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Paulo Jorge Monteiro de Cambra

**Supervisor**: Doctor Filipe Manuel Mercier Vilaça e Moura

Thesis approved in public session to obtain the PhD Degree in Transportation Systems

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# Abstract

Cities worldwide are investing in infrastructural interventions towards the promotion of pedestrian-friendly, walking conducing urban environments. On one hand, walking has been associated with numerous social, health and economic benefits, being the most elementary mean of people moving around, integrating and living the urban space and accomplishing salutary physical activity. On the other hand, current challenges cities face regarding sustainability goals and affirmative action on the climate crisis have called for a shift in the urban mobility paradigm towards active travel.

Making cities more walkable has been put forward as a mean to achieve such goals. The rationale for it is that a friendlier walking environment can positively influence walking behaviour, increasing pedestrian activity, hence making more people walk more. There is solid evidence on the benefits of walking and on the influence of the built environment in shaping walking behaviour. However, there is a lack of clear evidence on a causal relation between built-environment interventions and walking behaviour change.

As a result, planning –and implementation- of environmental interventions to promote walking seems to be made on the reasonable expectation of “if you build it they will come”. The effectiveness of such interventions in walking behaviour has been addressed only in few studies, which in turn and have provided mixed evidence. Other current literature gaps include the lack of longitudinal walkability analysis and the identification of relevant factors in triggering walking behaviour change.

This study aims is to deepen the understanding of how built environment interventions towards the promotion of walking can influence walking behaviour. A relational model of the influence of built environment change in walking behaviour change was developed drawing from various travel theoretical behaviour frameworks, leading to the formulation of the following hypothesis: 1) Positive association between walkability and pedestrian activity and walking experience; 2) Exposure, Perception and Experience to be significant predictors of behavioural change; 3) Pedestrian segments are associated to different outcomes; and 4) Intervention results bear distinct "success" levels in relation to the type of walking behaviour of interest.

A comprehensive longitudinal analysis was performed in a real world case study - the Eixo Central street improvement project in Lisbon. Data on walkability, pedestrian activity and walking behaviour was collected before and after the intervention, by performing respectively walkability audits, pedestrian counts and a survey.

The results confirmed the existence of a significant and positive association between improving walkability and increasing pedestrian activity. Moreover the actual use of the improved environment, the perception of improvement in a few attributes and satisfaction with the walking experience were found to be significant predictors of increasing walking for five different purposes, namely utilitarian, recreational, walking for public transport, walking for exercise and route change. Another finding was that attitudes towards the role of the car in the city vs. public space were the main differentiator of pedestrian segments and that attitudes played a role in how the individual perceived the environment.

Findings of this study suggest that the magnitude of environmental improvements are determinant in the behavioural response. Small scale interventions may produce effects in well being, but are not effective in increasing walking levels. Larger scale interventions which de facto change walkability levels significantly may produce desired, yet moderate, effects in increasing physical activity levels and modal shift towards walking. However, larger scale interventions are more prone to public and political opposition especially if road space is reallocated. Integrated land use-transport planning with clearer goal setting is key to achieve urban sustainability goals.

**Keywords:** Walkability, Walking behaviour, Longitudinal, Before-After, Street improvement

# Resumo (in portuguese)

Um pouco por todo o mundo, várias cidades tem investido em intervenções e obras públicas visando a melhoria do espaço público que se pretende mais de encontro às necessidades do peão, visando a promoção do andar a pé. Por um lado andar a pé tem sido associado a numerosos benefícios – sociais, de saúde, económicos- constituindo o modo mais elementar da pessoa se deslocar mas também de interagir e vivenciar o ambiente urbano e, ao mesmo tempo, realizar níveis salutares de atividade física. Por outro lado as cidades enfrentam hoje sérios desafios para ir de encontro às metas estabelecidas no que se refere aos objetivos da sustentabilidade e combate à crise climática. Para tal tem sido considerado imprescindível alterar o paradigma da mobilidade urbana, limitando a mobilidade em transporte individual e promovendo a mobilidade ativa.

Tornar as cidades mais caminháveis é hoje considerada uma forma de atingir esses objetivos. O racional base é que um ambiente mais amigo do peão influencie positivamente os hábitos de mobilidade, levando a que mais pessoas passem a andar mais a pé. A relação de influência entre o ambiente urbano e o andar a pé entre estão bem estabelecidos na literatura, tal como os benefícios de andar mais. No entanto, existem poucas evidências claras numa relação causal entre a alteração das condições de andar a pé e a alteração de comportamento.

Como tal, o planeamento e a implementação das intervenções para promoção do andar a pé tem sido aparentemente fundamentadas pela expetativa de “se o construíres, as pessoas virão – if you build it they will come”. A avaliação dos efeitos das intervenções em meio urbano nos hábitos de andar a pé não é suficientemente cocnhecida, existindo apenas num reduzido número de estudos, que, para mais, apresentaram resultados contraditórios: em alguns casos houve um aumento de atividade pedonal, noutros casos não. Outros “gaps” da literatura incluem a ausência de análise longitudinal de caminhabilidade e a identificação dos fatores mais relevantes para espoletar uma alteração comportamental.

O objetivo deste estudo é aprofundar a compreensão de como as intervenções em meio urbano para a promoção do andar pé influenciam o comportamento. Desenvolveu-se um modelo relacional desta interação a partir de várias teorias comportamentais aplicadas aos transportes, possibilitando a formulação das seguintes hipóteses: 1) Existe uma associação positiva entre a alteração na caminhabilidade, e a alteração na atividade pedonal e experiência de andar a pé; 2) A exposição à intervenção, a percepção dos fatores alterados e a experiência resultante são fatores explicativos da alteração comportamental; 3) Diferentes segmentos de peões estão associados a diferentes efeitos; e 4) A avaliação do “sucesso” da intervenção depende da variável comportamental considerada.

Este estudo contemplou uma análise longitudinal a um caso real – o projeto de requalificação Eixo Central em Lisboa – implicando a recolha de dados pré-pós relativos às condições de caminhabilidade, atividade pedonal e comportamento pedonal. A caminhabilidade foi obtida através da aplicação in situ da ferramenta IAAPE; a atividade pedonal foi observada através de contagens a peões em movimento e estacionários; enquanto o comportamento pedonal foi caracterizado através de um inquérito dirigido aos utilizadores do Eixo Central.

Os resultados confirmaram uma relação significativa e positiva entre a melhoria da caminhabilidade e o aumento da atividade pedonal. Os resultados também revelaram que a utilização efetiva do ambiente requalificado, a percepção da melhoria de certos fatores ambientais e a satisfação com a experiência de aí andar a pé constituiam preditores significativos do aumento da frequência de andar a pé tendo em conta cinco motivos diferentes - utilitário, recreativo, para apanhar transportes públicos, andar como exercício e alteração de caminho. Outro resultado obtido prendeu-se com o papel das atitudes na segmentação de grupos de peões, em que as atitudes pró-carro e pró-espaço público se revelaram o principal elemento diferenciador, e também no papel das atitudes como factor de influência na forma como o ambiente urbano é percepcionado.

Os resultados deste estudo sugerem que a escala da intervenção é determinante para a resposta comportamental. Intervenções de pequena monta poderão produzir efeitos a nível da experiência e bem-estar pessoal mas não serão eficazes a produzir efeitos na atividade pedonal. Intervenções de maior monta poderão ser mais eficazes em aumentar os níveis de atividade física e de alteração modal de encontro aos objetivos de saúde pública e mobilidade urbana. No entanto, intervenções de maior escala são mais suscetíveis à oposição pública e política, em particular quando há lugar à realocação do espaço rodoviário. A integração do planeamento urbano e o de transportes com maior clareza na determinação de objetivos é considerada chave para atingir os objetivos de sustentabilidade urbana.

**Palavras-Chave (Português):** Caminhabilidade, Requalificação urbana, Alteração comportamental, Estudo longitudinal, Caminhar

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My deepest gratitude to my mother and father for their endless support.

To the reader who made it up to here, thank you for your interest, i hope you find this study insightful for your research.

***Walking is so much more than walking.***

Jan Gehl

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# Acronyms

BE : Built Environment
WB : Walking Behaviour
WS : Walkability Score
PA : Physical Activity
AT : Active travel

# Chapter 1

# Introduction

Cities worldwide are changing.

Cities worldwide are investing in making their urban environment more pedestrian friendly. Factors like the urgency in counteract the climate crisis, the health consequences of a sedentary lifestyle and, more recently, the global Covid-19 pandemic have driven policy makers to react and to adapt to a new urban mobility paradigm where people come first.

The benefits of walkable urban areas have become recognized as having positive effects for the social, health and economic well-being of a society, and regarded as an essential factor in the creation of liveable communities. Walking is the elementary mean of people moving around, integrating and living the urban space and accomplishing salutary physical activity.

There is now solid evidence on the influence of the built environment in shaping walking behaviour. However, evidence on a causal relation linking a physical change in the built environment to a change in walking behaviour remains less clear. Causal inference requires meeting four conditions (van de Coevering *et al.*, 2015): 1) Association – a significant statistical relationship between two variables; 2) Non-spuriousness – the relationship of the two variables cannot be attributed to a third variable; 3) Time precedence – cause should precede the effect; and 4) Plausibility – plausible explanation for why the alleged cause should produce the observed effect. Existing research on the relationship between the urban environment and active transportation has been based in cross-sectional studies. Hence extensive evidence for associations has been produced but without meeting the three other conditions for causal influence. Multi-period designs on the other hand, allow stating the temporal order of cause and effect. To date, the use of multi-period designs has been rather limited given its practical issues, being considered to be more complex, expensive and time consuming (van de Coevering *et al.*, 2015; Kamruzzaman *et al.*, 2016).

Changing the built environment involves high costs and has long lasting implications yet there is little robust evidence that such interventions are an effective strategy to promote walking (Panter *et al.*, 2016; van de Coevering *et al.*, 2015). As a result, planning –and implementation- of environmental interventions seems to be made on the reasonable expectation of ***"if you build it they will come".***

If one hand "The potential to moderate travel demand by changing the built environment is the most heavily researched subject in urban planning" (Ewing & Cervero, 2010), on the other hand only few studies have addressed walking behaviour change in relation to an environmental intervention. Krizek *et al.* (2009a) has pointed several limitations that may explain this gap, which include the complexity of addressing walking behaviour and a lack of communication between policy makers and researchers which prevent the timely preparation of longitudinal studies. Moreover the results of the studies reporting on before-after intervention effects have produced mixed evidence. For instance in some cases there is an observed increase in pedestrian usage (Jensen *et al.*, 2017b) while in others no differences are found (Jung *et al.*, 2017).

Walking behaviour is a barely defined concept in the literature. While general travel behaviour can be broadly defined as the study of what people do over space and how they use transportation (Burbidge, 2008), walking is more than using or choosing a transport mode - the walk itself may be the motivations for a trip or an expression of physical activity (Handy *et al.*, 2006). Depending on the research field - transportation, planning, geography, psychology and public health - different measures for walking behaviour are used in the studies, and accordingly in can be hypothesized for an environmental intervention to produce distinct effects in distinct observed behaviours (e.g. frequency of walking trips vs. time spent walking). Other behavioural expressions may be less observable (e.g. satisfaction with walking) but equally relevant. Subsequentially, the evaluation of the efficacy of environmental interventions to promote walking is currently a subject in contention.

The goal of the present research study is to deepen the understanding of how the built environment interventions towards the promotion of walking influence walking behaviour, by performing a longitudinal analysis using a real world case - the Eixo Central project in Lisbon.

It is worth mentioning that this research study does not start from scratch. It expands previous work done by the researcher: first the development of a walkability assessment framework (Cambra, 2012), then the IAAPE research project (Moura *et al.*, 2017)[1] where a positive and significant association was found between walkability at the street level and pedestrian flow, as shown in Figure 1.1:

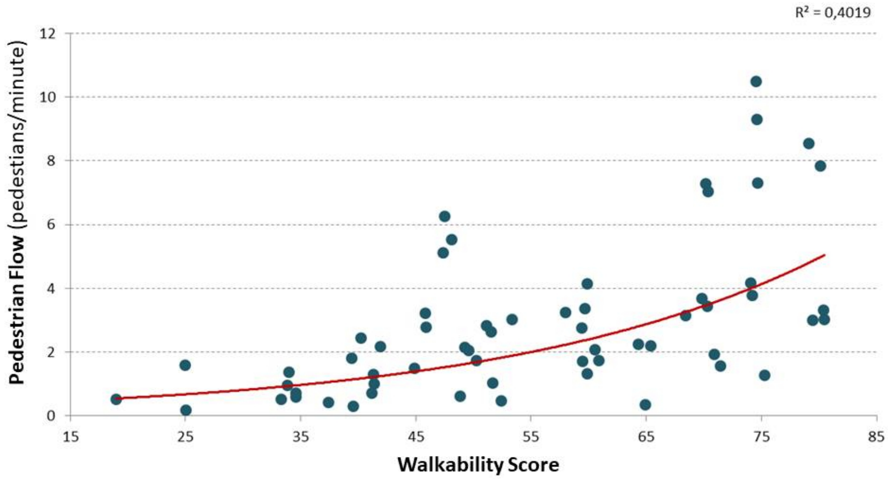



Figure 1.1: IAAPE findings: walkabilty score vs. pedestrian flow

One of the questions raised at the end of the IAAPE research project was related to the presence of outliers, i.e. streets whose walkability score did not match the expected pedestrian flow. It was then hypothesized that more than being the result of a weaker model fit, the unaligned elements actually revealed critical situations of demand/supply balance. For instance, a street with low walkability score and a high pedestrian flow could mean that the quality of the walking environment of that street (offer) was somehow less achieved in order to meet a desirable level of service for the pedestrian (demand).

A sequent question set for future research was then formulated - if one can associate the Built Environment (BE) to Walking Behaviour (WB) via walkability, then would changing the walkability of the BE be associated to a change in WB (for instance in pedestrian flows)? - and expanded - what other WB changes could be identified in relation to a BE change? (see Figure 1.2)

This question, along with the arguments related to promoting walking, to the evaluation of street improvement and the research gap in longitudinal walkability analysis

[1] EXPL/ECM-TRA/2416/2013: "Pedestrian Accessibility and Attractiveness Indicators: Tool for Urban Walkability Assessment and management"

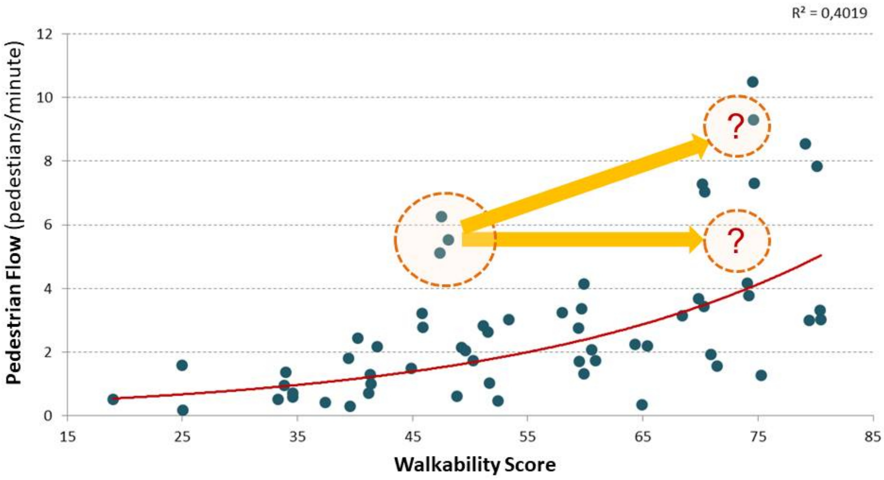



Figure 1.2: Hypothesized effects of walkabilty change in pedestrian flow

motivated the fundamental research question of the present study:

**Q: How does changing the Walking Environment relate to a change in Walking Behaviour?**

Which opens up to a set of subquestions

Q.1: How does a change in walkability affects pedestrian activity?
Q.2: Which factors influence walking behaviour change?
Q.3: How do distinct pedestrian segments respond to environmental change?
Q.4: How can the success of a walking promotion intervention be evaluated?

To address these questions, the present research follows a combination of quantitative and qualitative methods applied to a real-world case study. The selected case study is the Eixo Central project in Lisbon, Portugal, which consisted of a comprehensive intervention in one of the cities' main transportation corridor. The study follows a longitudinal design. Most of the required data ought to be collected using several methods: walkability audits; pedestrian counts and a survey targeting residents, workers and visitors of the study area. Several approaches are used to analyse data, such as geospatial processing and statistical modelling tools, namely pairwise distribution comparison, logistic regression and structural equation models.

The present research focuses in studying the effects of changing the urban built environment in walking behaviour - which in the course of the study is referred to as ***environmental change***. Likewise, the urban built environment, which includes the pedestrian infrastructure, public space, and activites that are supported by the physical environment is referred to as ***walking environment***. The thesis is structured as follows: Chapter 1 starts by presenting the context and rationale that motivated the research, next the aim and research questions are presented, finishing with a summary of the research design, which covers the thesis contributions. Chapter 2 presents the background research that framed the study, namely on the walkability of the BE and walking behaviour theoretical framework, comprising also a literature review of studies on walking behaviour change in relation to a built environment interventions. The chapter ends with a brief discussion on the identified literature gaps and challenges. Chapter 3 covers the methodology and data used in the study. The study design is presented first, followed by the description of the Eixo Central case study. Next, the methodological approaches to the walkability analysis and walking behaviour data collection are presented. A brief discussion on the identified methodological limitations closes the chapter. Chapter 4 examines the Eixo Central intervention effects on the pedestrian activity on the area. Chapter 5 explores the potential triggers to walking behaviour change considering distinct walking purposes. The meaning of success is evaluated in Chapter 6 along with a discussion on the policy implications of environmental interventions to promote walking. The research conclusions are presented in Chapter 7, covering a review of the main findings, of the study strengths, limitations and scientific outreach, finishing with an overview of further research topics in this field.

The proposed research questions, their base hypothesis and the thesis part that addresses them are presented in Table 1.1:

Table 1.1: Proposed reasearch questions

**Main research question: How does changing the Walking Environment relate to a change in Waking Behavior ?**

| **Research sub-questions** | Hypothesis | **Chapter** |
|---|---|---|
| How does a change in walkability affects pedestrian activity? | Positive association between walkability and pedestrian activity and walking experience | 4 |
| Which factors influence walking behaviour change? | Exposure, Perception and Experience are significant predictors | 5 |
| How do distinct pedestrian segments respond to environmental change? | Pedestrian segmentation via preferences and attitudes is associated to different outcomes | 5 |
| How can the success of a walking promotion intervention be evaluated? | Intervention results bear distinct "success" levels in relation to the type of walking behaviour of interest | 6 |

It is expected that the research findings can bring innovative approaches to the current body of knowledge, namely by using a tested and validated walkability assessment framework on a longitudinal study and by addressing walking behaviour changes for distinct walking purposes. Also, the results will contribute to enlarge the pool of quasi-experimental designs, adding geographical diversity to current knowledge.

The results of this research are expected to benefit urban planners and policy makers. The understanding of how walking behaviour is affected by changing the urban environment will provide valuable insights to planning and projecting more accomplished interventions aimed at improving the walking conditions in cities.

Above all, it is desired that the research findings may inform policy, namely in the design of comprehensive policy packages aimed at increasing walking in the urban population.

# Chapter 2

# Background research

This chapter presents the background research related to the main topics covered in the present study: walkability; walking behaviour; and behavioural change related to built environment interventions. The chapter begins by elaborating on the context and rationale of the research study. The next section tours around theoretic behaviour frameworks used in transportation research, featuring also walking behaviour. The following section presents and explores the concept of walkability and walkability evaluation. The last section comprises a literature review on the specific topic of walking behaviour change relating to environmental change. The chapter ends with a discussion on the identified literature gaps and challenges.

