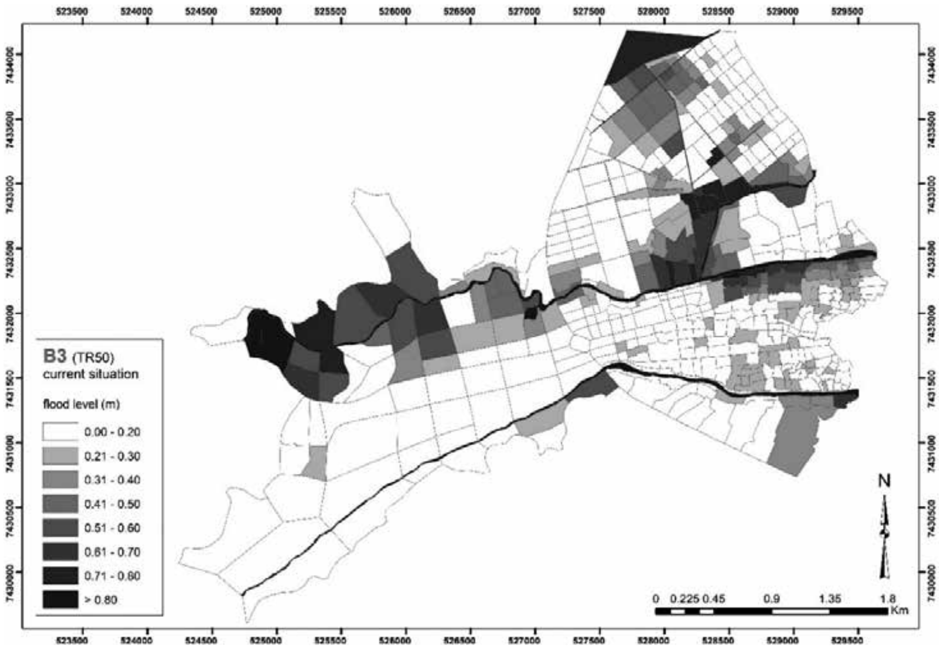

Figure 2. Hydrological map of the current situation.

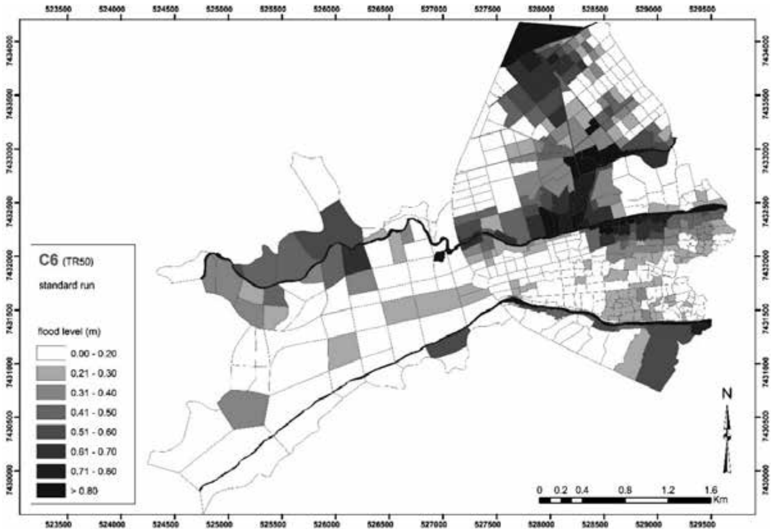

Figure 3. Hydrological map of the standard-run scenario, considering the continuity of the current trend of urban expansion and the aggravation of flooding conditions due to climate change.

Figure 2 represents the present situation and figure 3 shows the impacts of the ongoing urbanization trend. The results of the modeling exercise show in a quantified and localized way that urban expansion into the floodplain will result in increasing flood risks in Paraty.

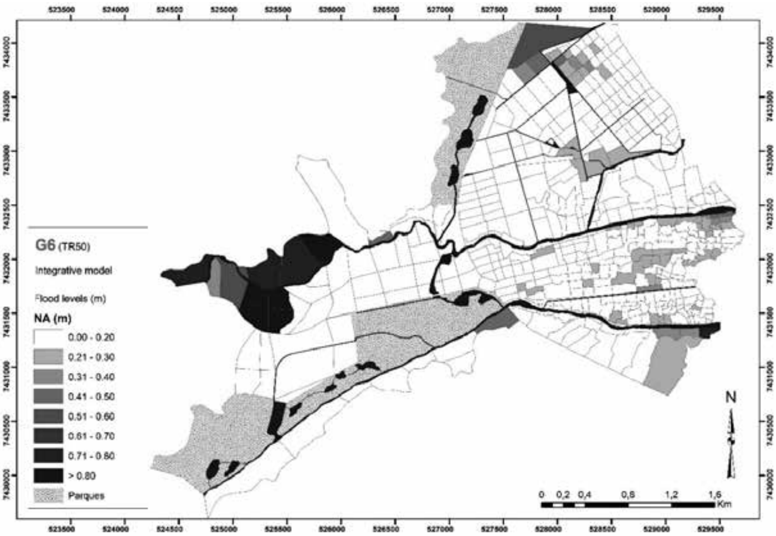

Figure 4. Hydrological map of the integrative scenario, simulating the implementation of a set of preventive measures, combining land-use and hydraulic solutions.

Negative impacts of new urbanizations will not only affect the future residents in these areas, but will also contribute significantly to increased flooding both in depth and extension in the consolidated urban area. This is because the consequent changes in land filling and soil sealing, as well as the reduction of green open spaces in the areas located in upstream regions, will contribute to the diminishment of important water-flow regulation services in the basin, decreasing water retention capacity and increasing the runoff. Figure 4 simulates a blend of preventive measures, combining land-use and hydraulic solutions. The results confirm previous findings (Barbedo et al 2014) that changes in land use are the determining factor in the exposure to flood risks, not only in its probable aggravation (as shown in the middle map) but in the substantial diminishment of these risks if the preventive measures modelled were taken. Testing hypothetical scenarios of urban development showed the benefits of adopting a more concentrated pattern of urban development, as well as the associated costs of urban expansion into upstream reaches of the floodplain. According to these results, while the densification of downstream areas would have a minimal impact on flood risk, the further occupation of the upstream areas along the floodplain will not only lead to the worsening of flood risks in the recently urbanized areas, but will also bring additional pressure to downstream areas, endangering the existing built heritage and generating high costs for hard engineering infrastructure and maintenance services. These findings show the importance of land-use decisions at the local level and how they influence human exposure to flood risks in the future.

The information yielded throughout the field work helped to unfold the mechanisms through which the formal market of urban land is, to a large extent, regulated by the agents operating inside the circuits of transaction between developers, construction companies, and extraction industries. As in many sectors of the Brazilian economy, the construction sector constitutes an oligopoly within a pyramidal structure topped by extractive industries, which in turn have a relationship of dependency with the energy sector (i.e. electrical energy supply and oil industry). The presence of these powerful industries is remarkable in the area of influence of the Municipalities of Paraty. In this case, the regional monopoly of asphalt provision is controlled by the powerful multinational giant Vale Sul (the second biggest mineral extraction company in the world). The formal market of urban land is therefore self-regulated by a powerful lobby where the extraction and energy industry sector play a determinant role in the viability of new urban allotments. The regional monopoly of an indispensable raw material for this type of urban operation makes it possible to set the price of this commodity and related installment services for each land allotment on a case-by case basis. This is a clear example of a non-explicit, but very effective influence on land-use decisions exerted by a private player. It is useful to understand how the pace of territorial changes is connected with the self-regulating mechanisms of this segment, through which the logics of transformation of land resources are determined by the imperatives of maximization of capital gains. The supply of formal urban land finds here a determinant bottleneck, since the optimal margins of profit depend on the scarcity of available urban land for development. The economic model usually adopted by these agents is the gradual construction of low-density residential areas, exclusively serving the interests of the prevailing elite in the forms of gated communities and allotments for the upper-classes, or simply properties kept away from development for speculative reasons. Following this logic of the maximization of profit margins, the oligarchic circuits of real estate-construction businesses can set the price of each plot of land, where each residential unit is turned into a luxury product of outstanding value. In some cases, the first allotments are sold at much lower prices in order to pay for the necessary infrastructure works such as road paving and landfilling. However, this opportunity is only given to investors with privileged information, and the remaining lots establish the market price and stimulate a progressive escalation of land costs over time.

Real estate sector respondents in the case-study, explained that the land price increases in the remaining areas available for development close by the city are fueling speculation of the land market and inducing urban expansion. According to the respondents, the price per square meter within the physical boundary established by the national road IC101 increased more than 1000% between 2000 and 2015. This has been confirmed by various reports of investors about the impressive margins of profit obtained during this period–plots of 360m^2 in the year 2000 ranged between R$30 and R$60 per square meter, while in 2015, an equivalent plot in the same location was evaluated between R$350 and R$500 per square meter (R$1.00 is approximately US$0.25, considering values from February, 2016). A real estate agent reported that after buying a property in 2002, he sold this plot after two years for the double of the price and used the surplus of this transaction in a similar investment in more distant locations. He explained that the increasing price per square meter of the remaining areas available for development close by the city encourages speculation of the land market and urban expansion in upstream areas of the floodplain, constituting interesting business opportunities for investors, especially in a context of tourism expansion such as is seen in Paraty.

For analytical purposes, it can be distinguished two inter-related dynamics of land-use change, which I have termed the segregation dynamic and the suburbanization dynamic. Reconstructing the symbiotic relations between these two patterns of land-use change, and unfolding the fluxes of influence within decision-making processes, suggest that segregation and suburbanization dynamics, although reflecting divergent interests at play, are not necessarily antagonistic, but rather complement each other. If it was possible to identify a trend of profit maximization by private investors targeting high-income groups, another trend emerges from the necessity of the sectors of society that are excluded from this process of wealth accumulation. This second dynamic of suburbanization is configured by a wide range of social groups, resulting from the pressures and demands irradiating from the base of the society. These social groups are composed of a considerable portion of the population taking part in the production of territorial changes that vividly reflect the daily struggles of the people living in the urban periphery. This evolving social fabric is composed not only of the poor, the landless, or the migrant population, but also by an emerging middle-class with growing acquisitive power. Within this group, former small property owners whose land has been acquired by private players purchase new properties in the new residential sites. The land-use changes resulting from the activities promoted by these agents are predominantly manifested through the sprouting of informal housing in peripheral areas, characterized by ad-hoc processes of land subdivision and illegal constructions, which are radically transforming the physical and cultural landscape of previously rural and forested areas.

Individuals operating land-use changes in upstream reaches of the floodplain (such as landfilling and embankments) have shown reluctance in recognizing the impacts on flooding and landslides produced by these territorial transformations. Short-term economic goals have been the most common justification for expanding urbanization toward these areas, varying from job creation to less specific notions of economic growth. In the interviews conducted with this segment of the population, the most common complaint referred to the scarcity of affordable land for urban development. The majority of the representatives of this group of agents, when asked about their interests, were also very prominently concerned with short-term economic goals, such as being close to job opportunities or opening small businesses. The tourism sector is also creating substantial incentives for expanding into new areas, generating jobs and commercial gains with many ramifications within the local economy. Along the river banks in upstream regions of the basins, settlements, hotels, lodges, and restaurants flourish and end up competing for land with the local population. Considering the number of urban land parcel operations made in a fragmentary fashion across the municipality, the piece-meal actions of the informal market exert strong influence on land-use change processes, where land subdivisions are normally obtained by breaching the formal institutions through illegal means, contributing to increasing fragmentation of land ownership.

4 Discussion

The results of this study show that the reproduction of socioecological conflicts result from a specific dimension of inequality, related to various modes of capital accumulation that ultimately contributes to deepening socio-spatial disparities. This specific dimension of inequality is fundamentally reflexive - in the sense defined by Beck (1999), as reflexive unawareness - because it continually refers to the very process of social change of the population at large, by which socioecological conflicts are reproduced in the fragmented actions of individuals. In referring to this specific meaning, Beck claimed that new forms of inequality develop on the basis of the distribution of the unawareness of unintended consequences, contributing to the individualized reproduction and distribution of socioecological conflicts.

Along this discussion I argue that it is by furthering the understanding of the relationships between formal and informal processes of land-use change, that the root causes of increasing exposure to climate related risks may be understood at a deeper level. These relationships may be unfolded by unmasking the interdependencies between these processes; identifying the various modes of regulation, deregulation, and legitimation dictated by economic agents and government institutions; and by disclosing the multiform tactics of individuals and social groups involved in land-use change processes. Each of these aspects will be discussed in the following lines, forming the argument that socioecological conflicts are reproduced by a non-explicit and tacitly accepted socioeconomic-political pact through which the interests of both extremes of the social pyramid are more or less satisfied by a hybrid solution composed of formal and informal processes of appropriation and transformation of the territory, at the cost of increased vulnerabilities and risks unequally distributed among the various segments of society. In order to unfold this argument, it is worthy to relate the findings of the spatial analysis with the population data presented in the previous section.

A striking finding of this analysis is that the conversion of land for urban expansion has been disproportionately higher than population growth, while population densities have generally decreased. Another trend found in this case, which is common to many other small and medium cities in Brazil, is the growing informality of land parceling and illegal occupation of peripheral areas, while the formal housing market remains exclusively directed to a privileged minority of investors. These findings suggest an interdependent relationship between the speculation of land markets and the growing informality of land parceling, through which the first can only be sustained by the reproduction of the second. Indeed, it is precisely the shortage of urban land for a large majority of the population, and the consequent generalization of illegal land parceling and occupation of peripheral areas, that better explains the increasing vulnerabilities of urban communities to flooding and landslides after the occurrence of extreme weather events.

The lack of recognition of this crucial aspect by many policy makers is partly due to the more granular perception of migration flows to large metropolitan areas, which in Brazil has decreased significantly during the last two decades, while the more complex migration dynamics within peri-urban spaces in between small and medium Brazilian cities is least understood. In this regard, Maricato (2006) notes that if there is an indicator that expresses in a synthesized way the critical dimension of urban problems in Brazil, it is the huge illegality that characterizes the unlawful occupation, invasion, and parceling of land. This phenomena, the author argues, makes it possible to state that the exception is now the rule and the rule has become the exception. The present case corroborates this observation, where informal urbanization and the illegal subdivision of land increased at a very fast pace throughout the last decade, while a significant proportion of the population with growing acquisitive power boosted a new wave of (sub)urbanization occurring in peripheral areas.

Equally important is the observation of how recently urbanized areas, which resulted from an initial phase of informal process of land subdivision, are making room for a new type of housing for various segments of the population. In this perspective, it is also important to note the changes in access to credit and the recent changes in the composition of capital invested in the real estate and construction sectors (Costa and Mendonça, 2010). In the surrounding areas of cities with strong attraction for tourism, such as Paraty, the more "ad-hoc" informal occupations and land subdivisions are likely to turn into new business opportunities for the formal market of urban land, as well as to open new areas for the construction of housing units promoted by realtors and small scale entrepreneurs. All of these concerning factors reflect different social dynamics and a high complexity, which brings a whole new urgency to the problems rooted in the lack of affordable urban land for the local population.

The findings of the analysis carried out suggest that this chronic deficit of urban land gave rise to a characteristic mode of appropriation and transformation of the territory, where suburbanization appears as the flipside of the coin of an economic model based on speculation of land markets directed to the elites. As noted by Ribeiro and Cardoso (2003), the continual reproduction of inequalities in the urban space is sustained by land-use change dynamics of permanent expansion and fragmentation, which allow for the accommodation of social conflicts inherent to the process of urban growth. These dynamics of land-use change are particularly evident in the empirical study of this research, where the specificities of its property regime resulted in the presence of large open spaces in peri-urban areas where the most appropriate locations for urban development are reserved for the maximization of profits in real-estate transactions. As a consequence, the poor are continuously pushed into the most vulnerable peripheral areas, resulting in serious environmental degradation and increasing vulnerabilities to climate-related risks.

Looking at the results of the spatial analysis together with the results presented in the stakeholder analysis, it is possible to identify a number of links between the current trend of urban expansion and the speculation of land markets. As it has been seen, the imperative to maximize capital gains stimulates a market directed toward a minority of the society (in marketing jargon known as classes A and B), thereby mobilizing interests to economic groups and individuals seeking the maximization of rents for investors and property owners. On the other hand, a new type of smaller scale housing development is sprouting along recently urbanized areas, which have been originally subject to informal processes of land subdivision. As it has been noticed in other studies, these new developments (directed to a more varied range of segments of the population) are gradually being transformed by new desires of consumption, generating a demand dictated by the logic of the market (Mendonça and Costa, 2008). Indeed, there seems to exist a more intimate connection between the observed trends of urban expansion and the logics of buying and selling urban land, which together generate a self-reinforcing cycle: the shortage of available land close to the city causes the demand and price for that land to rise, thereby stimulating illegal parceling of environmentally-sensitive areas in the urban periphery that, in turn, are over-valued because of their comparison to price increases in the real-estate markets of the most preferred locations.

The most problematic issue that deserves to be highlighted from the results yielded in this study is the underutilization of strategic resources (which could be used for responding to the actual demand) motivated by speculation purposes, while the price of urban land is artificially increased by turning each plot into a special commodity of outstanding value. In this regard, Evans (2004) sets forward various arguments showing why the owners of land may want to keep their land undeveloped. This problem is aggravated by the interactions between these players in wider logics of investment and an increasingly globalized economy where the deterritorialization of real-state investments allows new forms of financial capital accumulation. The fact that investors and property owners are no longer tied to a specific location allows for more flexibility in managing their portfolios to their best advantage. Throughout this process, property owners wait for rising land prices and simultaneously use their capital for other investments. This flexibility favors the extension of speculation strategies in time and space, enabling property owners to hold underutilized land while waiting for higher returns. In the case analyzed here, this lack of motivation of landowners results not only in an overall inefficient land market, but also in a chronic land supply deficit for a large part of the population.

The perverse effects of such logics reflect a classic economic problem of correlation between supply and demand: if the valorization of urban land depends on its scarcity, then prices tend to be distorted by the contraction of supply by restraining alternatives for affordable urban land in adequate locations. This contraction of land markets is only possible in contexts where the number of key players are very reduced, holding the bulk of land resources. In the case studied, this group is configured by a small group of large land owners, the corporative circuits of construction and real estate business, and large extractive industries involved in land speculation markets. These key players constitute a powerful political block who not only have a massive presence in the region of the study area, but who also hold large properties in other Brazilian states and worldwide.

As noted by Evans (2004), the key aspect to be understood within this problem is related to the supply side, even though the speculative nature of the market is basically concerned with the demand of selected segments of society, which make possible the maximization of profit margins. This mercantile logic is dictated by a self-regulated market economy, which may be described, in the words of Bourdieu (1998), as "an economic thinking inclined to take the things of logic for the logic of things." Ultimately, this logic contributes to the aggravation of housing deficits, while the needs of the larger proportion of the population are more or less fulfilled by informal processes of land-use change. As observed by Harris and Todaro (1970), it is the informal sector that absorbs the excess (of demand), and it is the informal sector that adjusts (to the lack of alternatives of affordable land). Especially in small land markets limited to a reduced number of players, the process of speculation of land markets is artificially sustained by the growing informality of land markets to the lower segments of society (the larger proportion of Brazilians within the so-called classes C, D, and E).

Within this dual economy composed by formal and informal land markets, the fragmentation and expansion of the urban space are the by-products of a symbiotic relationship between the two interrelated dynamics of segregation and suburbanization.

In neoclassical economics, the flaws of economic systems are said to be market failures through which negative externalities are not internalized by market players. Bardhan and Dayton-Johnson (2002), for example, argue that such market failures result from the difficulties of cooperation between the various actors using a certain natural resource. However, such problems find a more complete explanation in the "privatization of benefits, socialization of costs" (Lipshutz and Rowe, 2005) - in disagreement with the neoclassical point of view, these authors note that it is not necessarily the case that the markets "fail," but rather it may be that market players have organized with the intention of socializing certain costs and realizing private benefits.

Furthering the understanding of this socialization of costs is an essential step toward understanding the economic logics behind land-use change dynamics:

i) the speculation of land markets is, in itself, expansionist, since it can only be sustained by an ever-expanding consumption of natural resources. Such a model of expansion of urban space does not account for the inherent costs of expanding infrastructure and services, contributing to a fragmented, inefficient, and expensive urban infrastructure;
ii) the logics of economic growth do not account for the negative environmental externalities produced by the fragmented actions of each of the agents involved in land-use change processes, leading to an increasing spiral of social and ecological costs;
iii) when the societal needs for affordable urban land are not properly considered by formal land markets, informal occupation of the remnant areas (usually the most vulnerable to natural hazards) eliminates the possibility of mitigating the effects of new urbanizations through the adoption of flood mitigation measures;
iv) a large informal economy imposes heavy costs that deteriorate services and public goods, contributing to the reproduction of spatial divides and social inequalities, while flood risks are continuously created and amplified. This is because the ecosystem services of previous natural conditions fail to be considered in unplanned urban operations, neglecting important economic, social, and ecological costs.

It is important to consider that the abovementioned factors are interrelated: if natural hazards hit harder the most vulnerable groups (in the sense that these are more exposed to environmental variability), the costs of natural disasters affect the community as a whole since the financial burden of damages is ultimately paid by public expenditure. Within the back and forward of these economic logics of appropriation and transformation of the urban land, the State assumes a central position on the reproduction of socioecological conflicts, whether by over-regulating land-use change processes or by relaxing norms and control mechanisms. In the absence of ex-ante solutions to increasing needs for affordable land for the majority of the population, local governments chase behind the process of urban expansion by legalizing new illegally subdivided areas. The tolerance of government institutions with respect to the illegal occupation of lands is also a reflex of the absence of effective policies to facilitate access to urban land for lower income groups. While pushing for the regularization of land tenure is in itself a desirable goal, it is not a sufficient response to the enormous deficits of urban land for the lower segments of the population, and ends up fostering illegality by stimulating the continuation of irregular and costly practices.

Equally counterproductive, the overregulation of formal processes of land parceling constitutes an impediment for the lawful acquisition of urban land, making it too expensive for the population at large to acquire a piece of serviced land via the formal market. In practice, the limits imposed by municipal and federal laws concerning the minimum size of a plot, turn urban lots provided by the formal market, unaffordable to anyone below a certain income range. The obligation of paving new allotments is another example of a mechanism that limits the access to the formal city to the most disadvantaged social groups. Moreover, the definition of reduced lot sizes for low-income residential areas is in itself discriminative, contributing to further urban divides through institutionalized modes of segregation. These sort of bureaucratic standards can thus be used precisely toward the opposite end of what is supposed to be the role of the State, contributing to the reproduction of socio-spatial asymmetries.

When discussing the role of the State on mediating private and public interests regarding land-use, it is important to distinguish between constitutive and prescriptive rules, in order to understand how the counterproductive effects of overregulation are aggravated by the lack of effective enforcement of fundamental principles of social and environmental justice. In Brazil, the 1988 Constitution and the City Statute of 2001 clarifies the links between the exercise of property rights and the socioecological functions of the city (2016), relegating more detailed definition to supplementary legislation and Municipal Master Plans. In this regard, many authors criticize the fact that the effective enforcement of the Social Function of Property as defined in the constitution, is delegated to the local level of government. According to Ondetti (2015), this ambivalence of the law makes the effective enforcement of this constitutive rule highly dependent on local conditions. Fernandes (2007) goes further with this criticism, sustaining that the lack of enforcement mechanisms "make this principle merely rhetorical." Nevertheless, and despite its failure to date for its practical application, its internalization in legal instruments such as the Statute of the City is groundbreaking in Latin America, and more generally, in the Global South. Although attempts to extend the social function principle to urban contexts are not unprecedented internationally, Brazil's efforts to create a legal framework that specifically outlines how this principle should be enforced in the urban context are rather exceptional (Ankersen and Ruppert 2006) Conceptually, it constitutes a new paradigm for dealing with property rights (Alfonsim, 2005) by linking the exercise of urban property rights to economic, social, and environmental ends. The relevance of the Social Function of Property in the context of climate change, is that it constitutes at least potentially, a strategic entry point for giving legitimacy to an urban policy where the right to the city is at the center of its normative basis.

5 Conclusions

Considering the above discussion, it may be concluded that there is no way of talking about climate adaptation without assuring the necessary flows of land for urban development. Land has to be amply available, affordable, and accessible to all, while at the same time, essential ecosystem services on which urban communities depend must be safeguarded. This requires the mediation of the State in assuring not only the right balance between supply and demand of urban land, but also the appropriate location of supply. While these constitute the basic ingredients for effective adaptation policies, eliminating the shortages of urban land involves perhaps some of the most difficult sets of problems to be addressed in the public domain, requiring a profound transformation of the relationships between the state, the society at large, and the owners of economic capital participating in the production of the urban space.