## 2.1 Context and Rationale

The most primary need for the mobility of people is to be able to walk. Most, if not all, journeys have some walking involved, even if only in the first and last stages. Walking is affordable and equitable, it does not need special infrastructure, technology or equipment. Yet, walking levels have been steadily declining in most developed world cities. Conversely, the use of motorised transport and the adoption of sedentary lifestyles have increased. The preponderance of sedentary lifestyles and car-dependence have raised a concern on both health and transportation fields (Lee & Moudon, 2004). Not only the lack of adequate physical activity increases health risks relating to obesity, overweight, cardiovascular disease, anxiety and neurosis (Wang *et al.*, 2016) but also the mass adoption of the private car as a main transport mode has resulted in a series of negative health impacts such as road deaths, injuries, respiratory illness and, primarily, contributing to the lack of salutary exercise (Milne, 2012). The promotion of active travel has been recognized as a mean to achieve essential exercise. Walking, in particular, has been found to provide a broad influence on public health given the associated physical and psychological benefits that can be incorporated for free into everyday life (Frank *et al.*, 2006; Green & Klein, 2011; Ogilvie *et al.*, 2007). Using walking as a mode of transport offers also the potential to reduce transport costs and the consumption of fuels, contributing to positive economic and environmental effects (Adams & Cavill, 2015).

The promotion of walking as a transport mode can therefore be regarded as a public health concern but also as an environmental and social concern. Various studies have addressed strategies to promote walking, which can be broadly categorized as "hard levers", relating to the layout, design and infrastructure; and "soft levers", relating to education, marketing or pricing strategies (Forsyth & Krizek, 2010). Regarding the "hard levers", the role of the built environment in facilitating or hindering walking has been well established and reviewed in walkability research, which in turn draws from the fields of public health, transportation and urban planning (Ewing *et al.*, 2016).

Following the rationale of walkability, it can be hypothesized that improving the walking environment can positively influence walking behaviour, increasing pedestrian activity (e.g. the number of trips, minutes of walking, modal change). Accordingly, many cities aim in improving their built environment in order to increase residents' health and well-being, driving investments to interventions that reshape the urban space into a more walking friendly environment (Ferreira *et al.*, 2016).

**Such investments, often involving high-costs, are made on the premise that a better environment will have effects in walking behaviour, without reliable evidence of their effectiveness**. (van de Coevering *et al.*, 2015; Keall *et al.*, 2015).

Various studies support the hypothesis that improving the walking environment at the street level can positively influence walking behaviour. If on one hand it has been said that "micro-design elements are too 'micro' to exert any fundamental influences on travel behaviour" (Cervero & Kockelman, 1997), on the other hand evidence on the influence that such micro-scale elements can exert in walking, adding to the attractiveness of walking environments, has been put forward (Foltête & Piombini, 2007; Adkins *et al.*, 2012; Ewing *et al.*, 2016; Cain *et al.*, 2017).

Despite the considerable body of research related to the environmental factors that enable walking, few studies have addressed the assessment of before-after walking behaviour following a built environment intervention (see also Section 2.4). These have focused mainly in two types of interventions: the provision of new walking infrastructure and improvements to the pedestrian environment. For instance, focusing on the provision of new walking infrastructure, Panter *et al.* (2016) studied the effects of the opening of the Cambridgeshire Guided Busway (Cambridge, United Kingdom) which comprised a new bus network, and a 22km traffic-free walking and cycling route. Their 3 year study found no evidence of effects on time spent walking for transportation or recreation. Contrastingly, Pazin *et al.* (2016) reported a higher increase in leisure time walking (around 30 min/week) of adults following a new walking route along the seashore of the city of Florianópolis (Brazil). The new 2.3 km long walking and cycling route was said to bring a pleasant and traffic safe place for leisure along the shore. Regarding environmental improvements, Sun *et al.* (2014) followed the effects of improved pedestrian connections and the addition of bus stations in a Hong Kong University campus finding an increase in the average distance walked by students. Jensen *et al.* (2017b) addressed two street renovations in Salt Lake City (U.S.A.) which involved the addition of a new light rail line and stops. They observed changes in pedestrian volumes in the two street interventions and in two control streets finding an increase of pedestrians' use in the renovated environments but not a significant change on the control locations. Jung *et al.* (2017) conducted a comprehensive study on the effects of a large street environment program on the pedestrian volume and satisfaction in Seoul (Seoul's Design Street Project, South Korea). The Design Street project comprised 23 retrofit projects targeting sidewalk and public space improvements. They examined the impact of the physical improvements in the pedestrian volumes and satisfaction observing 28 retrofitted locations (treatment group) and 218 control locations. They found a general increase in the pedestrian volumes of treatment group location but also an increase in the pedestrian volume of the control areas, hence no evidence was found that the environmental intervention attracted more pedestrians. On the other hand, pedestrian satisfaction increased only the streets of the Design Project whilst decreasing in the control locations, showing evidence of a positive influence of environmental improvements in pedestrian satisfaction.

The evidence found in existing studies is therefore mixed. Some interventions seem to have been more successful than others in influencing walking behaviour. However the outcomes are not clearly comparable. Not only the analysis timespan varies from a few months to 3 years, but also the dependent variable -walking behaviour- is addressed in various ways: time spent walking for transportation (Panter *et al.*, 2016); time spent walking for leisure (Pazin *et al.*, 2016); distance walked (Sun *et al.*, 2014); pedestrian counts (Jensen *et al.*, 2017b; Jung *et al.*, 2017) and pedestrian satisfaction (Jung *et al.*, 2017). Regarding the latter, walking experience and the influence of experience in triggering walking behaviour have been somehow overlooked in travel behaviour research (Ameli *et al.*, 2015; Dadpour *et al.*, 2016). Experiential qualities and satisfaction are factors believed to trigger and sustain behaviour change (Isaacs, 2010; Ettema *et al.*, 2011; Kim *et al.*, 2014; Bornioli *et al.*, 2018), whose importance in shaping walking behaviour has been long recognized in the urban planning field (e.g., Lynch, 1960; Gehl, 1987, 2010; Jacobs, 1993).

Also, while previous studies have reported on walking behaviour change there is still a gap in reporting the extent of the environmental changes in relation to behavioural change. Few studies have provided a comprehensive analysis of the context of the intervention, namely in terms of before-after walkability levels. This poses a relevant implication: while the extent of effects in walking behaviour may be related to the magnitude of the walkability change, in turn such magnitude (i.e. size and importance) is not addressed, possibly conducing to the mixed results found in the literature.

Walkability, simply put, is the extent to which the built environment is walking friendly, being straightly related to the influence of environmental factors in walking behaviour (Handy, 2005a; Cambra, 2012). Numerous methods and tools for measure the walkability of an environment have been proposed, spanning to the health, transportation, and urban planning fields (see for instance the reviews of Gebel *et al.*, 2007; Holle *et al.*, 2012; Asadi-Shekari *et al.*, 2013; Lee & Talen, 2014; Vale *et al.*, 2015; Wang & Yang, 2019).

Some of these methods have been recognized and adopted by researchers in cross sectional studies but only limited applications are found in longitudinal street improvement studies (e.g., Jensen *et al.*, 2017b). This kind of environmental change comprises mostly micro factors, setting the scale of analysis to street level walkability. Established walkability measurement methods often work on larger scale analysis, such as the neighbourhood (Saelens & Sallis, 2002; Frank *et al.*, 2005b; Leslie *et al.*, 2007b). Others, like Walk Score ™, use gravity models to assess activities within walking reach disregarding environmental factors (Hall & Ram, 2018).

Walkability measures focusing on micro scale modifiable elements are somewhat less well established, probably due to a more complex operationalization: street audits are usually required to collect street level data, being time consuming and prone to subjectivity. Recent development proposals aimed to improve the feasibility of micro scale walkability measures. For instance Cain *et al.* (2017) worked on the Microscale Audit for Pedestrian Streetscapes (MAPS) scale (Millstein *et al.*, 2013) in order to reduce the number of audited items and associated burden from 120 to 54. Later, the authors proposed an "international version" of this tool, highlighting the importance of addressing a wider diversity of environmental factors found in different countries (Cain *et al.*, 2018). In their recent review, Wang & Yang (2019) found that the majority of walkability measurement tools are still originating from the USA, Australia and Canada, despite a growing number of studies adapting walkability measures to local settings.

Active transport is also a goal in the European context. The promotion of active transport is becoming a common goal in many European cities, which contributes to improve the health and well-being of residents and also the environment quality at local level (e.g. air quality). However, walkability studies of European urban areas are still limited (Holle *et al.*, 2012; Ferreira *et al.*, 2016). Some of these studies have focused in the urban context of Lisbon (Portugal), which constitutes the setting of the present research case study. Cambra (2012) has proposed a set of pedestrian accessibility and attractiveness indicators for walkability assessment suitable for different analysis scales (city, neighbourhood and street), designating it as the IAAPE framework; Moura *et al.* (2017) have further refined the IAAPE walkability assessment framework, while the work of Cambra *et al.* (2017a) validated tool's walkability measures in relation to walking behaviour.

Recalling the walkability rationale, the built environment exerts a significant influence in walking behaviour. Environmental improvements can provide increased accessibility, attractiveness and safety as well as stimulate changes in perceptions, attitudes, and other psychological factors which theoretically can in turn result in behaviour changes (Krizek *et al.*, 2009b). In order to attempt to understand such relation, and the understanding of how can interventions in the walking environment influence human behaviour, it is necessary to use sound theoretical models that draw from transportation and psychology research.

## 2.2 Walking behaviour

The works of Handy (2005a), Schneider (2011, 2013) and Singleton (2013) among others provide a comprehensive review of the most relevant behavioural theories related to travel behaviour. This section provides a brief description of the theoretic frameworks drawn from the aforementioned literature, followed by an overview of the variables used to address walking behaviour.

### 2.2.1 Theoretical frameworks

As stated by Ewing & Cervero (2010), "The potential for moderating travel demand by changing the built environment is the most researched topic in urban planning". In fact, the role of built environment features as a driver of travel behaviour change has been extensively addressed in the literature and a number of literature reviews has been published, including reviews of reviews. Focusing on active travel alone, Saelens & Handy (2008) have reviewed 13 literature review papers on built environment correlates of walking published between 2002 and 2006. Active travel has also been researched for its role in achieving salutary physical activity levels in an ever growing urban population with a sedentary lifestyle. From this perspective, literature on the influence of the physical environment in physical activity has been thoroughly reviewed: Gebel *et al.* (2007) have presented a critical review of 11 literature reviews published between 2000-2005 whilst Europe-specific evidence found in 70 papers has been reviewed by Holle *et al.* (2012).

Introducing the elementary concepts, the concept of “built environment” is intrinsically related to the concept of “walkability” and although being widely referred to in the literature, few definitions are available. It can be thought primarily as being a main component of the urban environment, together with the natural environment and the social environment. Cervero & Kockelman (1997) have defined built environment as “the physical features of the urban landscape (i.e. alterations to the natural landscape) that collectively define the public realm, which might be as modest as a sidewalk or an in-neighbourhood retail shop or as large as a new town”. Handy & Niemeier (1997) have defined built environment as comprising urban design, land use, and the transportation system, and encompassing patterns of human activity within the physical environment. Cao (2006) proposed a more synthetic definition in which the built environment consists of three primary components: land use pattern, urban design, and transportation system. Nevertheless, the literature focusing on built environment features acting as determinants of travel behaviour assumes many interpretations of “built environment” (BE). In some cases, features of the natural or of the social environment are considered as part of the BE, such as topography, climate and safety. In other cases only land use, urban design and transport infrastructure attributes are considered, leaving out the transportation system. As noted by Handy (2005a) there is a lack of agreed-upon conceptualization of the term, which may have reflections in the inconsistent approach on the definition and measurement of built environment dimensions linked to travel behaviour.

Regarding the concept of "travel behaviour", a comprehensive definition can be found in Burbidge (2008), consisting in "the modelling and analysis of travel demand on the basis of theories and analytical methods from a variety of scientific fields. These include, but are not limited to, the use of time and its allocation to travel and activities, the use of time in a variety of time contexts and stages in the lives of people, and the organization and use of space at any level of social organization, such as the individual, the household, the community, and other formal or informal groups".

Simply put, "travel behaviour" can be said to deal with the decisions and habits associated with displacements/trips. Several theories support the understanding of the decision mechanisms within the context of individuals' displacements. Conventional travel behaviour research has been based upon the utility maximization theory. It has roots on the economic theory of random utility maximization, being adapted to the analysis of discrete choices -such as travel mode choice- by Daniel McFadden under the proposition that "people make decisions to advance their self-interest" (Handy, 2005a). According to this rationale, utility is assumed to be a linear combination of attributes, each with a weight coefficient reflecting its relative importance. Conventional travel demand models often work around two main attributes - travel monetary cost and travel time, where the probability of making a particular choice is a function of the utility (e.g. cost and time) of that choice relative to the utility of alternative choices. Generally, the utility maximization seeks the minimization of cost and/or travel time.

In the field of active travel, efforts have been made to find other conceptual frameworks that are better suited to decision-making mechanisms and the formation of walking or cycling habits. It is argued that utility theory tends to simplify and rationalize behaviours around the time and cost attributes, when there are several other more relevant factors that motivate or condition walking or cycling. For example, the individual may or may not like walking, may or may not find the urban environment attractive, may feel social pressure or may not feel able to walk or cycle. Contrary to car travel, where travel is considered te be a derived demand (meaning that travel is a mean to reach activities, not an activity on its own), active travel can be valued for its own sake, providing the individual with a positive utility (Mokhtarian & Salomon, 2001).

Thus, several alternative theories have been proposed, either complementary or concurrent, incorporating psychological and subjective factors to better frame active travel behaviour (where walking behaviour and cycling behaviour have their own specificities). These can be tentatively divided into three broad groups: Activity based theories; Psychological based theories and Comprehensive behaviour frameworks.

Very briefly, in the context of "walking behaviour", activity-based theories suggest that displacements derive from the individual's activities and walking can be considered an activity per se. In the same context, psychological based theories suggest that factors such as perceptions, attitudes, preferences and habits are more relevant to walking than objective factors (eg distance, duration). Comprehensive behaviour frameworks suggest that, in addition to intrapersonal mechanisms, there is an influence of environmental factors (eg urban context) in the decision-making process.

### Activity based theories

Activity based theories have generally considered travel as a mean to access activities that are spatially separated. In the 1970s several contributions bridged the perspectives of the geography field to travel behaviour (e.g. Hägerstrand (1970), Chapin (1974) and Cullen and Godson (1975), as cited in Van Acker *et al.* (2010) and Singleton (2013)). Various concepts emerged from these studies, such as Hägerstrand's space-time prism and travel time budget describing the constraints of time and place in individual behaviour shaped by the travel velocities allowed by the transportation system. These have constituted a major contribution to the development of activity-based travel demand models. Chapin's work introduced a motivational framework influencing the individual activity patterns. The activities that individuals engage may be facilitated or constrained by motivation and personal characteristics such as gender and age. Accordingly, different socio-economic groups adopt different activity patterns, which supports the incorporation of a socio-economic component in travel behaviour models. Another relevant contribution of Chapin's work was that activity patterns result from both demand (the motivation to engage) and supply (the opportunity to engage), where the latter is affected by the availability and quality of transport facilities. Cullen and Godson addressed the activity scheduling process, suggesting that some activities (such as work related) have a more rigid nature than others (such as leisure activities), tending to be fixed in space and time and acting as cores around which more flexible activities are arranged. Their findings also suggested that the activity pattern could be the planned consciously or more routine-like, linking also to habit formation, which in turn links to psychological based theories.

#### Psychological based theories

Psychological based theories brought a different level of analysis to travel behaviour research by focusing on the individual (as opposite to an aggregated population) and underlying subjective factors, such as the individual's perceptions, attitudes, preferences and beliefs (in addition to travel cost and time). Some of the most relevant approaches include the Theory of Planned Behaviour (TPB), the Theory of Repetitive Behaviour, Social-Cognitive Theory and the Trans-theoretical model (Ma, 2014; Van Acker *et al.*, 2010; Singleton, 2013). The Theory of Planned Behaviour (Ajzen, 1991) postulates that behaviour is guided by behavioural attitudes, subjective norms (including the expectation of others) and the person's perceived control over the behaviour. Attitudes consist in favourable or unfavourable reactions towards the behaviour (e.g. a positive attitude toward cycling); subjective norms concern the influence of other people's attitudes (e.g. cycling is for someone who does not own a car); and perceived control is the extent to which people believe they can control the intended act of behaviour (e.g. I don't think I could cycle to work). The Theory of Repetitive Behaviour (Ronis et. al, 1989 as cited in Singleton (2013)) suggests that although an initial behaviour can be shaped by similar mechanisms of the TPB, the repetition of the behaviour is a result of habit formation. Changes in life or external stimuli may lead to a reprogramming of the usual behaviour. For example, a home to work trip can be considered a repetitive travel behaviour that does not result from permanent decision making but from a habit. Changing the home location may break the previous habit, resulting for instance in a change in travel mode. Social-Cognitive Theory (Bandura, 1986 as cited by Singleton (2013) and Van Acker *et al.* (2010)) holds that behaviour is influenced by both personal and environmental factors. Moreover it suggests reciprocal relationship between the person and the environment, the latter referring to the person's social environment and to the household in particular. For instance, the presence of young children in the household can influence the parent's travel behaviour. The Trans-theoretical model (Prochaska and Velicer 1997, as cited by Singleton (2013)) posits a multi stage process to explain behaviour change. The approach to behaviour change instead of behaviour choice has given the trans-theoretical model a central role in the study of interventions to influence healthy behaviour changes.

#### Comprehensive Behaviour Frameworks

A diverse body of theoretical concepts and approaches can be fit into the group of Comprehensive Behaviour Frameworks. These include for instance the Theory of Human Motivation (also known as the "Hierarchy of Needs"), The Hierarchy of Walking Needs, the Socio-Ecological Model and the Stimulus-Organism Response Model. The Theory of Human Motivation (Maslow 1954, as cited in Singleton (2013)) presented one of the most recognizable psychology concept - a pyramid of hierarchical needs. Following this concept, five layers of human needs are arranged from the very basic ones at the bottom (e.g. food, shelter) to higher-order needs (e.g. love, self-esteem). According to Maslow's theory a person can only achieve a superior need if the inferior needs are fulfilled, driving motivation and behaviours. Drawing from the Theory of Human Motivation, Alfonzo (2005) proposed the The Hierarchy of Walking Needs. In Alfonzo's arrangement of the needs that determine walking behaviour (Figure 2.1), the most basic need to be fulfilled refers to feasibility (i.e. Is it feasible to walk there?). The next level is Accessibility, relating to the existence of a pedestrian infrastructure that provides a place to walk (i.e. can I walk there?). When feasibility and accessibility needs are met then the next need can be considered - safety. Safety, as laid by Alfonzo, refers to personal security and fear of crime, which can result from the perception of certain environmental factors such as litter, broken windows and derelict buildings. Following is the Comfort level, referring to factors that influence the levels of ease, convenience and contentment of walking, such as amenities (e.g. street furniture), sidewalk quality (e.g. width and maintenance). The final level of the walking needs is Pleasurability, which is straightly related to the person's walking experience and to the enjoyment of walking in a place. Pleasurability can be influenced by factors as urban design features, architectural quality, presence of trees and public spaces. Alfonzo recognizes that "the realization of these five needs is neither necessary nor sufficient to induce walking", stating that walking can occur at any stage of the hierarchy, or in other words, people may choose to walk even if just the lower-order needs are fulfilled.

The Socio-Ecological Model (Sallis et al. (2008), as cited in Montano, Daniel E; Kasprzyk (2008) and Ma (2014) ) takes into account an interwoven relationship between the individual and the environment to explain travel behaviour. Three main factors are considered: the individual level, the social environment (the relationships with other people) and the physical environment. The Stimulus-Organism-Response model (Mehrabian and Russell (1974), as cited in Ma (2014)) introduced a mechanism for how environmental factors affect the individual emotional responses which, in turn, influence behaviours. This model emphasizes the role of the perceived environment as a mediator between the environment and behavioural response.

Wrapping it up, theoretic frameworks are an essential guide to the understanding of behavioural conceptual models. No theory alone provides a complete framework to understand the relationship between the built environment and active travel behaviour. Active travel, such as walking, adds a further complexity layer as it can be looked at

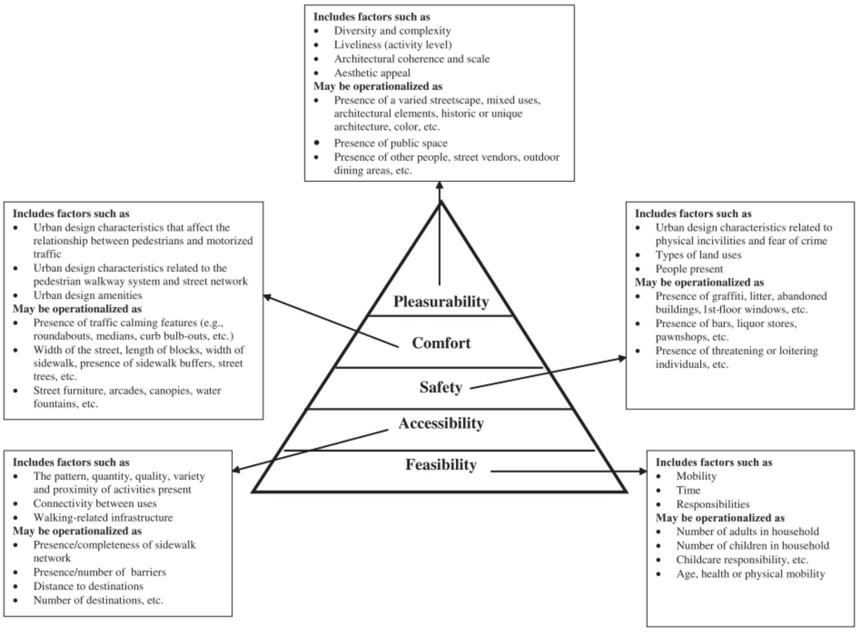



Figure 2.1: The Hierarchy of Walking Needs. Source: Alfonzo(2005)

from the travel perspective or from the physical activity perspective. Understanding the connection between active travel behaviour and the constructed environment cannot be formulated by theory alone. As Handy (2005a) emphasized, these theories can form a whole, as it is possible for one researcher to start with one theory and borrow ideas from the other in the development of their conceptual research model.

### 2.2.2 Walking behaviour variables

Walking behaviour is a barely defined concept in the literature. According to Burbidge (2008), general travel behaviour can be broadly defined as the study of what people do over space and how people use transportation. However, walking is more than using or choosing a transport mode as the walk itself may be the motivations for a trip or an expression of physical activity (Handy *et al.*, 2006). Depending on the research field - transportation, planning, geography, psychology and public health - different measures for walking behaviour are used in the studies. The multiplicity of approaches in defining and modeling walking behaviour is illustrated in the non-exhaustive list below:

Time related walking behaviour variables:

- Time spent walking for transport (Kamruzzaman *et al.*, 2016)
- International Physical Activity Questionnaire (IPAQ): usual week time spent walking for transport – (DeBourdeaudhuij 2005, as cited in Saelens & Handy (2008))

- Walking or not walking at least 150 minutes per week (Hooker et al.2005, Bopp et al. 2006, Spence et al.2006, as cited in Saelens & Handy (2008))

Frequency related variables:

- Likelihood of none or some walking activity, (Burton 2005, as cited in Saelens & Handy (2008))
- Strolling frequency in last 30 days (Cao *et al.*, 2006)
- Walk to store frequency in last 30 days (Cao *et al.*, 2006)
- Walk trips in last week ( Clifton and Dill 2005, as cited in Saelens & Handy (2008))
- Walk trips total and by type ( Clifton and Dill 2005, as cited in Saelens & Handy (2008))
- Number of walk trips on travel day (Clifton and Dill 2005, as cited in Saelens & Handy (2008))
- Number of times walked to store in past 30 days (Handy *et al.*, 2006)
- Number of times walked to selected destination in typical month (Handy *et al.*, 2006)
- Walk trips (Khattak & Rodriguez, 2005; Krizek & Johnson, 2006)
- Likert rating of frequency of walking activity in neighbourhood (Li *et al.*, 2005)
- In the past 7 days, within neighbourhood transportation walking (Suminski et al.2005, as cited in Saelens & Handy (2008))
- In the past 7 days, within neighbourhood walking a dog (Suminski et al.2005, as cited in Saelens & Handy (2008))
- Number of walk trips in two days (Greenwald & Boarnet, 2001)
- Walking for transport in past 2 weeks (y/n) (Giles-Corti & Donovan, 2002)

Modal share related variables:

- Percentage of individuals who walk to work (Gauvin et al.2005, as cited in Saelens & Handy (2008))
- Percent non-motorized trips for all trips (Kitamura, Mokhtarian and Laidet 1997, as cited in Saelens & Handy (2008))
- Percent of trips by walking (Krizek, 2003)
- Percent of residents walking to work (Craig *et al.*, 2002)

Leisure and Physical activity related variables:

- International Physical Activity Questionnaire (IPAQ), usual week time spent walking for leisure (DeBourdeaudhuij 2005, Saelens & Handy (2008))

- Number of times strolled around neighbourhood in past 30 days (Handy *et al.*, 2006)
- In the past 7 days, within neighborhood exercise walking (Suminski et al.2005, as cited in Saelens & Handy (2008))
- Choice of walk or bike as principal commute mode (Cervero, 1996)
- Walking for recreation in past 2 weeks (y/n) (Giles-Corti & Donovan, 2002)
- Meets public health recommendations (Parks et al.2003, Powell et al.2003, as cited in Handy (2005a))

### Walking behaviour datasets

The numerous possibilities of characterizing walking behaviour make it a challenge to collect harmonized datasets. Despite the advancements in data collection methods and the availability of online resources, comprehensive data regarding walking behaviour is still lacking from official datasets especially when comparing to other transport modes. In various countries, travel data is collected through regional or national travel surveys. In the portuguese context, travel data has not been systematically collected, being the main official country-wise data source the "Censos"[1], collected once each 10 years. The Censos focuses on population and housing data, providing only a small subset of travel behaviour data and only marginal information on walking behaviour. This is mostly related to commuting (home based trips to work or school), referring to modal choice, average travel distance and trip duration. Moreover, the walking modal share is only considered if the whole trip is done walking. This leaves out critical walking behaviour characterization such as the number of walking trips made, their purpose and duration. Such harsh reality is not exclusive to Portugal. Various researchers have pointed that walking data collection is usually underestimated and rarely harmonized, leading to an international initiative to "establish a set of international guidelines for the collection, analysis and dissemination of quantitative and qualitative techniques for measuring walking" [2]. Recently, there was an advancement in walking collection data in Portugal with the launch of the 2017 mobility survey to the metropolitan areas of Lisbon and Porto. This survey provides data on general trips, similarly to a travel diary, recording walking trips longer than 200m for various purposes, showing a higher use of walking for transport (23%), in contrast to the walking modal share found in the Censos 2011 (15%).

[1]Short name for "Recenseamento Geral da População e Recenseamento Geral da Habitação"
[2]https://www.measuring-walking.org/about-us

## 2.3 Walkability of the Built Environment

Walkability is now a current word, a current concept used from the academic realm to people's comments in social media. Googling the term produces about 20.000.000 results. Google Scholar provides about 50.000 results. The Wikipedia entry on walkability is presented in 12 languages and provides a brief yet concise definition of the concept: "Walkability is a measure of how friendly an area is for walking". Walkability is a rather recent concept, traced to the 1990s. The earliest mention to walkability is presumed to be from Chris Bradshaw in 1993, who presented the conference paper "Creating -and using- a rating system for neighbourhood walkability towards an agenda for Local Heroes" in the 14th International Pedestrian Conference at Boulder, Colorado (USA). The history behind the concept takes us to Ottawa (Canada) where in 1992 a property tax raise in connection to road infrastructure improvements was proposed. The new tax faced resistance from land owners and local shop owners who argued that most people in their neighbourhood walked in their daily trips instead of driving, hence had less need for the road infrastructure expansion and therefore should not pay the tax. To overcome this issue, Bradhsaw, at the time a city planner expert, proposed an index to rate the "walkability" of the neighbourhoods in order to calculate the tax rates applicable to each neighbourhood(Bradshaw, 1993; Cambra, 2012). Since then walkability emerged as a popular topic in transportation and urban planning forums and consistently gained the attention from the public health field. A wide range of actors became involved in the understanding of the relations between urban environment and pedestrian behaviour, and all had a different definition on how to measure walkability (Lo, 2009).

Walkability research has become a trend. The number of yearly published papers on this subject has been growing steadily, and the relations between the built environment and the walking behaviour have been gaining growing attention from different research fields, namely transportation, urban planning and public health.

Transportation researchers have been traditionally focusing in understanding and institutionalizing the design of space for motorized transport modes, being pedestrian transportation a more recent addition to their planning processes (Lo, 2009). The dominant documents shaping the pedestrian environment have been developed from engineering road design manuals. These manuals' purpose was to create efficient traffic flow, and it wasn't until the early 1970's that walking behaviour started to be included on them. Still some of the derived studies continue to adapt traffic engineering concepts to walking (Park, 2008).

The urban design literature relating to walking has been largely inspired from the work by Jane Jacobs in the early 1960's In this field, the questions have been addressed to the quality and the enjoyment of walking rather than the efficiency of traffic flow. For that purpose more subjective aspects of walking, such as visual interest, complexity or human scale have been looked at (Jacobs, 1961). Other pedestrians have been considered, in this field, as attractors instead of conflicts, as they increase the general sense of security. In the following years, other seminal authors from the urban planning theory developed work on the pedestrian environment, such as Kevin Lynch, Gordon Cullen, Jan Gehl and Donald Appleyard.

The approaches from the urban theorists also have had some degree of criticism. Urban design researches and observations have been the base for urban planning guidelines but there has been little effort into developing objective ways of measuring the walking environment and testing those observations and intuitions. They have been sometimes considered as "just suggestions" thus being less influential than engineer's road design manuals in shaping the urban form. (Lo, 2009; Park, 2008).

The public health field has been the top contributor to walkability research (Tong *et al.*, 2016). One of the main drivers of public health research is related with fighting obesity and sedentary lifestyles. The sedentary lifestyle has been considered by the World Health Organization (WHO) as a global public health problem. Sedentary and physically inactive lifestyles have been adopted by a significant population in various countries: more than 30% of the adults of 122 countries were found to be physically inactive, with a tendency to grow Wang *et al.* (2016). Physical inactivity has been proved to increase all causes mortality, to double the risk of cardiovascular disease, type II diabetes, and obesity, being a major underlying cause of death, disease, and disability. According to the WHO, 2 million deaths every year are attributable to physical inactivity [3], whereas walking could provide essential daily physical activity, preventing excess deaths.

However, in the field of public health, the role of the built environment has been studied as a basis for physical activity promotion in general, not focusing in walking in particular. This field's research scope was in some ways better situated in addressing the built environment's role in explaining physical activity. Accordingly, behavioural theory has been the basis for the research and the primary goal has been to understand behaviour, being then able to derive effective ways of changing it (Handy, 2005a). Also, studying the influential role of built environment in behaviour has emerged as a high priority for public health research given that the more prevalent obesity and cardiovascular conditions occur in areas where land use and urban pattern makes it difficult to walk to destinations

[3] https://www.who.int/docstore/world-health-day/2002/fact_sheets4.en.pdf

(Frank *et al.*, 2003). Hence, the public health field has been researching actively the environmental variables correlated to physical activity (where walking is included) and has contributed greatly to the finding that built environment does affect walking behaviour. Existing studies documenting these associations have been considered sufficient to consider transportation and urban planning as critical public health issues (Frank *et al.*, 2005a).

It should be noted that there have been many interpretations of "built environment", and the lack of an agreed-upon conceptualization of the term has been an apparent cause to the inconsistent approach to defining and measuring dimensions of the built environment. The "built environment" concept this research has followed has been the one used by Cervero & Kockelman (1997), defined as "the physical features of the urban landscape that collectively define the public realm (ranging from a sidewalk to a neighbourhood)

Looking from another side of the equation, the question can be set to which built environment factors influence or shape travel and, more specifically, walking behaviour. There is a vast collection of research targeting this issue, but these studies have been considered insufficient to produce "definitive conclusions" on which particular attributes of the built environment relate to which particular walking behaviours (Vale *et al.*, 2015). Moreover, these studies have produced consistent evidence, if moderate only, on associations between environment factors and walking.(McCormack & Shiell, 2011)

### 2.3.1 Walkability assessment

Besides the various fields active in walkability research, there are different approaches in the conception and measurement of walkability. To be clear, walkability is a construct that expresses a concept. It cannot be "measured" as there is no walkability standard for comparison. It can be, and has been, assessed and estimated either quantitatively or qualitatively, following experts readings or passers opinions on the street.

The walkability of a community has been conceptualized as "the extent to which characteristics of the built environment and land use may or may not be conductive to residents in the area walking for either leisure, exercise or recreation, to access services, or to travel to work" (Leslie *et al.*, 2007a), or in simpler terms, "the extent to which the built environment is walking friendly" (Abley & Turner, 2011). Research in walkability research is recent compared to other travel modes and agreement on what to measure and how to measure is still very much in contention. A wide range of actors have been involved in pursuing the evaluation of the relations between the urban environment and the pedestrian behaviour, and all have a different definition on how to measure walkability (Lo, 2009).

One of the defining differences in walkability approaches deals with scale. At which scale does walkability analysis make more sense? Handy (2005a) has argued that different characteristics of the built environment are more or less relevant at each spatial scale, and the influence of the built environment on physical activity at one spatial scale may depend on the influence of the built environment at another spatial scale.

There are two main scales of analysis: the Macro scale and the Micro scale. Macro scale walkability is about classifying a whole area, such as a neighbourhood. At this level the most relevant factors deal with density and diversity of land uses and with street connectivity. For instance, the broadly adopted macro scale walkability assessment method developed by Frank *et al.* (2005a) uses only three variables: land use diversity, population density and road density per geographic unit.

Micro scale walkability on the other hand is about what the pedestrian encounters on his path. It usually deals with sidewalk quality and street attributes, which include sidewalk width, pavement quality, street lighting or trees. One example is the Irvine Minnesota Inventory which considers 168 items at street level. Walkscore, perhaps the most known walkability tool, lies in between these scales. It provides a score for a street section (micro reading) which is calculated taking in consideration the distance to, and variety of, activities (macro analysis).

Walkability can be assessed through a large variety of indicators and variables. Many tools have emerged, during the past few years, for measuring the quality of the built environment, or the walkability of neighbourhood designs. The assessment of the walking environment has been done using various methods, such as audit tools; checklists; inventories; level-of-service scales; surveys; questionnaires and indices. A review of a small sample of walkability measurement methodologies has identified approximately 150 different indicators that illustrate the multiplicity of approaches (Cambra, 2012). Some of these indicators may express local concerns or simply the researcher's perspective of what factors were more relevant to the walkability assessment. The issue of subjective versus objective measurements of the built environment has been considered to merit particular attention as some aspects of the pedestrian environment can be measured objectively and therefore with more ease being others are more subjective in nature (Handy, 2005a; Maghelal, 2011). Objective measures have been suggested to be better predictors of behaviour (and as such, have been the main trend) than perceived (subjective) ones. On the other hand, perceptions and beliefs have been suggested to affect behaviour in more direct ways than reality (Ewing & Handy, 2009). Adding to the problem, it has been shown that perceived measures may differ significantly from objective measures with the assessment of perceived and objective measures of the same environment finding mostly fair to poor consistency of the results (Handy *et al.*, 2005).

Although they may differ in their operationalization the walkability measurement methods are usually simple additive algorithms of these multiplicity of indicators (both objective and subjective) and have two major types of outcome: either a single number that categorizes the environment as high vs. low suitability for walking; or the measurement of the amount of features that support or hinder walking. Finally, the validation of the walkability measurement methods has been considered a challenge and only few methodologies have been, in practice, validated to some extent (Adams *et al.*, 2014; Glazier *et al.*, 2013; Lee & Talen, 2014).

The importance of providing walkability assessment metrics has been acknowledged in several transport and urban plans (Kuzmyak *et al.*, 2014; Weinberger & Sweet, 2012) but, to date, there has not been one walkability measurement methodology fairly accepted, validated, and pervasively implemented in planning offices. The most "popular" walkability tool used is perhaps WalkScore™. This tool provides a walkability metric for a street segment based on a gravitational model that uses the distances to points of interest (shops, restaurants, public spaces, etc) with a distance decay function. Hence it provides a measure of potential walking accessibility, not considering the characteristics of the environment itself, namely its attractiveness for walking. The WalkScore™ tool has been fairly used in walkability research and has been validated to some extent (Duncan *et al.*, 2011) albeit its criticism (Koschinsky *et al.*, 2017).

### 2.3.2 The IAAPE walkability assessment framework

The IAAPE walkability framework, developed by Moura *et al.* (2017) is an attempt to produce a more robust tool, considering both accessibility and attractiveness of the pedestrian environment. This tool, drawing its structure from Cambra (2012), is suitable to address different walking purposes, distinct pedestrian groups and can be tailored to the local urban context.

The IAAPE framework stands out from the majority of similar tools due to its participatory nature, by involving the main stakeholders into the selection and ranking of the indicators that structure the backbone of the pedestrian environment assessment. It also allows the measurement to meet distinct pedestrian groups and trip purposes. Similarly to other walkability tools, the IAAPE framework assesses the pedestrian environment by performing street audits. A set of indicators related to the 7 key dimensions (Connectivity; Convenience; Comfort; Conviviality; Conspicuousness; Coexistence; Commitment) is used to score the street environment qualities. Data is collected and stored in a GIS platform where a pedestrian network was previously built. This pedestrian network represents the extent of the pedestrian realm (sidewalks, crossings, footpaths and corresponding attributes – for instance, curbed sidewalks for inclusive accessibility) in a more accurate way than commonly used road centreline networks. The IAAPE tool uses a simple multi-criteria compensatory model, where the walkability score of a street segment (link) is obtained by adding the 7 C's indicators multiplied by their relative weight, being represented on a 0 to 100 scale.

Within these factors, it is expected some to be less respondent to change within a consolidated mixed-use urban area (e.g. network structure, land use diversity) whilst others can undergo significant change following a street retrofitting (e.g. pavement quality, crossing safety).

This tool has been previously applied in the walkability assessment of two neighbourhoods in Lisbon – Avenidas Novas and Arroios. It has been validated by a comprehensive observation of pedestrian flows (Cambra *et al.*, 2017a). In this regard, a positive and significant association (p= .456) between the audited walkability scores and the observed pedestrian flows was found, providing evidence for the IAAPE walkability framework validation. The IAAPE tool can therefore be considered suitable for application in the in the proposed research as the measurement tool of the walkability changes related to our case study environmental intervention. Section 3.3 provides further information on the case study intervention and on the walkability assessment task.

## 2.4 Walking behaviour change relating to environmental change - a review

Monitoring and evaluation have long been regarded as key components of urban plans and projects. Despite the terms "monitoring" and "evaluation" being closely linked their operationalization is different. According to Crawford & Bryce (2003), monitoring is "an ongoing process of data capture and analysis for the purpose of control" with an emphasis on the *efficiency* of the project; while evaluation is "a periodic process of assessment for the purpose of learning" with an emphasis on the *effectiveness* of the project.

There are various approaches for the evaluation of transport-related urban projects. These include for instance cost-benefit analysis, life cycle analysis, multi-criteria frameworks and before-after evaluations. Before-After evaluations fall within the *ex post* evaluation concept. Ex post evaluation is retrospective, happening upon the project implementation and focusing on "what happened", being seldom applied in a formalized and systematic manner (Landeiro *et al.*, 2009).

There are limited ex-post evaluation studies concerning the influence of changing the built environment in changing walking behaviour. These come from two main research lines. One regards the environmental change resulting from relocation. People may adapt their travel behaviour when they move to live or to work in a new location. If, by chance, a person relocates to a new environment of higher walkability, than it can be hypothesized that the walking behaviour of that person will change accordingly, resulting in more walking trips, or more minutes walked. The other one regards an intervention, a physical change in the environment, either by the supply of new walking infrastructure, connections, public space or land use or by the retrofitting of the existing conditions. In this case, it can be hypothesized that people who are “exposed” to a walkability improvement will change their behaviour accordingly.

In the existing literature more studies focus on relocation than on interventions. This may be related to the study design itself and to the availability of data. People move and relocate their homes on a constant basis and this population can somehow be easier to engage in participating in panel surveys. The present study is set in the context of interventions, i.e., on the relation between a physical change in the built environment and its effects in changing walking behaviour.

The study of before-after built environment interventions in walking behaviour has been a recurrent claim but to date there are still limited literature resources addressing such effects. Either researchers are not in the place where interventions take place or the interventions are not where researchers are, or there is a lack of communication between planners and academics (Ogilvie *et al.*, 2007).

Existing literature reviews have pointed out mixed evidence on the behavioural outcomes. However these reviews have addressed cycling or general physical activity in addition to walking and included relocation or policy-level interventions in addition to built environment interventions.