A number of observations have been made along this paper that help to explain the impediments for changing the current trend of uncontrolled urban expansion and corresponding climate vulnerabilities. This case evinces that the logics of capital accumulation assume a dominant role in the creation of a dual economy, characterized by oligopolistic structures of influence that exercise hegemony over land-use decisions. It has also been possible to show how these logics are related to the shortages of urban land and, more importantly, to broaden our understanding of its interdependent relationship to informal land markets. The identification of symbiotic relationships between formal and informal processes of land subdivision is useful for understanding how partial solutions to the governability dilemma are combined, while the elected representatives depend on established structures of capital accumulation. These interdependencies explain why a more interventionist role of the state in assuring sufficient flows of urban land for the overall population has barely been taken as a serious political compromise by successive democratic governments in Brazil.

As it has been shown throughout the empirical study, the logics of appropriation and transformation of the territory are manifold, and the State is itself a socioecological player that develops rationalities and techniques to handle economic interests and social pressures. By discerning the logics of economic capital and the logics of state institutions, I have intended to show that there is a general complicity between a certain model of economic production and government rules, and this complicity is matched by the satisfaction of social expectations by the practical legitimation of informal parceling and illegal occupation of land. The rules and conditions imposed by state institutions shape the fragmented responses of individuals, which in turn reflect the wider process of social change by continuously creating new socioecological conflicts. As such, the vulnerability of urban communities to climate-related risks is not only socially and economically constructed, but configure a non-explicit social pact involving the logics of territorial transformation both from above and below the social pyramid. In fact, the first is the consequence of the second, and the second is reflected through the first, while the hegemonic influence of private pressure groups involved in land-use change processes plays an important role in expanding and distributing climate-related risks. This complicity is configured by a set of practices of governance, expressed in the micro-scale of territorial transformations, where economic, social, and political logics of different social groups are *governmentalized,* by which the process of continuous depredation of natural resources is transformed in *raison d'État.*

These logics have been hereby described as the shaping elements of what I call the *governmentality of urban land*. Based on the findings directly extracted from this study, it is this specific mode of governmentality that best captures the social, economic, and political causes of reproduction of socioecological conflicts that are at the origin of climate vulnerabilities. However, the validity of this hypothesis cannot be conclusively proven in the wider context of tropical urban regions, requiring more comparative studies to confirm or deny common aspects that may allow its further generalization. In order to advance in this direction, future research could test in other socio-economic and geographical contexts, the theoretical framework presented in this study, evaluating its explanatory power for understanding issues of environmental risk, climate vulnerability and socioecological conflict.

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Collaborative backcasting for transport policy scenario building

Julio Soria-Lara[1]**, David Banister**[2]

[1] TRANSyT - Transport Research Centre / Technical University of Madrid
[2] Transport Studies Unit / University of Oxford
julio.soria-lara@upm.es; david.banister@ouce.ox.ac.uk

Scenarios are often used to examine different futures where there is considerable uncertainty or where the business-as-usual is no longer appropriate. Backcasting is one form of scenario building where a normative view is taken about desirable futures, and the method then investigates different policy packages that can be used to reach those futures and the alternative pathways that can be followed. Where most difficulties have arisen in the past has been in bridging the conceptual elegance of the approach with the practicalities of implementation. Collaborative backcasting bridges this 'implementation gap' through a participatory approach in which different stakeholders take an active role in building scenarios, in identifying policy measures and packages, and in evaluating different pathways. Using the region of Andalusia (Spain), this paper brings together the different strands of this collaborative methodology where a set of future alternative for transport have been considered, together with the means to achieve a sustainable transport system for 2050. It discusses eight issues: (i) the selection of participants; (ii) the combination of participatory techniques; (iii) the development of learning processes; (iv) the need of mediators and their role; (v) the diversity of transport futures and integration of policy pathways; (vi) the timeline and future horizons; (vii) the acceptability of different pathways; and (viii) the legal and institutional constraints to effective implementation. Conclusions on the appropriateness of collaborative backcasting are drawn.

1 Introduction

Increasingly, policy-makers are being asked to think about the longer term futures for their cities and regions that embrace sustainable transport, but also have the flexibility to address uncertainty and potential unintended consequences (Lyons and Davidson, 2016; Seidl and Van Aaken, 2009). Scenario analysis has helped to provide a set of approaches that meet these requirements, and backcasting is one particular form of scenario building (Hickman and Banister, 2014; Vergragt and Quist, 2011). Its aim is essentially to explore divergent and innovative policy trajectories to reach desirable transport futures when the business-as-usual (BAU) projection is no longer appropriate. (Åkerman and Hojer, 2006; Hickman *et al.*, 2009; Olsson *et al.*, 2015; Wangel, 2011; Tuonimen *et al.*, 2014). The backcasting approach fundamentally responds to the following question "how can a specific transport target be reached (e.g. CO_2 reduction, energy efficiency, etc.), when the prevailing structure (e.g. institutional frameworks, legal systems, etc.) blocks necessary changes?" (Börjerson *et al.*, 2006, p.372).

The basic argument is that the BAU pathway is unsustainable and policy measures (combined as policy packages) cannot achieve the targets set for sustainable transport (e.g. for CO_2 reduction). Backcasting identifies desirable futures, and then looks at different pathways that can be followed to achieve the stated objectives – this is the backcasting process from the future to the present (Banister and Hickman, 2013). Conventionally, there are three stages used (figure 1). The first is the "visioning phase", that establishes a baseline showing the BAU projection, together with the construction of a series of images of future for desirable transport alternatives in the longer-term (25-30 years). The second stage, "policy packaging", focuses on elaborating a set of policies and packages that might help in reaching the images of desirable futures, with detailed pathways and timelines for implementation. Finally, the third stage is "appraisal", based on assessing the impact of policy pathways against environmental, social, and economic issues, as well as the feasibility, acceptability and potential barriers to the proposed pathways.

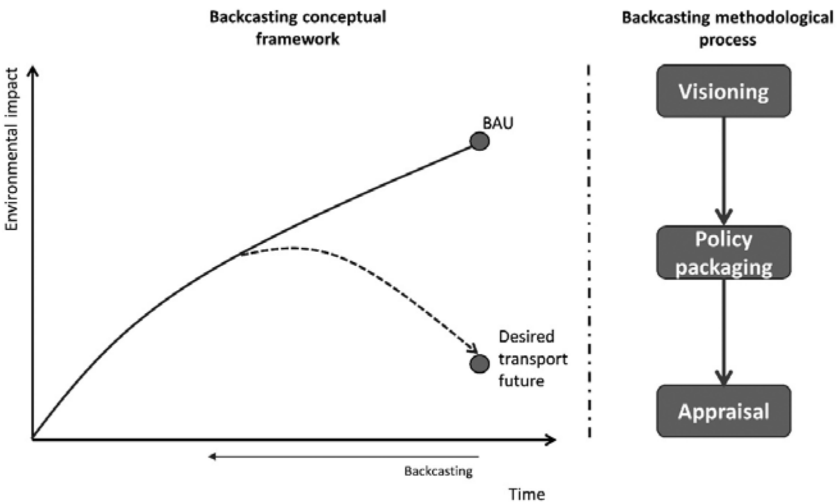

Figure 1. The Backcasting Process (Inspired by Banister and Hickman, 2013).

The backcasting process has been traditionally seen as an expert-led analysis, with little opportunity for stakeholder engagement apart from the workshops to discuss the options at each of the three stages (figure 1). This has generated a growing gap between academic backcasting studies and real transport practice – the implementation gap (Banister and Hickman, 2013). One of the main objectives of the "BACK-SCENE project[1] has been to further develop backcasting methodology by examining two sets of issues: (i) the assessment of backcasting scenarios and collaborative learning processes in transport and climate policy analysis through the explicit incorporation of participatory methods; and (ii) the means by which the links between research and action could be made more effective. The context of Andalusia (Spain) was taken as spatial laboratory for experimentation, and this location has been held constant all three stages of the project (figure 1): (i) to generate visions for the Andalusia transport sector by 2050 using participatory techniques (Soria-Lara and Banister, 2017a); to construct participatory policy packages for reaching targets established in the transport future visions (Soria-Lara and Banister, 2017b); and (iii) to test with policy-makers the impact and implementability of transport scenarios, and to evaluate the different pathways (Soria-Lara and Banister, 2017c). Around 100 participants, including the public, policy-makers, consultants from different professional domains, and academics have been actively involved in the different backcasting stages.

This paper presents the main results obtained during all three of the papers that address the BACK-SCENE implementation, and it reflects critically on the findings and lessons learned during the research, including future issues. It has two main objectives, one to bring together the findings from the three separate stages in the backcasting process, and the second is to reflect on the usefulness of the approach in addressing issues of sustainable transport, and whether intensive involvement of stakeholders in a fully participatory process results in closer linkages between research and action – the bridging of the implementation gap. Section 2 summarises the three main stages investigated in the collaborative backcasting framework implemented for Andalusian transport sector. Section 3 presents a discussion on the positive and negative findings, looking constructively at lessons learned, as well as the ways forward. Section 4 closes the paper with some further comments, reflections and concluding remarks.

2 A collaborative framework for Backcasting Scenarios in Andalusian transport

This section presents an overview of the collaborative framework that the BACK-SCENE project has implemented in Andalusia, covering the elements from the three backcasting stages: "visioning", "policy packaging", and "appraisal" (figure 1).

[1] *Backcasting scenarios as collaborative learning process: involving stakeholders in transport climate policy*" is an EU Marie Skłodowska-Curie action (Agreement nº 291780)

1.1 Visioning stage

The region of Andalusia is located in the south of Spain and has 8,402,305 inhabitants (figure 2). Andalusian authorities have a clear policy desire to implement a sustainable transport strategy for the region (2050). The primary target has been to reduce transport CO_2 emissions of 60% by 2050, compared with 1990 levels. However, the BAU projection does not create sufficient change for the region, and it fails to achieve the CO_2 reduction targets. The BAU means that tourism and the agricultural sectors will continue to dominate the Andalusia GDP, there will be a consolidation of a car-oriented society, there will be low penetration of information and communications technologies (ICT) and new transport technologies, an increase in distance to daily destinations, as well as difficulties in promoting high level of non-motorised mobility at city level (Agencía Andaluza de la Energía, 2014; Soria-Lara *et al.*, 2015). This future is not sustainable.

To address this problem, alternative and desired transport futures for Andalusian were created for 2050, exploring the preferences and the concerns from the perspective of key stakeholders in Andalusian society. The participatory process involved a wide range of Andalusian interests, combining Delphi analysis (with two rounds of interactions) and semi-structured interviews. In contrast to the BAU-projection, the storylines identified for the desired Andalusian transport futures are based on: (i) fundamental changes in Andalusian economic model; (ii) decreasing coastal tourism, and reducing both air and car traffic; (iii) preferences for railway transport at the regional level; (iv) a higher implementation of low emission vehicles; (v) more liveable cities, including strong promotion of walking and cycling; (vi) increasing the number of multi-modal transport facilities (for a more detailed version see Soria-Lara and Banister, 2017a).

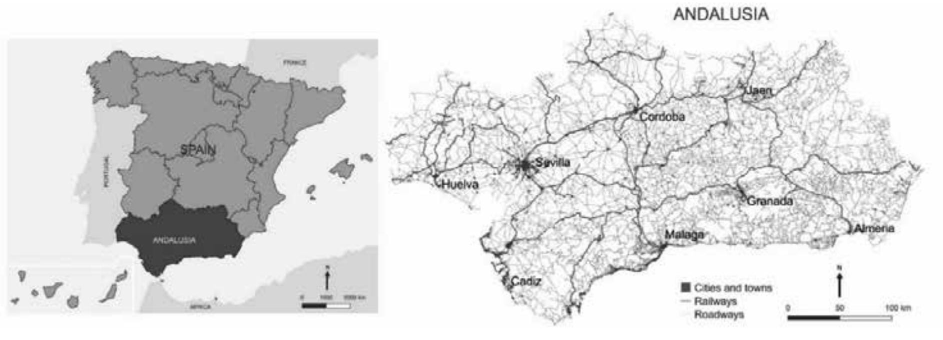

Figure 2. Case study location.

1.2 Policy packaging stage

To reach the transport visions identified for 2050, three policy pathways have been formulated, following a dynamic participatory process based on a series of face-to-face workshops. Participants (practitioners from different professional domains and policy-makers) firstly clustered a long list of 53 individual policies into 10 policy packages (PP1 Low emission vehicles; PP2 ICT; PP3 Pricing regime; PP4 Freight transport; PP5 Multimodality; PP6 Liveable cities; PP7 Non-motorised modes; PP8 Traffic management; PP9 public awareness; PP10 infrastructure investments), and the policy packages were then combined to be consistent with the following three policy pathways (figure 3), including timelines for implementation:

- The lower carbon emissions pathway consisted of the combination of five policy packages. The highest priority was given to PP5 Multi-modality and PP10 Infrastructure investments.
- The technological innovation pathway consisted of the combination of four policy packages. The highest priority was given to two PPs: PP1 Low emission vehicles and PP2 ICT. The urban compactness pathway consisted of the combination of five policy packages. The highest priority was given to four PPs: PP5 Multi-modality, PP6 Liveable cities, PP7 Non-motorised modes and PP8 Traffic management.

For a more detailed presentation of this stage, see Soria-Lara and Banister (2017b).

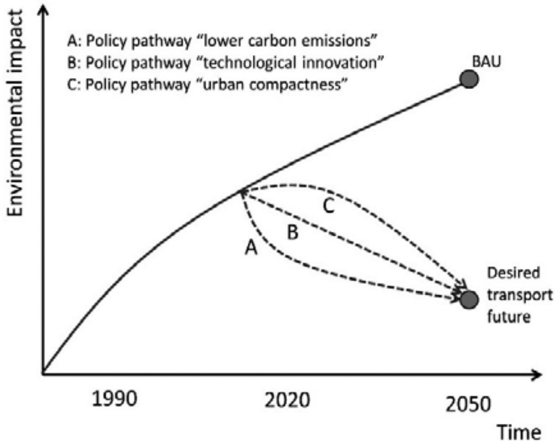

Figure 3. Policy pathways scheme.

1.3 Appraisal stage

To assess the effects of the three policy pathways implementation against environmental, social, and economic impacts, a collaborative framework was developed, combining multi-criteria analysis (MCA) with face-to-face workshops (Soria-Lara and Banister, 2017c). Policy-makers from local and regional institutions took part in the process. Firstly, policy-makers determined potential sustainability impacts (environmental, social and economic) of the series of Andalusian transport future images, together with the respective policy pathways outlined in Sections 2.1 and 2.2. Secondly, MCA was used to rank the sustainability impacts produced by each policy pathway. Thirdly, the feasibility, acceptability, and potential barriers to each of the three policy pathways in the region of Andalusia were discussed.

The results demonstrated that positive environmental and economic impacts will be generated through the implementation of the three policy pathways, but the social impacts were less positive. In this respect, an integrated approach to transport policy-making was seen as being fundamental to the achievement of significant progress towards sustainable transport futures. This includes behavioural change incentives, alternative fuels, high levels of technological penetration, greater energy efficiency, and other policy interventions that all need to be introduced as part of a consistent set of mutually supporting policies. In this way, a sustainable transport future can be realistically implemented over the period to 2050.

3 Lessons learned

Here, we present a set of issues and emerging questions, taking into consideration which elements of the Andalusian case study have worked well (or not), and why. The purpose is both to reflect on the methods used, and to comment on what has been learned about collaborative processes. Has the effort involved in developing participatory methods really been worthwhile? Throughout this project, the primary concern has been over developing the collaborative backcasting methodology, and this has involved extensive and time consuming surveys, interviews, and face-to-face meetings to bridge the implementation gap between theory and practice. Eight issues have been identified and each one is discussed here in turn, together with a set of comments.

3.1 The selection of participants

The research findings have shown the convenience of a custom designed participatory process that matched the stages of backcasting analysis, rather than a traditional expert-guided process across the backcasting process (Banister and Hickman, 2013; Mattila and Antikainen, 2011; Shiftan *et al.*, 2003). This means that specific participants are selected at different stages (Wangel, 2011). The recommendation here is that "visionary participants" are used to draw a normative view of desirable endpoints in the futures (visioning phase). "Visionary participants" refer to a wide variety of agents (the public, policy-makers, consultants, academics, etc.) that are able to think 'outside the box' about transport futures and to provide legitimacy over the process. Conversely, "instrumental participants" are recommended during the "policy packaging stage". These people have included policy-makers and consultants, as participants who can debate policy alternatives and understand how policy options can work together in mutually supporting ways. Finally, policy-makers from different institutions (local, regional, sectorial, etc.) have been involved during the "appraisal phase", given their capacity and experience to anticipate potential consequences of transport scenarios, as well as to assess the scenario´s feasibility and acceptability. This custom designed participation process has worked well.

The size of the sample is also an important issue to be considered, and there is no single answer to this issue. In most cases, sample size is affected by considerations not strictly related to the research themes such as time and cost. For this reason, the crucial determinants are to ensure that the sample reflects both the heterogeneity and the spatial distribution of the participants. The use of matrixes that combine expertise, spatial location and socio-economic aspects of participants proved to be very useful in the BACK-SCENE project, in the selection of participants. Larger samples are recommended during the "visioning stage", when it is considered that the visualisation of the desired futures should be a democratic exercise where "all voices" can be heard. However, stages of "policy packaging" and "appraisal" are more technical (figure 1), and a smaller number of participants could be sufficient, provided that they include knowledgeable people, with a certain level of practical experience in the field.

When the aim is to compare views from sub-groups of participants as a method to establish transport futures and policy pathways for implementation, then participants that represent the different sub-groups of affected people (e.g. the sub-group of local policy-makers; participants older than 65 years old, etc.) should be carefully included in the sample size, guaranteeing the right variability and representativeness. From this research it was also noted that the mix of several generations of participants worked well together, and it is important to have a variety of views in all phases of the backcasting process. In the case of Andalusia was evidenced how the most radical transport future visions came from the youngest participants (people between 14 and 35 years old). However, realistic views were also needed to reach a balance between the plausibility of views, meaning that older participants are also needed. A combination of different levels of experience during the phases of "policy packaging" and "appraisal" was also perceived as positive in Andalusia, combining more traditional views (frequently pessimistic on the capacity to reach sustainable outcomes in the region of Andalusia) with more modern views (more optimistic on the effectiveness of the policy process).

Comment:

- Sample size is important in collaborative studies, but it will vary according to the purpose of the participation, and the different stages in the process;
- All sectors of the population need to be considered so that the societal heterogeneity is reflected, and this means involving those affected by decisions as well as the decision makers themselves.

3.2 The combination of participatory techniques

Shifting the paradigm of transport backcasting scenario, from a form of scientific, instrumental rationality to a form of qualitative reasoning based on stakeholders´ views, means that there is a need for a combination of multiple and complementary participatory techniques at the three different stages. The backcasting process implemented in Andalusia clearly demonstrated the usefulness of different participatory methods, and this conclusion is supported by other research in the field (Tuominen *et al.*, 2014). However, many previous participatory studies have been limited to a single participatory method to reduce complexity in favour of a more structured process (Shiftan *et al.*, 2003; Hickman *et al.*, 2011; Zimmerman *et al.*, 2012). In BACK-SCENE project, a range of participatory methods have been used including group discussions, questionnaires, Delphi techniques, semi-structured interviews, and ranking methods.

A balanced approach that combined top-down and bottom-up participatory processes is recommended. Top-down methods (e.g. Delphi techniques, questionnaires, multi-criteria analysis, etc.) guarantee a certain level of control by the research team. But, bottom-up methods (e.g. face-to-face meetings; in-depth interviews, etc.) provide a more creative space for participation, where participants can talk about options with each other, and feel more able and confident to participate, and in coming to a consensus. This mix of information sources is key when collaborative scenarios are pursued, combining more guided situations on certain topics of interest with open views and opinions. In the case of the BACK-SCENE project, top-down and bottom-up participatory methods were simultaneously implemented during each backcasting stage (figure 1), as well as across the full backcasting process. During the "visioning stage", Delphi techniques were combined with semi-structured interviews, showing how the participant´s views involved in semi-structured interviews opened new transport topics that complemented the questionnaire distributed in the Delphi process. On the other hand, face-to-face workshops used during the "policy-packaging stage" were assisted by questionnaires that summarised and nuanced the general agreements achieved between participants. Finally, multi-criteria analysis was used in combination with face-to-face workshops in the "appraisal stage" of backcasting scenarios, identifying and ranking potential impacts generated by those scenarios in the region of Andalusia.

The integration of information from different participatory methods is often complex, and this might contribute to bias. While the codification of information in top-down participatory methods is more systematic and easily translated into numbers, information from bottom-up participatory techniques is much more subjective and diverse, and difficult to translate into numbers. In the BACK-SCENE project, several rounds of codifications were carried out to translate the obtained views from bottom-up techniques into information that can be compared with results from top-down methods. Nevertheless, these codification rounds can originate a relevant loss of information. The latter was especially relevant during the "visioning stage".

Comment:

- No single method should be used, as both more directed and less directed approaches are required to generate creative thinking, and real value being obtained from participation;
- The aggregation of quantitative and qualitative information requires careful consideration about the values assigned, and the potential loss of detail. The range of methods available are extensive, but compromise is necessary.

3.3 Development of learning processes

A major contribution of the BACK-SCENE project has been the use of transport backcasting scenarios as a tool for promoting learning processes between participants, rather than using the scenarios as a deliberative tool that primarily assists in policy-making. Andalusian backcasting scenarios have not been used as an end in themselves, but as a means by which participants could discuss and confront each other, as well as finding a means to modulate their particular discourses and learn from the perspectives of others. The results produced were collaborative, complex, and mature views of the Andalusian transport policy. This differs to the deliberative process of one single participant or group of participants, as it has traditionally occurred in the transport backcasting field (Ashina *et al.*, 2012; Shade and Shade, 2005; Winyuchakrit *et al.*, 2011).

One of the conclusions concerns the development of collaborative transport scenarios, considering that they are weak when learning processes are not activated. Such an approach only provides one set of particular points rather than a process where the participants' views co-evolve into significant agreements and disagreements. The activation of learning processes requires a scenario building structure that is mainly sequential and iterative, facilitating situations where participants build new knowledge upon insights and views from other participants. For example, during the "policy-packaging stage" in Andalusia, a dynamic participatory process was implemented based on face-to-face dialogue spaces, which evolves from generic and preliminary discussions to specific and focus-group views. This process was iterative and continuous, and it built on the combined knowledge and experiences of the participants. A key element when learning processes are implemented is to guarantee a certain level of continuity in the reasoning. This was made during the BACK-SCENE project in both the "policy-packaging" and "appraisal stages", and it worked well. In particular, a core group of participants (3-6) were common to the different participatory phases, ensuring continuity. A crucial point here is to avoid the possibility that the discourse of the core group has a dominant role in the process. All participants should have an equal opportunity to contribute to the discussion.

When learning processes are implemented, the design of the dialogue spaces is also very important. It is recommended face-to-face meetings where participants can meet each other in an informal setting, as this makes them abler to participate. Understanding the point of view of others means that participants can moderate their discourses and increase the opportunities of finding win-win solutions. Another relevant consideration seen in Andalusia has been the time allocated to discussion. Substantive discussions require considerable time and energy from the participants.

The main barriers in learning processes are related to how participants' views are processed and distilled for the rest of participants in subsequent phases. A protocol must be carefully designed before starting the participatory process, where the objectives for discussion are clearly framed. The results obtained inthe discussion also need to be processed in a meaningful way for the subsequent participatory steps (e.g. using leaflets; multi-media presentations; etc.).

Comment:

- Participatory approaches allow debate and discussion between the different stakeholders, and the development of more holistic understandings of the choices to be made. This complexity probably reflects reality;
- The main difficulty was the continuity between the three stages, and in the way the narratives are constructed, overcoming the inconsistencies that can arise over time between different participants.

3.4 The need and role of mediators

During face-to-face meetings, The BACK-SCENE project used an experienced Andalusian transport planner as mediator, and the result is considered satisfactory. Using an independent professional as mediator ensures that the research team only acted as external observers, avoiding interferences between researchers and the dynamic of participants. Some aspects must be taken into consideration when a mediator is included in the participatory process. First, the mediator background should have a clear transport policy and spatial planning focus, with experience in both public and private sectors, as well as being a "peacemaker" and sensitive to different discourses. Second, the mediator must be supported by certain rules for participation, previously discussed with the research team. These rules are important to ensure that the participatory process fulfils minimum requirements, and will be focused on topics of interest for the research objectives. Third, the mediator must be clear in issues such as language style, allotting equivalent speaking time to each participant, especially ensuring that no participant/group takes a dominant role in discussions. Fourth, the mediator should give voice to all participants avoiding situations, during the meeting, where individuals are excluded.