To better understand walking behaviour outcomes, a literature review was conducted targeting studies reporting on built environment interventions and walking behaviour, hence excluding studies dealing with relocation or public policies without physical BE change, and also excluding studies focusing only in cycling or general physical activity. Also, eligible studies should follow a before-after, longitudinal design, excluding cross sectional studies.

The selection of eligible studies was made using a mixed approach, combining snowballing and systematic database search. Snowballing consists in directing the search from a starting set of reference papers, which can go forward, i.e. finding citations to a relevant paper, or backward, i.e. reviewing the citations found in the relevant paper (Van Wee & Banister, 2015). Snowballing is usually regarded as an addition to database systematic search, however, in specific topics, especially in the cases when the keyword include general topics (e.g. "walking") snowballing can be a more efficient and reliable tool to use. (Jalali & Wohlin, 2012; Webster & Watson, 2002)

The starting point was a rather limited set of papers relating to the effects of environmental interventions in walking behaviour (n=8), collected for previous research. The citations from these studies were reviewed and Google Scholar and Web of Knowledge were searched for citations to the starting reference papers. Upon this search 12 literature review articles were found which were then used to conduct another backward and forward snowballing search. A total of 25 papers were found reporting on the effects of environmental interventions in walking behaviour using a pre-post study design.

This search was then complemented search with a systematic database search in SCOPUS database, using the following search string:

*( ( TITLE-ABS-KEY ( "natural experiment" OR effect* OR change* OR longitudinal OR impact OR quasi OR evaluat* ) SUBJAREA ( engi ) ) AND ( TITLE-ABS-KEY ( walking OR pedestrian* OR "active travel" OR "active transportation" OR walkability OR "travel behaviour" OR "travel behaviour" OR "behaviour change" OR "behaviour change" ) SUBJAREA ( engi ) ) ) AND ( TITLE-ABS-KEY ( urban OR renewal OR street OR*

*improvement OR infrastructure OR retrofit* OR change ) SUBJAREA ( engi ) ).*

The systematic search returned 12.637 documents. Studies published in journals not related to transportation or urban studies were excluded. A sample of 1.646 records was then screened by their title and subject. Nonetheless no new studies were found to add to the previous search strategy.

Hence, 25 studies were considered for review. Data from the included studies was extracted into a predefined data extraction document, which included the following items: study characteristics (country, date, location, study design, population, controls); intervention type; observed variables (behaviour, exposure); statistical analysis applied; outcome; intervention scale and suitability for before-after image analysis.

The items intervention scale and suitability of before-after image analysis were assessed qualitatively. A large scale intervention was considered to produce evident changes in the walking environment, such as altering the cross section design, introducing a new transport mode or new land uses. A small scale intervention in the other hand would only consider street improvements to a lesser extent (e.g. repaving a sidewalk). The suitability of before-after image analysis consisted in locating the intervention using Google StreetView$^{TM}$ tool and in verifying the suitability of online imagery to assess the before and after situations.

### 2.4.1 Characteristics of reviewed studies

Research focusing in walking behaviour changes following environmental interventions is very recent. Nearly 90% of the studies (n=23) were produced in the last decade, and the majority (n=18 , 69%) dates from 2015 and onwards. Most studies were conducted in Europe (n=11), more specifically in the United Kingdom (n=9), followed by North America (n=10), Asia (n=2); New Zealand (n=1) and Brazil (n=1). Some of the studies refer to the same intervention. For instance, the nine studies made in the U.K. refer to three distinct interventions. Hence the considered studies report on 19 unique intervention cases. Various scientific fields have been active in researching walkability and walking promotion, namely health, urban studies and transportation. The considered studies are largely drawn from a health perspective (n=20), with only few contributions from the transportation (n=4) and urban planning (n=1) fields.

The eligible studies used a varied study design description. For example, longitudinal quasi-experiment; longitudinal cohort study; natural experiment; quasi-experimental analysis nested within a cohort study or quasi-experimental non-control pre-post design. The study design has implications on its strength to infer causal mechanisms between the intervention and the observed outcomes. Quasi-experiments and natural experiments are considered to have a higher ability for causal inference than longitudinal designs, which in turn are more robust than repeated cross-sectional and single cross-sectional design (van de Coevering *et al.*, 2015). Nonetheless various studies considered as natural or quasi-experiments actually follow less robust designs, such as repeated cross section (e.g., Pazin *et al.*, 2016).

According to van de Coevering *et al.* (2015) a quasi-experimental design is a type of experimental design whilst a natural experiment is a type of observational design. In experimental designs researchers have control over the interventions, dividing participants into an "experimental group" and a "control group" (or multiple groups). If participants can be randomly assigned to the groups the study can be considered a randomized experiment. Often, full randomization of the participants into experimental and control groups is not possible, leading to a quasi-experimental design. In observational designs the assignment of the intervention is not controlled by the researchers. A natural experiment presumes that an intervention occurs "naturally", i.e. the circumstances of its implementation (e.g. when, where) are not controllable by researchers (Leatherdale, 2019). This is often the case with physical interventions in the urban environment, hence a recommended approach to study the effects of such is a natural experiment design with comparison groups and before and after data collection.

In a longitudinal design data is collected for the same population in different time periods with a clear temporal precedence. In a quasi-longitudinal design data is collected in one moment in time and participants are asked to recall information on past events. If the multi period data collected is not related to the same individuals then the study follows a repeated cross section design. When no control groups are used, studies fall within non-experimental designs such as the longitudinal pre-post design (Leatherdale, 2019).

Typically physical interventions in the walking environment are set up and implemented by local authorities, following a determined policy agenda and calendar. Typically, researchers are not involved in the design of the intervention; hence they have little or no control whatsoever of what, where and when environmental changes take place. Researchers can however be involved in the evaluation of an intervention, knowing in advance what is going to happen and prepare study designs accordingly. Some notable exceptions include participatory public space making initiatives (see for instance Cilliers & Timmermans, 2014), which could be considered quasi-experiments. The predominant type of interventions, such as street improvements, seem however to be closer to natural experiments than to quasi-experiments.

A key component of these robust study designs, natural or quasi-experiments, is the assignment of an intervention group and a control group. In the scope of urban environment interventions the control group can be an urban area (and the population living within) with similar or at least comparable characteristics to the area where the intervention took place (Ogilvie *et al.*, 2006).

Nonetheless the majority of the 25 reviewed studies did not assign a control area or population. A control group was used only in 9 studies. In accordance to the presented concepts, of the 25 reviewed studies 9 were natural experiments using control groups, 13 were considered to follow a non-experimental longitudinal design, and finally 3 studies were considered to have a repeated cross section design. The natural experiments studies used neighbourhood areas, street sections or locations as comparison groups. Four of these studies used a single comparison group whilst five used two or more comparison groups.

### Type of intervention

The environmental interventions examined by the studies were of different scales, ranging from street level improvements to comprehensive street redesign with implementation of new transportation infrastructure. Interventions were classified into three categories: 1) street improvements, 2) new paths and 3) comprehensive redesign. Street improvements included changing street furniture (e.g. placement of planters, removal of bollards) improving the walking infrastructure (e.g. pavement, curbs) or adding street lighting. Such interventions were addressed in seven studies. The second category included the provision of new walking paths, altering the pedestrian network configuration to some extent, being addressed in 13 studies. Of these, 5 studies reported to the same intervention case. The comprehensive redesign category consisted in interventions that changed the street layout, including widening sidewalks, adding bike lanes or transport corridors such as light rail or bus rapid transit. This type of intervention was reported in 6 studies. Some specific intervention types include "complete streets" and "greenways": Complete streets is a urban design approach related to transportation that requires streets to cater for pedestrians, cyclists, public transport users and traffic. A greenway is a landscape design approach consisting of a shared use path suited for recreational uses, such as walking, hiking, running and cycling.

Figure 2.2 presents a summary of the reviewed studies, classified tentatively by study design robustness and by potential magnitude of environmental change.

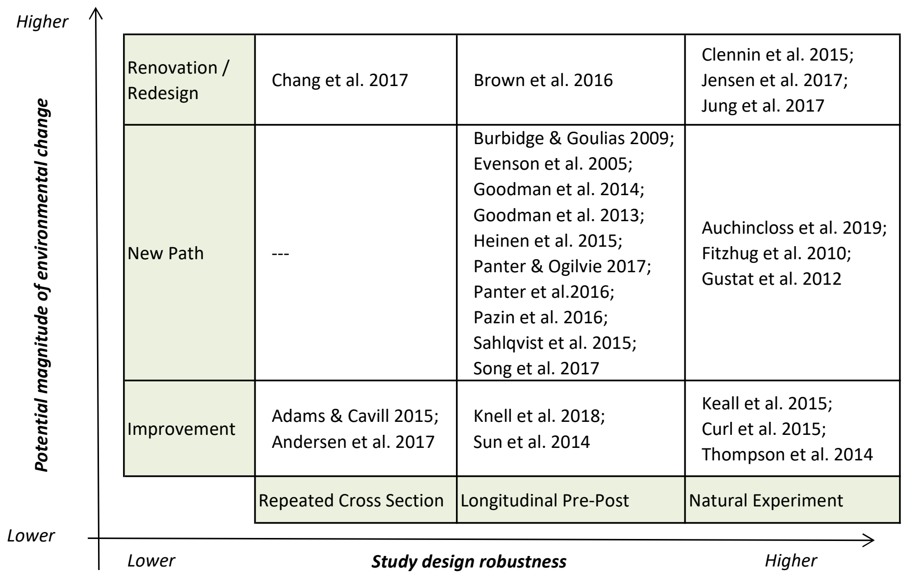



Figure 2.2: Summary of reviewed studies

### Data collection methods

Methods for data collection included self-report methods (i.e. surveys, questionnaires, activity diaries); measurement instruments (i.e. accelerometers, GPS) and direct observation (i.e. pedestrian counts). Most studies (n=15) used surveys or questionnaires. Two studies used objective measures from accelerometers. Three studies counted people on the streets. A combination of collection methods was used in 6 studies, of which 4 used both pedestrian counts with surveys and 2 used both accelerometer data and surveys. The population participating in the surveys varied from 112 to 1906 individuals. The studies typically addressed adult residents in the intervention area, with only a few focusing in workers (n= or in specific age groups, such as children (5-14 years old, n=1) or seniors (>65 y.o., n=1). Consistently, studies that used pedestrian counts as a main data collection method addressed users of the street in general. Data was generally collected in two periods (n=16) with several studies using 3 data collection waves (n=9). The time interval between baseline and follow-up spanned from 5 months to 4 years, being 2 years the average and most common (n=13) time interval.

### Walking behaviour variables

A multiplicity of walking behaviour variables was used in the reviewed studies. Walking was not always considered as a specific targeted variable but also as an implied variable (e.g. frequency of outdoor trips or minutes of moderate to vigorous physical activity). Few studies addressed specific walking purposes, differentiating between walking for transport from walking for leisure or recreation. The variables of interest were grouped into 6 main categories: *Frequency related* (e.g. percentage of walking trips to work; Frequency of outdoor trips; number of walking trips; number of days with at least 60 minutes of moderate to vigorous physical activity; frequency of non-transit walking trips); *Duration related* (e.g. time spent walking; Time spent outdoors; minutes of physical activity; mean trip duration, minutes of physical activity); *Distance related* (e.g. number of steps; walking distance); *Transport mode related* (e.g. commute mode share; modal choice); *Usage related* (e.g. pedestrian volume; reported use of the infrastructure) and *Experience related* (e.g. satisfaction, awareness).

Duration related variables, reporting on the amount of time spent walking, were the most studied subjects, appearing in 15 studies. The observed usage of the infrastructure was the base of 8 studies while the frequency or the number of walking trips was addressed in 6 papers. At a lesser extent, transport mode choice appeared in 4 studies, experience related variables were addressed in 3 studies and walking distance was of interest for 2 researchers. While most research focused in a single category of walking behaviour variables, various studies included two different variable categories (n=8) or covered three categories (n=2).

### Walkability change

Relating to the type of intervention, some could be considered as having a potentially low impact on the local walkability whilst others could have a significant impact. The tools used to assess walkability usually calculate a walkability score by assigning scores to a number of surveyed items which are then combined together using a simple sum (e.g.

Irvine Minnesota Inventory) or by a weighted sum (e.g. IAAPE framework). Hence the more items accounted for in an environmental intervention would, in simple and generic terms, have a larger impact in walkability. In this regard, from the considered interventions categories – street improvements, new paths and comprehensive redesign – a higher change in walkability would be expected following a comprehensive redesign rather than following a street improvement.

However, given that these walkability assessment methods are of a compensatory nature, theoretically a very large improvement in one of the items (e.g. improving connectivity by building a new bridge) could bear a similar impact on the walkability score as small improvements across various items (e.g. simultaneously improving accessibility by lowering curbs; improving pleasantness by planting trees and improving comfort by renewing pavement). From this point of view either type of intervention could have a similar impact in measured walkability.

Various walkability assessment tools have been proposed but only one of the considered studies examined the walkability associated to the environmental intervention. The study by Jensen *et al.* (2017b) used the Irvine Minnesota Inventory (Day *et al.*, 2006), auditing over 160 items grouped in 6 measurement scales (population density, diverse destinations, pedestrian accessibility, attractiveness, traffic safety and crime safety). The audit tool was used in two analysis periods. In the first one to verify if the study sample included high-, low- and mixed walkability streets as intended, and in the second one to verify walkability enhancements in the renovated streets. The effect of each intervention in the walkability of its environment is therefore unclear in the current body of research.

### 2.4.2 Outcomes of reviewed studies

The outcomes of the studies are summarised in Figure 2.3. The outcomes are grouped by the type of behavioural variable addressed, where:

- +) denotes a positive and significant change in walking behaviour (WB) following an environmental intervention
- -) denotes a negative and significant change in WB
- mixed(+/-) denotes opposing variations in WB in the same study, for instance in different data collection points
- o) denotes no evidence of change or a not significant change in WB

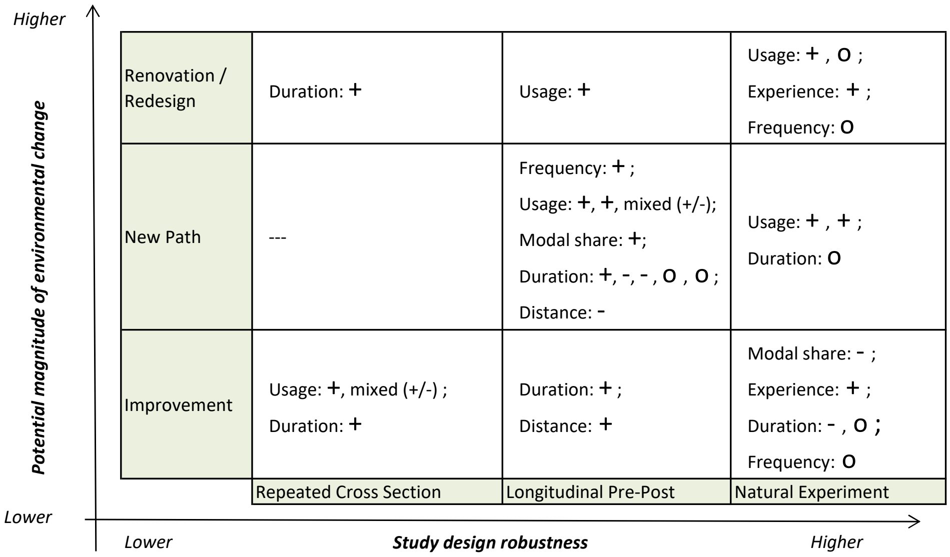



Figure 2.3: Summary of findings of reviewed studies

Most studies found a positive and significant change in WB following an environmental intervention. Also a positive WB change was found in every intervention type: street improvement, new paths or street renovation/redesign. Some studies reported non-significant changes or neutral effects. Interestingly, most of the neutral effects were found in the most robust study design group -natural experiments- making use of control/comparison sites. There are mixed findings in about every WB variable type addressed, as presented in Tables 2.1, 2.2 and 2.3.

Table 2.1: Summary of reviewed studies' outcomes (part 1/3)

| **Author** | **Date** | **Study design category** | **Type** | **Walk Behaviour Variable** | **Outcome summary** |
|---|---|---|---|---|---|
| Adams & Cavill | 2015 | Repeated cross section | Environmental change; street level improvement | Pedestrian volume; Trip purpose; Travel mode; Time spent walking | Mixed outcomes (+/-) in Usage; |
| Andersen at al. | 2017 | Repeated cross section | Urban renewal of an area | PA variables: Light physical Activity; MVPA - moderate to vigorous physical activity; SED sedentary | + in usage;<br>+ in duration |
| Auchincloss et al. | 2019 | Natural experiment / Repeated cross section Pre-Post | new greenway | MVPA - moderous to vigorous physical activity, such as walking fast, bicycling or running/jogging | 0 - same change as control area |
| Brown et al. | 2016 | longitudinal pre-post / not experimental + no controls | Complete street intervention | Trip frequency (count) | + in usage (walking trips) |
| Burbidge & Goulias | 2009 | longitudinal pre-post / not experimental + no controls | New trail | N trips per activity type; Mean trip diration by activity type; modal choice; total walking trips | - in number of walking trips |
| Chang et al. | 2017 | Repeated cross section | Complete street intervention | Reported minutes of: (i) walking for transport; (ii) walking for transport and recreation; and (iii) cycling for transport in the last 7 days | + more minutes walking |
| Clennin et al. | 2015 | Natural experiment / Repeated cross section Pre-Post | Urban renewal of an area | PA variable: how many days MVPA for at least 60 minutes per day | 0 no increase |
| Curl et al. | 2015 | natural experiment | small improvements | Frequency of outdoor trips; Time spent outdoors | Mixed outcomes: 0 in trip frequency; + inperceptions |

Table 2.2: Summary of reviewed studies' outcomes (part 2/3)

| Author | Date | Study design category | Type | Walk Behaviour Variable | Outcome summary |
|---|---|---|---|---|---|
| Evenson et al. | 2005 | longitudinal pre-post / not experimental + no controls | new multi-use trail | Time spent | 0 no change |
| Fitzhug et al. | 2010 | Natural experiment / Repeated cross section Pre-Post | new greenway | Pedestrian counts (Active travel to school), Direct observation of PA | +increase in people observation |
| Goodman et al. | 2014 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Time spent | Mixed outcomes in usage: 0 in short term; + in lnoger term |
| Goodman et al. | 2013 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Reported use of infrastructure | + increased use |
| Gustat et al. | 2012 | Natural experiment / Repeated cross section Pre-Post | new walking path (A) + new playground (B) | Self reported PA + Counts | +increased use |
| Heinen et al. | 2015 | longitudinal pre-post / not experimental + no controls | new walking and cycling path | Commute mode share and number of commute trips | + active travel modal share |
| Jensen et al. | 2017 | Natural experiment / Repeated cross section Pre-Post | Complete street intervention | Pedestrian counts | + increase in usage (pedestrian counts) |
| Jung et al. | 2017 | Natural experiment / Repeated cross section Pre-Post | street improvements | Pedestrian counts + satisfaction | Mixed findings: 0 in usage; + in experience |

Table 2.3: Summary of reviewed studies' outcomes (part 3/3)

| **Author** | **Date** | **Study design category** | **Type** | **Walk Behaviour Variable** | **Outcome summary** |
|---|---|---|---|---|---|
| Keall et al. | 2015 | Natural experiment | Environmental change; street level improvement | % walking trips to work; Hours walking last 7 days | - decrease in active travel |
| Knell et al. | 2018 | longitudinal pre-post / not experimental + no controls | sidewalk improvement | self reported PA + accelerometer data | + increase in walking time |
| Panter & Ogilvie | 2017 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Time spent | - decrease in median time spent walking |
| Panter et al. | 2016 | longitudinal pre-post / not experimental + no controls | new traffic free walking and cycling route | Time spent; Transport mode | 0 - no evidence |
| Pazin et al. | 2016 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Leisure time PA | + increase in walk time |
| Sahlqvist et al. | 2015 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Use of infrastructure; Env.Perceptions | + increase in use and perception |
| Song et al. | 2017 | longitudinal pre-post / not experimental + no controls | new walking and cycling routes | Travel behavior | - decrease in walking travel time and distance |
| Sun et al. | 2014 | longitudinal pre-post / not experimental + no controls | improvement pedestrian infrastructure + transit | Walking behavior | +increase in walking distance |
| Thompson et al. | 2014 | natural experiment | small improvements | Minutes of PA | 0 no change |

Research addressing duration related variables were mostly drawn from the health field. It is well established that participating in regular physical activity is associated with health benefits. Public health recommendations mention a duration of 60 minutes of moderate to vigorous physical activity, such as walking. Hence it is desirable, from a health perspective, to stimulate people into walking more time in order to meet public health recommendations. The studies addressing duration related variables form the majority of the reviewed literature, but again, providing mixed findings.