One of the mediator's difficulties is to determine whether participants with different backgrounds are really prepared to share knowledge with each other. Specific attention should be paid to this possibility, finding a balance between scientific/technical, environmental, sociological, economic, and other terminologies. Converting individual knowledge to collective knowledge requires a particular capacity from the mediator to generate a "common language" between different participants. The use of illustrations, practical examples, and best practices from other places can facilitate this task, and it was demonstrated as a useful way to generate common communication frameworks during the phases of "policy packaging" and "appraisal", in Andalusia.

Sometimes, starting a conversation is difficult, but at other times stopping discussions is also hard. Bad choices on how and when to stop discussions can trigger exclusion situations between participants, as well as decreasing the confidence of participants to interact again. In the case of the BACK-SCENE project, the mediator was encouraged to stop discussions when a generalised consensus was reached (> 70% participants agreed). However, the limit was difficult to identify in many situations. Furthermore, the mediator was also encouraged to give continuity to discussions when participants less confident were interacting. This is a matter of judgement and experience for the mediator.

Comment:

- It is important to have high quality, knowledgeable and independent mediation between the participants and between the issues under discussion. The continuity issues raised earlier, and the usefulness of the outputs depends on the effectiveness, briefing and understanding of the mediator. He/she is a crucial part of the success of the participatory process;

- The mediator needs to have a perspective on the whole process and a clear understanding of the research objectives. This means there must be continuity throughout, and a mutual trust and understanding between the mediator and the research team.

3.5 Diversity of transport futures and integration of policy pathways

While scenario building is mainly constructed from the past and present towards the future (forward-looking) as happen in forecasting and exploratory approaches (Böjersson *et al.*, 2016), backcasting scenarios usually look backwards from a single desired future. The main focus is not on likely futures, but on which policy pathways can reach the desirable endpoint. For this reason, and taking into account this research perspective, multiples futures visions are strongly needed to generate complementary and divergent policy pathways that increase the opportunities to reach sustainable outcomes in the future (Tuominen *et al.*, 2014). This logic was implemented in Andalusia, where three desirable future visions (lower carbon emissions, technological innovation, and urban compactness) were used as starting points for the backcasting exercise ("visioning stage"), elaborating three complementary and divergent policy pathways to reach them ("policy packaging stage"). The "appraisal stage" during the backcasting process revealed how the implementation of the three policy trajectories simultaneously increased the capacity to generate positive impacts related to environmental, social, and economic issues.

While the generation of multiple images of transport futures and the associated pathways is seen as an essential point, difficulties occur where there is agreement between participants, as it was seen in the Andalusian case study. During each of the backcasting phases, the usefulness of the participatory process was limited when the generation of disruptive transport futures and unusual policy solutions were considered. The way in which "black swans" are introduced, and the participant's reaction during the backcasting process, were recognised as one means to overcome the problems that people had not only in thinking about very different transport futures, but also in designing potential measures to reach those futures. These "black swans" are events that have a very low probability of occurring, but would have a major impact on the outcomes. With respect to sustainable transport, this might include very substantial increases in energy costs or the widespread adoption of a new technology (e.g. electric vehicles). Another used approach results from combining consensus-based views with the more radical outliers that were also proposed to broaden the debate. Those outliers might provide a basis for more radical transport futures visions, as well as more unusual and innovative policy solutions to reach desirable transport endpoints in the longer-term.

Comment:

- One of the main difficulties has been to get participants to think about rather different or novel futures. Methods are needed to address the levels of innovation and speed of change required to reach the 2050 targets, and what they mean to participants;
- "Black swans" or major (but rare) events provide one set of concepts that can be used. Participants should be able to engage with these alternative futures, but they are difficult to communicate to participants, and for many participants to relate to.

3.6 Timeline and future horizons

The appropriateness of using timeline and future horizons were issues recurrently discussed with participants during the backcasting process in Andalusia, and many difficulties were found when participants were faced with discussions about their reasoning in the context of the longer-term. However, the backcasting exercise must be contextualised in the longer-term (25-30 years), since its main objective is to implement changes to re-orient existing trends when BAU-projection is no longer appropriate. This problematic was most apparent during the "visioning stage". Participants contextualised their discourses in the mid-term, and they were frequently encouraged to change the future horizon in their interventions. But this proved difficult. Policy-makers and consultants provided the main participants during the "policy packaging and appraisal stages", and they had less difficulty in projecting their reasoning over the longer-term, as they may be more familiar with the concept of working on different temporal horizons. Nevertheless, participants highlighted the need to establish intermediate temporal milestones during the visualisation of transport visions ("visioning stage"), during the design and implementation of policy pathways ("policy packaging stage"), as well as during the evaluation of potential impacts associated to pathways ("appraisal stage").

Accordingly, multi-temporal backcasting could be an interesting conceptual innovation to be explored in future research. It relates to the process of creating multiple desirable transport futures in the shorter and mid-term, as intermediate check-points in the pathways towards longer-term futures. The idea of multi-temporal backcasting would be interrelated to designing adaptive policy pathways that can be modified according to the capacity to reach desirable transport future in the shorter and mid-term (temporal check-points). Nevertheless, the adaptive and flexible frameworks developed in the past have been complicated products, with high risk to become vague and non-transparent. Another way to overcome barriers related to timeline and temporal horizons is to focus on incorporating training activities for participants as part of the participatory process. For example: using narratives on how past technological interruptions have dramatically changed the way in which people experience transport systems.

Comment:

- The timeline is an issue that needs careful consideration as views are clear on the short term (up to 5 years), but less so on the longer term, and the associated questions about when change is needed has proved difficult for participants to engage with;
- One suggestion here is for training activities to be run in association with backcasting, so that learning can take place as part of the process. Care is needed to ensure that no contamination (or bias) enters into the process.

3.7 The acceptability of different pathways

The BACK-SCENE project conducted a face-to-face workshop to discuss on feasibility, acceptability and potential implementation barriers to policy pathways. Strong limitations were seen from an economic viewpoint, fundamentally as a consequence of the effects of financial crisis in the south of Spain, and the effects of political corruption associated with the creation of new transport infrastructures. Methodological distinctions were made between financial and political feasibility to facilitate discussion between participants. While political feasibility referred to the possibility that policy measures would be implemented without paying attention to financial issues, and it is focused on aspects such as: direct or indirect implementation from institutions, ease of communication, social acceptability, etc. Financial feasibility referred to the possibility that policy implementation would be influenced according to their costs. This distinction strongly facilitated the discussion between participants, avoiding misunderstanding and mixing of information. Lines for future activity are related to the level of synergies and contradictions between divergent pathways, the use of urban-labs to test the social acceptability of some measures, as well as the determination of the level of responsibility of different sectors (public institutions, private companies, citizens, etc.) in implementing such policy options implementation process.

Comment:

- Competences are important, as some participants had high levels of knowledge on financial and political feasibility, whilst others have strong views on social acceptability and responsibilities. All these issues are important for effective implementation and need further work on how these competencies can be shared;

- There are inconsistencies between outcomes, as there are contradictions and possible synergies, but these issues have not been explicitly addressed in this research.

3.8 Legal and institutional constraints

The experience from the Andalusia context indicates that participatory processes associated with backcasting scenarios need to be customised for each particular situation, providing "unique experiences". Factors affecting to the design of the participation process include: time, cost, cultural traditions, level of participatory-oriented education, and other factors. For example, in the context of Spain, people are not used to participating in public decisions, feeling that their opinions are not frequently taken into consideration by policy-makers, consultants and politicians. In this case, a strong effort at educational level was initially made to starting the participatory process. The need to customise collaborative processes for backcasting limits its usability due to the difficulty in providing universal prescriptions. Furthermore, many BACK-SCENE´s participants noticed the added value of collaborative scenarios, but recognised that those scenarios are not likely to be usable in Andalusia in the near future. Legal barriers and the low commitment of Andalusian politicians to participatory processes are seen as obstacles to overcome in real practice. In this context, the BACK-SCENE project should be seen as an initial point of innovation that still needs to be refined. The use of controlled experiments and/or simulations close-to-real-practice could facilitate a process to distil current findings triggering more generally applicable solutions (Straatmeier *et al.*, 2010).

Comment:

- The diversity of responses and issues raised at all stages in the backcasting process illustrate the strength of feeling and political nature of the options being considered. This is both a strength and weakness, as it reflects the complexity of the problems being considered and the difficulties of coming to a resolution with a consensus seeking process;
- Collaborative processes should be seen as a continuous process that extends over time and space, but they should also address the legal and institutional barriers that impede effective implementation. This might be the best way to bridge the implementation gap.

4 Conclusions

Significant changes are taking place in transport policy, resulting in the emergence of new approaches, including those that involve greater levels of participation. This means that a wide range of actors and professional domains –sooner rather than later- should engage in different ways with issues of sustainable transport and climate policy. However, certain ways of thinking prevail, impeding an effective involvement of stakeholders in favour of more structured processes. This paper has provided some commentary, reflections and discussions on collaborative backcasting scenarios in transport, as an instrument for climate change mitigation, where the gap between academic research and real practice needs to be satisfactorily bridged. Some of the main results obtained during the BACK-SCENE project have been summarised, together with a set of issues that reflect on the strengths and weaknesses of collaborative backcasting. The overall conclusions are positive, as indicated by these four concluding points:

1. Collaborative backcasting provides a learning framework. The aim of the present paper is not to give a complete list of research challenges to be addressed in the field of transport backcasting under collaborative schemes, but it has focused on interesting lessons learned in the Andalusian experience (Spain) that might form part of any follow-up study. It has specifically covered some of the situations where participatory aspects in Andalusia worked well (or not), providing more generic set of discussions for going forward. Although Andalusia has been used as the specific case study, the overall objective has been to think more about the "universal prescriptions", and the clear messages that would help in the (re)orientation of future backcasting transport studies. Both instrumental and process-related considerations have been showed in this paper. Firstly, instrumental-related considerations refer to conceptual improvements to reframe backcasting scenarios as central in determining policy options and packages for climate change mitigation. Instrumental innovations would include the development of "multi-temporal" backcasting, the role of "black-swans", and the need to create divergent policy pathways to reach sustainable transport outcomes. Secondly, process-related innovations would focus on the methodological aspects of how stakeholders can be engage in a more effective way. Examples would include: the refinement of learning processes; the issue of sample-size, and the combination of "top-down" and "bottom-up" participatory methods.

2. Collaborative backcasting explicitly includes the interrelationships between topics. The above discussions are not only relevant for future backcasting research as

stand-alone topics, but there are also combinations between them that can provide interesting research avenues for the future. Examples of this can be the development of a multi-temporal backcasting methodology combined with the exploration of legal constraints to facilitate its practical implementation, the connection between the creation of multiple desirable transport futures and the social acceptability of pathways for implementation, as well as the combination of several participatory methods with the development of disruptive and divergent transport policy pathways.

3. Collaborative backcasting has academic gains. A key objective of this paper has been the bridging of the implementation gap between academic insights on backcasting and real transport practice. A more active role has been assigned to stakeholders as part of the BACK-SCENE project, and promising outcomes have been achieved. Some of these positive achievements have been highlighted, such as the dynamic learning process, the new research challenges, and the innovative policy opportunities that can be discussed. In addition, the potential for practitioners being subjected to more academic ways of thinking means that their discourses can be better structured and become more consistent. This in turn means that acceptability and action are both more likely. A key challenge here is to determine whether participants with different backgrounds are really prepared to share knowledge and experiences with each other. The transformation of "individual knowledge" into "collective knowledge" requires the use of systematic processes of codification. This may be problematical, and needed of certain procedural rules. Furthermore, the mediator should be able to translate the individual discourses into a "common language" so that all participants fully understand the discussions, but most of them may be rooted in the professional experience (and language) of participants. If this barrier is not overcome, the backcasting process may become biased or subverted, with certain forms of knowledge being privileged over others.

4. Collaborative backcasting has social benefits. The richness of the discussions outlined in this paper has been essentially ignored in much of the previous research that is mainly technical in its focus. Research discussions currently being carried out are directed at the means by which climate change can be faced, as well as moving towards more liveable cities, including ways for overcoming transport-related social exclusion. These are often limited in scope, as they tend to be technical in nature, looking primarily at issues in isolation rather than as part of the wider societal view of sustainable transport futures. This study has found that a wide range of participants have clear views on these topics, and they are very concerned about being part of the debate over their own future, and the means by which they are going to be moving

around in the future. Their inclusion may be a crucial element in the acceptability of different future options, and reconciliation between what the experts expect that happens and what actually does happen. Their involvement in the process will make a real difference.

The present research has presented a transport policy-making process based on a collaborative approach that helps to understand, analyse and respond to the existing gaps between normative futures identified through scenario building and real transport practice. In this way, it is concluded that the implementation gap can be bridged in a positive and creative way that has the understanding and support of stakeholders. In this way real progress can be made towards sustainable transport. But, equally important is that through participatory processes outcomes are more likely to match expectations.

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Application of ANN in Pavement Engineering

Miguel Abambres, Adelino Ferreira

CITTA - Research Centre for Territory, Transport and Environment / DEC-UC - Department of Civil Engineering, University of Coimbra

abambres@uc.pt; adelino@dec.uc.pt

There has been much discussion about the impact and future of artificial intelligence (AI) in our lives and future generations. Many experts even believe that AI will "rule" the world. Artificial Neural Networks (ANN) have provided a convenient and often extremely accurate solution to problems within all fields (e.g., engineering, biology, medicine, chemistry), and can be seen as advanced general-purpose regression models that try to mimic the behaviour of the human brain. The only requirement for the suitability of this approach is the need of solving problems much quicker and/or more accurately as long as they involve large amounts of data. The adoption and use of ANN-based methods in the Mechanistic-Empirical Pavement Design Guide is a clear sign of the successful use of neural nets in geomechanical and pavement systems. This paper aims to highlight the main features and potential of ANN in general and in their application to pavement (i) management, (ii) materials and (iii) design – a summary of the actual state-of-the-art is presented. Hopefully this will serve as motivation to experts in any field within transportation engineering and planning to start taking advantage of what is the most powerful and disseminated machine learning technique worldwide.

Keywords: Artificial neural networks (ANN); pavements materials and design management; state-of-the-art.

1 Introduction

1.1 Artificial Neural Networks

Although Artificial Neural Networks (ANN) are the oldest artificial intelligence technique, it is still the leading application if one counts the number of practical applications (Wilamowski and Irwin, 2011), such as Civil Engineering, Bioinformatics, Chemistry, Finances, Internet, Medicine, Organization and Management, Robotics, Speech Processing or Meteorology, just to name a few. In its most general form, an ANN is a hardware or software "machine" designed to perform a particular task or function of interest based in the way the human brain processes information. ANNs have been employed to perform several types of relevant "real-world" basic tasks, such as (i) classification, like (i_1) sequence / pattern recognition, (i_2) identification of new data, or (i_3) decision-making, where the goal is to map each input with an output class; (ii) functional approximation/forecasting; (iii) clustering (grouping data into classes by analyzing the similarities or dissimilarities between input patterns), etc. Furthermore, ANNs have proven to be very competitive when compared to more popular data analysis methods, usually based on explicit statistical modelling. Just like any nervous system, which need to evolve in order to adapt to the surrounding environment, ANNs need to go through an adaptation/learning process in order to perform well. Artificial neural networks can be seen as advanced general-purpose regression models that try to mimic the behaviour of the human brain, although at present no ANN is anywhere near to recreating the complexity of the brain (Haykin, 2009). However, the progress that has been made since their inception is remarkable, and it is certain that the development and applications of these algorithms will keep growing in the future (Flood, 2008; Prieto et. al., 2016).

1.2 Application of ANN in Civil Engineering

Expert systems and ANN have been the most commonly used AI techniques in Civil Engineering since the latter's inception in mid-1980s (Mosa *et al.*, 2013). ANN have provided a convenient and often highly accurate solution to problems within all branches, appearing from the statistics on publications to be one of the great successes of computing (Flood, 2008). The first journal article on civil engineering applications of neural networks was published by Adeli and Yeh (1989). Since then, many other applications of ANN within all fields of Civil Engineering have arisen with increased complexity and sophistication (Adeli, 2001). Areas like (i) buckling and bearing capacity prediction, (ii) constitutive modeling, (iii) structural reliability and/or optimization (e.g., Papadrakakis and Lagaros, 2016), (iv) structural health monitoring (e.g., Min *et al.*, 2012), or (v) transportation engineering (e.g, Alkheder *et al.*, 2016; Ceylan *et al.*, 2014; Dougherty, 1995; Flintsch and Chen, 2004; Kim *et al.*, 2009), have received special focus until today. The adoption and use of ANN-based methods in the Mechanistic-Empirical Pavement Design Guide (NCHRP, 2004) is a clear sign of the successful use of neural nets in geomechanical and pavement systems.

1.3 Aim

Due to (i) the extent of ANN-based applications to pavement engineering since the 1990´s, and (ii) the rising potential of neural nets to the performance of more accurate and efficient engineering, this work aims to provide an overview of the state-of-the-art application of ANN models in the design and management of pavements. Unlike previous review articles published on these topics before 2014 (Ceylan *et al.*, 2014; Dougherty, 1995; Flintsch *et al.*, 2004; Kim *et al.*, 2009), it is worth noting that the present work is far more descriptive and makes the review much more appealing to the reader by highlighting numerically and/or graphically the effectiveness and possible drawbacks of each ANN application.

Due to paper size limitation, a truly brief overview of ANN features and fundamentals is presented in the next section. The applications of neural nets to several types of pavement problems is described in section 3. An extended version of this paper was recently submitted for publication by Abambres *et al.* (2017).

2 Brief overview of ANN features and fundamentals

This section aims at addressing the main neural network features and giving a quite short overview about the main concepts inherent to the most typical ANN models employed in pavement engineering so far. Further details about virtually any topic regarding ANN can be found in well-known books like Haykin (2009) or Du and Swamy (2014).

The general ANN structure can be seen as several partially or fully connected processing units (neurons), which are disposed in several vertical layers (the input layer, hidden layers – if there are some, and the output layer), as illustrated in figure 1. Associated to each neuron is a linear or nonlinear transfer function which receives an input and transmits an output – a typical neuron's model is described in 2.1. Each connection (link between two nodes in the network) is associated to a synaptic weight, which is a typical example of a network unknown to be determined during the network design process. The way in which the neurons of a neural net are structured and linked define what is known as the network architecture. In sub-section 2.2, the multi-layer perceptron (MLP) is briefly addressed since it is the most commonly used network type in pavement engineering applications.

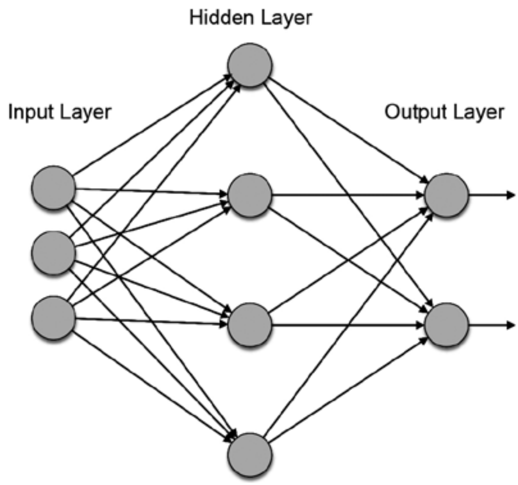


Figure 1. Example of a Multi-Layer Feedforward Network.

The ANN's computing power, making them suitable to efficiently solve complex (small to large-scale) intractable problems, can be attributed to their (i) massively parallel distributed structure and (ii) ability to learn and generalize, i.e, produce reasonably accurate outputs for inputs not used during the training phase. Besides, neural networks offer features like (i) nonlinearity, (ii) ability to handle imprecise/noisy and/or missing data (Basheer and Hajmeer, 2000), and (iii) input-output mapping – ANN-based solutions are frequently more accurate than the ones provided by traditional approaches (e.g., multi-variate nonlinear regression), despite not requiring a good knowledge of the function shape being modelled (Flood. 2008).

2.1 Model of a Neuron

Each processing unit of any ANN is called a neuron, and it plays a crucial role in the network's behaviour. There are three basic elements in a typical model of a neuron, as depicted in figure 2: (i) connecting links (also called synapses) between each "input" signal (x_j , j = 1,...,J) and the k^{th} neuron, which are characterized by their synaptic weights ($w_{jk} \in R$), (ii) a summing junction ($s_k = x_j w_{jk}$) – Einstein summation convention employed, to add up the weighted input signals that converge to the neuron, and (iii) an activation (or transfer) function φ_k, which receives s_k plus neuron's bias ($b_k \in R$) as input – also known as the induced local field, and provides neuron's output y_k. In ANN design, the activation functions are user-defined (e.g., logistic, linear).

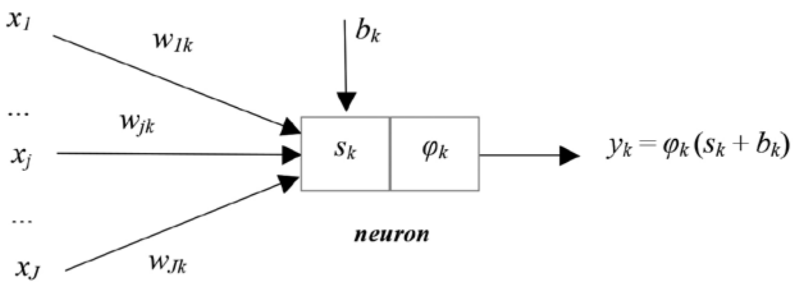


Figure 2. A typical model of a neuron.

2.2 The Multi-Layer Perceptron (MLP)

This is a feedforward ANN, i.e. the signal flow through the network progresses in a forward direction from left to right, and on a layer-by-layer basis, and exhibits at least two neuron-based layers and the input node layer. Each layer of neurons that is not the output layer is called a "hidden layer" and the corresponding units are called "hidden neurons". By adding one or more hidden layers, the network is enabled to extract higher-order statistics from its input (Haykin, 2009). Figure 1 represents a 3-layer feedforward network, also referred to as 3-4-2 (3 input nodes, 4 hidden neurons in the single hidden layer, and 2 output neurons). As can be seen, each node in each layer links to every node in the next layer (typically called a fully-connected network), i.e. the output signals of the 2^{nd} (hidden) layer will serve as input signals of the 3^{rd} (output) layer – unless stated otherwise (e.g., PC - partially connected), all MLP networks referred in this paper are fully-connected. Nodes in each layer do not connect to each other and no connections across layers (between the input and output layers, in this case) are allowed. The synaptic weights and bias mentioned in 2.1 are network unknowns to be computed by a major task for any ANN, called Learning – the most used learning algorithms in pavement problems so far are called error Back-Propagation (BP) (the most popular) and Levenberg-Marquardt (LM).

2.3 The universal approximation theorem

For a nonlinear input-output mapping, this theorem states (Haykin, 2009) that a single hidden layer MLP, with (i) any bounded, monotone-increasing and continuous activation function for the hidden neurons, and (ii) an identity (linear) transfer function for the output neurons, is sufficient to compute an arbitrarily good approximation of any continuous function in a general n-dimensional space – the absolute difference between any estimated and target outputs can be less than any $\in > 0$, for all input space values. However, it is worth recalling that this theorem does not guarantee great network behaviour concerning learning time and/or generalization.

3 ANN applications in pavement engineering

In this section, a quick overview over the state-of-the-art application of ANNs in pavement engineering is addressed. Although only one reference per problem type is described due to paper size limitations, the main ANN features used in the most relevant references addressed in Abambres *et al.* (2017) are presented in Tabs. 1-4.

3.1 Pavement management

3.1.1 Pavement distresses

Roughness

A pavement profile (also called roughness) is one of the most effective vehicle environmental conditions that influences ride, handling, fatigue, fuel consumption, tire wear, maintenance costs and vehicle delay costs. Ziari et al (2016) proposed an ANN to predict international roughness index values in short- and long-term for flexible pavements. Sensitivity analysis using several LM-based MLP networks was performed and (i) the best performance regarding short-term was obtained for the topologies 9-80-50-30-1 and 9-3-1, whereas the 9-8-1 layout proved to be the best for long-term.

Skid Resistance

It is well known that weather and traffic influence the degradation of skid resistance between the tire and pavement surface over time. Bosurgi and Trifirò (2005) developed a neural net-based "sideway force coefficient" prediction model to be applied on a motorway. A LM-based 2-3-1 MLP was adopted, yielding errors inferior to 7 % in 91 % and 86 % of the cases in the training and validation phases, respectively.