Following a comprehensive 35 million euro multicomponent urban renewal project in a disadvantaged neighbourhood in Copenhagen (Denmark), Andersen *et al.* (2017) found an increase in time spent outdoors among adolescents (24.6 minutes), which included time spent in light physical activity (7.8 minutes) and moderate to vigorous physical activity (4.5 minutes). In a complete street implementation in Mexico City (Mexico), Chang *et al.* (2017) found that individuals living within a 500m distance from the intervention site tend to achieve 29 minutes more of walking for transport per week. Interestingly they found that socio-demographic clusters characterized by high education also increased recreational walking. Addressing sidewalk improvements in the city of Houston (USA), Knell *et al.* (2018) found that people living near (within 250 meters) of improved sidewalks reported an increase in the minutes per week of walking and leisure time physical activity. The study also collected accelerometer data for a different population sample finding no significant change in physical activity. However, as noted, accelerometry captures a wider range of movement, including ambulation in small bursts, such as walking around home or workplace. Leisure-time walking also increased for those living near to a new walking and cycling route in Florianópolis (Brazil) (Pazin *et al.*, 2016). In average an increase of 15min/week was found, whereas people living up to 500m reported a substantial increase of 30min/week walking. Gustat *et al.* (2012) investigated the effects of a new walking path in the physical activity among residents of a New Orleans neighbourhood (USA) taking two similar neighbourhoods of the city as control areas. They found only a modest, yet significant increase in the proportion of people that reported walking at least 30 minutes per day for at least 5 days per week the intervened area, from 36.7% to 41.0% (4.3% increase). No significant increase was found in the comparison neighbourhoods. The opening of the Cambridgeshire Guided Busway (UK) comprising a traffic-free walking and cycling route was studied by Panter *et al.* (2016), who measured the change in weekly time spent in active commuting (walking and cycling) from people living close to the intervention. While in overall a significant increase was found in the time spent in active commuting, the significant change only hold for cycling. Hence no evidence was found that the new infrastructure was effective in changing walking levels. Similarly, Goodman *et al.* (2014) studied the effects of providing traffic-free walking routes in 3 UK municipalities on the mean time spent walking of people living close to the interventions. Their study considered 3 waves of data collection - one at baseline (2010); one at 1-year follow-up (2011) and one ate 2-year follow-up (2012), resulting in mixed evidence. In the short term there was no evidence of change in the time spent walking, but 2 years later a significant increase was found in the time spent walking (15.3 additional minutes/week) for the people living closer to the infrastructure in comparison to those living further away. Another UK study addressing street improvements (Sustrans, 'DIY Streets) was conducted by Thompson *et al.* (2014). They focused in older residents (aged 65+) living in intervention and comparison streets, exploring changes in self-reported activity and well-being. While the environmental improvements were found to have an impact on the perception of street walkability no significant change was found in walking activity levels. Previously, Evenson *et al.* (2005) evaluated the effects of the conversion of a railway into a multi-use trail in North Carolina (USA) on the time spent walking among people living within 2 miles of the trail. Their results did not demonstrate an increase in either walking for leisure or walking for transportation among the population who reported having using the trail.

#### Frequency related variables

Brown *et al.* (2016) found that more people engaged in walking trips after a complete street renovation in Salt Lake City (USA) that provided new light rail, bike lanes and better sidewalks. They also found that living near (up to 1000m) of the intervention site was a significant factor for the likeliness of making a non-transit walking trip. On the other hand, the studies of Clennin *et al.* (2015) and Curl *et al.* (2015) found no evidence of an increase in walking frequency. The first focused on children's physical activity following a significant investment (35 million USD) in the revitalization of a neighbourhood in St.Louis(USA). They asked families with children between 5 and 14 years of age to report on their child's physical activity levels at baseline and follow-up. The collected variable was the number of days in the last week (0 to 7) their child participated in moderate to vigorous physical activity (such as walking) for at least 60 minutes per day. The study did not find that children's physical activity levels increased after the interventions. The latter addressed older people (65+) living in a number of locations in the UK where "Do It Yourself Street Interventions" took place. Participants in the study were asked to report on the frequency of going outdoors in the summer an in the winter. The participants were not only residents in the intervention sites but also in comparison neighbourhoods. The study found that self-reported levels of outdoor activity in summer did not change significantly, whilst decreasing in winter time.

#### Usage related variables

The liveability of the urban environment is of particular concern in the urban planning perspective. Accordingly it would desirable for an accomplished environment to attract people and to encourage various walking activities, such as walking either for transport or recreation and sojourning. As put by Jensen *et al.* (2017b) lively streets are valued by health researchers for inspiring more walking and by urban designers for enhancing city liveability. This is portrayed by the “sidewalk ballet” among regular users that makes a street enjoyable and friendly (Jacobs, 1961), no more no less than “life between buildings” Gehl (1987).

A comprehensive analysis of change in pedestrian usage and satisfaction was conducted by Jung *et al.* (2017) in Seoul (South Korea) to examine the influence of the "Design Street Project" comprising street improvements in 23 sites. Pedestrian counts and intercept surveys were conducted in 28 locations intervened by the "Design Street Project" and also in 218 comparable control locations. They found an increase in the pedestrian volume on the Design Street locations, but also an increase on the pedestrian volume of the control locations. Hence no evidence was found that the Design Street Project attracted more pedestrians.

On the other hand Jensen *et al.* (2017b) counted and compared pedestrian volumes in 4 streets in Salt Lake City (USA), of which 2 streets undergone "complete street" renovations. They classified the 4 streets in terms of their walkability in "high", "mixed" and "low" using the Irvine Minnesota Inventory (Boarnet *et al.*, 2006) finding that the low-walkability streets had the lowest pedestrian usage whilst the complete street and high walkable streets had the highest (and similar) number of people. The complete street renovation showed significant increases in the number of pedestrians at follow-up, suggesting that the street modification enhanced walkability and drew more users.

In 2004, Fitzhugh *et al.* (2010) conducted a natural experiment in Knoxville (USA) to examine the impact of retrofitting a neighbourhood with an urban greenway connecting the pedestrian infrastructure with nearby retail establishments and schools, using two control neighbourhoods. They recorded 2-hour counts of pedestrians (also cyclists and individuals performing other forms of physical activity). At baseline there was no significant relationship between the 2-hour pedestrian counts in the experimental and control neighbourhoods. At follow-up they found the number of walkers to be significantly higher in the experimental neighbourhood than in the control neighbourhoods (this significant difference was also noted among cyclists).

A similar time-related effect was reported by Adams & Cavill (2015). Their study aimed to evaluate changes in pedestrian use of local routes following environmental changes made by communities and local authorities in five locations in England. Route user counts were conducted at baseline and two follow-up occasions (12 months and 14–20 months after). At the first follow-up a decrease in pedestrian route use was recorded (-19.4%). However, at the second follow-up, an increase in pedestrian route use was found (14.9%) compared to baseline.

Drawing from the UK iConnect study, which aimed to evaluate new walking and cycling routes at three UK sites (Cardiff, Kenilworth and Southampton), Goodman *et al.* (2013) and Sahlqvist *et al.* (2015) used a two wave longitudinal survey to address the reported use of the new infrastructure. In the first wave 32% of participants reported the use of the new routes whilst one year later the number increased to 38%. The dominant use was walking for recreation (39%) with a lower use of walking for transport (17%).

Also in a more recreational view, Auchincloss *et al.* (2019) examined if the construction of a new greenway would result in an increase in moderate and vigorous levels of physical activity among residents of a Philadelphia neighbourhood (USA) using a paired location as a comparison site. However, the study found a significant but modest increase in the number of people walking (persons/hour) in the intervened area but found also a similar result in the comparison site, suggesting that the intensity of walking levels did not change as a result of the greenway implementation.

Addressing usage and distance walked, the study of Sun *et al.* (2014) in a Hong Kong University campus collected data from a walking diary finding that the increase in pedestrian infrastructure (length and number of intersections) predicted longer walking distances. The walking distance was also positively associated to the use of new recreational buildings highlighting the importance of providing meaningful destinations.

#### Transport mode related variables

Under the transportation research perspective the proportion of trips made walking, i.e. the walking modal share (or in broader terms the active travel modal share), is one of the most relevant outcomes to account for. An increase of the walking modal share could not only bring health benefits to the individual but could also mean a reduction in motorised travel, hence conferring wider benefits to the populations including reduced exposure to air pollution and injuries (Nazelle *et al.*, 2011). However only a few studies have addressed change in walking modal share and not a stand alone factor but as active travel as a whole. Furthermore the findings have provided mixed evidence on this outcome.

The study by Heinen *et al.* (2015) on the opening of a new path for walking and cycling in Cambridge (UK) collected a seven-day travel-to-work record before and after the intervention. They found evidence of an increase in the active travel modal share for the individuals who lived closer to the new path (up to 4km). However the results do not distinguish between walking and cycling travel. As noted by the authors, the result could be associated with cycling given the existent high local prevalence of cycling. In contrast, Keall *et al.* (2015) found that the rates of active travel decreased after the implementation of a active travel promotion programme in two New Zealand cities (New Plymouth and Hastings) that coupled infrastructure investment and active travel encouragement.

#### Experience related variables

The study of pedestrian satisfaction or walking experience (e.g. satisfaction, awareness) constitutes a relative novelty topic in walkability research. Travel satisfaction has been addressed for various transport modes (e.g. Beirão & Sarsfield Cabral (2007); Ettema *et al.* (2011)), with a recent focus in walking and cycling (De Vos *et al.*, 2018). There are only limited studies addressing the effects of environmental changes in the walking experience or satisfaction.

Curl *et al.* (2015) conducted a longitudinal study of changes to residential streets to make streets more 'liveable' (e.g. by creating shared space and reducing motorised traffic) in seven intervention sites in the UK, matched with comparison sites. They found a significant improvement in residents' perceptions of easiness to walk on nearby streets, which was not experienced in the comparison sites. A similar finding was reported by

Sahlqvist *et al.* (2015) in the UK iConnect study, where environmental improvements in 3 cities in the UK were followed by an improvement in resident's perceptions of pleasantness of the routes to walk. Interestingly, the results also revealed different changes in the three locations: large positive changes in perceptions of the route in Cardiff compared with much smaller changes in Kenilworth and even smaller changes in Southampton. The study hypothesizes that the findings could be related to a more accomplished project in Cardiff (catering more effectively to the needs of walkers and delivering a more convenient and pleasant route) or that the improvements made in Cardiff produced a more notorious contrast to a previous lower quality environment.

These findings are corroborated by Jung *et al.* (2017) in the study of the Seoul Street Design Project. The results of two waves of intercept surveys in 23 intervention sites and 218 "typical streets" control sites showed a significant increase in the pedestrian satisfaction of users of the intervention site. Noteworthy, at baseline (2009) the pedestrian satisfaction was higher at the control sites than at the interventions sites, while in 2012 (follow-up) the pedestrian satisfaction had decreased for users of the control sites.

### 2.4.3 Summary of findings

The outcomes of the reviewed studies provide mixed evidence on the effectiveness of interventions to promote walking. Some findings suggest an increase in walking following an urban intervention, while other studies found no changes in walking behaviour. The mixed behavioural outcomes can be somehow heightened by the variety of approaches in addressing walking behaviour. From the 25 reviewed studies, 12 yielded a positive outcome, 5 did not signal any significant change and 4 found a decrease in some kind of walking behaviour following an environmental intervention. In some cases more than one behavioural category was studied, of which 4 reported mixed outcomes. For instance two independent studies showed an increase in pedestrian satisfaction but no change in pedestrian flows or self-reported trip frequency. Pedestrian experience was the only behavioural category that showed a positive outcome in every study that considered it.

Counter-intuitively a few studies reported a decrease in walking levels following an environmental improvement towards walking promotion. For instance, Song *et al.* (2017) found a decrease in time spent walking and in walked distance among the population living within 5km of 3 interventions sites in the UK (Cardiff, Kenilworth and Southampton) concluding that the investment in infrastructure alone is not a sufficient condition to promote active travel.

The existing evidence seems to support that improving walking conditions can be associated to an increase in pedestrian satisfaction and a more positive perception of the environment. Improved environments also seem to attract more people, as found in 5 of the 8 studies that observed the number of people using the intervention areas. However the existing evidence to day does not seem to support significant changes in walking frequency; time spent walking; walking distance or modal share associated with street interventions.

The effects of environmental interventions on walking behaviour are still not sufficiently backed by the existing studies. There are several factors contributing to this status quo. First, the variety of behavioural variables used make it less clear to summarise the effects of BE change in WB. Walking can be regarded as a mean of transport but also as a type of physical activity, and accordingly people can walk for utilitarian purposes but also for recreation or exercise. The drivers, or the environmental factors than can trigger an effect in utilitarian walking may be different from the ones that affect recreational walking. Hence focusing on one type of WB outcome alone may blur potential effects on another. Second, not sufficient studies used control groups or areas, despite the call for more robust study designs, stepping out from cross-sectional studies to longitudinal studies. Third, WB variables are most often collected by surveys, relying on self-assessment, which is prone to bias and only in some cases more objective measures were used, such as by accelerometer data. One study actually compared self-reported and accelerometer data finding a mismatch (Knell *et al.*, 2018). On the other hand, accelerometers may collect walking data but also other types of low intensity physical activity, tangling the results.

In conclusion, the findings generally show light to moderate effects in WB. Even large investments (35 million euro in Denmark; 35 million USD in USA) seem not to be effective as "game changers". However there is not a proper assessment of the magnitude of BE change that results from those investments - walkability change is not assessed. Given that walkability assessment is not a regular procedure in before-after analysis and given the availability of walkability assessment tools and methods, **the lack of walkability change assessment associated to environmental interventions is clearly a gap.**

The intervention scale seems to play a role in increasing walking levels, as smaller scale interventions were more prone to non-significant or negative changes in walking behaviour than comprehensive street redesigns. On the other hand, some authors (e.g.Adams & Cavill (2015)) support that small-scale environmental improvements may be an effective, low-cost strategy for increasing walking for transport.

Time and public awareness seem to play an important role for addressing potential intervention effects. Having more people walking on newly improved routes may take a long time and require additional promotional initiatives, requiring more study waves to distinguish between sustained behaviour and the effect of wanting to ‘try it out’ once.(Goodman *et al.*, 2013).

Importantly, a number of studies did not include a control population/area to clarify the association between intervention and outcome. Additionally, more longitudinal studies are needed to understand the effects of environmental changes in long term walking behaviour. Hence, forthcoming studies should fill this gap, adopting more robust study designs, contributing with evidence to sustain a clearer causal relation between environmental change and behaviour change.

# Chapter 3

# Methodology and data

This chapter presents the methodology and datasets used in the research project. Methodology is the framework within which the research is conducted, hence this chapter covers the description of methods, approaches and designs used in the research and also the considered assumptions. A major goal of this chapter is to provide the means for other researchers in the field to replicate the experiment. The main datasets used are also presented in this chapter and briefly discussed: walkability data; pedestrian count data and pedestrian survey data.

This chapter is structured as follows. Section 3.1 first presents the study design and its conceptual relational model, followed by the description of the Eixo Central case study in section 3.2. Next, Section 3.3 presents the walkability assessment method and collected walkability data. This is followed by the methods for walking behaviour data collection. Section 3.4 deals with pedestrian count data and Section 3.5 presents the pedestrian survey and a characterization of the survey dataset. The chapter finalises with a brief discussion in Section 3.6.

## 3.1 Study design

The literature review on before-after studies presented in Section 2.4 pointed out the claim for robust study designs to better identify possible cause-effect relations between walkability change and walking behaviour change. Most studies addressing the environmental walkability-walking behaviour relation are cross-sectional. This means that in a single moment in time the walkability and the walking behaviour of a population are evaluated.

The use of longitudinal study designs allows to address the "before-after" variation.

This means that data is collected at least in two occasions, one at baseline, prior to the intervention, and one at follow-up, some time after the intervention. More data collection events could be added. The use of longitudinal designs in the study of environmental interventions requires the researchers to plan ahead. This implies knowing when and where the interventions take place and being able to dispose of the necessary resources (human, budgetary) for timely data collection. As highlighted by Krizek *et al.* (2009b) this is not always the case.

By adding a comparison group (while maintaining the longitudinal facet) the study can be said to follow an experimental design, which is considered more adequate to infer possible causal relations. Hence researchers have been appealing to a more generalized use of at least longitudinal designs in order to clarify the existing evidence. (Kärmeniemi *et al.*, 2018)

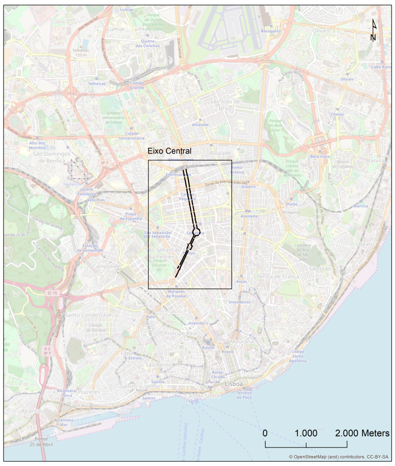
In practical terms, and in the context of environmental interventions that can act on a large population, the experimental design is less feasible. In transport behaviour research the use of quasi-experiments has been suggested to enable firmer causal inferences than cross-sectional observations (Krizek *et al.*, 2009b; Chapman *et al.*, 2014). Quasi-experimental designs meet most advantages of experimental designs without the burden of randomly assigning control units (individuals in this case), assigning treatment and control groups at a larger scale, such as neighbourhoods (Shadish *et al.*, 2002; van de Coevering *et al.*, 2015). Such control areas should match the characteristics of the area where the intervention takes place, or, in practical terms, they should be at least "broadly comparable" as each area of a city is unique to some extent. (Ogilvie *et al.*, 2006)

The design of the present study followed a balance between robustness and feasibility. It coupled three designs approaches: quasi-experimental; longitudinal and quasi-longitudinal. Namely, the observed walking behaviour part of the study followed a quasi-experimental design, while the walkability assessment followed a longitudinal design and the self reported walking behaviour followed a quasi-longitudinal design. The latter, involved asking respondents to recall information on a number of characteristics from a previous point in time as well as for the current time. Retrospective surveys, being prone to memory errors and other inaccuracies are considered less reliable than longitudinal studies. However, the use of retrospective surveys could be considered when longitudinal studies are not feasible (Behrens & Mistro, 2010; Milakis & van Wee, 2018). This is often the case in studies addressing travel behaviour change following environmental change (Handy, 2005b; Cao *et al.*, 2007; Vale, 2013).

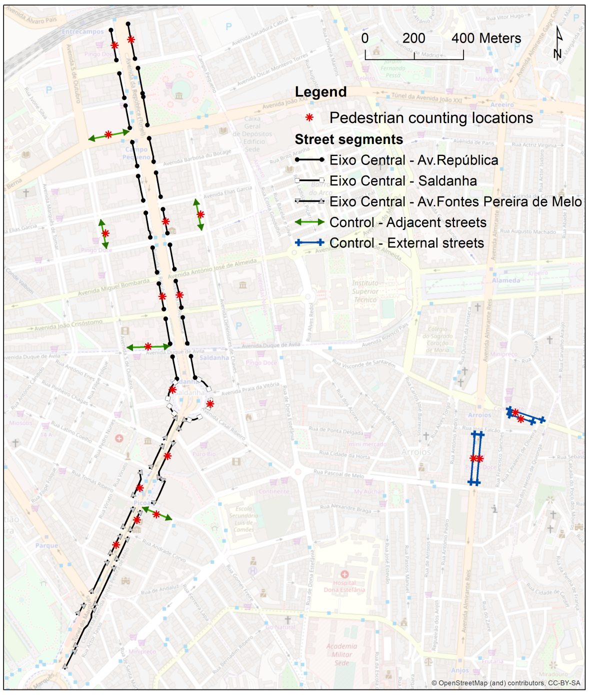
The case study choice was the Eixo Central project in Lisbon, Portugal. This was a large scale street improvement project whose implementation was expected to take place within the horizon of the research project (2015-2019), presenting an opportunity to conduct a quasi-experimental before-after assessment on the effects of enhanced walkability in pedestrian volumes and walking experience. A more detailed description of the project is provided in Section 3.2.