Cracking

Paris' law, which is based on linear elastic fracture mechanics, has been adopted to analyze pavement cracking problems. However, one of the drawbacks of this model regards the quick and accurate computation of the stress intensity factors (SIF), a parameter that amplifies the magnitude of applied stress, at crack tips. Finite element analysis (FEA) is a powerful tool for that purpose, but the 3D pavement behaviour can only be accurately predicted through heavy (slow) FEA when using today's available resources in practical applications. Lee (2004) presented three ANN to classify crack types from digital pavement images, as alternative to pixel-based ANN (higher processing time), namely designated as image-based (INN), histogram-based (HNN) and proximity-based (PNN). Each model has a different number of input nodes and each output neuron represents a crack type. The best performance was obtained with architectures 180-90-5 (INN), 27-60-5 (HNN) and 3-150-3 (PNN). The INN is similar to the pixel-based neural net except that it uses crack tiles. The matrix of crack tiles (1 if there is crack, 0 it there isn´t) is injected into the ANN input layer as an array with 180 binary values (12 rows x 15 columns in the "tiled" digital image) – inputs are read sequentially from the upper left corner tile to the bottom right corner tile. HNN networks inject two histogram arrays into input layer (27 nodes – 12 for the horizontal histogram and 15 for the vertical counterpart), as illustrated in Fig. 3. PNN nets' input layer is defined by three variables, which, to be determined, requires computing the following quantities: (i) vertical proximity (P_v), defined as

$$P_v = \sum_{i=1}^{Nc-1} \left| H_{v[i+1]} - H_{v[i]} \right| \tag{1}$$

where H_v is the vertical histogram and N_c the number of columns of the "tiled" image, (ii) horizontal proximity (P_h), defined as

$$P_h = \sum_{i=1}^{Nr-1} \left| H_{h[i+1]} - H_{h[i]} \right| \tag{2}$$

where H_h is the horizontal histogram and N_r the number of rows of the "tiled" image, and (iii) the number of cracked tiles in the image. The final results indicate that the PNN produced the best result, with a 95.2 % accuracy on real validation images, despite its simpler structure with the lesser computing requirement (INN and HNN corresponding performances were 70.2 % and 75 %, respectively).

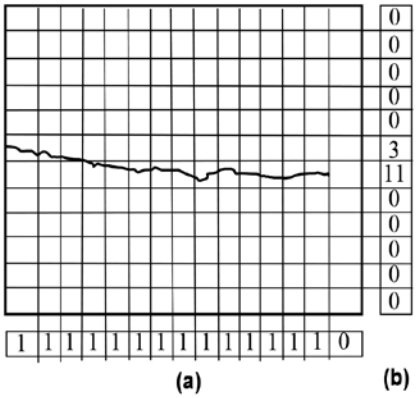


Figure 3. HNN (a) vertical and (b) horizontal histogram (Lee and Lee, 2004).

Joint Faulting

Transverse joint faulting is one of the main types of distresses in jointed Portland cement pavements. It can be defined as the difference in elevation between adjacent slab edges at a transverse joint. Saghafi *et al.* (2009) applied an ANN to estimate the effect of base layer conditions and pavement age on transverse joint faulting. Several BP-based MLP networks were assessed parametrically in order to find the optimal layout, which was 8-8-8-1. The proposed ANN was able to successfully predict the measured joint faulting with $R^2 = 0.94$ for the testing set.

3.1.2 Pavement Condition Indexes

Present Serviceability Index (PSI)

Prediction modelling of pavement deterioration (a stochastic and nonlinear phenomenon) is crucial for an effective PMS, where the goal is to find the appropriate period and method of rehabilitation. Tabatabaee *et al.* (2013) proposed a two-stage soft computing model to properly classify (using a support vector classifier - SVC) and accurately predict pavement performance. A PC LM-based 8-5-1 RNN is used for the second stage to predict performance in terms of PSI, as illustrated in Figure 4. The two-stage model results were compared with those yielded from a RNN-based single model, and it was concluded that the latter was less effective in the prediction of PSI values ($R^2 = 0.95$ vs. $R^2 = 0.98$).

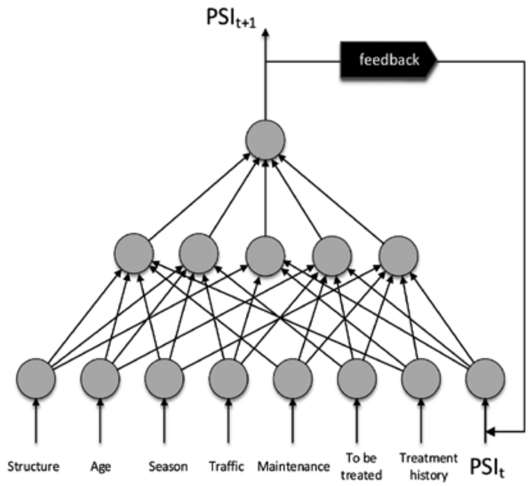


Figure 4. The RNN used in a two-stage soft computing model for PSI estimation (Tabatabaee *et al.*, 2013).

Condition Rating

One of the important activities of highway engineers is the determination of pavement condition ratings (PCR), i.e. assignment of relative weights to various levels of pavement distresses in order to obtain a combined score that indicates the current condition of a roadway section. Amin and Amador-Jiménez (2017) applied BP-based 5-3-2-1 MLP networks to predict pavement condition index (PCI) values. The study categorizes road segments into four categories based on pavement types (e.g., flexible or rigid) and road hierarchies (e.g., arterial or collector), so four ANN models were developed. Concerning accuracy, the relative errors obtained in {training, validation, testing} subsets were approximately {5, 9, 9} %, {11, 23, 72} %, {3, 3, 4} % and {4, 4, 4} % for Arterial-Flexible, Arterial-Rigid, Collector-Flexible and Collector-Rigid road segments, respectively.

3.1.3 Maintenance

Traditionally, ranking of highway sections requiring maintenance is based on experience of qualified personnel. Mathematical decision-making criteria have been proposed through the so-called "aggregate condition index", which has shown several drawbacks (Fwa and Chan, 1993). Abdelrahim and George (2000) evaluated the use of neural nets to predict the optimum maintenance strategy on the basis of realistic (i.e., noisy) data. A genetic adaptive algorithm is employed to train a 10-10-6 MLP network. Six outputs result from the fact that there are six different maintenance strategies to be considered – the selected strategy is coded 1 and the others 0. The proposed ANN was able to predict 83 % of the validation examples.

3.2 Materials and pavement design

3.2.1 Material physical properties

Xiao *et al.* (2011) developed several ANNs to predict the viscosity of various CRM binders at three mixing durations. A LM-based 4-3-1 MLP network was trained with experimental data and the quality of the ANN prediction was quite satisfactory ($R^2 \geqslant 0.96$).

3.2.2 Layer Moduli / Thickness, Poisson's Ratio

Backcalculation is an inverse methodology to determine pavement layer stiffness by matching the measured and theoretical deflection with iteration and optimization schemes. One of the drawbacks, besides time, is that minor deviations between measured and computed deflections usually result in significantly different moduli. Gopalakrishnan and Ceylan (2008) employed ANN-based structural models to accurately predict flexible airport pavement layer moduli from realistic FWD deflection basins. Two separate models were proposed for the prediction of AC and subgrade Young modulus, both consisting of a BP-based 8-60-60-1 MLP net, whose validation results are depicted in figure 5.

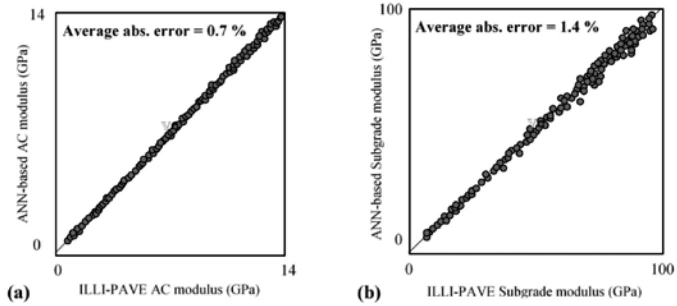


Figure 5. FEA vs. ANN validation results: (a) AC, (b) Subgrade (based on Gopalakrishnan and 2008).

3.2.3 Stress, strain, deflections and creep

Ghanizadeh and Fakhri (2014) proposed an ANN model to predict the effective length of longitudinal and transverse stress and strain pulses at the bottom of the asphalt layer. The LM-based 7-15-4 MLP network has proven to be a highly accurate model ($R^2 = 0.999$).

3.2.4 Equivalent Single Axle Load (ESAL)

AASHTO (American Association of State Highway and Transportation Officials) design equation has been used in pavement thickness design to calculate the structural number, i.e., the required pavement strength. Tigdemir (2014) developed a BP-based 7-20-2 MLP neural network aiming to predict (i) AASHTO-based design life and (ii) the relation between the AASHTO-based (computed by the first model) and the real design life of pavements, in terms of EVAL. Good correlations were obtained for each output variable, namely R^2 = {0.97, 0.94}.

3.3 Frequency of application of each ANN feature

In this final sub-section, Tabs. 1-4 summarise the main ANN design features employed in some of the most remarkable pavement engineering studies found in the literature, so that the reader can decide much quicker which features to include in a neural net-based parametric analysis of similar problems. Moreover, histograms based on all references addressed in Abambres *et al.* (2017) are presented in figures 6-9 and aim to give, for each pavement engineering field (1st column in tables 1-4), a graphical insight of the frequency of use of each ANN feature in the final design. It is possible to conclude that:

(i) The one hidden layer-MLP has been the most used neural net architecture by far in both pavement management (except distresses) (75.0 %) and pavement materials & design (60.7 %) problems, while it comes in second behind the two hidden layer-MLP (44.4%) for pavement distress studies;

(ii) The error backpropagation has been the most employed learning algorithm in any of the three pavement engineering fields addressed, having been used in more than 55 % of the works;

(iii) The logistic hidden node transfer function is by far (90.9 %) the “winner” in pavement management problems. In the other two fields, it also takes the lead but by less than an eleven percent point difference over the hyperbolic tangent function;

(iv) For the output neurons, the logistic transfer function predominates in all fields except pavement distresses, where the linear function was employed in 63.6 % of the cases;

(v) Figure 9 presents the distribution of the “ANN feature” in the fourth column of tables 1-4 for all the references analyzed in Abambres *et al.* (2017). That value represents the round of the constant amount of values (a) per input variable that needed to be considered if LD (total amount of learning data points) equalled the total number of input data combinations – “a” from a^{IV}=LD was computed and then rounded to the closest integer, where IV is the number of input variables.

4 Final Remarks

An overview of the state-of-the-art application of ANNs in pavement engineering has been presented, covering fields like pavement management, materials and design. This work aims to motivate and support the related expert community in the use of neural nets in problems where there is abundant data but the solving methods usually adopted are too lengthy and/or inaccurate. It should be noted that despite the great amount of applications and quite satisfactory results found in the literature, there is a lack of utilization of more advanced techniques in the design of ANNs – in most cases, the more traditional architecture (MLP) and learning algorithms (BP, LM) were employed, and not much reference was made to special trimming and data pre-processing techniques for the improvement of the network generalization ability. The authors of this paper are currently working to make a contribution to change this scenario in the near future.

Table 1. ANN features employed in pavement management problems (distresses not covered).

Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Functions	$10^{Log(LD)/IV}$	
Pavement Management	Skid Resistance	2-3-1 MLP	LM	-	27	Bosurgi & Trifirò 2005
	Maintenance	6-1-1 MLP	BP	Logistic	5	Fwa & Chan 1993
		12-22-5 MLP 12-28-5 MLP 12-34-5 MLP	BP	Logistic	1	Alsugair & Al-Qudrah 1998
	Condition Rating	5-3-2-1 MLP	BP	Logistic	-	Amin & Amador-Jiménez 2017
	PSI	8-5-1 RNN	LM	Hyp. Tg / -	-	Tabatabaee et al. 2013

Table 2. ANN features employed in pavement distress problems.

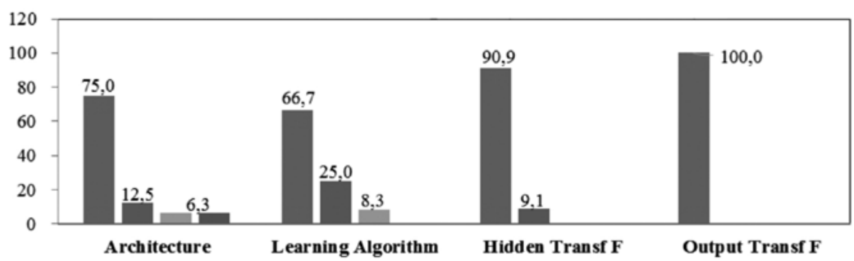
Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Function	$10^{Log(LD)/IV}$	
Pavement Distresses	Roughness	x-15-4 WNN	BP	Mexican Hat Wavelet / Linear	-	Solhmirzaei et al. 2012
		3-50-50-2 MLP	LM	Hyp. Tg / Linear	16	Ngwangwa et al 2014
		9-80-50-30-1 MLP 9-3-1 MLP 9-8-1 MLP	LM	Hyp. Tg / Linear	2	Ziari et al 2016
	Cracking	3-150-3 MLP	BP	-	8	Lee 2004
		8-40-40-1 MLP 9-40-40-1 MLP 7-40-40-1 MLP 9-40-40-1 MLP	BP	Logistic	3 2 3 2	Ceylan et al. 2011
		26-7-7-7-1 MLP 26-5-5-1 MLP 29-7-7-7-1 MLP 31-6-6-1 MLP	BP	Hyp. Tg / -	1 1 1 -	Thube 2012
		4-7-2 MLP	BP	-	-	Gajewski Sad. 2014
		8-12-8-2 MLP	BP	Logistic	3	Yoo, Kim 16

Table 3. ANN features employed in pavement materials and design problems: layer moduli / thickness and Poisson's ratio.

Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Function	$10^{Log(LD)/IV}$	
Materials and Pavement Design	Layer Moduli / Thickness, Poisson's Ratio	6-60-60-2 MLP 12-60-60-1 MLP	BP	-	5 2	Ceylan et al. 2007
		8-60-60-1 MLP	BP	-	4	Gopalakrishnan & Ceylan 2008
		8-60-60-1 MLP 7-60-60-1 MLP	BP	-	4 5	Bayrak & Ceylan 2008
		6 - 4 - 1 MLP 3 - 5 - 1 MLP	BP	Logistic / Linear	3 6	Park et al. 2009
		5-3-1 MLP 5-6-1 MLP	BP	Logistic	2 2	Xiao & Amirkhan. 2009
		3-2-1 MLP	LM	Hyp. Tg	6	Kok et al. 2010
		10-10-1 MLP 9-9-1 MLP 7-6-1 MLP	BP	Hyp. Tg / Logistic Hyp. Tg / Linear Logistic / Linear	-	Nazzal & Tatari 2013
		7-15-3 MLP	LM	-	2	Saltan et al. 2013
		13-20-20-3 MLP	BP	Hyp. Tg	2	Leiva -Villac. et al. 2016

Table 4. ANN features employed in pavement materials and design problems: stress, strain, deflections, creep, material physical properties and ESAL.

Field	Problem	ANN Feature				Ref
		Architecture	Learning Algorithm	Hid./Out. Transfer Function	$10^{Log(LD)/IV}$	
Materials and Pavement Design	Stress, Strain, Deflections & Creep	6-29-29-3 MLP	BP	Logistic	6	Ceylan et al. 99
		5-60-60-2 MLP 5-60-60-3 MLP	BP	Logistic	5	Ceylan et al. 2005
		11-20-6 MLP 15-20-6 MLP 12-20-6 MLP	BP	Hyp. Tg / Linear	2 2 2	Zofka & Yut 2012
		7-9-1 MLP 6-8-1 MLP 6-3-1 MLP 6-10-1 MLP	LM	Logistic / Hyp. Tg	-	Tapkin et al. 2012
		7-15-4 MLP	LM	Hyp. Tg / Linear	3	Ghanizadh & Fakhri 2014
		3-60-60-6 MLP	LM	Logistic	35	Ceyan et al. 2014
		7-13-1 MLP	LM	-	2	Shafabakhsh et al. 2015
	Material Phys.Props.	4-3-1 MLP	LM	Logistic	4	Xiao et al. 2011
	ESAL	7-20-2 MLP	BP	Logistic	2	Tigdemir 2014



Architecture	Learning Algorithm	Hidden Transf F	Output Transf F
1 Hidden Layer-MLP	BP	Logistic	Logistic
2 Hidden Layer-MLP	LM	Hyperbolic Tangent	-
1 Hidden Layer-RNN	Genetic Adaptive	-	-
MC-HARP	-	-	-

Figure 6. Frequency of ANN features in pavement management problems (distresses not covered – table 1).

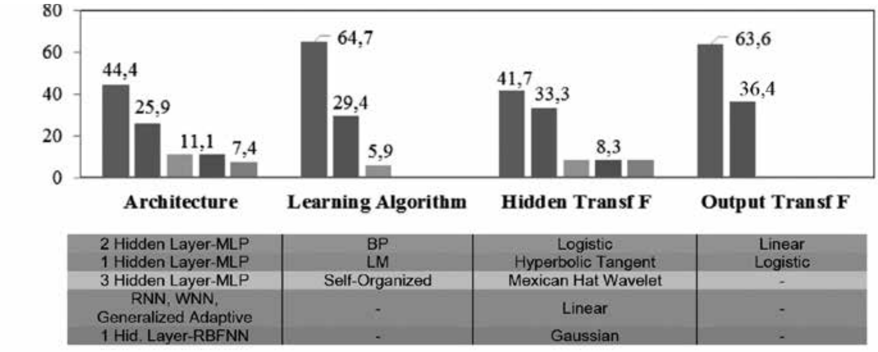


Figure 7. Frequency of ANN features in pavement distress problems (table 2).

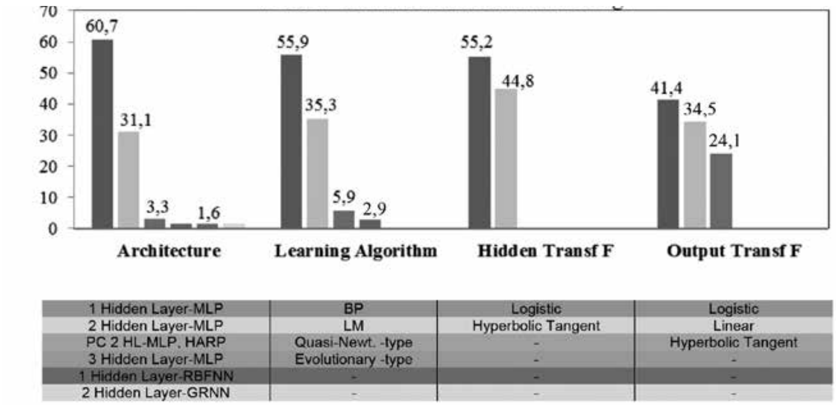


Figure 8. Frequency of ANN features in pavement materials and design problems (tables 3-4).

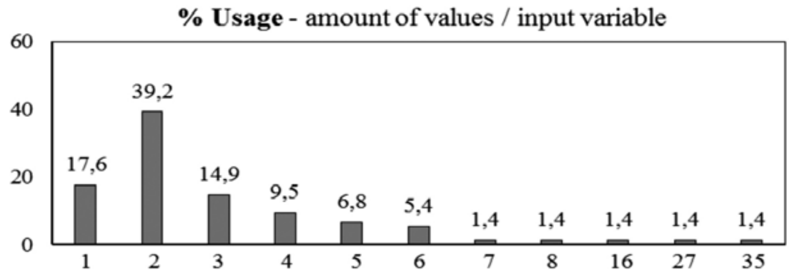


Figure 9. Fictitious number of values per input variable according to the amount of learning data.

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The publicness of urban spaces: planning for urban change

Miguel Lopes, Sara Santos Cruz, Paulo Pinho

CITTA - Research Centre for Territory, Transport and Environment / FEUP - Faculty of Engineering of the University of Porto

mnlopes@fe.up.pt; scruz@fe.up.pt; pcpinho@fe.up.pt

Larger and inextricably more complex than the first examples of modern civilization, contemporary cities are characterized by intricate physical, economic and social structures. Fuelled by a global competition between cities, large amounts of money and resources have been poured into urban areas to attract businesses, residents and overall recognition. New forms of space provision and management have emerged, creating social and spatial shifts, and redefining social values, needs and routines, changing the way we look to the city, and particularly to its public spaces. These new spaces, often built around the culture of the automobile, are not only social but environmentally unsustainable. To reduce its carbon footprint, cities need quality public space, evenly spread across the urban territory, increasing the overall attractivity of the urban environments. By having more quality spaces easily accessible, public space fruition increases, generating a more socially and environmentally conscious behaviour. While many public spaces have been created, and redeveloped in the process, quite often, experimentation sets the tone for these attempts, with varying results.

This paper is framed on a PhD thesis which tries to develop a new comprehensive framework for the evaluation of a space's publicness, allowing the creation of a planning support system, divided into four major themes. The first concerns the space's activity, allowing the assessment of each space's usage patterns. Physical design, the second dimension, includes all physical aspects relevant to a space's success, ranging from accessibility features, amenities and comfort conditions. The third dimension analyses the interpretation of human practices, contextualizing them into the user's perception of the space. The fourth and final dimension addresses the management component, evaluating the degree of involvement of the management authorities towards the success of the space. Eight spaces will be analysed, equally distributed in the city centres of Porto and Newcastle and among public and semi-public spaces. This allows the integration of the influence of different weather conditions, planning methods and space usage culture into the definition of a concept of publicness that can be applied universally. The performance in each dimension, measured through 50 indicators, is afterwards combined into a unified indicator, defining how its different components help each other, with the creation of a successful space in mind, where aspects such as sociability and sustainability are essential.

Keywords: Publicness; urban spaces; public space performance; evaluation methodology.

1 Introduction

Urban areas gather today more than half of the world's population, with a natural increasing tendency in the following decades. Energy demand, mobility, air and water quality, and waste management are just some of the most pertinent issues that come to mind when analysing this growth. While being the largest contributor to the emission of greenhouse gases (UN Habitat, 2014), cities are the ones who often suffer first-hand the impacts of climate change. Heat waves, heavy and continued precipitation and coastal flooding concerns hang over some of the world's largest cities, as a reminder of the need for immediate action.

However, in an increasingly globalized world, cities compete against each other for the attraction of investment, essential for fuelling its growth, which often turns sustainability concerns secondary.

One of the first aspects of change is the inclusion of quality of life concerns in the growth process, supporting local economic development. Whereas quality of life conditions were measured through access to basic facilities and infrastructures such as food, water, housing and medical assistance, in the contemporary society the stakes are higher. Conditions for the establishment of public life are also needed, such as the possibility to engage in meaningful interaction with the broader community, civic engagement, and the proximity to family and friends (Lopes and Camanho, 2013). Agglomeration economies are what define urban centres, allowing a concentration of jobs, facilities and amenities, surrounding the private space that defines each resident's dwelling. However, urban life cannot be solely defined by these private patches, as public space is what binds all these different spaces together, and therefore of great relevance to the understanding of the city. Although studies addressing the importance of public spaces in the urban context have come a long way, the constant redefinition of urban dynamics, social needs, values and routines generates the necessity to revisit the main aspects of these spaces.

This research is part of a PhD thesis focused on the creation of a new methodology of space assessment, based on the concept of publicness. Given the broad range of its scope, it is possible to assess the sustainability of spaces, in order guide its redevelopment and creation.

2 Planning for climate change

The energy crisis of the 1970s was crucial to the beginning of the implementation of sustainability concerns in the design of buildings and urban spaces (Evans, 1980).

Climate change refers to the change in average weather patterns, measured by indicators such as temperature, precipitation and winds, but also the frequency of the occurrence of extraordinary events. Much of the stress in planning for climate change is focused on the reduction of greenhouse gas emissions (Gill *et al.*, 2007). To prevent the adverse impacts of both current and future climate change, there is a need to adopt "planned adaptation" strategies (Fussel, 2007). This means using all available information about present and future climate change, to review the suitability of existing and future planning practices, policies and infrastructure.

According to the framework developed by the United Nations, planning processes and development activities across all sectors have a valid role in the fight against climate change (UN Habitat, 2014), being ecosystems protection, improving disaster risk reduction, improving infrastructure capacity and support local economic development the main aspects in this strategy.

In fact, the climate change planning process is not linear, requiring an iterative process to include new information, stakeholders and strategies. Furthermore, it is highly context-specific, depending on climatic, environmental, social and political conditions (Fussel, 2007).

In all urbanization processes, vegetated surfaces, essential to provide evaporative cooling, rainwater collection and infiltration, are replaced by impervious built surfaces (Whitford *et al.*, 2001). The development of compact settlement forms, although undeniably more sustainable than urban sprawl in terms of energy consumption and resource spending, must consider the social consequences of increasing densities. One of the main reasons that led to the proliferation of urban sprawl was the possibility for everyone to have their own share of open space. With the growing densification of urban areas, the amount of public space tends to reduce and the pressure for quality public space increases.

Since the establishment of modern civilization, public spaces have been the backbone or public life, being used for commercial transactions, social exchange, entertainment, protest and contemplation.

Besides, public spaces, and especially the ones of larger dimensions, have an important role that extends beyond these contributions, fact that research has often neglected. By creating a break in the artificialized urban fabric, these types of spaces often have their own microclimate. While large paved surfaces, such as the traditional public squares may irradiate heat, the inclusion of green elements support ventilation, provide shadow and increase relative air humidity. Vegetation can also reduce solar heat gain in buildings and thus reduce the demand for air conditioning usage, which contributes both to the reduction of greenhouse gas emissions as well as to the urban heat island. Facing increasing average temperatures, cities must preserve existing areas of green space and enhance it where possible, both in private gardens or public spaces (Gill *et al.*, 2007).

3 Public space and publicness

Public, placed in the opposite sense of private, is important in the definition of a number of concepts, targeting aspects such as physical space, social life, democracy and common interests. In the end, all these different interpretations are targeted to ensure public order, the practice through which the public is ordered, through a series of thresholds and complex boundaries. For Francis (1989), this defines its publicness. Even though Benn and Gaus (1983) were some of the first authors to provide clear insights regarding the complexity of this term, publicness was left apart from the overall public space debate until the end of the last century. At this point, publicness was viewed as an important tool to justify cause-effect relationships, such as the impact of securitization and privatization (Németh and Schmidt, 2011; Van Mélik *et al.,* 2007), as a tool to analyse changes in public spaces (Akkar, 2003) or as a discrimination of its distinct features (Varna and Tiesdell, 2010). As a result, publicness has become widely accept as defining a public space's main features and qualities. However, as most authors have focused on specific aspects of space, they failed to grasp all the dynamics and features that make a public space work and be understood as one.

Beyond its inherent complexity, public spaces are characterized by unpredictability. They are living testaments to different ages in city building, often accompanying its urban structure, architectural style and social background. These changes have become more frequent, and public spaces, unable to cope to events such as globalization, privatization schemes, urban dispersion, and the development of electronic communication technologies (Banerjee, 2001; Ellin, 2003; Madanipour, 2003), saw a decline in urban life, as streets and squares were replaced by 'suburban living rooms', turning them into simple passage sites (Sennett, 1992).

The promotion of networked cities, where their visibility in the global sphere is a key to success, fostered the development of large urban projects, often with public spaces as key elements, turning them into an instrument to sell the city (Madanipour, 2003). Public authorities, faced with the reality of budgetary limits, started to rely on the private sector to execute these projects. Although this guaranteed the creation of new spaces, it would also mean the inevitability of their exposure to commercial and corporate interests. Driven by profit, exchange value became more important than the symbolic value of the space, leading to space commodification (Kohn, 2004; Madanipour, 1996; Sorkin 1992).

With varying degrees of success and intensity, different methods have changed the nature of public space, often featuring the implementation of restriction schemes and stricter policing methods (Low and Smith, 2006). The creation of Business Improvement Districts which monitor and control public areas (Németh and Schmidt, 2007; Zukin, 1995), and the creation of privatized plazas (Miller, 2007; Németh, 2009), and other semi-public spaces such as shopping malls, theme parks, and closed condominiums (Santos Cruz, 2003), are the most prominent examples.

Public spaces began to coexist with these new arenas for public life, fragmenting urban space, as the public sought new experiences. In these 'disneyfied spaces' (Sorkin, 1992; Zukin, 1991) the public realm is deliberately shaped as a theatre (Crilley, 1993), where all activity is carefully staged for the sake of creating spectacle (Madanipour, 2003). Even so, this did not deter users from changing their minds.

New information technologies fuelled an exponential growth in the number of gathering spaces, while simplifying communication and reducing the need for conventional forms of social interaction, negatively affecting public space usage. Neither public nor private, these new spaces appear to respond to the public need, blurring the boundaries between public space, focus of the public life, and private space, home of the personal and the intimate.

Although this scenario posed the apparent death of traditional public spaces, it is important to note that the most basic human needs are still delivered by traditional public spaces. By providing identity and meaning to the city, society still depends on these common grounds to develop important aspects of civility and democracy (Carr *et al.*, 1992; Madanipour, 1996). When adequately 'populated', public spaces can also contribute to the reduction of crime levels and anti-social behaviour (Jacobs, 1961).

Several authors have since been defending a return to the study of traditional forms of public space (Gehl and Gemzoe, 2001; Loukaitou-Sideris and Banerjee, 1998). Through events such as farmers markets, antiques fairs, open-air cinema displays, and outdoor theatre and music events, contemporary societies have reacquired the 'taste' for traditional public spaces, recovering the once 'thought as lost' public life, and recovering back the city. For them, despite the growing tendencies towards privatization, opportunities for association and exchange have increased. Public space is not in decline, but is instead expanding (Worpole and Knox, 2007).

Interventions in public spaces must target the real needs of the city and its residents, to avoid overspending resources, both material and financial. By adapting projects to the local context, sustainability concerns become a part of this process of urban development. Is this process of private sector involvement positive to the sustainability of the city? The readjustment of the concept of public space through its publicness can indeed be of great assistance in urban development, with great value to improve existing planning support systems and guide the development of cities into more sustainable forms.

4 The Publicness Evaluation Model

4.1 Introduction

Defining publicness is more than assigning a label of public or private, or checking if a space meets any given criteria (Kohn, 2004), thereby requiring the inclusion of a wide range of urban dynamics through a series of inter-connected components.

It is expected that good public spaces work as intended, responding to the needs of its users, while balancing different urban dynamics. The features commonly identified as describing successful spaces and realms should form the groundwork for the definition of publicness' components.

Designed as social locations, the evaluation of public spaces' activity is the first step to be made. Jane Jacobs (1961) was one of the first to defend activity in order to achieve a successful public realm, identifying as key determinants a mixture of primary uses, intensity, urban form, permeability, as well as building types, ages and sizes (Carmona *et al.*, 2003).

For Montgomery (1998), three main features must be in place in order to achieve successful urban places, being those activity, image and form. As one's opinion regarding a space relates in a great manner to what 'meets the eye', its physical appearance and conditions, i.e., its design features are also vital to define its quality.

Carr *et al.* (1992) gave great emphasis to the established connection between space and its users, identifying the need to respond to the users' needs for comfortable, peaceful, sociable, and stimulating spaces. Jacobs and Appleyard (1987) had already defended the need for maintaining a discoverable space, with a strong communal and public life, considering issues of sustainability, equality of access and control, and democracy. Gehl (2001) defines public space quality through protection, comfort, and enjoyment, all related to how users perceive and feel the space. Shaftoe (2008) moves further, establishing a connection between physical design, activity levels and psychological stimulation in his definition of 'convival spaces', which combine good landscaping, public art and entertainment.

Project for Public Spaces (2000), a non-profit organization that carries on the work of its founder, William H. Whyte, developed a systematic process to program and design space, identifying as key qualities access and linkages, uses and activities, comfort and image, and sociability. In a way, these qualities combine the three main elements that consensually define a successful public space: high levels of activity, a strong connection between the space and their users, and a 'good' image and form.

Still, changes in management schemes, on which privatization is its most visible form, require the study of the implications of distinct management strategies over the way these spaces operate and how they are seen by its users. As a result, a division in four themes seems appropriate, being those urban life, physical design, user connection and management.

4.2 Urban life

All cities have distinctive identities and characters, in what is normally referred to as a 'pulse', a rhythm of everyday life, or simply an 'urban buzz'. The creation of opportunities for different activities and uses is therefore essential, to justify one's level of freedom. Here, it is important to assess the strength of the space's main dynamics measurable through the intensity of pedestrian flows, use and activity variety, as well as the existence of any restrictions inhibiting the space's full usage. The uses that surround it, as well as some particular elements of the neighbouring urban environment, are also vital to achieve the needed user flows that allow natural surveillance.

Table 1. Indicators for the urban life dimension.

Indicator		**Value**	**Measured elements**	
			E1	**E2**
A1	Freedom of use	3 2 1	Open 24/7 With operation schedule Sections permanently closed	No visible restriction on uses 1-2 restricted used >3 restricted uses
A2	Use variety	3 2 1	>4 distinct uses 2-4 distinct uses 1 use	<25% of single user group 25-75 of single user group <75% of single user group
A3	Static occupation	3 2 1	>75% of space used at peak 25-75% of space used at peak <25% of space used at peak	>50% of stays over 10 min. <50% of stays over 10 min. Movement only space
A4	Dynamics	3 2 1	>60 ped./ min. 10-60 ped./min. <10 ped./min.	>1 weekly event during Summer <1 weekly event during Summer No scheduled events
A5	External dynamics	3 2 1	<10% of blank frontages 10-50% of blank frontages >50% of blank frontages	Transport on site Transport at <500m Transport at >500m

4.3 Physical design

The physical aspects of a space have an important role in determining what can and what cannot happen there, shaping the initial user opinion, and controlling the degree of natural material degradation, which can lead to its unintended rundown. Here is where the values of sustainability are more visible. The physical features of a place affects the choices users can make, ranging from its physical presence, the opportunities for use and the extent to which people can put their own stamp on a place. Also important are the effects over its degree of comfort, in aspects such as seating, quality of the materials, urban furniture, inclusive design, and consideration over shading and microclimates.

Table 2. Indicators for urban design dimension.

Indicator		Value	Measured elements	
			E1	**E2**
B1	Access freedom	3 2 1	No physical access restrictions Some restricted entrances All entrances restricted	Full inclusive design Alternatives to bypass obstacles Areas not fully accessible
B2	Restrictions through design	3 2 1	No restrictive urban elements < 2 restrictive urban elements > 2 restrictive urban elements	No visible desire lines Weakly defined desire lines Defined desire lines
B3	Visual quality	3 2 1	No signs of degradation Few signs of degradation Widespread degradation	Distinct materials and green el. Low variety of materials Focus on a single material
B4	Legibility	3 2 1	Legible physical structure Incomplete legibility Illegible physical structure	Visual connection (all directions) Visual connection (2-3 direct.ions) Visual connection (< 1 direction)
B5	Seating choice and enga-gement	3 2 1	Seating available Seating often full Seating always full	> 3 interact.ive elements p.1000m^2 < 3 interact.ive elements p.1000m^2 No interactive elements
B6	Seating features	3 2 1	Moveable seating Fixed seats oriented to activity Fixed seats away from activity	Seating with back rests Seating without back rests Improvised seating
B7	Climate comfort	3 2 1	Sun/rain and wind protection Sun/rain or wind protection No protection	Water features and trees Water features or trees No water features or trees
B8	Safety through design	3 2 1	Overall well-lit area 25-75% of well-lit area <25% of well-lit area	No fencing delimitation See-through fencing Tall opaque fencing
B9	Amenities	3 2 1	Trash bins readily available Insufficient trash bins No trash bins	Other amenities available Other amenities at short distance No other amenities

Indicator		**Value**	**Measured elements**	
			E1	**E2**
B10	Vehicle connection	3 2 1	No vehicular presence Occasional vehicular presence Frequent vehicular presence	Available bicycle parking Insufficient bicycle parking No bicycle parking

4.4 User connection

When the physical space is contextualized in human practices, a more complete understanding of the space is achieved. Users are entitled to some rights, such as free access, appropriation and other kinds of 'soft' possession, and must be able to fulfil their needs, to test themselves, intellectually and physically, or they'll lose interest in the space and generate an overall negative view of it. However, the sole consideration of the evaluator perspective is often out of focus with reality and can induce strong bias into the analysis. The assessment of the space's effective users' opinion can therefore provide insights on the degree of satisfaction of necessities such as freedom, comfort, identity, or sense of place.

Table 3. Indicators for user connection dimension.

Indicator		**Value**	**Measured elements**	
			E1	**E2**
C1	Freedom opinion	3 2 1	> 70% feel free 30-70% feel free < 30% feel free	> 70% classify as public 30-70% classify as public < 30% classify as public
C2	Dynamics opinion	3 2 1	> 70% consider proper use 30-70% consider proper use < 30% consider proper use	> 70% are frequent users 30-70% are frequent users <3 0% are frequent users
C3	Space overall opinion	3 2 1	> 70% consider proper upkeep 30-70% consider proper upkeep < 30% consider proper upkeep	> 70% consider space as safe 30-70% consider space as safe < 30% consider space as safe
C4	Comfort and surprise opinion	3 2 1	> 70% consider comfortable 30-70% consider comfortable < 30% consider comfortable	> 70% felt surprised 30-70% felt surprised < 30% felt surprised
C5	Value and involvement	3 2 1	> 70% give special value 30-70% give special value < 30% give special value	> 70% want to be involved 30-70% want to be involved < 30% want to be involved

4.5 Management

Management is a very sensible subject regarding public space, as the slightest shift from the equilibrium point can pose severe constraints on aspects such as control, security, and maintenance. When studying the management of these types of spaces, aspects such as resource coordination, partnership mechanisms, and user involvement in the operation processes and schemes should also be taken into consideration assessing the real intention of management authorities regarding what can be achieved with the space.

Table 4. Indicators for management dimension.

Indicator		Value	Measured elements	
			E1	E2
D1	Safety approach	3 2 1	No security personnel One security guard/ police >1 security guard/ police	No CCTV cameras Concealed CCTV cameras Visible CCTV cameras
D2	Comple-mentary amenities	3 2 1	< 25% of site to consumption > 25% of site to consumption No consumption amenities	Free Wi-Fi in entire site Restricted Wi-Fi No Wi-Fi
D3	Dynamics approach	3 2 1	Active search for events Open to event partners No interest for events	Managed in network of spaces Aspects of others considered Space managed in isolation
D4	Mana-gement response	3 2 1	Immediate action Focus on smaller issues Inability to overcome issues	Frequent inner communication Occasional inner communication No inner communication
D5	Outer coordina-tion	3 2 1	Active society partnership Occasional society involvement No society involvement	Frequent outer communication Occasional outer communication No outer communication

4.6 Composite indicator creation

Each indicator's qualitative assessment is associated with a quantitative value, resulting from a combination of the pair E1/E2. In each pair, E1 was considered as having a stronger role in the definition of publicness, meaning that its changes are more relevant to the final indicator score. For the intermediate scores of 5 and 3, corresponding to shifts in the value of E1, two possibilities were considered, due to difficulties in selecting the most favourable publicness combination in some situations. All 9 possible combinations resulted in a growing composite score from 1 to 7, summarized in the following table.

Table 5. Composite indicator score formation.

Composite indicator score	E1 value	E2 value
7	3	3
6	3	2
5	3	1
5	2	3
4	2	2
3	2	1
3	1	3
2	1	2
1	1	1

4.7 Data collection process

In order to collect all the relevant information, three distinct stages of evaluation are required. Visual observations during different periods of year, the week and the day are key to grasp a space's use dynamics and define the 'urban life' dimension. These observations also allowed the assessment of all necessary features to classify the 'physical design' dimension.

A second stage is based on closed-ended surveys to the space's users, with a minimum of 50 in each space, in order to characterize the 'human connection' dimension. A third and last stage relies in interviews with the space's management authorities, in order to determine the majority of the aspects of the management dimension. Only the combination of these three processes would allow for the collection of all necessary information that this Publicness Evaluation Model requires.

5 The application of the Publicness Evaluation Model

5.1 Case study selection

In order to allow for the possibilities of different interpretations of public space and its publicness among planning agents, designers and the general public, two different geographic contexts were analysed.

The cities of Porto, Portugal and Newcastle upon Tyne, England were selected for this study, for their similar dimensions and relatively recent initiatives of city promotion which culminated in public space intervention projects, but also by their relatively moderate level of private sector involvement in the development of the public realm. Within these two cities, the study was limited to spaces in central locations, in order to increase the possibilities of selecting comparable spaces. Four spaces were selected for analysis in each city (table 6), equally divided between new and rehabilitated spaces, and between public and private ownership, being the latter also identified as 'semi-public spaces'.

Table 6. Space selection.

Space	Location	Ownership	Space type
Trindade metro station square	Porto	Public	New space
D. João I square	Porto	Public	Existing space
Old Eldon square	Newcastle	Public	Existing space
Blue Carpet	Newcastle	Public	New space
Cardosas square	Porto	Private	New space
Lisboa square	Porto	Private	Existing space
Times square	Newcastle	Private	Existing space
Waterloo square	Newcastle	Private	New space

5.2 Urban life

A space guaranteeing a 24/7 operation without restricting any possible use, as is common with most public spaces, is not a guarantee of a good performance in use dynamics. When a space presents a variety of visible uses and user groups, it tends to be more evenly occupied and stays tend to last longer.

Old Eldon Square demonstrates this norm as it is the only which performs clearly above average, with maximum scores in terms of use variety and static occupation dynamics. Only in this space it is possible to identify what is considered to be a high volume of pedestrian traffic over its peak usage hours. Although public events are mostly absent, apparently they do not influence the space's level of activity.

However, exceptions can exist due to particular circumstances. In Trindade station Square, a high variety of user groups, probably explained by the Metro system user group homogeneous distribution, is combined with a high heterogeneity and reduced stay times, and in Praça de Lisboa a moderate focus on a single user group is combined with a high spatial heterogeneity.

Semi-public spaces analysed in Porto tend to perform worse than comparable spaces in the UK and, indeed, in the entire sample of analysed spaces, as an operation schedule is often in place. Use restriction, on the other hand, is more visible in UK spaces. While in Lisboa square staffed security max exert that sort of control, in Cardosas the lack of any form of surveillance can lead anyone to think that no use restrictions apply. This will be analysed further ahead in the assessment of the human dimension.

Public transport connections are provided in all spaces, due to their central locations in the overall urban context. Regarding the treatment given to blank frontages, the design features of the new station complex in Trindade resulted in the creation of blank edges along the western end. However, and overall, the existence of blank frontages is not a widespread condition across the entire range of analysed spaces, which could contribute to a weaker performance.

As expected, traditional public spaces classify, on average, higher than semi-public spaces on the urban life dimension, mainly due to the existence of use restrictions and a weaker focus regarding the animation of the space. Although this might not have a strong influence of the space's activity levels, it might represent an opportunity for improvement in the establishment of a livelier space.

Table 7. Urban life dimension results.

Spaces	A1	A2	A3	A4	A5	Urban life (%)	Total publicness (%)
Times	6	4	4	3	7	68,6	70,9
Waterloo	6	3	3	1	7	57,1	58,3
Old Eldon	7	7	7	5	5	88,6	77,7
Blue Carpet	6	4	4	3	5	62,9	64,6
Trindade	7	5	2	4	5	65,7	59,4
D João I	7	4	4	5	5	71,4	64,6
Cardosas	5	4	4	2	5	57,1	62,3
Lisboa	3	4	3	3	5	51,4	62,9

5.3 Physical design

Physical design features are one of the main factors that differentiate ownership schemes and physical context. In Porto semi-public spaces, physical access restrictions appear with the justification of safety and vandalism prevention during evening periods.

While full inclusive design is applied in the majority of spaces, it seems that no direct correlation exists between the adoption of physical access restrictions and other design-led limitations, such as the presence of restrictive urban furniture or the existence of desire lines over grassed areas. Legibility also seems to be unaffected by these choices, as the physical setting of the location is often more imposing than the adopted physical features. Still, semi-public spaces, due to its nature, tend to be more visually enclosed, negatively contributing to this dimension's score.

Visual quality is a factor often taking its toll on maintenance regimes. Privately owned public spaces are expected to have higher maintenance standards than its public counterparts, as they possess a higher exchange value. Although this is often true, mixed results can be found here, with Old Eldon square being classified above average for a publicly owned space, and Waterloo square on the other end of the table for privately owned spaces.

Differences in basic architectural languages between the two cities make formal seating provision surprisingly more common in Newcastle than in Porto, as Portuguese spaces often rely on street cafés to provide for this amenity. Interactive elements, on the other hand, are fairly uncommon in all spaces. Climate comfort, although not always thought off thoroughly when designing or redesigning public spaces, is mainly a consequence of some of its physical features, specifically through the use of large trees. Although there is not a clear pattern, designers of Porto's public spaces often have a stronger sensibility to the achievement of proper climatic comfort conditions than its Newcastle counterparts, and are often keen in resorting to shaded areas for that matter. This is expected, as Porto's average climate is characterized by higher temperatures and longer solar exposure.

While safety is often an important element in the design of a public space, most spaces suffer from poor lighting schemes, either by design or as a consequence of vandalism acts, combined with physical delimitation in some privately owned spaces, contributing to poor results in this this area. Isolation from vehicular traffic is more effective in semi-public spaces, and often dependent on maintenance schemes, as the malfunction of automated traffic bollards will lead to unwanted vehicle intrusion. Bicycle parking facilities are ubiquitous in Newcastle's spaces and a rarity in Porto.

On average, Newcastle spaces are characterized by higher scores in this publicness dimension. In both cities, semi-public spaces are also prone to have higher scores, due to the extra degree of care that is put upon them, in order to maximize each space's exchange value.

Table 8. Physical design dimension results.

Spaces	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**Physical design (%)**	**Total publicness (%)**
Times	5	7	6	4	4	5	4	7	6	5	78,6	70,9
Waterloo	7	7	5	4	2	3	4	7	5	5	70,0	58,3
Old Eldon	7	4	7	6	4	5	4	7	6	3	75,7	77,7
Blue Carpet	7	7	5	4	5	4	4	5	6	5	74,3	64,6
Trindade	5	5	3	5	1	3	6	3	4	5	57,1	59,4
D João I	7	7	5	7	1	3	6	5	3	1	64,3	64,6
Cardosas	2	7	5	3	7	5	4	4	6	5	68,6	62,3
Lisboa	4	7	7	4	1	3	6	6	2	5	64,3	62,9

5.4 User connection

Although publicly owned spaces often present themselves as the most 'free' spaces, the visual similarities between some public and semi-public spaces have often fooled users' perception. Adjacent residential function, when place, is responsible for an increasing the feeling of 'being watched', which can contribute to increased concerns regarding freedom restrictions, although simultaneously increasing safety feeling, as was the case with Cardosas and Waterloo squares. Physical access restrictions and the presence of staffed security appear also to be the factors shaping user opinion.

By being located in central areas of both Porto and Newcastle, with a considerable percentage of tertiary uses and services, all case studies have a considerable amount of non-frequent users.

Opinions regarding use adequacy fluctuate greatly among the assessed case studies. Users are highly critical of underused spaces, especially the ones characterized by large empty central sections, such as D. João I square. The evaluation of use dynamics opinion does not allow the creation of any assumptions regarding what ownership scheme provides the best results.

Physical degradation is often criticized by the space's users, with graffiti and degraded urban furniture being the most decisive factors. Safety opinions, on the other hand, can shift to some degree. Overall, night time safety is a common concern regarding public space users, slightly more expressive in Porto. These safety concerns are not expressed into the dynamic dimension of publicness, meaning that the high usage levels do not necessarily increase user safety perception, especially at evening hours, where usage will invariably be less intense. Ineffective lighting schemes are strongly penalized by users in what concerns their safety feeling.

The lack of places to sit is commonly identified as a comfort flaw in the spaces which lack this feature, with special incidence in Trindade, D. João and Lisboa squares. Seating provision is therefore an highly valued feature and therefore important to the success of a public space, at least in what concerns the provision of comfort conditions. Also, Porto's public space users are often keen to identify other reasons for the lack of comfort experienced, mostly criticizing the lack of shading. Although most of these spaces actually provide it, the negative user opinion might indicate its inefficacy in quantity and location.

User connection is hampered by a failure to provide a strong sense of surprise. Also, a widespread lack of concern for public issues can also be one of the explanations for the general absence of interest in being more involved in the operation and management of public spaces, more noticeable in Newcastle than in Porto. The recent increase in public space usage in Porto is most likely causing a growing reinforcement of the city's residents connection with them.

Generally, when public spaces cater for user needs, in terms of surprise and comfort, a symbolic value is more likely to be attributed, generating additional interest for common citizens to be involved in its general operation.

In publicly owned spaces, the intention to provide a valuable space, fostering interaction and meaning, tends to be higher, resulting in a higher level of identification and satisfaction with it, increasing this dimension's score. Old Eldon Square, by combining proper maintenance, good comfort conditions and an overall intense use, generates a stronger user connection.

Table 9. User connection dimension results.

Spaces	C1	C2	C3	C4	C5	User connection (%)	Total publicness (%)
Times	5	3	7	4	2	60,0	70,9
Waterloo	7	1	7	2	2	54,3	58,3
Old Eldon	7	5	7	6	4	82,9	77,7
Blue Carpet	7	3	4	5	4	65,7	64,6
Trindade	7	4	4	4	2	60,0	59,4
D João I	7	2	1	2	4	45,7	64,6
Cardosas	4	1	5	5	2	48,6	62,3
Lisboa	2	3	7	5	4	60,0	62,9

5.5 Management

Contrary to the usual assumptions that a public space relies fully on natural surveillance while a semi-public space is aided by CCTV or private security, the nature of the assessed case studies tells a different story. Newcastle's public spaces, either public or not, always rely on CCTV schemes to guarantee public safety. In Porto, CCTV appears to be less common, and staffed security is only used in some locations.