The control areas/population required for quasi-experiments were selected in the vicinity of the Eixo Central. Two control locations were considered for the analysis of pedestrian volumes: an “adjacent” area an “external” area (Figure 3.1). The “adjacent” area comprised all parallel and crossing street segments, similar to a 150m buffer around the Eixo Central. The “external” control area comprised two major streets (Av.Almirante Reis and R.Morais Soares) linked by a round plaza –Praça do Chile, with an average pedestrian volume similar to the one of Eixo Central. The nodes of the “external” area and of the Eixo Central area are located at a straight line distance of 900m, which correspond to a walking distance of 1.2 km and 16 minutes (using Google Maps online routing service). The “external” area was considered to be sufficiently similar in terms of urban characteristics to the Eixo Central but also to be sufficiently far apart. Likewise we considered the “adjacent” control area to be comparable in terms of population and urban characteristics.

The required data for the characterization and analysis of walkability and walking behaviour are not usually collected systematically by cities’ planning departments. Even when this data exists and is made available, it is hardly suitable for before-after analysis due to specific location and timing of the interventions. For this study it was necessary to collect all data regarding walkability and walking behaviour. Hence, data collection was a nuclear task of this research, involving street auditing, pedestrian counts and a survey (refer to Section 3.3)




(a) Location of Eixo Central




(b) Study area, adjacent and external control locations

Figure 3.1: Eixo central, adjacent control and external control locations

### Conceptual relational diagram

A conceptual relational model was developed to support and guide the study, providing the necessary relational framework between variables and outcomes while backed from transport behaviour theories. In general terms, travel behaviour relates to the decisions and habits of the individual regarding moving around. Several theories pursue to explain, or to foster some understanding on the mechanisms that shape a person's travel behaviour, as presented in Section 2.1.

Recalling the underlying research interest - change in walking behaviour - it is of interest to establish a relational scheme of factors whose interaction can result (or at least be associated with) in walking behaviour change. The relational scheme forms the conceptual model that guides the models presented in detail in Chapter 5. As mentioned, the conceptual model is drawn from existing theories, not necessarily being the application of a single approach.

The base rationale is that the built environment influences walking behaviour. Such relation forms the concept of walkability. Following the Comprehensive Behaviour theoretical frameworks, the environment has an effect on the individual that may lead to a behavioural response. Accordingly, a physical intervention that improves the environmental walking conditions may trigger a positive response in the individual resulting in an increase of walking (Figure 3.2).

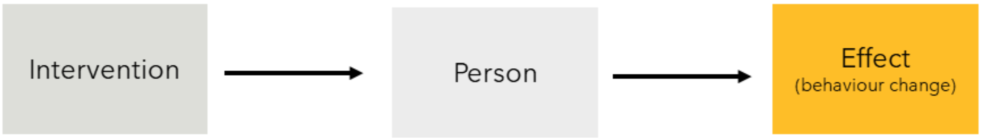



Figure 3.2: Starting point

The environmental improvements can be of various intensity, ranging from a simple sidewalk fix to a comprehensive land use change or to the redesign of whole streets. It is expectable (or at least hypothesized in this study) that the intensity of the intervention is positively related to the behavioural response, hence the more intense is the environmental improvement, the more likely it will trigger a behaviour change in favour of increasing walking levels.

However, as postulated by the Psychological based theories, the environmental factors that are to be improved are apprehended by the individual through his **perceptions** of the environment. Consequently, perceptions may be of greater relevance to trigger behaviour change than the objective factors themselves. Moreover, in order to form perceptions of the environment, some interaction is required between the individual and the environment. That is to say, the individual needs to be **exposed** to the environment it is required. Again, it can be hypothesized that the more exposed the individual is to the environmental improvement, the more likely there will be a behavioural change. Nevertheless such outcome may be dependent of the resulting **experience**, as initial positive perceptions and effective exposure may be irrelevant for someone following a negative walking experience (Figure 3.3). A feedback link connects the behaviour to a sequent experience in a cycle. If the feedback is continuously positive, the experience reinforces the behaviour, which can lead to the point of habit formation (Duhigg, 2012).

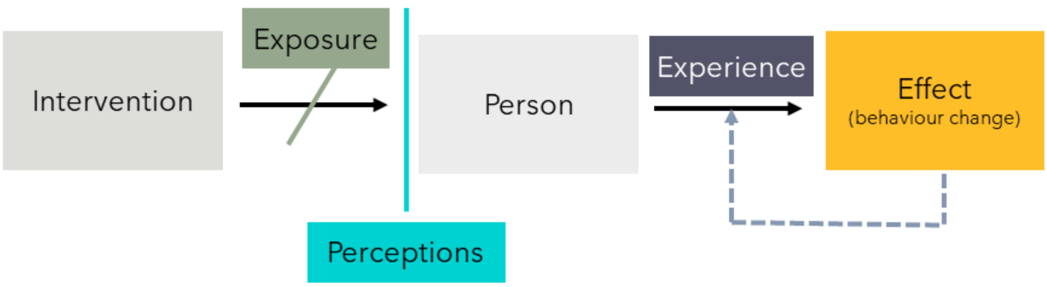



Figure 3.3: Role of exposure, perceptions and experience

Drawing from both theoretical perspectives, it can be admitted that the individual characteristics, namely socio-demographic, preferences and lifestyle, also play a role in the way the person perceives and experiences the environment, whilst his activity pattern and usual travel patterns influence his exposure to the environment. It can be hypothesized that from an homogenous population smaller groups with similar characteristics can be formed, forming pedestrian segments that are expected to have similar behavioural responses (Figure 3.4).

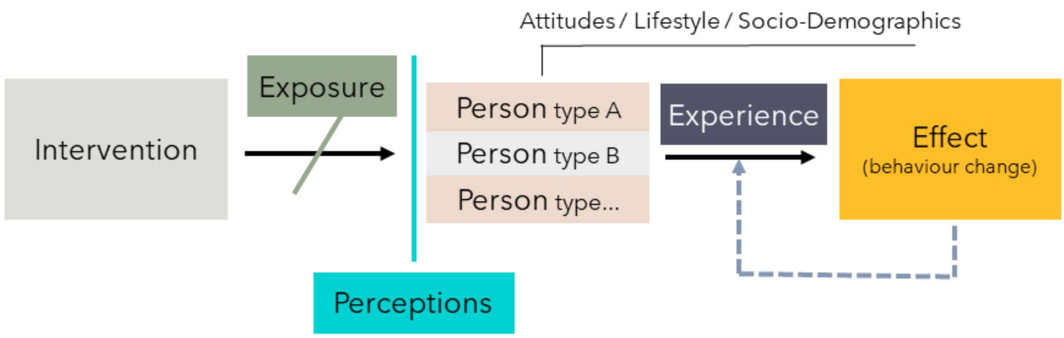



Figure 3.4: Pedestrian segmentation

## 3.2 Case study description

The case study of the present study is the Eixo Central intervention project, which was implemented in Lisbon in 2016/2017. At the time it was one of the boldest urban qualification project to take place in the central part of the city, stretching along approximately 2.5 km of some of the most important and notable streets: Avenida da República, Praça Duque de Saldanha e Avenida Fontes Pereira de Melo. It is located in the Avenidas Novas area, which is a central, a consolidated mixed-use area dating from early 20th century when it was designed according to the French "boulevard" urban standards of the time, consisting in a regular grid, with wide and long avenues with tree alignments. It became an important office location and a cluster of private clinics, serving also as a main transportation corridor. This section provides an overview of the planning process and a summary of the interventions.

The Eixo Central project has its roots in the 2012 "Orçamento Participativo" (an annual public participation event where the city residents can propose and elect projects), where a project called "Lisboa Acessível/Accessible Lisbon" was victorious. The goal of the "Accessible Lisbon" project was to create a pedestrian route accessible to all (in particular to people with impaired mobility) from Entrecampos and Marquês de Pombal, which would serve most of the city's CBD. This project was developed and proposed by a number of associations involved in helping people with disabilities.

The major lines of action of the project targeted the removal of barriers and obstacles in order to provide an inclusive and accessible pedestrian environment, namely by 1) levelling the pedestrian crossings (dropping the existing high kerbs); 2) removal of obstacles on the sidewalk; 3) enforce the specific regulation on sidewalk minimum width (Disability act – Portuguese Decree Law 163/2006); 4) improve the pavement conditions; and 5) make bus stops accessible.

In 2014, the Municipality of Lisbon presents the first drafts of the intervention project now called "Eixo Central". At the same time, another municipal project called "Uma Praça em Cada Bairro/ A square in each neighbourhood" is developed, proposing the qualification (or retrofitting) of two important spaces of the Eixo Central - the Duque de Saldanha square and the Picoas square. Parallelly, the Municipality had approved the Pedestrian Accessibility Plan, which established the guidelines for public space interventions in Lisbon.

From this moment onwards the project evolved from an accessibility oriented intervention to a more comprehensive and ambitious environmental intervention aiming to reduce noise, to provide more pedestrian space, to create novel and comfortable sidewalks, to introduce bicycle lanes, to create more green spaces, to improve road safety, and to provide more parking places for residents and for loading/unloading goods. Between 2015 and 2016 the project was developed and discussed, having various public participation sessions. The intervention principles were then stated [1]:

- To give back space to the pedestrian, by enlarging the sidewalks;
- To restore the original "boulevard" concept marked by tree alignments;
- To reduce traffic speed whilst not reducing significantly traffic capacity;

[1] https://www.lisboa.pt/cidade/urbanismo, assessed in October 2018

- To reduce car parking places in the Eixo Central street sections, balanced with an increase of parking in the surrounding area;
- To balance the street space allocation, reducing the space allocated for cars;
- To create a dedicated busway;
- To promote the use of active travel, in particular cycling;
- To improve the image of the Eixo Central, creating a strong sense of place;
- To qualify all public space elements (e.g. paving, lighting, furniture);
- To create an accessible to all pedestrian pathway between Entrecampos and Marquês de Pombal.

There was fierce public opposition to the project, namely from car users (especially residents) concerned with having less parking spaces and more congestion due to the reduction of traffic lanes. The implementation started in June 2016 and was finished in February 2017.

#### The project

The project considered distinct design approaches along the Eixo Central, namely within three sections:

1. Avenida da República: A 1.500m long and 50m wide avenue with dense (8 stories) occupation, served by bus, underground lines and train.

2. Avenida Fontes Pereira de Melo: A 900m long and 30m wide avenue, with a relatively less dense occupation, served by bus and underground lines

3. Saldanha square: A round plaza (65m radius) connecting the afore-mentioned avenues to the other three links.

Figures 3.5, 3.6, and 3.7 show the before and after phases of the street interventions using imagery from the Project communication (a, b) and from online map services (c, d). The interested reader can browse time lapse imagery of the Eixo Central sections from 2009 and 2014 (before) to as recently as 2018 (after) using Google Maps™ Street View application.

(a)

(b)

(c)

(d)

Figure 3.5: Av.da República site - project expectations a) before and b) after; street imagery c) before (Jun 2014) and d) after (Aug 2018)

(a)

(b)

(c)

(d)

Figure 3.6: Saldanha site - project expectations a) before and b) after; street imagery c) before (Jun 2014) and d) after (Aug 2018)

(a) (b) (c) (d)

Figure 3.7: Av.Fontes Pereira de Melo site - project expectations a) before and b) after; street imagery c) before (Jun 2014) and d) after (Aug 2018)

## 3.3 Walkability assessment

The walkability of the built environment can be assessed through several approaches. Although the process of evaluating walkability is sometimes referred as "measuring", walkability can not be truly measured as there is not a standard to use as a measure comparison.Walkability was assessed using the IAAPE framework proposed by Moura *et al.* (2017) (see also section 2.3.2). This method addresses micro-level walkability (i.e. street-level), providing 8 distinct specifications for assessing walkability according to 2 walking purposes (utilitarian and leisure) and 4 pedestrian groups (adults, children, seniors, mobility impaired). A walkability score between 0 and 100 is obtained by means of a weight function whose inputs are 7 key-concerns: connectivity; convenience; comfort; conviviality; conspicuousness; coexistence and commitment.

The 7 key-concerns are evaluated using a set of indicators. Moura *et al.* (2017) have provided a database of indicators for quantifying or qualifying the different dimensions of the 7 C's layout, which could be adopted and/or adapted according to the prevailing urban characteristics of the study area. The IAAPE followed a participatory process, having involved stakeholders and decision-makers in the selection process of key-concerns and in the weighting of the indicators.

As the IAAPE framework considers the differences between pedestrian groups and trip motives in the urban design evaluation. Accordingly each model specification provides specific measurement indicators and weights. The indicators can be of qualitative or quantitative nature, being operationalized using street audits and GIS analysis. Prior to the calculation of the walkability score all indicators are normalized with value functions that convert qualitative and quantitative scales into a 0–100 range of values (the value functions were based on the work of Mello (2015)).

Importantly, IAAPE bases its analysis on a pedestrian network, not adopting the centreline of the road network as commonly used by other walkability assessment methods. The digitial pedestrian network is presented with more detail in section 3.3.1.

The walkability score for each street segment is calculated using the following equations for each specification (Moura *et al.*, 2017):

**Adults group, Utilitarian walking**

$$WalkabilityScore_{Adults;Utilitarian} = 0.17 * Connectivity + 0.06 * Convenience + 0.17 * Comfort$$
$$+0.17 * Conviviality + 0.11 * Conspicuousness + 0.22 * Coexistence + 0.11 * Commitment$$

**Adults group, Leisure walking**

$$WalkabilityScore_{Adults;Leisure} = 0.04 * Connectivity + 0.19 * Convenience + 0.12 * Comfort$$
$$+0.23 * Conviviality + 0.19 * Conspicuousness + 0.15 * Coexistence + 0.08 * Commitment$$

**Senior group, Utilitarian walking**

$$WalkabilityScore_{Seniors;Utilitarian} = 0.11 * Connectivity + 0.16 * Convenience + 0.21 * Comfort$$
$$+0.11 * Conviviality + 0.05 * Conspicuousness + 0.21 * Coexistence + 0.16 * Commitment$$

**Senior group, Leisure walking**

$$WalkabilityScore_{Seniors;Leisure} = 0.07 * Connectivity + 0.27 * Convenience + 0.17 * Comfort$$
$$+0.17 * Conviviality + 0.03 * Conspicuousness + 0.17 * Coexistence + 0.13 * Commitment$$

**Children group, Utilitarian walking**

$$WalkabilityScore_{Children;Utilitarian} = 0.19 * Connectivity + 0.15 * Convenience + 0.19 * Comfort$$
$$+0.04 * Conviviality + 0.12 * Conspicuousness + 0.23 * Coexistence + 0.08 * Commitment$$

**Children group, Leisure walking**

$$WalkabilityScore_{Children;Leisure} = 0.09 * Connectivity + 0.23 * Convenience + 0.18 * Comfort$$
$$+0.18 * Conviviality + 0.14 * Conspicuousness + 0.14 * Coexistence + 0.05 * Commitment$$

**Impaired group, Utilitarian walking**

$$WalkabilityScore_{Impaired;Utilitarian} = 0.11 * Connectivity + 0.16 * Convenience + 0.21 * Comfort$$
$$+0.11 * Conviviality + 0.05 * Conspicuousness + 0.21 * Coexistence + 0.16 * Commitment$$

**Impaired group, Leisure walking**

$$WalkabilityScore_{Impaired;Leisure} = 0.15 * Connectivity + 0.10 * Convenience + 0.20 * Comfort$$
$$+0.15 * Conviviality + 0.05 * Conspicuousness + 0.15 * Coexistence + 0.20 * Commitment$$

The indicators used to evaluate each of the 7 key concerns vary according to the specification of the pedestrian group (refer to Section 2.2.2). Regarding the specification for the Adult pedestrian group, the indicator used for connectivity is “Pedestrian infrastructure continuity”, convenience is related to “land use diversity”, comfort to “pavement quality”, conviviality to “service hours of activities”; conspicuousness to the “presence of distinctive landmarks”; coexistence to “traffic safety at pedestrian crossings”; and commitment to “the enforcement of pedestrian accessibility regulation”. The evaluation was operationalized as follows:

- Connectivity: the **pedestrian infrastructure continuity** indicator was measured using a topological sinuosity indicator, i.e. the ratio between least-cost topological length and the Euclidean distance between census block centroids. The measures were performed over a digitized pedestrian network (presented in more detail in the next section).
- Convenience: **Land use diversity** was measured by field observation in a 0 to 4 scale, observing the presence of up to 4 classes of land uses – residential; commercial;

services and public facilities – within a street segment, classifying as 0 a vacant lot.

- Comfort: **Pavement quality** was measured qualitatively on site, in a 1-5 scale, ranging from presence of holes, irregular pavement (1) to smooth and regular pavement (5).
- Conviviality: The **Service hours** indicator was measured by a dummy variable where 1 denoted any activities located in the street segment working after 19 p.m. (e.g. cafes, shops).
- Conspicuousness The **existence of landmarks** was measured on site, in a 0-2 scale where 0 corresponded to inexistent or visible landmarks (e.g. monuments, distinctive buildings or shops, squares, etc.); 1 if landmarks could be seen from the centre of the street segment and 2 if landmarks were located at the street segment.
- Coexistence: **Traffic safety at pedestrian crossings** was obtained calculating the ratio of formal crossings (signalized intersections and crosswalks) to informal crossings present for the street segments' census block.
- Commitment: **Enforcement of pedestrian regulations**/law enforcement was calculated by the ratio of street segments complying with the local pedestrian accessibility regulations within the street segment's census block.

Concerning the Senior pedestrian group, the indicator used for connectivity is the "Pedestrian infrastructure continuity" also used for the Adult group, convenience is evaluated by the existence of "daily commerce and services"; comfort uses the same "pavement quality" indicator used for the Adult groups, conviviality refers to the existence of "meeting places"; conspicuousness is also evaluated by the "presence of distinctive landmarks"; the same happening with coexistence -"traffic safety at pedestrian crossings"- and commitment -"the enforcement of pedestrian accessibility regulation". The evaluation of the specific indicators of this group (i.e. not considering the ones also used for the Adult group) was operationalized as follow:

- Connectivity: **pedestrian infrastructure continuity**, as above.
- Convenience: **Daily commerce and services** was measured by field observation, counting in each street segment the number of occurrences of the following activities: grocery stores, bakeries, cafes, pharmacies, newspaper stands/shops and ATMs. The score of this indicator is relative to the study area characteristics, being dependent of the maximum and minimum scores observed in the study area, given by $DailyCommerceservices(DCS) = (1 - \frac{maxDCS_{area} - DCS}{maxDCS_{area} - minDCS_{area}}) * 100$

- Comfort: **Pavement quality**, as above.

- Conviviality: The existence of **Meeting places** was measured on site, in a 0-2 scale where 0 corresponded to inexistent or not visible meeting places for people to meet and stay (e.g. esplanades, benches, parks); 1 corresponded to inexistent but visible meeting places from the audited segment; and 2 corresponded to the existence of at least one meeting place in the segment.

- Conspicuousness The existence of **landmarks**, as above.

- Coexistence: **Traffic safety at pedestrian crossings**, as above.

- Commitment: **Enforcement of pedestrian regulations**, as above.

In the case of the Children pedestrian group, several indicators differ from the Adult and Senior specifications. The indicator used for connectivity is "Path Directness”; convenience is evaluated by "land use diversity"; comfort is related to the "vigilance effect" which in turn relates to façade transparency and conviviality here refers to the "existence or visibility of anchor places" (e.g. shopping malls, transport interfaces or public services). Conspicuousness relates to the existence of "landmarks" as in the Adult group; coexistence to the "location of pedestrian crossings" while commitment is evaluated by the "existence of design standards" and planned public space design interventions. For this group, the walkability evaluation was operationalized as follows:

- Connectivity: **path directness** was obtained by the ratio between the actual network distance (AD) and the straight-line distance (direct distance - DD) between census block centroids. The centroid of the census block where the audited segment is located is taken as "Origin" while the centroids of all census blocks located in the study area are taken as "Destinations". The measures were performed over the digitized pedestrian network.