As a way to generate additional profit, privately owned spaces dedicate part of its area to consumption spaces, while publicly owned spaces are quickly following this tendency. On the other hand, Wi-Fi provision, although more common in Porto's spaces, is often marked by its irregular availability.

Semi-public spaces tend to be managed in isolation with other spaces in the vicinity, as communication between different management entities often fails to go beyond maintenance and security issues. The potential to achieve further benefit from the proximity of other publicly accessible spaces is therefore lost. The search for space animation is probably the largest differentiation point between Porto and Newcastle spaces. With the exception of Times Square, all of Newcastle's spaces are managed without major concerns for space animation, either programmed or spontaneous. In Porto, on the other hand, space animation is seen with good eyes, either through an active attitude, or just by being open to event partners. It therefore appears that the focus on space animation is not a question of ownership but of a city-wide tendency. Private operators will most likely follow the public approach, in order to stay in the race.

Private authorities often have a stronger concern towards space issues, guided by an effective inter-agent communication. In Porto, particularly in publicly owned spaces, problem solving usually takes the path towards the solving of minor issues. Public participation is often not on the management perspective's main list of concerns, although with higher possibility for intervention in publicly owned spaces.

In the end, the large amount of spaces under the umbrella of public authorities is often the main reason for a less than ideal capacity of response, which ends up affecting their management dimension of publicness.

Table 10. Management dimension results.

Spaces	D1	D2	D3	D4	D5	Management (%)	Total publicness (%)
Times	5	6	4	7	5	77,1	70,9
Waterloo	5	5	1	2	5	51,4	58,3
Old Eldon	5	5	3	6	5	68,6	77,7
Blue Carpet	5	1	4	2	5	48,6	64,6
Trindade	5	3	3	5	5	60,0	59,4
D João I	6	6	7	4	6	82,9	64,6
Cardosas	7	5	3	7	7	82,9	62,3
Lisboa	5	6	4	7	5	77,1	62,9

6 Conclusions

The importance of creating a successful public space and maintaining it as such has for long been a concern for public authorities, particularly for the benefits provided to the city, its inhabitants, and visitors.

Despite the recent attempts at using public spaces to promote cities, at the expense of large amounts of resources, the space's different levels of success demonstrate that this strategy is not fully understood by the different agents involved in city production. Although being in central locations, some of the assessed public spaces did in fact experience little use and therefore connoted with being unsuccessful.

Frequently, semi-public spaces have been associated to restrictions over the basic premise of freedom, and considered as less appealing than traditional ones. In the evaluation of the urban life dimension, this fact is demonstrated, as traditional spaces, on average, have higher scores than semi-public spaces, mainly due to the existence of use restrictions and a weaker focus regarding the animation of the space in the latter. Although this might not have a strong influence of the space's activity levels, it represents an opportunity for private authorities to establish a livelier space.

Physical features, which account for 40% of the total score, are important to the definition of the overall publicness of a space. Here, privately owned spaces gain an important advantage towards its public counterparts, due to greater concerns in visual aspect, in order to maximize its exchange value.

It is often assumed that one of the most effective measures of responding to the needs of users is by enabling them in the space's design and management stage. Safety and comfort, two of the main concerns of users, are frequently included in the range of concerns of designers and management authorities. Its execution, however, occasionally often falls short of the users' expectations, who have little power in the processes of shaping and reshaping the urban environment, especially in semi-public spaces. These tend to be managed in isolation with other spaces in the vicinity, as communication between different management entities often fails to go beyond maintenance and security issues. However, private authorities often have a stronger concern towards space issues, guided by an effective inter-agent communication. The large amount of spaces under the umbrella of public authorities is often the main reason for a less than ideal capacity of response, which ends up affecting their management dimension of publicness.

In the end, the score differences between publicly and privately owned spaces are not as significant as expected, indicating that the existing stigma associated with semi-public spaces puts them in an unfair position.

The provision of proper of basic comfort conditions, namely formal seating and acceptable climatic comfort conditions, allied with proper maintenance and a location within important pedestrian routes are the main requirements for the creation of a successful space, regardless of its patronage.

Planning for climate change involves, first, the recognition that the current patterns of resource spending are not sustainable. Maximizing the efficiency of urban development strategies, on which the vision over its public spaces can bring important benefits to the city and its residents, can be aided by the application of the Publicness Evaluation Model.

In existing spaces, occasionally, small changes, either physical or operational, are the only required ones to improve its performance. Other spaces might suffer from severe design problems, meaning that large redesigns are the only possible path in order to establish proper vitality levels. In semi-public spaces, the legislation of civility, let it be through an addition to the gamut of prohibited uses or behaviours, change in operation schedules, or increased surveillance, is considerably easier to enact for its management authorities, and hence understood as more effective than physical changes.

In the end, the Publicness Evaluation Model indicates not only a space's current level of publicness, but also identifies its unexplored potential, and where and how is possible to improve.

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Eastern and West-Central Asprela Parks, Porto – Portugal: a new green infrastructure to mitigate climate change in the urban context

Paulo Farinha-Marques, José Miguel Lameiras

FCUP - Department of Geosciences, Environment & Spatial Planning / Research Centre in Biodiversity and Genetic Resources, University of Porto, Portugal

pfmarque@fc.up.pt; jmlameiras@fc.up.pt

Climate change mitigation strategies have become an increasing concern at all scales of planning and design. In Portugal, besides the national strategy to face climate change, several municipalities have developed, and are currently implementing, their own regional plans. Research shows that investments in the green infrastructure are cost-effective strategies for the mitigation of the negative effects of climate change. This paper looks into the design of two recent parks in the city of Porto, that were developed having climate change adaptation strategies in consideration. By looking and measuring several design components it was possible to identify and estimate some of the prospective contributions that the development of both considered parks. The paper presents calculations for storm water management, surface permeability, carbon sequestration and economic benefits. The role of parks as a climate change adaptation strategy in the urban context is discussed.

Keywords: Urban parks; urban resilience; climate change adaptation; climate change and urban parks.

1 Introduction

Urban areas face demanding challenges due to the effects of climate change, for example flood draughts and heat waves. The need for climate change adaptation is a certainty. Carter *et al.* (2015) identified three reasons why cities occupy a central position in the adaptation agenda: 1) continued urbanisation is set to define and shape the 21st century; 2) the morphology and metabolism of cities create unique micro-climates that affect variables including temperature and wind; 3) cities are particularly threatened by climate change due to factors including their heavy reliance on high population densities, interconnected networked infrastructure, large numbers of poor and elderly people and major concentrations of material and cultural assets.

To address these questions, significant attention has been given to the role of urban green and blue structures (Demuzere *et al.*, 2014). Green spaces such as parks, gardens, urban forests, wetlands, green roofs and green walls can contribute to ecosystem resilience (Pauleit *et al.* 2011). Green urban infrastructure reduces the adverse effects of climate change, by regulating water flows and aiding at storm water management, providing thermal comfort by the presence of vegetation with its unique physiology and shading effects (Demuzere *et al.*, 2014).

In order to develop climate resilience in the urban context, parks can play a significant role, as they provide multiple benefits for its inhabitants, they are important to relieve environmental challenges such as air quality, water storage, mitigating urban heat island effect (Klemm *et al.*, 2017; Tzoulas *et al.*, 2007).

This paper addresses the role of parks in climate change adaptation, particularly by creating opportunities for efficient and low cost strategies to mitigate the negative effects brought about by the phenomenon This reflection starts by identifying through literature review which park characteristics are considered more relevant to minimize the expected main threats. Then the identified characteristics, are evaluated in two park case studies of the city of Porto The selected case studies are two recently designed parks for the Asprela University Campus, situated in the north of the city of Porto – Portugal. Both parks were conceived according to a multipurpose program regarding general environmental and aesthetic improvement of the area, but particularly focused on maximizing permeability, flood management, microclimate improvement and biodiversity promotion.

2 Research Methods

To assess the parks potential for climate change adaptation and mitigation using landscape design strategies, a methodology was devised and implemented as follows:

a) identification of the design solutions that may have a positive impact towards climate change adaptation through literature review;
b) list of the measurable parameters aiding at better understanding the relevance of the implemented strategies (ex. economic parameters, carbon related parameters, temperature parameters; permeability and stormwater runoff;
c) measurement of the parameters in each park and associate them with specific design solutions (ex. intensification of pervious areas, maximization green area according to vegetation cover type, optimize number of tree planting, shading, land grading for storm water retention capacity);
d) Assessment of the design solutions, discussion and conclusion about their efficiency towards the mitigation of the impacts of climate change.

3 Design strategies towards mitigation of climate change effects

In urban areas, due to the urban heat island effect, the climate change impacts associated with increases in temperature are exacerbated (Carter *et al.*, 2015), which can result in temperature differences of up to 7 C between large cities and their surrounding rural areas (Wilby, 2003).

The Portuguese climate change observations are consistent with a pattern of global warming and rates of warming since the 1970s are above the global mean (Almeida, 2008). The main expected negative impacts of climate change are: 1) reduction of average annual precipitation; 2) increase of average annual temperature, particularly the maximum temperature; 3) rise of the average sea level; 4). increase of extreme rain events.

Urban parks can help to reduce vulnerability to heat stress; shading provided by the tree canopies is considered to be the most effective cooling strategy in parks (Brown *et al.*, 2015). Planting trees is a very effective way to achieve shaded green space; an efficient tree canopy blocks penetrating solar radiation while at the same time offers evaporative cooling effects through transpiration (Carter *et al.*, 2015). According to Abreu-Harbich *et al.* (2015), the shading performance of the urban vegetation should be more considered by landscape designers; concentrating tree species with high leaf area index along pathways and sitting places may improve significantly thermal comfort.

The spatial configuration of vegetation structure affects the thermal conditions of a park. Klemm *et al.* (2017) present the following three main guidelines that should be pondered in the design of a park: 1) consider solar exposure (especially afternoon solar patterns) to design spaces with microclimatic variance, including sunny, half shaded and shaded spaces for various times of the day; the ratio of 40% sun, 20% half shaded and 40% shade can provide a guideline; 2) provide 'edges' (gradients and borders) between open and shaded areas where sun and shade occur in close vicinity and alternation; 3) consider open and multi-functional spaces, in which visitors can create their own thermally comfortable microclimates by bringing their own parasols etc.

Parks with high vegetation cover may participate very positively in the urban green infrastructure, by influencing the circulation of water and minimizing the risk of urban flooding (Fletcher *et al.*, 2015). Through the implementation of sustainable urban drainage system (SuDS) the natural drainage processes are replicated, typically through the use of vegetation-based interventions such as storm water detention basins, swales, rain gardens, and green roofs, which increase localised infiltration, attenuation and/or detention of stormwater peak flows (Ossa-Moreno *et al.*, 2017). Being a vegetation-based solution, SuDS contributes to mitigate heat island effect, to improve water and air quality, to stimulate plus biodiversity and also provides places for recreation and aesthetic amenity, amongst others (Ashley *et al.*, 2010).

The Arbour day Foundation, a non-profit conservation and education organization produced a document entitled "Benefits of Trees and Urban Forests: A Research List", compiling data on the benefits of urban forests (ACT, 2011). Following, a selection of the measurable tree benefits that could have an impact on climate change mitigation is presented. All measurable effects listed were recalculated to the metric system, are expressed in Euros (€) and have been indexed to one adult tree (20 years old).

According to ACT (2011) the reduction of stormwater runoff can be substantially mitigated: 1) a tree retains between 0.2 to 0.4 m3 of water during a large storm event; 2) for the same amount of money invested, tree planting is estimated to be 3 to 6 times more effective in stormwater management that conventional methods, that will result in a benefit valued at 6.5 € per tree; 3) during a storm event a tree reduces water runoff in approximately 3.2 m3 of water; and 4) a street tree absorbs 5.8 m3 of stormwater annually.

Although these remarks may sound general, in terms of carbon benefits ACT (2011) points out that: 1) the planting of a tree can store and avoid up to 3.5 tons of carbon over the next 50 years; 2) one urban tree contains about four times more carbon that individual trees in non-urban forests.

As far as energy efficiency is concerned: 1) one strategically planted tree can reduce energy costs up to 16.7%; and 2) one 7.5 m tall tree may reduce the heating costs of an average house in 2 - 8% and cooling costs in 8 -18% (ACT, 2011).

4 Case studies

In December 2016, the Municipality of Porto presented a strategy for climate change adaptation, a document produced in the scope of the project ClimAdaPT.local, which aids municipalities to develop strategies for climate change adaptation and implement them in their territorial management tools. In what concerns the mitigation of negative impacts of climate change, the document identifies and classifies the strategies that are expected to be the most effective for the specific context of the municipality. The strategy that was given the highest effectiveness towards climate change mitigation was the "rehabilitation of the municipality's watercourses with the assistance of natural engineering practices". This strategy reinforces and confirms the importance of the selected case studies, as both Asprela parks feature the promotion of natural drainage systems focused on the existing watercourses as a main driving force in the design master plan and the overall intervention strategy.

Eastern and West-Central Asprela Parks (figure 1) sit on 8.3 hectares of permeable land located in a highly urbanized area in the city of Porto – Portugal. Both parks were designed having social, ecological, economical and aesthetic considerations.

The design brief reflects into the existing situation and proposes solutions focused on: 1) the conservation of pre-existing biophysical values; 2) the storm water and flood management; 3) the multipurpose use and connectivity (green, blue and social); 4) the recreation and aesthetic opportunities; 5) urban cohesion; 6) biodiversity promotion; and 7) micro-climate improvement.

The devised master plans answered the design brief by creating an organization and outline of the outdoor space in order to: 1) promote a continuous urban green system of mostly wooded areas (open and closed woodlands) alternating with clearings dedicated to active recreation and the siting of sports facilities; 2) protect the existing riparian woodlands linked with a remaining natural metabolism of existing watercourses and wetlands; 3) construct a pedestrian and cycling network associated to tree alleys that connect several spots in the parks and the surrounding areas; 4) provide access to green areas with high micro-climatic amenity and to open spaces with opportunities for playing, picnicking, partying; 5) encourage nature watch in semi-naturalized habitats; 7) create new high quality visual settings dominated by trees and other natural elements stimulating and overall pleasurable landscape aesthetics in the urban fabric.

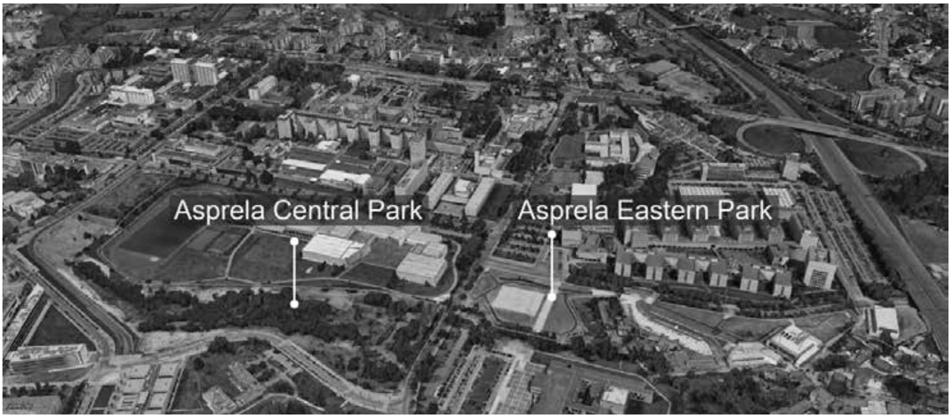

Figure 1. Location of Eastern and West-Central Asprela Parks at the university campus. The orange polygon outlines the park intervention areas.

The design style of both parks followed a semi-naturalistic and minimalist trend based on the combination of straight and gently curved lines wherever applicable and contrasting spatial pattern of open, tree lined and wooded spaces. Construction materials are meant to be inexpensive, simultaneously functional, contemporary and local significance; plant materials mainly adopted autochthonous species with a few non-invasive exotic ones, relevant to the Portuguese cultural landscape character.

Asprela Eastern Park (Parque da Quinta de Lamas) completed in 2015 (figure 2), is located between the Faculty of Engineering and the Faculty of Economy of the University of Porto. The project and the implementation of the park was led by the University of Porto. The existing site included abandoned fields, rural buildings, university buildings, an improvised parking space and a tubed watercourse. The program intended to create an unified green structure that promotes an environmental and landscape quality throughout the space (Farinha-Marques *et al.*, 2013).

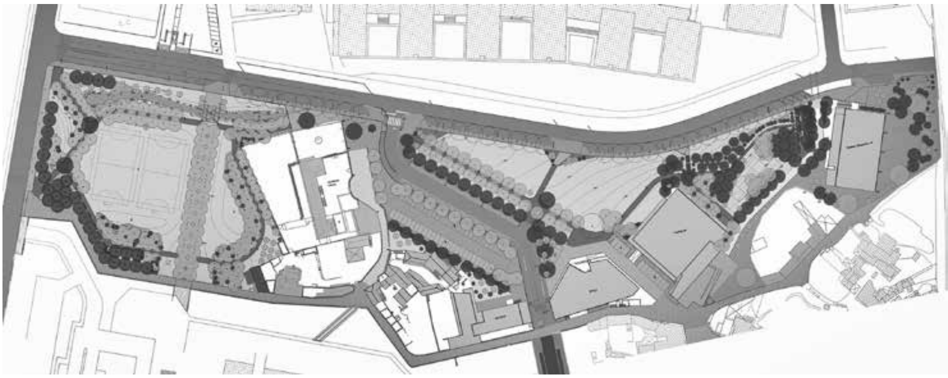

Figure 2. Eastern Asprela Park.

Asprela West-Central Park is still in a project under development, in the phase of previous study which master plan has already been approved by the promoting consortium (University of Porto, Polytechnic of Porto and the Municipality of Porto). For that reason, the results presented in this paper are based on the approved master plan (figure 3).

Until the late 1990s this area maintained a dominant agricultural character, with fields of ryegrass, vegetable gardens, and watercourses bordered by alder and willow. The succeeding urban transformations, especially the construction of the metro line and associated road network, profoundly altered what remained of the pre-industrial agricultural landscape. These transformations intensely changed landform, the position of the watercourses the vegetation cove and habitats. The decrease of water permeability of the surrounding urban space, the underground channelling of the western stretch of Asprela stream and the decrease of the flow capacity after heavy rain, may cause serious flooding problems for the subway tunnel which reaches the area at it southern corner (Farinha-Marques *et al.*, 2016).

The intervention area focuses on vacant and disturbed green spaces mostly remaining floodplain areas of the Asprela stream. Two main character zones can be identified: 1) wetland zones - low level areas directly influenced by water flow dynamics; 2) dry zones - higher elevation areas not subject to regular flooding.

The concept of the proposed master plan was strongly induced by the biophysical qualities of the terrain, which decisively guided the organization and design of the space. The overall solution tries to adapt and positively take advantage of the landform, the hydrography and the existing tree cover, in order to comply with the multipurpose program, suitable to the natural metabolism of the place, and the necessity of eventual occurrence of large runoff peak flows. The proposal is also firmly oriented by a tight expenditure control and relying on a rather strict budget.

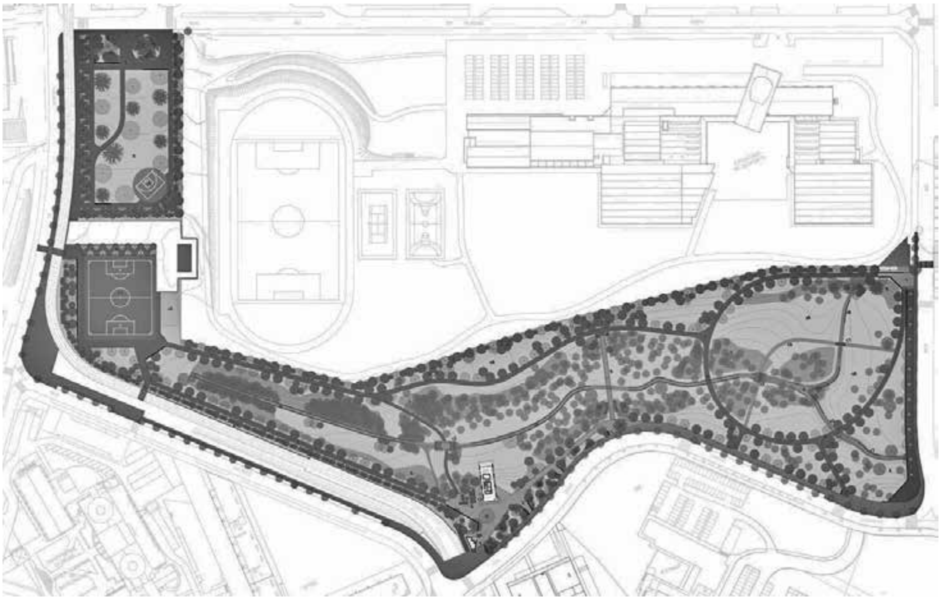

Figure 3. West-Central Asprela Park.

5 Results and discussion

By analysing the spark according to the previously identified park characteristics it is possible to estimate the contributions that each one will have towards the mitigation of climate change negative impacts.

5.1 Asprela Eastern Park

Water course restoration

The intervention area features 398 m of a forced tubed watercourse (box culvert, figure 4). It was possible to bring to surface and naturalize 108 m. The remaining section could not be naturalized due to grading and land use restrictions. The open-air section behaves like a micro-dam, forming a small reservoir, with a slow flow velocity. The channel is cast in irregular stone all the way up to the maximum flood elevation, whose banks are planted with riparian trees (such as poplar, ash and plane trees) and patches of reeds (*Typha latifolia*, *Juncus effusus* and *Nymphea alba*) that also contribute to process random occurrence of organic wastewaters.

Figure 4. The existing watercourse flows in a box culvert.

Stormwater management

Rainwater is managed onsite as no water is sent to constructed drainage systems. This was possible due to grading of water retention basins that receive the surface runoff. The retention basins are connected through the use of hydraulic bypasses that allow the water to flow between them and expand the water retention capacity in the event of a huge storm. All paved surfaces are highly porous surfaces, filtrating a large percentage of water and sending the excess towards the retention basins.

The site is now able to retain the storm water volume that is expected to flow to this area during a one-hundred-year flood event. This volume will be primarily accumulated in the section of the watercourse (figure 5), and retention basins (figure 6) but in face of extreme events, it is still possible to extra flows use the existing box culvert system that has been preserved and connected through a hydraulic bypass.

Figure 5. The watercourse currently flows in the open air. The section is able to store water during a storm event.

Figure 6. Water retention basins that were made using landform grading _ north-western entrance.

Permeability to water

Total area of 22886 m^2, from which 19938 m^2 are green areas, 2526 m^2 are permeable pavements and 422 m^2 are impervious surfaces, which grants 98% of permeability across the park. For this reason, all water that falls in park will be infiltrated on site. Furthermore, in extreme events, the park will also receive waters from the supplying watershed and will be able to infiltrate a percentage of that water. The synergies between site permeability and water retention capacity reduce the negative effects caused by extreme flood events.

Tree cover

A total of 523 trees were planted, using 25 different tree species. At the maturing period, 20 years after construction, the tree canopy is expected to cover 50-60% of the intervention area, providing shade and amenity. Considering solar exposure, thorough the development of a 3d model it was possible to calculate the ratios for sun lit spaces, half shaded and shade. Results, including both for trees and built solutions, estimate that the calculated ratios are of 40% sun, 35% half shaded and 25% shaded. These statistics inform that the park follows the recommended shading and tree ratios by Klemm *et al.* (2017), providing both thermal comfort and minimizing the negative effects of extreme temperature events.

5.2 Asprela West-Central Park

Water course restoration

In this intervention area, two intersecting watercourses with 594 meters in total will be requalified (figures 7 and 8). Through terrain modelling it was possible to preserve the path of the stream and consolidate the eroding slopes. In the downstream section it was necessary to guarantee the minimum slopes for water flow. In the upstream section, it was necessary to ensure a smooth transition between the different elevation levels along the stream; this was achieved with a system of weirs and small waterfalls.

Figure 7. Asprela stream in the area where the new park is about to be shaped, has been significantly altered with the construction of the metro line, that caused new landfills of the valley and re-alignment of the drainage channel.

Figure 8. Asprela stream coming out of an underground concrete channel.

Stormwater management

The designed landform is expected to accommodate a volume of water equivalent to a rainfall with a return period of 100 years. This storage capacity was achieved by modelling a 1:3 slope embankment with a pedestrian path on top the levels rises from the 104.50 to 106.30. height of the full capacity of water. In figure 9, a simulation of the maximum flood elevation is presented. According to the hydraulic calculations, the expected retention volume is 10.000 m^3. As pointed in the literature review, one of the expected effects of climate change is the peak concentration of extreme rainfall in a very short period. The proposed land grading allows the retention of flood water and slowly releases it to the stream system, reducing the peak concentration of water and flooding problems.