- Convenience: **Land use diversity** as used for the Adult group.

- Comfort: The **vigilance effect** was assessed on site in a 1-5 scale of overall façade transparency at ground level. The minimum score corresponded to street segments with no transparency, such as walls, opaque fencing or high hedges. Wide open sites, such as car parks also corresponded to the minimum grade. The maximum score corresponded to street segments with a relevant façade transparency, as in the case of shops with large windows.

- Conviviality: The **existence or visibility of anchor places** was measured by field observation, counting in each street segment the number of occurrences of the following activities: schools; sporting facilities; parks and gardens; retail centres and supermarkets; theatres; metro stations and bus stops. The score of this indicator is relative to the study area characteristics, being dependent of the maximum and minimum scores observed in the study area, given by

  $AnchorPlaces(AP) = (1 - \frac{maxAP_{area} - AP}{maxAP_{area} - minAP_{area}}) * 100$

- Conspicuousness The existence of **landmarks**, as above.

- Coexistence: The **location of pedestrian crossings** was evaluated as the ratio of formal pedestrian crossings to the number of "desire lines" within the street segment's census block. This data was obtained from the digitization of the pedestrian network.

- Commitment: The **existence of design standards** tests for three regulatory standards - 1) the presence of a paved sidewalk; 2) no tripping hazards in the sidewalk; 3) a minimum walking of 1.2m - for all the segments within the census block level. The minimum value (0) is obtained if no street segment fulfills the three conditions while the maximum value is obtained if all the street segments of the census block fulfill the three conditions.

Regarding the group of pedestrians with mobility impairments, the indicator used for connectivity is the "Accessible pedestrian network" while convenience is evaluated by the "sidewalk effective width". Comfort uses the same "pavement quality" indicator used for the Adult and Senior groups, while conviviality uses the "existence or visibility of anchor places" indicator used for the Children group. On its turn, conspicuousness relates to the provision of wayfinding elements (e.g. street toponymy, signs). The coexistence indicator is given by "traffic safety at pedestrian crossings" and commitment given by "the enforcement of pedestrian accessibility regulation", similarly to the Adult and Senior groups. For this group, the walkability evaluation was operationalized as follows:

- Connectivity: the evaluation of the **accessible pedestrian network** comprised evaluating three conditions: 1) sidewalk minimum width higher than 1.2m; 2) no presence of steps/stairways; and 3) average slope less than 10%. If any of these conditions was not met at the street segment then the street segment was considered inaccessible (score=0), otherwise considered accessible (score=100)

- Convenience: **Sidewalk effective width** was measured on site, at the most narrow section of the sidewalk, deducting a pre defined preemption distance. The values ranged from 0 for a sidewalk width smaller than 1,2m to 100 for a sidewalk width larger than 2m.

- Comfort: **Pavement quality**, as above.
- Conviviality: **Existence or visibility of anchor places**, as above.
- Conspicuousness: The provision of **wayfinding elements** was evaluated on site, checking for the presence of street toponymy signs or other directional signs in the street segment.
- Coexistence: **Traffic safety at pedestrian crossings**, as above.
- Commitment: **Enforcement of pedestrian regulations**, as above.

Several indicators required on site assessment whilst others required spatial analysis. The on site assessment was made by means of street audits, using a predefined entry sheet (refer to Annex 1). The audits comprised street segments, i.e. block fronts, and pedestrian crossings. The calculation of the indicators that required spatial analysis was performed using ESRI ArcMap 10 Network Analyst package. Further spatial analysis and output production were performed in QGIS 3.4 Madeira.

Walkability scores were calculated using the adult group specification. The rationale for selecting this specification deals with the characteristics of the study area: the intervention occurred in an area that could be considered to be a central business district and pilot on site observations revealed the majority of pedestrians using the area to fit into the adult group. Other specifications could have been used if for instance the study subject was school active travel by children.

### 3.3.1 The digital pedestrian network

The digital pedestrian network consists of a simplified representation of the pedestrian street environment. It serves a twofold objective: to store geo-located attributes of the street environment (such as the audited indicators) and to support spatial measures using GIS network analysis. In transportation research many of the studies using network measures have relied on the road network, that in the urban environment is often represented by street centrelines. These datasets have become generally available to researchers and also to the general public, hence providing ample baseline data. However, this conventional approach based on street centrelines mainly serves the motorized vehicle drivers' point of view (Ballester *et al.*, 2008) and its application for the estimation of pedestrian accessibility and connectivity measures may result in biased results, as centrelines do not effectively model pedestrian movement (Chin *et al.*, 2008; Tal & Handy, 2012; Parker, J.S.; Vanderslice, 2011).

The urban environment is a complex space composed of a variety of physical features and associated functions. In its most simple representation, the pedestrian network could be composed of sidewalk links and crossing links. There are other typologies that compose the richness of the pedestrian environment (e.g. squares, open spaces, stairways) and that can work as a pathway for some and as a non-traversable barrier for others.

Numerous applications call for the development of dedicated pedestrian network models. These include not only the calculation of pedestrian accessibility to facilities to the assessment of local walkability (Moura *et al.*, 2017) but also the inventory and management of the pedestrian infrastructure (Li *et al.*, 2018) and the support for pedestrian navigation services and route planning (Karimi *et al.*, 2014).

In some cases, such as mapping or infrastructure inventory, the pedestrian network can be represented by attribute fields attached to standard centreline geometry. On the other hand, applications that relate to walking behaviour and walkability require a more realistic representation of the pedestrian environment. The pedestrian network can be significantly different from standard street networks as it can incorporate both formal and informal paths, composed by a variety of path segment and crossing types that include sidewalks, pedestrian bridges and tunnels, signalized and non-signalized pedestrian crossings, among others.

Although various studies provided evidence on the substantial accuracy issues of using a street network for the representation of walking travel (Chin *et al.*, 2008; Tal & Handy, 2012; Lundberg & Weber, 2014) there remains a gap in addressing the challenges, methods and best practices for the assembly of the pedestrian network (Karimi & Kasemsuppakorn, 2013). Moreover, urban environment network datasets that include pedestrian routes do not usually exist, being rarely available or collected (Beale *et al.*, 2006; Chin *et al.*, 2008). To overcome this gap there has been growing interest in the use of user-generated geographic content to complement the traditional approach of collection of geographic information by agencies or organizations (Jiang & Thill, 2015). One of the leading free access geo-information platforms is OpenStreetMap (OSM), which provides global map coverage relying on the contribution of more than 1 million registered volunteers (Neis & Zielstra, 2014). Although the OSM project provides a comprehensive guide to the representation of the pedestrian network, these guidelines call for the representation of sidewalks as a text attribute of the road network geometry. Hence pedestrian crossings are not represented, being assumed the pedestrians can cross the streets at any location, which cannot be regarded as a realistic representation of the urban walking environment, where walking is constrained by the existence of other transport modes, namely motorized traffic.

Alternative approaches to the construction of the pedestrian network dataset have been proposed, ranging from the manual digitization of sidewalks to the automated generation of the pedestrian network. Automated methods include buffering the street centrelines (Karimi & Kasemsuppakorn, 2013) or using the geometry of city blocks (Ballester *et al.*, 2008; Li *et al.*, 2018). While automated generation methods can be regarded as less resource intensive compared to the standard manual digitization, they still present significant limitations. Manual inspection and editing is still required to correct aggregation errors, which can be time consuming.

Hence, a procedure for the construction of the digital pedestrian network was developed and used in the scope of the present research project. The foundation of the methods for digitizing the pedestrian network derive from previous research by the author (Cambra, 2012), further elaborated within the FCT exploratory project EXPL/ECM-TRA/2416/2013: "Pedestrian Accessibility and Attractiveness Indicators: Tool for Urban Walkability Assessment and management".

The study of the digitization of the pedestrian network resulted in the publication of the research paper "The digital pedestrian network in complex urban environments: a primer discussion on typological specifications" (Cambra *et al.*, 2019b). The methodology used in the present study for the digitization of the pedestrian network is presented next.

The digitization was performed in GIS environment, using ArcGis v.10. Baseline cartographic information was required to guide the digitization process. In the present case, the 1:10.000 cartographic data of the city of Lisbon was used, in combination with satellite imagery from Bing Maps ©. A single polyline shapefile was used to store the pedestrian network, comprising three main attributes: an unique ID field; a typology field and a length field. The pedestrian network comprises two levels of representation, each composed by various typologies:

1. the formal pedestrian network, combining standard sidewalks and formal crossings;
2. the detailed pedestrian network, regarding non formalized crossings and additional pathway typologies such as pedestrian paths in open and green spaces.

The digitizing procedure started by creating the formal pedestrian network, which comprises distinguishable and discernible pathways and crossing features over the cartographic data. Standard sidewalk line features were created in the centreline of the sidewalk space, typically between buildings and roads. Pedestrian crossings features connected sidewalk features over the road space (zebra crossings or signalized intersections). Importantly there was a need to ensure that the connection between features occurred in the feature vertexes. Failing to do so would result in a disconnected network, biasing the result of the spatial analysis.

The formal pedestrian network was then complemented by elements of the detailed pedestrian network, namely informal crossings. Pedestrian crossings are critical to accessibility analysis and underline the necessity of using a pedestrian network instead of a centreline street network. In various urban contexts, all allowed pedestrian crossings are formalized, either via pavement paintings or by signage (including light controlled). In other urban contexts, such as Lisbon, there are cases where formal crossings simply do not exist, either because the area was developed prior to the existence of the automobile or because the existing traffic and pedestrian volumes do not justify the presence of a formal crossing.

The representation of informal pedestrian crossings is a challenge. If informal crossing possibilities are not represented at all, we might be considering blocks as islands where pedestrians are stranded, namely in low traffic residential streets. On the other hand, if all informal crossing possibilities are represented we might be considering that people (including children and seniors) can cross wide, heavy traffic streets where they are not meant to.

In order to overcome this challenge and to produce uniform, realistic and parsimonious pedestrian crossing representations the following guidelines were used:

- Informal crossings ought to be placed at an intersection when in presence of single lane, one way streets, assuming relatively low traffic volume and speed, favouring a safe pedestrian crossing - Type I informal crossing.
- In 2-way streets, informal crossings ought to be placed at an intersection if no formal crossing exists within a 50m distance (the Portuguese road regulations states that it is illegal for the pedestrian to cross the road if the nearest formal crossing is in a 50-meter vicinity) - Type II informal crossing..
- Informal crossings are not considered suitable features for streets that have three or more traffic lanes.

Figure 3.8 illustrates the digital pedestrian network around a section of Avenida da

República. Notice the location (or absence) of pedestrian crossing opportunities across Av. República.

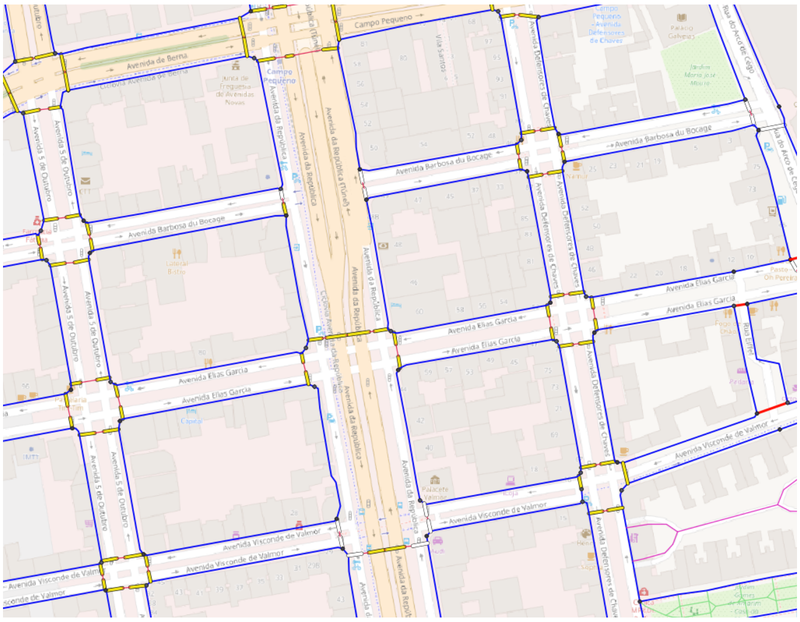



Figure 3.8: Example of the digitized pedestrian network

The digitization was performed in 2015, prior to the Eixo Central intervention, and revised in 2016, after the intervention. As larger network datasets tend to provide better estimates of connectivity, the digitization of the pedestrian network stretched beyond the Eixo Central intervention area. It is worth mentioning that a considerable amount of the pedestrian network of this area was already digitized in the context of the aforementioned FCT exploratory project EXPL/ECM-TRA/2416/2013. A total of 185 km of pedestrian network was digitized. Table 3.1 shows a summary of the network elements.

Table 3.1: Digitized pedestrian network elements

| **Network class** | **Typology** | **Number of features** | **Total lenght (m)** |
|---|---|---|---|
| Formal pathawys | Sidewalk | 2,135 | 146,119 |
| Formal pathawys | Local acess street | 95 | 3,438 |
| Formal pathawys | Stairways | 92 | 1,648 |
| Formal crossings | Signalized intersections | 650 | 7,465 |
| Formal crossings | Pedestrian zebra crossings | 572 | 5,995 |
| Formal crossings | Medians | 419 | 2,454 |
| Detailed net. Pathways | Open spaces (e.g. parking lots) | 80 | 2,026 |
| Detailed net. Crossings | Informal pedestrian crossings (type I) | 718 | 6,770 |
| Detailed net. Crossings | Informal pedestrian crossings (type II) | 35 | 631 |
| Detailed net. Crossings | Access to garages | 61 | 572 |
| | Other typologies | 247 | 7,856 |
| Total | | 5,104 | 184,974 |

### 3.3.2 Walkability data collection

The implementation of the project produced different environment changes within the 3 sites of Eixo Central. The intervention can be described according to the "7 C" layout of the walkability model as follows:

- 1.Connectivity: The pedestrian network structure presented only marginal changes, relating to the repositioning of pedestrian crossings locations. No changes were observed in the control areas.
- 2.Convenience: The land use mix remained stable. There were no evident changes in the activities present either in Eixo Central or in the control areas. The buildings under construction or renovation as well as the vacant commercial spaces observed at baseline were not completed nor at use at follow up.
- 3.Comfort: The sidewalk pavement quality was improved in Av.República and Saldanha but not in Av.Fontes Pereira de Melo nor in the control area. The change consisted in the implementation of a "comfort stripe" – a stripe made of concrete providing a more regular, smooth and comfortable pavement when compared to the standard Portuguese cobblestoned pavement used in Lisbon.
- 4.Conviviality: Kiosks offering drinks and light meals were placed in the plazas created in Saldanha and Av.Fontes Pereira de Melo, providing outdoor sitting places with extended working hours. In Av. República and in the control areas there were no noticeable changes.
- 5.Conspicuousness: The new plaza design in the Saldanha and Av.Fontes Pereira de Melo created distinguishable urbanscape elements and a new sense of place.
- 6.Coexistence: Crossing safety was targeted by the Eixo Central project. In all main intersections of the area, the turning radius was reduced in order to slow down turning traffic; and crossing refuges were enlarged.
- 7.Commitment: Existing regulations on pedestrian accessibility were enforced along the Eixo Central area, namely by levelling sidewalk curbs; providing a minimum obstacle free walking width of 1,5m; introducing tactile paving at pedestrian crossings. In some cases, in the adjacent streets, these measures were also applied. In the external control area, there was no change.

Other factors not addressed by the particular walkability model specification (adults; utilitarian walking)

- Amenities: New amenities were installed in all Eixo Central sites, namely benches, LED lighting oriented to the sidewalk, greenery and trees. No change was noticeable in control areas.

- Transportation system: A new cycle infrastructure was created along the three Eixo Central sites. There were no changes in the local public transportation services (bus, metro and train), including control areas.

- Human scale and enclosure: The intervention produced different results in each of the three sites. In Av.Republica, the sidewalks were enlarged by more than 2m (taking up a parking lane) doubling their width, consequently changing the centreline perspective of the street. In Saldanha, the plaza layout provided more open public space for walking and sojourning. In Av.Fontes Pereira de Melo there was also a plaza created but the majority of the street kept the original design. There were no noticeable changes in control areas.

- Sensorial factors: The replacement of traffic lanes by pedestrian space led to fewer nuisances from traffic close when walking in Av.Republica and Saldanha.

#### Walkability before-after

The aforementioned changes were captured and measured to some extent by the models' indicators and translated into quantitative walkability scores. Tables 3.2 and 3.3 show the mean walkability score for each site, obtained by the average of the site's individual street segment score. Figure 3.9 illustrates the differences in walkability scores before-after by walkability dimension and purpose. Walkability was assessed for all street segments, i.e. block faces, found in the Eixo Central sections, in a total of 37 street segments (Figure 3.1b). Of these 20 were located in Av.República; 5 located in Saldanha square and 12 located in Av.Fontes Pereira de Melo. Walkability audits were performed at baseline (June 2016) and follow-up (June 2017) using the IAAPE walkability framework. Previous work tested the tool to uncertainty relating to data collection, finding reliable inter-rater agreement and acceptable robustness (Abreu, 2017). Nonetheless, for convenience, the audits were conducted by the same trained auditor at baseline and follow-up. For each site, data of the individual segments walkability score were aggregated into a mean walkability score using their mean value, in a 0-100 scale. The surrounding area (adjacent and parallel streets) was surveyed for noticeable environment and land use changes. No evident changes in the pedestrian environment were observed therefore walkability scores were assumed constant between the baseline and follow-up period.

Average walkability scores show that initial conditions were very similar in the 3 sites, with a score around 71 points. This is a relatively high score when compared to average values of other streets in Lisbon, considering Cambra *et al.* (2017a) who reported an average walkability score of 64 for a comprehensive sample of streets in the same neighbourhood. While the increase in walkability scores was primarily related to the improvement of pavement quality and comfort, the distinction between each site can be related to the sojourning opportunities introduced, providing a more convivial environment.

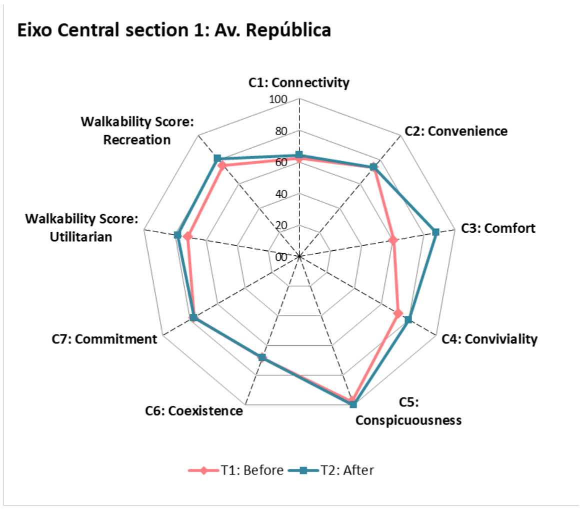
The three sections were analysed before and after the intervention, collecting walkability data and pedestrian volumes. Pedestrian volumes were controlled in two control locations: one "adjacent group" consisting of neighbouring locations and one "external group" located in a neighbourhood approximately 1km away from Eixo Central with comparable urban characteristics. During the implementation of the Eixo Central project, no other environmental interventions occurred in the control locations. A comprehensive table of before-after walkability scores is provided in Annex 3.