Likewise the Eastern Park, all rain water is managed onsite, which means no artificial drainage systems have to be built. The proposed pavements are porous and the excess of water is guided towards the retention basins or to the streams.

Figure 9. Simulation of the water level at the event of a 100-year storm.

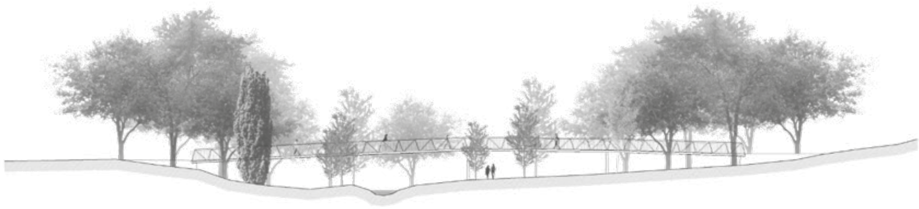

Figure 10. The proposed transversal section of the park. This area will work as a retention basin, accumulating a large volume of water

Permeability

The total area of intervention is 60591 m^2, 54712 m^2 are green areas, 6879 m^2 are permeable pavements and 5879 m^2 are impervious surfaces, which also grants 91% of permeability in the intervention area. The expected lower permeability of this park, when compared to the Eastern Park, is mainly due to pre-existing paved entrance to the transformer substation of the metro line, and the new soccer field conceived with a traditional constructed drainage system. The permeability index is still above the majority of urban parks and since the majority of water runoff is drained towards retention basins and the existing watercourse, all rain water will have good usage, being either infiltrated on site or guided to a natural drainage system.

Tree cover

The existing tree cover is one of the main assets of this space. In order to protect as many specimens as possible, areas with vegetation to be preserved were identified, in which the terrain was not modified. The proposed intervention protects 754 existing trees (mainly willows, poplars and alders) and intends to plant new 645 trees. Almost 60%% of existing trees are already at a mature stage, providing shade, shelter, opportunities for biodiversity and aesthetic delight. For the maturing period (20 years after construction), tree canopy is expected to cover 60-70% of the intervention area. Similarly to the Eastern park, solar exposure was calculated through the development of a 3d model; it was then possible to determine that the sun – shade ration are 35 % sun lit areas, 30% half shaded areas and 35% shaded areas. On average, this park has more shaded areas that the Eastern park. Comparably, the maximum temperatures in the park area are expected to be lower and the tree cover provides a higher coolness feeling during heat waves.

5.3 Synergies between the two Parks – the ***redeeming*** effect of trees…

When both parks are fully developed (in 20 years-time), the total number of trees will be 1913 (654 existing + 523 planted in the Eastern Park + 754 planted in the Central

Park). By crossing this number with the data provided by the Arbour Day Foundation, it is possible to estimate that:

1) bearing in mind that during a storm event, one tree retains on average 0,3 m^3 of rain water during a storm, the total water retained by the population of trees in both parks will be approximately 550 m^3 of water;
2) considering that one tree absorbs about 5 m^3 of water per year, all trees mentioned will absorb 9.065 m^3 water;
3) considering that one tree, on average, can store and avoid up to 3.5 tons of carbon over the next 50 years, the total carbon sequestered in both parks is expected to round 6300 tons of carbon;
4) on average, all trees in the parks will contribute for lowering the temperatures 3 to 6° C in the areas influenced by their canopies.

These results contribute to consolidate the importance of trees and parks (or green spaces, in general) in mitigating of the adverse effects of climate change. Tree planted spaces can also be regarded as low cost investments with a high benefit return in the long run. However, trees need minimum space do develop properly and that is the main challenge in densely built urban contexts.

6 Conclusions

Green spaces, green structures and green infrastructures, particularly urban parks, have an important function in making cities more resilient to the negative effects of climate change. The two parks analysed in this article were planned and designed to protect some areas of the city and major transport infrastructure (the metro line) from the hazards caused by extreme storm water events, aiming at preventing major ecological and economic difficulties. It was also possible to measure and estimate the effects that landscape design projects mainly supported by water permeable areas and planting solutions will have towards the reduction of peak temperatures, carbon sequestration and water absorption. These are some contributions to address climate change adaptation at a reduced investment cost, endorsing that planting design is a highly efficient solution. The prospect and objective of this paper is to encourage the increase of green areas in cities, particularly those that can accommodate large trees, permeable surfaces and promote landscape connectivity (*blue* and *green* connectivity). Climate change adaptation is one of many benefits, as new green areas will become fundamental places for people to recreate, contact nature and promote general health and well-being of the urban landscape.

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Design Team:

Coordination: Paulo Farinha Marques, Landscape Arch.; Associate Professor FCUP

Landscape Architecture: Paulo Farinha Marques; José Miguel Lameiras, Landscape Arch.; Lecturer FCUP; Luís Guedes de Carvalho, Landscape Arch., Lecturer FCUP; Gonçalo Nunes de Andrade, Landscape Arch., Lecturer FCUP; Nuno Costa, Landscape Arch., FCUP; Jorge Barbosa, Landscape Arch.

Architecture: Francisco Guedes de Carvalho, Architect (ABBV)

Engineering (Hidraulics): Rodrigo Maia, Eng.; Associate Professor FEUP; Hélder Magalhães, Eng.

Engineering (Built Structures): José Cardoso Teixeira, Eng. (JCT, Lda.); Associate Professor UMinho; Susana Sousa, Eng. (JCT, Lda.); António Murta, Eng. (JCT, Lda.)

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Design Team:

Coordination: Paulo Farinha Marques, Landscape Arch.; Associate Professor FCUP

Landscape Architecture: Paulo Farinha Marques; José Miguel Lameiras, Landscape Arch.; Lecturer FCUP; Luís Guedes de Carvalho, Landscape Arch., Lecturer FCUP; Gonçalo Nunes de Andrade, Landscape Arch., Lecturer FCUP; Nuno Costa, Landscape Arch., FCUP; Natália Bruno, B.Landscape Arch.

Architecture: Francisco Guedes de Carvalho, Architect (ABBV)

Engineering (Hidraulics): Rodrigo Maia, Eng.; Associate Professor FEUP; Hélder Magalhães, Eng.

Engineering (Built Structures): José Cardoso Teixeira, Eng. (JCT, Lda.); Associate Professor UMinho; Susana Sousa, Eng. (JCT, Lda.); António Murta, Eng. (JCT, Lda.)

Engineering (Lighting): Daniel Moreira, Eng. (Gatengel, Lda.)

Urban Policy-making as Policy Assemblage

Tatiane Serrano, Isabel Breda Vázquez

CITTA - Research Centre for Territory, Transport and Environment / FEUP - Faculty of Engineering of the University of Porto

tatiane.serrano@fe.up.pt; ivazquez@fe.up.pt

The policy world seems to be one in constant motion. There is a movement in urban policy, whereby 'the new' – ideas and initiatives – have been replacing 'the old' with increasing regularity. We notice new paths to urban policy-making – successful policies are transferred, adapted, imitated, and translated by several stakeholders across multiple spatial and temporal scales. So, what is urban policy-making in this contemporary policy world? In order to answer this issue, this essay introduces new theoretical and methodological parameters: 'Thinking Assemblage' and 'Urban Policy Mobilities'. We concluded that urban policy-making as policy assemblage are composition processes between heterogeneous entities – policies, institutions, objects, ideas, discourses, places, among others. In addition, in the contemporary globalized context, almost every policy can be seen as an assemblage of expertise and resources from elsewhere.

Keywords: Urban policy-making; thinking assemblage; policy mobilities.

1 Introduction

The policy world seems to be one in constant motion. In a figurative sense, policy makers seem to be under increasing pressure to 'get a move on' – to keep up with the latest trends and 'hot' ideas that sweep into their offices, to convert those ideas into locally appropriate 'solutions' (McCann and Ward, 2010:175). There is a movement in urban policy, whereby 'the new' – ideas and initiatives – have been replacing 'the old' with increasing regularity (McCann and Ward, 2010).Temenos and McCann (2012) argue that policy makers of all types – not just politicians and policy professionals such as planners, but also members of local business communities and activist groups –'scan' globally for policy models that can be expected to yield success and that can be moulded to local conditions and expectations. In other words, they look for "policies that can be helpful practically, but also politically" (Temenos and McCann, 2012:1393).

We can present two situations from this context. First, there are new paths of urban policy-making – successful policies are transferred, adapted, imitated, and translated by several stakeholders across multiple spatial and temporal scales. Second, currently, urban policy-making has implications. Since mobile policies are not simply travelling across a landscape but are actually remaking this landscape, and they are contributing to the interpenetration of distant policy-making sites (Peck and Theodore, 2010a).

Thus, *what is urban policy-making in this contemporary policy world?* We do not claim to answer this question completely. On the contrary, we intend with this communication to initiate a debate, 'an essay', introducing new theoretical and methodological parameters from different emerging theories, such as 'Thinking Assemblage' and 'Urban Policy Mobilities'. Our intention is to contribute with new insights, different viewpoints, and some guidelines for future investigations.

2 Less 'transit and transaction', more 'mobility and mutation'

The literature discusses the transformation capacity of concepts. First, a concept (or notion) is constantly changing, since it reflects the reality but the reality is mutable. Second, a concept is interconnected with other concepts, although it is 'new' concept (Lencione, 2008). This process of conceptual transformation occurs with the urban policy mobilities – it emerges from a critical analysis of policy transfer.

The proposal of *urban policy mobilities* is not only a change of nomenclature but a conceptual and methodological evolution. 'Mobility' instead of 'transfer' intends to highlight the multiple and complex nature of policy-making (McCann and Ward, 2013). Urban policy mobilities propose a different approach to the traditional literature of policy transfer – "[...] the governing metaphors in critical policy studies are not those of *transit* and *transaction*, but of *mobility* and *mutation*" (Peck and Theodore, 2010a:170). In contrast to the policy transfer tradition (notions of rational diffusion and best-practice replication), critical approaches to policy mobilities tend to explore open-ended and politicised processes of networking and mutation across shifting social landscapes (Peck and Theodore, 2010a).

Is this sense, McCann and Ward (2013:3) advocate a multidisciplinary perspective for urban policy transfer: "The emergence of multi-disciplinary perspectives on how, why, where and with what effects policies are mobilised, circulated, learned, reformulated and reassembled highlights, on the other hand, the benefits of understanding policy-making as both a local and, simultaneously, a global socio-spatial and political process."

Recent work on policy mobilities broadens the understanding the globalisation of ideas and policies' because it views policy transfer from a more dynamic and more political point, considering the current discussions on complex productions of spaces and places (Stein *et al.*, 2015). Thus, the evolutionary process of urban policy mobilities is defined, on the one hand by the break with some principles of policy transfer and, on the other hand, by the openness to multidisciplinary perspectives (beyond political sciences).

3 Urban Policy Mobilities

Urban policy mobilities are assemblage processes through which ideas from different places are pulled together in various combinations (Cook and Ward, 2012) – disparate 'things' are gathered and collected, and subsequently combined into an assemblage (Kennedy, 2015) for a specific purpose. In addition, for McCann and Ward (2012) they are complex processes, power-laden, rather than a straightforward a-to-b movement, connecting several practices and places. However, urban policy mobilities are not only focused on criticisms of policy transfer. On the contrary, it has been developing a theoretical body concerned with alternative approaches and new paths to research.

In this sense, policy mobilities purpose, as starting point the notion of '*assemblage, mobility and mutation'* (McCann and Ward, 2013) which has conceptual and methodological consequences. The research becomes, on the one hand, more multidisciplinary and, on the other hand, more qualitative and ethnographic. These notions are important principles to conceptualise the urban policy mobilities. Thus, it is necessary to explore some individual particularities (although the notions work together).

The notion of 'mobility' is concerned with the social content of movements of people and objects from place to place, at various scales, and the immobilities and moorings that underpin and challenge these dynamics. This approach is a "[…] useful frame for our discussion of mobile policies because it emphasizes the social and the scalar, the fixed and mobile character of policies." (McCann and Ward, 2011:xxiv).

The notion of 'mutation' is concerned with the transformation of policies – at the same time that policies are transformed during travel, several places, institutions and communities are also (re)made. Mobile policies "are not simply traveling across a landscape – they are remaking this landscape […]" (Peck and Theodore, 2010a: 170).

The notion of 'assemblage' is used as a descriptor to encourage both an attention to the composite and relational character of policies and cities and also to the various social practices that gather, or draw together, diverse elements of the world into relatively stable and coherent 'things' (McCann and Ward, 2012).

Assemblage, mobility and mutation are interconnected notions. For example, Business Improvement Districts (Ward, 2006), anti-poverty programmes (Peck and Theodore, 2010b), planning strategies (McCann, 2011) and creativity policies (Prince, 2010) are models, assembled in different places and transformed during mobilisation.

In short, they are processes of policy-making and, then, they can be understood as assemblages (McCann *et al.*, 2013).

4 Assemblages in Urban Studies

The notion of assemblage has an important role in the conceptualisation of urban policy mobilities. This notion is not only used to analyze the policy mobilisation and mutation, but also the policy mobility concept itself can be understood as assemblages processes.

The concept of assemblage has been adapted from the work of Deleuze and Guattari (1987) – '*agencement*' – that refers to the process of putting together a mix of relations (Dewsbury, 2011 cited by Kamalipour and Peimani, 2015), and in its original French sense refers to 'arrangement', 'fixing', and 'fitting' (Kamalipour and Peimani, 2015). Basically, assemblage can be thought as a set of relations between heterogeneous entities, working together for some time. But they are more than this (Müller and Schurr, 2016:219): "Terms such as 'contagions', 'epidemics' and 'the wind' hint at the fluidity and ephemerality of assemblages and at their unpredictability, while 'sympathy' and 'symbiosis' suggest that there is a vital, affective quality to them."

Over the years, assemblage has been adopted a diverse genealogy, such as the influential works 'Assemblage Theory' by Manuel DeLanda (2006) and 'Actor-Network Theory' by Bruno Latour (1996, 2004) and his followers. However, the concept of assemblage in urban studies is more recent.

McFarlane (2011) argues that assemblage has been deployed in various ways in urban geography. First, *assemblage as a descriptor of sociomaterial transformation* in accounts on urban socionatures, cyborg urbanisms, or urban metabolisms. In addition, *assemblage as an analytic*, 'tests' the contribution of ANT for rethinking the city Farías (2011). Second, *assemblage related with the urban policy mobilities* to describe the relations between travelling policies and their localised substantiations. McCann and Ward (2011) use assemblage to capture the production of urban policy as, simultaneously, mobile and territorial.

In summary, the assemblage is "both a particular object in the world (e.g. a policy assemblage) and an orientation to the world that focuses on the interactive co-constitution of human and nonhuman agents through relations of exteriority and unequal capacities" (McFarlane, 2011:208). Assemblage refers to the ways in which urbanism is produced not as a 'resultant formation', but as an ongoing process of construction. Assemblage relates to the city as a '*verb*' in 'making urbanism' through historical and potential relations (McFarlane, 2011).

5 Urban policy-making as policy assemblage

Urban policy-making involves the constant scanning (Gilbert, 2002) of the policy landscape, via professional publications and reports, the media, websites, blogs, professional contacts, and word of mouth for ready-made, 'off-the-shelf policies' and best practices that can be quickly applied locally (McCann and Ward, 2011). "In the contemporary globalized context, almost every policy can be seen as an assemblage of expertise and resources from elsewhere." (McCann *et al.*, 2013:583).

Policies are not only local constructions, neither are they entirely extra-local impositions on a locality. They are gatherings, or relational assemblages of elements and resources – fixed and mobile pieces – from close by and far away (McCann and Ward, 2013). In addition, Farías (2011) argues that urban politics are not about subjects, subjectivities or discourses, but about things, complex entangled objects, socio-material interminglings. For the author, issues of urban politics are indeed nothing but complex assemblages of objects, natures, technologies, individuals.

Thus, we can think in 'urban policy assemblage' (Prince, 2010), since assemblage is not a static arrangement of parts, whether organised under some logic or collected randomly. But it indicates a perspective focused on the detailed qualitative and ethnographic study of the practice of assembling some form of coherence, such as a policy (McCann and Ward, 2013).

However, we can highlight two important features. First, policies are not generated abstractly in 'deterritorialised' networks of experts, rather they emerge in, and through, concrete 'local' situations that constitute wider networks (Baker *et al.*, 2016). The process of assemblage – assembling a scale like the 'local' or assembling a policy, or a city –, is fundamentally spatial. Assemblage, as a concept, is spatial, not only in the territorial sense, but also in the closely related scalar sense (McCann and Ward, 2013). In other words (Olds and Thrift, 2005 cited by McCann and Ward, 2011: xvi), "Assemblages will function quite differently, according to local circumstance, not because they are an overarching structure adapting its rules to the particular situation, but because these manifestations are what the assemblage consists of." It means that policy-making must be understood in its relational-territorial form – on the one hand, dynamic and relational, on the other hand, fixed and territorial (McCann and Ward, 2011). This perception has consequences for the 'notion of scales'. Scales (e.g. local, national and global) are social constructs. Scales are not understood as discrete 'levels', instead of they are relationally constructed, in that one only makes sense and only has power in relation to others (Marston, 2000 cited by McCann and Ward, 2013).

Second, policies are assembled in particular ways and for particular interests and purposes (McCann and Ward, 2013). "This process of territorializing and deterritorializing policy knowledge is highly political" (McCann and Ward, 2011:xxi). There is a politic in the policy mobilisation (and immobilisation), whether through formal guidelines (policies), statements of ideal policies (policy models), or expertise in the implementation and evaluation of policy (policy knowledge) (McCann and Ward, 2011).

In an interesting work entitled '*Urban policy mobilities, argumentation and the case of the model city*', Kennedy (2015) states that 'assemblage thinking' is an appropriate metaphor for understanding policy-making in a local context. However, the author argues – this assemblage always arises as a result of compromise – that the decisions are made locally because people have persuaded other people to endorse them. Since unanimous consent is difficult to achieve, the outcome of deliberation is often an assemblage comprised of disparate ideas advanced by a multitude of actors and then modified to fit the local context.

Therefore, there is a local politic of policy mobilities to persuade the several actors involved in the process (Temenos and McCann, 2012). Politics or "the raising and resolution of issues through collective decision-making" (Stoker, 1998 cited by Kennedy, 2015) is essential to local policy-making.

Clarke (2012:34) argues that "most municipalities are democracies of some kind or another". Thus, the urban policy must be negotiated between local politicians and council officers, on the one hand, and national or international politicians, bureaucrats, consultants, researchers, journalists etc. on the other hand. However, the author highlights the importance of participation of the local citizens and their representatives, groups, movements, and organizations. In this regard, Kennedy (2015) suggests opening the processes for broader groups and coalitions of actors. This means that several agents are involved at different stages, some with clearer territorial attachments than others, some with longer geographical reaches than others, and often spurred by previous failures (McCann and Ward, 2011).

In short, it is undeniable that new ways for policy-making carry different practices, assembling various stakeholders (from diverse origins and purposes) and linking policies and places (beyond hierarchical scales). Thus, *what is urban policy-making in this contemporary policy world?* This essay presents some 'partial answers' to raise deeper discussions on this topic. Urban policy-making, therefore, can be characterised by:

- multiple and complex nature – global-local and, simultaneously, socio-spatial and political nature;
- process (socially) constructed – power-laden processes, connecting several practices and places;
- terms such as fluidity, mobilisation and deterritorialisation, but also 'moorings', stabilisation and territorialisation;

- constant 'scanning' the policy landscape;
- political process of policy mobility (and immobility);
- complex assemblage of objects, natures, technologies and individuals.

6 Conclusion

Policies do not result from 'off the shelf' models – complete and immutable. Urban policy-making as policy assemblage assumes that policies are a composition of heterogeneous entities – policies, institutions, objects, ideas, discourses, places, among others. However, they are not simple compositions of 'parts of elsewhere', disconnected and meaningless, since "[...] being connected, being interconnected, being heterogeneous is not enough." (Latour, 2004:63). It all depends on the sort of action that is flowing from one to the other, hence the words 'net' and 'work' (Latour, 2004).

Thus, policy assemblages are (re)made through 'work' of heterogeneous entities apparently disparate, co-functioning for a purpose. It is an alliance, a symbiosis, not a simple set of 'political things'. Policy assemblages are sometimes stabilised (territorialised and reterritorialised) or destabilised (deterritorialised), but always through the mutual overlap.

Finally, despite reaching a certain level of maturity, the concept of urban policy mobilities is recent. We can see an important legacy from policy transfer (political sciences), but more recently have increased the theoretical-methodological contribution from different disciplines. Thus, urban policy mobilities' scholars suggest some conceptual and methodological commitments (see table 1).

Table 1. Conceptual and methodological commitments (Baker *et al.*, 2016:9)

Conceptual commitments	Methodological commitments
• To political-economic and social constructivist approaches to policy mobilisation that take poststructuralist and postcolonial critiques seriously. • To conceptualisations of policymaking's role in wider geographies of ideas and knowledge. • To analyses of policies as powerful and productive technologies • To analyses of inter-local, rather than necessarily international, mobilisations. • To analyses of assembling, emergence, hybridity, mutation, relationality and translation. • To analyses of the immobilities, inertia, barriers and 'differential mobilities' that also constitute policy.	• To primarily qualitative investigations of the practice, process, and meaning of policymaking through interviews, observation, site visits, and documentary analysis. • To empirically tracing the pathways taken by policy through communities, institutions, places, and situations. • To 'extended' or multi-sited case study analysis. • To detailed description, informed by theory and directed toward theory-building.

These commitments show that it is possible (and necessary) new ways to urban policy mobilities research. We need to produce studies that capture and reproduce more clearly the processes and practices. We hope that this 'essay' will contribute or instigate a differentiated look at urban policy-making.

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Energy payback time and CO_2 mitigation potential of energy efficient appliances in India: an EIO-LCA based approach

Vivek Kumar Singh[1,5], Carla Oliveira Henriques[2,3,5], António Gomes Martins[3,4,5]

[1] MIT - Portugal Program, University of Coimbra, Portugal

[2] Polytechnic Institute of Coimbra, Coimbra Business School ISCAC, Portugal

[3] Dept. of Electrical Engineering and Computers University of Coimbra, Portugal

[4] INESC Coimbra, Portugal

[5] Energy for Sustainability Initiative, University of Coimbra, Portugal

Viv.jsingh@gmail.com; chenriques@iscac.pt; agmartins@uc.pt

India is a large developing country facing rapid economic growth, resulting in higher living standards accompanied by a consistent increase of the purchase of electric appliances. The government star labelling program is aimed at motivating the consumers to adopt energy efficient appliances and thus contributing to the reduction of energy consumption and greenhouse gas emissions. In this paper, we propose a methodological framework to assess the energy requirements and CO_2 mitigation potential of nine domestic electrical appliances in India - light sources, refrigerators, air-conditioners, water heaters, televisions, computers, washing machines, ceiling fans and water pumps. The energy requirements to produce the energy efficient appliances herein assessed are computed considering the Economic Input-output lifecycle approach. Total energy savings during their lifetime are estimated by considering the replacement of business as usual technology with best available technology. This information allows obtaining the energy input during the best available technology life cycle (which includes the energy requirement for manufacturing, installation and energy use during operation) and the annual energy savings due to the investment on BAT technology. An analogous approach was conducted regarding the assessment of CO_2 emissions (either generated and/ or reduced). This information was then used to obtain the expected energy payback time and the greenhouse gas payback time of each appliance. Valuable insights were attained with the use of these two indicators. The energy payback time for present-day domestic appliances in India is not relatively high, being always lower than their expected lifetime. Finally, it was concluded that the greenhouse gas payback time shows higher values than the energy payback time.

Keywords: Energy efficient appliances; energy payback time; CO_2 mitigation potential; EIO-LCA.

1 Introduction

Climate change has been extensively discussed in academic as well as in the political domain (Ahmad and Choi, 2010). The National Action Plan on Climate Change (NAPCC) in India was launched in 2008 and it identified a number of measures that simultaneously advanced the country's development and climate change related objectives of adaptation and mitigation (GoI, 2008). The NAPCC was formulated based on the country's specific circumstances, especially incorporating energy efficiency concerns (Ahmad and Choi, 2010). Policy options for reducing energy demand are equally important for India and energy efficiency adaptation in end-use technologies in the residential sector is one of such important policies (Chaturvedi *et al.*, 2012). Energy efficiency of Indian industries and other sectors vary widely, and have an important role on India's emission mitigation strategy. Several studies focusing on energy efficiency highlight the lack of awareness/information, financial reasons, and split incentives as some important barriers to energy efficiency improvement in buildings (see e.g. Nassen *et al.*, 2008; Reddy, 2003; Schleich, 2009).

The support of energy efficiency policies can thus be seen as a cost-effective driver of energy consumption and greenhouse gases (GHG) reduction, while providing economical energy services in different activity sectors (Henriques and Coelho, 2017).

There are two environmental indicators of Life cycle assessment (LCA), the energy payback time (EPBT) and the greenhouse gas payback (GPBT), which can measure the energy and GHG performance of energy systems, respectively. The EPBT is a common metric used to evaluate the energy performance of electricity generated from renewable systems, mainly applied to assess photovoltaic (PV) systems installations (Alsema, 2000; Fukurozakia *et al.* 2012; Lu and Yang, 2010; Piano and Mayumi, 2017) and fuel cell stacks (Babu *et al.* 2015).

The application of the EPBT as an indicator can be extended to the assessment of energy efficient retrofit actions (Fulvio *et al.*, 2015; Yvan and Daniel, 2012). Although less used, the GPBT can be helpful since it allows expressing the GHG mitigation potential of energy efficient retrofit actions.

The novelty of this work lies on the fact that the energy embodied in each lighting source (TFL), refrigerators (FR), air-conditioners (RAC), water heaters (GY), televisions (TV), computers (COM), washing machines (WM), ceiling fans (CF) and water pumps (WEP) herein assessed has been computed by means of national average Input-Output (IO) data to fill the gaps usually found on traditional lifecycle inventories.

The main objective of this study is to provide a modelling framework which allows supporting public bodies in the assessment and selection of energy efficient retrofit actions that can be implemented in the residential sector in India.

This paper is organized as follows: in Section 2 we briefly describe the methodological approaches herein used; section 3 provides the main underpinning assumptions regarding data collection; in Section 4 a discussion of the illustrative results obtained is presented; finally, some conclusions are drawn and future work developments are suggested.

2 Methodology

In the case of renewable energy technologies, the EPBT depends on the energy spent on the materials used for the fabrication of the system and on its components (Tiwari and Mishra, 2012). The EPBT is the period of time required to recover the total energy spent to manufacture the materials used in the renewable energy system (embodied energy) and it corresponds to the ratio of embodied energy and annual energy output from the system. Embodied energy inputs include the energy requirement for manufacturing, installation, energy use during operation, and energy needed for decommissioning, while the energy output corresponds to the annual energy savings due to electricity generated by the renewable technologies (Alsema, 2000).

In the assessment of the energy performance of energy retrofit actions, the EPBT is the period of time needed for the retrofit action to recover the total energy spent in the manufacturing of the materials used in it and it is ratio of the embodied energy and the annual energy savings obtained. In this last case, the energy invested should not account for the energy used by the device, but should rather consider the energy required to implement the solution or install the equipment (from resources extraction to commissioning not from the cradle to the grave).

The traditional Economic Input-Output Lifecycle Assessment (EIO-LCA) model is based on an (IO) matrix with the economic flows between industries that can be extended with information regarding the energy use, creating additional columns and rows that represent the energy use per each activity sector/industry (Hendrickson. et.al,2006). According to the traditional IO framework, the productive system at a national level can then be represented in its matrix form following the basic IO system of equations (Miller and Blair, 2009):

$$x = A\mathbf{x} + \mathbf{y}, \quad (1)$$

where A is a matrix of technological coefficients, **y** is a vector of final demand (households, government, firms and foreign countries) and **x** is a vector of the corresponding outputs.

An approach for obtaining the energy requirements associated with inter-industry activity consists of assuming a matrix of direct impact coefficients, E, where each generic element is the amount of energy each type consumed (GHG emissions generated) per monetary unit of industry j's output (Hendrickson *et al.*, 2006). Hence, the level of energy use (GHG emissions) associated with a given vector of total outputs can be expressed as:

$$\mathbf{e} = E\mathbf{x}, \quad (2)$$

where **e** is the vector of energy use (GHG emission) levels. Thus, we can compute vector **e** as a function of final demand, i.e., the total energy of each type used (GHG emissions generated) by the economy directly and indirectly in supporting that final demand:

$$e = E\,(I - A)^{-1}\mathbf{y}, \quad (3)$$

Finally, from (3) we can interpret $E\,(I - A)^{-1}$ as a matrix of total energy use (GHG emission) coefficients; i.e., an element of this matrix is the total energy use (GHG generated) per monetary unit of final demand presented to the economy.

IO tables cannot identify in their present form the economic impacts that are likely to be created from an increase in the demand for the use of a typical best available (BAT)/ business as usual (BAU) appliances. One way to surmount this problem is to decompose BAT/BAU appliances into their various activities/components and associated costs, and then match these to the sectors identified in the IO table of the economy under analysis and obtain the relevant coefficients and multipliers to arrive at final impact estimates (either embodied energy or GHG emissions). In order to assess these estimates, the economic impulses that originate these impacts must be identified (as in figure 1). Therefore, the lifecycle of a BAT/BAU appliances is divided into different lifecycle phases (i.e. installation and O&M) and then these phases need to be further decomposed into their corresponding activities/components. After collecting information on the total expenditure connected to each lifecycle phase, along with data on the cost share of each relevant activity/component as a percentage of the corresponding lifecycle phase, it is possible to calculate the total output (in monetary units) of each of these relevant activities/components.

The lifecycle phases can then be economic activities that provide impulses in the form of expenditures that can generate different economic effects (see figure 1). Impulses (e.g. expenditures for operation and maintenance (O&M), manufacturing and construction of BAT/BAU appliances) are regarded as exogenously determined parameters that trigger an economic mechanism that leads to several effects. Effects (e.g. a direct positive effect could be an increase in BAT/BAU appliance production;

a negative induced effect could be a decrease in the consumption of goods) relate to how impulses influence the economy – positively, negatively, directly, indirectly or induced. The most important impulses herein analyzed are: investment and O&M expenditures, including impacts in upstream industries (direct and indirect effects – obtained through type I multipliers, i.e. (direct effect + indirect effect) / direct effect); the impulse from household income due to changes in the investment on BAT/BAU appliances (obtained through type II multipliers – i.e. (direct effects + indirect effects + induced effects)/ direct effect).

Divide into lifecycle phase	• Manufacturing and Installation.
Decompose lifecycle phases into their activities/components	• The BAT/BAU appliance activities/ components
Calculate total output of each relevant activity/ component	• Total expenditure connected to each relevant activity/component as % of lifecycle phase. • BAT/BAU appliances cost and material shares.
Match the domestic output of each relevant activity/ component of BAT/BAU appliance to industry in IO table	• Match the domestic output of each relevant activity/component of BAT to the industries within the IO table, based on (WIOD,2012). • Match the domestic output of each relevant activity/component of electricity from BAU to the industries within the IO table
Calculate the multiplier effects of each activity/component	• Use IO multipliers (for each emission type considered, for obtaining embodied energy), to arrive at indirect and induced effects.

Figure 1. Methodology application of the EIO-LCA analysis framework.

The energy payback time of each BAT technologies in years is then obtained as (Henriques and Coelho, 2017):

$$EPBT_i = E_{input}i/E_{saved}i \quad (4)$$

where $E_{input}i$ is the energy embodied in manufacturing and installation of BAT technology i obtained by means of the EIO-LCA approach and $E_{saved}i$ is the yearly energy savings of BAT technologies i.

The GPBT of each BAT technologies in years is:

$$GPBTi = GHG_{input}i/GHG_{avoided}i \quad (5)$$

where $GHG_{input}i$ is the GHG embodied in manufacturing and installation of BAT technology i obtained by means of the EIO-LCA approach and $GHG_{avoided}i$ is the yearly avoided emission of BAT technologies i.

3 Data and Assumptions

An IO modelling framework has been built with real data based on the World Input-Output Database (National IO tables for India, http://www.wiod.org/) to assess the energy and environmental impacts of several energy efficiency measures/energy efficient technologies in India's residential sector (see figure 2). A large size platform of real data for the residential sector in India has also been gathered considering different data sources (see, e.g. TERI, 2006; BEE, 2007, 2008; LABL, 2005, 2007; Murthy *et al.*, 2001; PEG, 2007; World Bank, 2008; International Energy Initiative (IEI); and Centre for Monitoring Indian Economy Pvt. Ltd. (CMIE, 2000)). The household building stock characterization, the number of operating days according to the climatic regions of India and the life span and the investment cost of each energy efficient equipment/measure considered are provided in tables 1-4. The average share of materials (see e.g. ELC, 2010; Hotta, 2003; Welz *et al.,* 2011) and the costs used for each BAT appliances were obtained from web based market research on several shopping websites and star labelling efficient appliances as defined by the Bureau of Energy Efficiency. Data regarding energy consumption has been obtained from the energy balance of India and then combined with the World Input-Output Database.

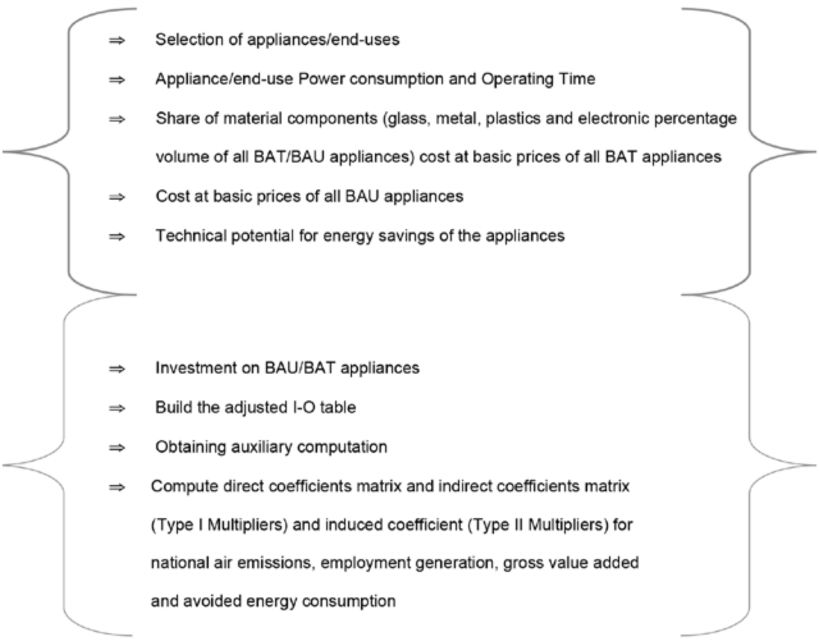


Figure 2. Implementation step.

Table 1. Appliance/end-use average rated power.

Appliance/end-use	BAU (W)	BAT (W)
WEP	1460	730
TFL	60	36
EG	2400	1750
TV	150	80
CF	75	55
FR	600	330
RAC	2400	1677
WM	1000	400
COM	250	150

Table 2. Appliance/end-use annual operating hours.

Appliances / end -use	*TFL*	*EG*	*TV*	*CF*	*FR*	*RAC*	*WM*	*COM*	*WEP*
Uses Hrs/day	4	0.5	6	8	24	6	1	4	1.5
Operating/days	365	365	365	200	365	120	365	350	365
Average Hrs/day	4	1	6	4	24	2	1	4	2
Hrs/year	1460	183	2190	1600	8760	720	365	1400	548

Table 3. Specific features of BAT Technology.

Appliances / end -use	*Life Span*	*Annual energy saving (kWh)*
TFL	14	35.04
EG	15	40.00
TV	10	153.30
CF	15	32.00
FR	5	98.55
RAC	10	520.56
WM	13	219.00
COM	10	140.00
WEP	14	399.68

Table 4. Share of Material, Cost.

		TFL	*EG*	*TV*	*CF*	*FR*	*RAC*	*WM*	*COM*	*WEP*
Share of Material	Glass	90.0%	00.0%	10.0%	80.0%	0.0%	0.0%	0.0%	55.0%	0.0%
	Metal	6.0%	70.0%	10.0%	15.0%	60.0%	60.0%	60.0%	10.0%	75.0%
	Rubber	0.0%	0.0%	0.0%	0.0%	5.0%	5.0%	5.0%	10.0%	0.0%
	Plastics	6.0%	0.0%	60.0%	0.0%	10.0%	20.0%	5.0%	0.0%	10.0%
	Insulation material	0.0%	25.0%	0.0%	0.0%	10.0%	10.0%	20.0%	0.0%	0.0%
	Electronic	2.0%	5.0%	20.0%	5.0%	15.0%	5.0%	10.0%	20.0%	15.0%

		TFL	EG	TV	CF	FR	RAC	WM	COM	WEP
Share of cost	Glass	40.0%	40.0%	15.0%	35.0%	0.0%	0.0%	0.0%	20.0%	0.0%
	Metal	0.0%	0.0%	20.0%	15.0%	25.0%	35.0%	20.0%	25.0%	40.0%
	Rubber	0.0%	0.0%	0.0%	0.0%	5.0%	5.0%	5.0%	20.0%	0.0%
	Plastics	30.0%	0.0%	15.0%	0.0%	5.0%	10.0%	5.0%	0.0%	10.0%
	Insulation material	0.0%	30.0%	0.0%	0.0%	5.0%	10.0%	10.0%	0.0%	0.0%
	Electronic	30.0%	30.0%	50.0%	50.0%	60.0%	40.0%	40.0%	35.0%	50.0%

4 Illustrative Results

The illustrative results regarding the EIO-LCA impact assessment of the nine BAT technologies herein considered are presented in the next sections.

4.1 Energy impacts (EPBT)

The embodied energy computed considering the manufacturing to installation stages according to the EIO-LCA approach is provided on table 5. The energy savings obtained when contrasting the BAU with BAT technologies are given in table 6.

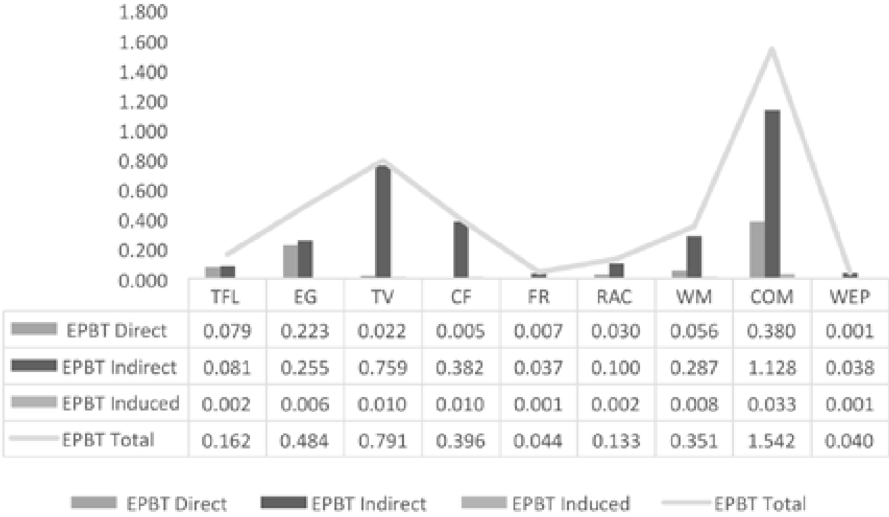
From our assessment, it was possible to conclude that from the nine BAT appliances handled in this study only COM present an EPBT higher than 1.5 months and TFL, EG, TV, CF, and other BAT technologies have less than 1 month of EBPT (see figure 3). The EBPT for the distinct energy efficient retrofit systems depend on the number of operation days and on operation hours.

Table 5. Embodied energy of BAT technologies.

Appliance/ end-use	Coal (Toe)	Lignite (Toe)	LPG (Toe)	Naphtha (Toe)	Diesel (Toe)	Heavy fuel oil (Toe)	Total KWh	Electricity GWh	Total electricity (W)
TFL	0.0000010	0.0000001	0.0000000	0.0000000	0.0000000	0.0000000	14	0.0000005	472
EG	0.0000154	0.0000010	0.0000000	0.0000002	0.0000001	0.0000001	195	0.0000046	4785
TV	0.0000263	0.0000019	0.0000000	0.0000005	0.0000000	0.0000003	337	0.0000103	10631
CF	0.0000065	0.0000004	0.0000000	0.0000000	0.0000000	0.0000000	81	0.0000010	1057
FR	0.0000443	0.0000027	0.0000000	0.0000002	0.0000003	0.0000002	555	0.0000082	8755
RAC	0.0000723	0.0000044	0.0000000	0.0000005	0.0000005	0.0000004	910	0.0000153	16192
WM	0.0000288	0.0000018	0.0000000	0.0000002	0.0000002	0.0000002	362	0.0000060	6404
COM	0.0000742	0.0000046	0.0000000	0.0000006	0.0000005	0.0000005	936	0.0000171	17989
WEP	0.0000091	0.0000005	0.0000000	0.0000000	0.0000001	0.0000000	113	0.0000012	1324

Table 6. Annual energy saved with BAT technologies.

Appliance/end-use	BAU Technologies(Wh)	BAT. Technologies(Wh)	Total Energy Saved (Wh)
TFL	87600	52560	35040
EG	438000	319375	118625
TV	345721	184385	161337
CF	120000	88000	32000
FR	5256000	2890800	2365200
RAC	4852603	3390756	1461847
WM	365000	146000	219000
COM	350000	210000	140000
WEP	799350	399675	399675



	TFL	EG	TV	CF	FR	RAC	WM	COM	WEP
EPBT Direct	0.079	0.223	0.022	0.005	0.007	0.030	0.056	0.380	0.001
EPBT Indirect	0.081	0.255	0.759	0.382	0.037	0.100	0.287	1.128	0.038
EPBT Induced	0.002	0.006	0.010	0.010	0.001	0.002	0.008	0.033	0.001
EPBT Total	0.162	0.484	0.791	0.396	0.044	0.133	0.351	1.542	0.040

Figure 3. EPBT in Months for each BAT technologies.

4.2 Environmental impacts (GPBT)

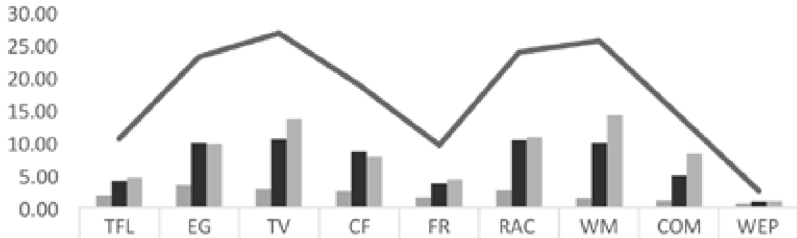
The avoided GHG emissions were computed by considering that each GHG has a different global warming potential and persists for a different length of time in the atmosphere (Solomon *et al.*, 2007).

The embodied GHG emissions were calculated by considering the manufacturing to installation EIO-LCA stages (see table 7). Avoided GHG emissions are given in table 8.

Our analysis allowed us to conclude that from the nine BAT appliances assessed in this study the direct GPBT ranges from 1 to 3.5 months, the indirect GPBT is within 1 to 12 months and the induced GBPT is between 1 to 15 months (see figure 4).

Table 7. Embodied GHG emission in CO_2 equivalent.

Appliance/end-use	Gases /Tonne of CO_2 equivalent.	Direct	Indirect	Induced
WEP	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00069	0.00243	0.00009
	N_2O	0.00210	0.00050	0.00005
TFL	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00016	0.00091	0.00004
	N_2O	0.00052	0.00023	0.00002
EG	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00089	0.00735	0.00035
	N_2O	0.00345	0.00195	0.00021
TV	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00074	0.00912	0.00048
	N_2O	0.00382	0.00359	0.00029
CF	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00022	0.00169	0.00007
	N_2O	0.00064	0.00047	0.00005
FR	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00953	0.05633	0.00237
	N_2O	0.02835	0.01342	0.00146
RAC	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00340	0.03338	0.00159
	N_2O	0.01112	0.00947	0.00098
WM	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00082	0.01336	0.00066
	N_2O	0.00256	0.00388	0.00040
COM	CO_2	0.00000	0.00000	0.00000
	CH_4	0.00289	0.03580	0.00185
	N_2O	0.01009	0.01015	0.00114



	TFL	EG	TV	CF	FR	RAC	WM	COM	WEP
GPBT Direct	1.82	3.46	2.82	2.56	1.52	2.64	1.46	1.03	0.66
GPBT Indirect	4.08	9.85	10.42	8.51	3.71	10.34	9.89	4.85	0.92
GPBT Induced	4.59	9.73	13.49	7.76	4.26	10.81	14.20	8.21	0.94
GPBT Total	10.49	23.04	26.73	18.83	9.48	23.80	25.55	14.09	2.53

GPBT Direct   GPBT Indirect   GPBT Induced   GPBT Total

Figure 4. GPBT in months for each BAT technologies.

Table 8. Avoided GHG emissions in CO_2 equivalent.

Appliance/end-use	Gases /Tonne of CO_2 equivalent.	Direct	Indirect	Induced
WEP	CO_2	0.000311	0.000090	0.000000
	CH_4	0.000034	0.000173	0.000007
	N_2O	0.000007	0.000003	0.000005
TFL	CO_2	0.000027	0.000008	0.000000
	CH_4	0.000003	0.000015	0.000001
	N_2O	0.000001	0.000000	0.000001
EG	CO_2	0.000092	0.000027	0.000000
	CH_4	0.000010	0.000051	0.000002
	N_2O	0.000002	0.000001	0.000003
TV	CO_2	0.000119	0.000034	0.000000
	CH_4	0.000013	0.000066	0.000003
	N_2O	0.000003	0.000001	0.000002
CF	CO_2	0.000025	0.000007	0.000000
	CH_4	0.000003	0.000014	0.000001
	N_2O	0.000001	0.000000	0.000001
FR	CO_2	0.001841	0.000532	0.000001
	CH_4	0.000201	0.001021	0.000041
	N_2O	0.000040	0.000016	0.000032
RAC	CO_2	0.000405	0.000117	0.000000
	CH_4	0.000044	0.000225	0.000009
	N_2O	0.000009	0.000003	0.000010
WM	CO_2	0.000170	0.000049	0.000000
	CH_4	0.000019	0.000095	0.000004
	N_2O	0.000004	0.000001	0.000002
COM	CO_2	0.000926	0.000268	0.000001
	CH_4	0.000101	0.000514	0.000021
	N_2O	0.000020	0.000008	0.000009

Table 9 illustrates the CO_2 mitigation potential calculated considering the electricity consumption both implied with BAU and BAT appliances. In the case of India, a carbon conversion factor for electricity of 0.82 kg CO_2/kWh has been considered (IPCC 2006).

From our analysis it was possible to conclude that out of these nine BAT appliances only three (FR, RAC and WEP) are responsible for more than 86 % of the CO_2 emissions potential (see figure 9). For example, the replacement of the current less efficient models (BAU appliances) with BAT appliances corresponds to a technical CO_2 emissions mitigation potential of about approx. 4 tonnes/year.

Table 9. BAU/BAT Technologies' CO2 emission/annum.

Appliance/ end-use	BAU CO_2 emission (kg CO_2/kWh)	BAT CO_2 emission (kg CO_2/kWh)	CO_2 mitigation potential (kg CO_2/kWh)
TFL	72	43	29
EG	359	262	97
TV	283	151	132
CF	98	72	26
FR	4310	2370	1939
RAC	3979	2780	1199
WM	299	120	180
COM	287	172	115
WEP	655	328	328

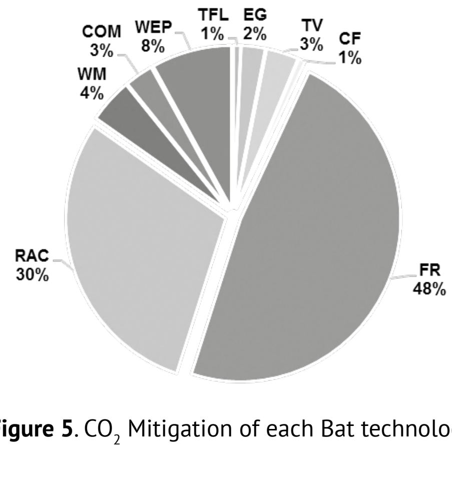


Figure 5. CO_2 Mitigation of each Bat technology.

Conclusions

The EBPT and the GPBT assessment in renewable energy technologies has been widely used. In this paper, we propose the extension of this sort of analysis to distinct energy efficient retrofit actions in India's residential sector by means of the EIO-LCA approach. The EIO-LCA has been used for the assessment of the direct, indirect and induced embodied energy throughout the life cycle phases of nine BAT technologies (from manufacturing to installation). Then an approach for obtaining the EPBT and GPBT for these nine energy efficient technologies was herein suggested.

It was possible to conclude that the EPBT for domestic appliances in India is always lower than the corresponding expected life spans. On the other hand, it was also possible to conclude that the GPBT for the domestic appliances under analysis is always higher than the corresponding EPBT.

Based on the results obtained, some guidelines can be drawn to help and support energy decision planning and energy decision-makers, in particular in a context where BAT technologies are designed to reduce energy consumption, bringing to light the need to consider a lifecycle approach in their performance assessment. Future work is currently under way to couple this type of assessment with other modelling tools to better explore the main potentialities offered by the different approaches, in particular, MOLP models.

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