Table 3.2: Walkability Scores, T1: Before

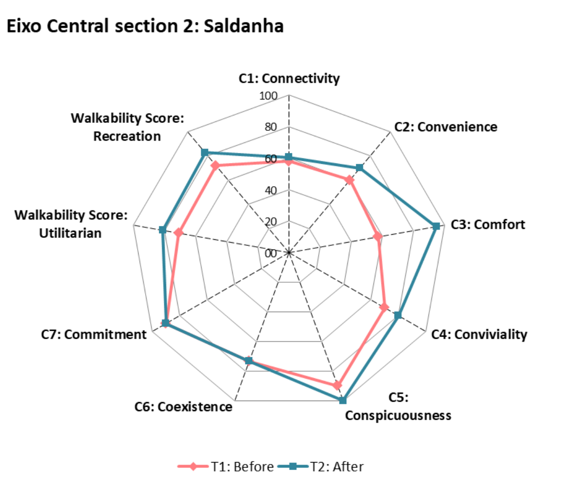
| Walkability assessment T1 - Before | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Area | Street segments (n) | **C1: Connectivity** | | **C2: Convenience** | | **C3: Comfort** | | **C4: Conviviality** | | **C5: Conspicuousness** | | **C6: Coexistence** | | **C7: Commitment** | | **Walkability Score: Utilitarian** | | **Walkability Score: Recreation** | |
| | | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* |
| Eixo Central, section 1 | 20 | 62.3 | *4.1* | 73.8 | *12.8* | 60.6 | *29.0* | 72.5 | *25.5* | 97.5 | *11.2* | 68.1 | *5.1* | 77.2 | *28.0* | 71.9 | *6.2* | 75.4 | *7.4* |
| Eixo Central, section 2 | 5 | 57.9 | *0.0* | 60.0 | *13.7* | 57.5 | *24.4* | 70.0 | *27.4* | 90.0 | *22.4* | 73.3 | *7.5* | 90.0 | *13.7* | 71.0 | *7.0* | 72.0 | *6.1* |
| Eixo Central, section 3 | 12 | 57.9 | *0.0* | 56.3 | *28.5* | 74.0 | *20.3* | 66.7 | *44.4* | 79.2 | *25.7* | 71.6 | *5.1* | 87.7 | *12.8* | 71.2 | *10.0* | 70.0 | *14.5* |
| Control Adjacent | 5 | 61.4 | *5.1* | 75.0 | *17.7* | 85.0 | *22.4* | 70.0 | *27.4* | 50.0 | *50.0* | 69.9 | *10.0* | 77.6 | *13.0* | 70.7 | *8.9* | 69.2 | *14.8* |
| Control External | 4 | 50.1 | *0.0* | 100.0 | *0.0* | 43.8 | *7.2* | 100.0 | *0.0* | 75.0 | *28.9* | 65.3 | *5.4* | 62.5 | *8.3* | 68.4 | *4.9* | 78.3 | *6.7* |

Table 3.3: Walkability Scores, T2: After

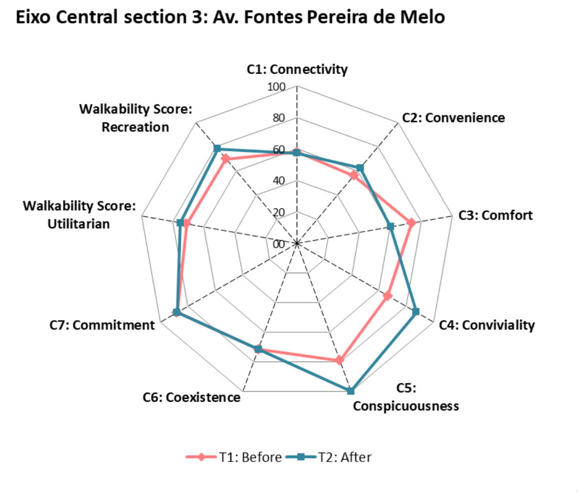
| **Walkability assessment T2 - After** | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Area | Street segments (n) | **C1: Connectivity** | | **C2: Convenience** | | **C3: Comfort** | | **C4: Conviviality** | | **C5: Conspicuousness** | | **C6: Coexistence** | | **C7: Commitment** | | **Walkability Score: Utilitarian** | | **Walkability Score: Recreation** | |
| | | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* |
| Eixo Central, section 1 | 20 | 64.4 | *3.6* | 73.8 | *5.6* | 88.1 | *24.2* | 80.0 | *25.1* | 100.0 | *0.0* | 68.1 | *5.1* | 77.2 | *28.0* | 78.4 | *8.0* | 81.0 | *8.5* |
| Eixo Central, section 2 | 5 | 60.4 | *0.0* | 70.0 | *11.2* | 95.0 | *6.8* | 80.0 | *27.4* | 100.0 | *0.0* | 73.3 | *7.5* | 90.0 | *13.7* | 81.2 | *6.2* | 82.7 | *6.7* |
| Eixo Central, section 3 | 12 | 57.3 | *1.4* | 62.5 | *27.2* | 60.4 | *35.3* | 87.5 | *31.1* | 100.0 | *0.0* | 71.6 | *5.1* | 87.7 | *12.8* | 75.0 | *6.8* | 78.3 | *9.7* |
| Control Adjacent | 5 | 61.4 | *5.1* | 75.0 | *17.7* | 85.0 | *22.4* | 70.0 | *27.4* | 50.0 | *50.0* | 69.9 | *10.0* | 77.6 | *13.0* | 70.7 | *8.9* | 69.2 | *14.8* |
| Control External | 4 | 50.1 | *0.0* | 100.0 | *0.0* | 43.8 | *7.2* | 100.0 | *0.0* | 75.0 | *28.9* | 65.3 | *5.4* | 62.5 | *8.3* | 68.4 | *4.9* | 78.3 | *6.7* |




(a)




(b)




(c)

Figure 3.9: Walkability Scores Before-After: by 7-C dimension, Utilitarian and Recreational purposes

## 3.4 Pedestrian counts

In the dawn of the Smart City concept, various cities have been implementing pedestrian counting systems. Albeit their limitations in identifying individuals in outdoor settings (prone to harsh environmental conditions) their major strength lies in the continuous counting process, which allows to collect data over large time periods. At the time the present research tool place this was still not the case in the city of Lisbon. In order to obtain pedestrian count data it was necessary to adopt a manual collection procedure.

Manual data collection has a series of limitations. First, it requires the presence of a person - the auditor. If various locations are to be observed simultaneously it requires the presence of a team, which in turn implies the allocation of resources (time, budget). Secondly, human auditors are prone to fatigue resulting in observation errors. Long counting periods, such as a day-long period, are not suitable. Thirdly, manual data collection is often done by a "pen and paper" tally at the counting location which is later processed into a computer database - a process prone to typos.

However, manual data collection offers several advantages over automated counting methods. First, it does not require specific equipment or technology. In most places it does not require special permits. Secondly, the auditor can move around covering various counting locations while automated counters are usually static, controlling a single location. Thirdly, the human auditor's interpretation abilities make it possible to collect a variety of qualitative attributes that, at this stage, are not available in automated pedestrian counting systems.

Finally, albeit manual pedestrian data collection could be regarded lo-tech, it has been confirmed as a valid and recommended method for active travel research, as stated by Félix *et al.* (2020). More generally the observation of people using the streets has long been regarded as a paramount, valuable tool for urban planning. On this subject, Gehl *et al.* (2013) provides a rich and comprehensive guide to the methods that can be used to observe and study pedestrian behaviour in public spaces. These include counting -providing numbers for making comparisons before and after or between different geographic areas or over time-, mapping -to locate the number and types of activities-, or tracing -plotting lines of movement of people in the study area - among others.

Regarding counting, Gehl *et al.* (2013) stresses the importance of registering not only the people that are moving (pedestrian flow) but also the people that are stationary (sojourning). The role of sojourning in general walking behaviour has also been addressed by the European joint research study Pedestrian Quality Needs [2].

If at first the study of pedestrian flow alone would seem more adequate in the scope of transportation studies, it should be noted that also in motorized transportation studies parking plays an important role. Hence one can consider that stationary pedestrians are to pedestrian flow what car parking is to urban traffic.

A variety of pedestrian counting methods have been proposed in walking related studies. One of the seminal studies relating network connectivity with pedestrian flow is Hillier *et al.* (1993) which laid the basis for the "Space Syntax" analysis - a technique of configurational analysis of the local and global structure of the urban grid. In this study, Hillier et al. proposed an observation technique in which the observer walked at a normal pace (5.5 km/h) along a set of selected street segments counting the people passed by the observer or were static as the observer passed. Qualitative data was also registered by the observer, namely distinguishing between man, women and children (16 years old or less if moving independently). To control for variations in the pedestrian usage of the streets, the counting was repeated between 20 to 30 times in each route. Also the observation ought to cover all times of the day, being considered five standard time periods: 8-10 a.m., 10-12 a.m., 12-2 p.m., 2-4 p.m., and 4-6 p.m.

Another approach to the moving observer method was proposed in the scope of the IAAPE project. This was an adaptation of the moving observer method proposed by Wardrop & Charlesworth (1954) in order to estimate directional flow data, hence complementing the method used by Hillier *et al.* (1993) which did not account for the flow direction. The method used consisted of a manual count performed by an observer walking at a regular pace, back and forth the street segment to be audited. The observed used a pre-defined tally table, recording the pedestrians at near distance from his position (1 to 2 meters) within the full width of the sidewalk, namely:

- People walking in the opposite direction of the observer ($m_a$);
- People walking in the same direction of the observer, overtaking the observer ($m_o$);
- People walking in the same direction of the observer, overtaken by the observer ($m_p$);
- People stationary when passed by the observer ($m_s$) (excluding people waiting to cross at intersections);
- The duration of each observation - time taken to walk from the beginning to the end of the street segment ($t_w$) and return ($t_r$).

[2] Available at: https://www.cost.eu/publication/cost-358-pedestrians-quality-needs-final-report/

Following Wardrop & Charlesworth (1954), the pedestrian flow *(q)* is calculated from the combination of the flow moving along the observer, the flow moving opposite to the observer and the travel time:

$$q = \frac{(m_o + m_p) + m_a}{t_w + t_r}$$

In line with Hillier *et al.* (1993), this method used several passes in each way for each audited street segment and a coverage of different time periods. The street segments were audited by 6 consecutive observations at 5 distinct daily periods. These were the morning peak (8:00-9:30 a.m.); morning off-peak (10:00-11:30 a.m.) lunch peak (12:30-2:00 p.m.); afternoon off-peak (3:00 -4:30 p.m.) and afternoon peak (5:00-6:30 p.m), taking place in 5 consecutive workdays plus a Saturday.

Although being adequate for registering a variety of pedestrian attributes, for counting moving and stationary pedestrians and for recording directional flows, the application of the moving observer methods to collect pedestrian data presented operational issues. In a previous study, Cambra *et al.* (2017b) stressed the burden posed to the observer, given the cumulated distances walked over a day: their team of auditors walked an average of 20 km per day, leading to fatigue and lack of accuracy in recording the observations, especially during the warmer periods of the day (the observations were made in May 2015 with the maximum temperatures reaching 30º C)

An alternative approach to the moving observer is the "gate method", where the observer is static, counting people passing through an imaginary screen line across the sidewalk (the "gate").

According to the Space Syntax Observation Manual (Vaughan & Grajewski, 2001), "the gate method is the workhorse of spatial observing techniques". It is a simple and widely adopted method, in particular within the Space Syntax research field, but also in urban planning or transportation studies (Kalakou & Moura, 2014; Hajrasouliha, 2015). Although static during the counting period, the observer can move around different count locations, covering a wide area. For instance, Barros (2013) observed 19 "gates" in a neighbourhood of Lisbon (Telheiras), imposing a maximum observation time of 2 hours to cover all locations, which included the time necessary to perform the count and also the time to move between "gate" locations. Vaughan & Grajewski (2001) recommend a counting period from 2.5 to 5 minutes, the former in busy city streets and the latter for quieter or suburban streets and a minimum of 25 "gates". Moreover, it is recommended that the "gate" locations should cover a range of well-used, moderately-used and poorly-used spaces in and around the area of study.

However, despite being a robust and simple method for counting people (or vehicles) moving, the gate method is unsuitable to register stationary people. Given the aim of the present study, the method of choice to perform the pedestrian counts should observe certain requirements:

- Suitable for counting moving and stationary pedestrians;
- Suitable for registering pedestrian attributes;
- Suitable for distinguishing pedestrian flow direction;
- Simple implementation;
- Not physically demanding on the observer

With this in mind, a novel pedestrian counting method was developed. Its foundation was the gate method, given its straightforward application and ease on the observer. In order to overcome the gate's method limitation in counting stationary people, which can be distributed along the audited street segment, a moving observer procedure was integrated in the process. This "hybrid" method of counting works as follows:

1. The observer carries a predefined entry sheet (paper) to the street segment to be audited
2. The observer makes a pass from one end to the street segment to the other, counting the stationary people and registering the activity types.
3. The observer picks an observation point around mid-segment. This point should have unimpeded view over the sidewalk, as comfortable as possible.
4. The observer positions as far from the sidewalk edge as possible (i.e. close to the block buildings), tracing an imaginary line perpendicular from his position to the sidewalk edge.

The predefined entry sheet used for the first wave of pedestrian counts (2016, before the Eixo Central intervention) is presented in Figure 3.10. For the second wave of pedestrian counts (2017, after the intervention), a few modifications were made in the entry sheet, presented in Figure 3.11.

As observed in Figure 3.10, the entry sheet had five distinct sections:

1. the heading: containing general characterization fields (date, observer name, time period, counting location) and the indication of sun exposure at the audited sidewalk (direct sunlight; partially shaded or fully shaded);

2. registry for stationary pedestrians, containing several attributes, categorized in three main categories: pedestrians entering or leaving the sidewalk (e.g. entering or exiting buildings or cars, jaywalking), standing pedestrians (e.g. next to buildings, looking at shop windows, talking, walking the dog), and sitting pedestrians (e.g. cafe outdoor tables, benches);

3. registry for moving pedestrians, distinguishing between able pedestrians and pedestrians with impaired mobility. The impaired mobility pedestrians included people on wheelchairs and with walking aids, but also baby strollers or elderly people walking with notorious difficulty. There were separated entries for either flow direction and an additional field to count people walking on the road, parallel to the sidewalk (which is not uncommon when the sidewalks are too narrow or have significant obstacles such as parked cars);

4. registry for cyclists, distinguishing between male and female cyclists and also if riding on the sidewalk;

5. footer section for additional notes from the observer.

As for the entry sheet used in the second count collection, there were four sections, mostly similar to the previous format:

1. the heading, keeping the previous format;

2. registry for stationary pedestrians: distinguishing only between standing or sitting pedestrians;

3. registry for moving pedestrians: additionally distinguishing elderly pedestrians (older than 65 years old);

4. footer section for additional notes from the observer.

**IAAPE:** Folha de registo de actividade pedonal. Mod. 30-06 | WALK_LAB

| Data: | Circuito / Código segmento. | **Período M**<br>☐ 8:00 - 9:30<br>☐ 10:00 - 11:30<br>☐ 12:30 - 14:00 | **Período T**<br>☐ 15:00 - 16:30<br>☐ 17:00 - 18:30 | **Exposição**<br>☐ Sol pleno<br>☐ Meio sol/sombra<br>☐ Sombra |
|---|---|---|---|---|
| Auditor: | Nº porta ( localização ) | | | |

**Hora Início**: _____hh______mm_______ss

| **A entrar ou a sair** | | **Estadia** | | | |
|---|---|---|---|---|---|
| | | **De pé** | | **Sentados** | |
| de edifícios/lojas | | Em pé, orla de edifícios (portas, montras, pórticos) | | Esplanadas | |
| de transporte (carro, bus, metro, taxi) | | Em pé, plena rua (falar, passear o cão, parquímetro) | | Mobiliário urbano | |
| atravessar a rua (fora de passagem peões) | | Em trabalho (polícia/ segurança, empregado mesa, obras, etc) | | Outros locais | |

**Hora Início**: _____hh______mm_______ss **0 : 5 mins**

**Peões**

Em contra-mão | Em mão

| | |
|---|---|
| | |
| Fora do passeio: | Fora do passeio: |

**Peões com mobilidade reduzida**

Em contra-mão | Em mão

| | |
|---|---|
| | |
| Fora do passeio: | Fora do passeio: |

*bengalas, apoios, canadianas, bebés/crianças em carrinhos, cadeiras de rodas, idosos marcha lenta*

**Bicicletas / Ciclistas**

| **H** | **M** |
|---|---|
| No passeio: | No passeio: |

**Notas / Observações:**

Figure 3.10: Pedestrian count entry sheet, 2016

**IAAPE:** Folha de registo de actividade pedonal. Mod. 172806 | WALK_LAB

| Data: | Circuito / Código segmento. | Período M | Período T | Exposição | |
|---|---|---|---|---|---|
| | | ☐ 8:00 - 9:30 | ☐ 15:00 - 16:30 | ☐ Sol pleno | ☐ Nublado |
| Auditor: | Nº porta ( localização ) | ☐ 10:00 - 11:30 | ☐ 17:00 - 18:30 | ☐ Sombra | ☐ Chuvisco |
| | | ☐ 12:30 - 14:00 | | ☐ Meio sol/sombra | |

**Estadia: hora de ínicio: _______hh _______ mm**

*percorrer segmento, não contar esquinas nem atravessamentos*

| De pé | | Sentados | |
|---|---|---|---|
| Em pé, orla de edifícios e quiosques (montras, átrios, portas) | | Esplanadas | |
| Em pé, plena rua (falar, passear o cão, parquímetro) | | Mobiliário urbano | |
| Em trabalho (segurança, empregado mesa, obras, etc) | | Outros locais | |
| Paragens BUS | | | |

**Hora início: _____ hh _____ mm ______ss**

***0 : 5 mins***

*contra-mão* *mão*

**Peões**

| | Mob.Reduzida | | Mob.Reduzida |
|---|---|---|---|
| | | | |
| na via/ ciclovia: | | na via/ ciclovia: | |

**Peões seniors > 65 anos**

| | Mob.Reduzida | | Mob.Reduzida |
|---|---|---|---|
| | | | |
| na via/ ciclovia: | | na via/ ciclovia: | |

***5 : 10 mins***

*contra-mão* *mão*

**Peões**

| | Mob.Reduzida | | Mob.Reduzida |
|---|---|---|---|
| | | | |
| na via/ ciclovia: | | na via/ ciclovia: | |

**Peões seniors > 65 anos**

| | Mob.Reduzida | | Mob.Reduzida |
|---|---|---|---|
| | | | |
| na via/ ciclovia: | | na via/ ciclovia: | |

*Seniors: o vosso melhor julgamento - pessoa senior +65, reformada, sem viagens obrigatórias casa-trabalho*

*Mob.Reduzida: bengalas, apoios, canadianas, bebés/crianças em carrinhos, cadeiras de rodas, idosos em marcha lenta*

**Notas:**

***Hora Fim***

*hh / mm / ss*

Figure 3.11: Pedestrian count entry sheet, 2017

Simply put, the ideal number of counting locations is the whole of street segments in the study area. A more practical option is to define the sample size. However, in practice the number of counting locations depends on several factors, of which budget and counting method play a leading role. In the present study a manual counting method was used, permitting the observer to move around through various locations. Of course, if the observation periods are bind to 2h periods and if there is a minimum observation time required to deal with flow variability (say 5 minutes) and a displacement time of 1 minute, then a single observer will not be able to cover more than 20 count locations. If the counting period is extended to 10 minutes then 2 simultaneous observers would be needed to cover the same counting locations. Large teams of paid observers over a long observation period usually have budgetary implications.

Hence, critical decisions were made, starting with the counting period. Walking volumes have been shown to have high variance, where streets with low pedestrian flow (20 people/15 minutes) tend to show a standard error of more than 20% relative to the mean (Cambra *et al.*, 2017a). A pilot test was run in June 2016, prior to the first counting event (July 2016). Two street segments in Av.República were audited in three consecutive 5 minutes intervals. The results showed that in the Eixo Central area a 15 minute counting period was sufficient to bind the standard error to a 20% error.

A series of iterations was made in order to maximize the number of counting locations given the observations time. The calculation of total observation time considered a 2 minute displacement time between locations plus 2 minutes to conduct the observation of stationary pedestrians plus 1 minute of preparation for the flow count plus 15 minutes of observation, resulting in a total of 20 minutes per counting locations. Given the counting period of 90 minutes, a single observer would be able to audit 4 street segments.

Furhter iterations dealt with the number of segments to audit in the Eixo Central sections but also in the adjacent streets and in a control area. Importantly, the cost factor was also included in this analysis, as the observers ought to be recruited and paid. In order to analyse and control for daily variations in the pedestrian flow, the counting would take place in five consecutive week days plus a Saturday, from 8 a.m. to 6.30 p.m., which required a certain degree of availability from the observers. Moreover, the observers required training in order to assure inter-rater reliability thus constraining the participation of many observers for short periods. In other words, a team of fewer observers participating full time was preferred over a larger team of part-time observers. At the end, the availability of observers and budget constraints were more critical to decide over the sample of street segments to audit than the previous sampling procedure.

A team of 6 observers was formed for the first counting event, in 2016. This would allow auditing 24 locations (6 observers * 4 street segments per observer) simultaneously per time period, much in line with the recommendations from Vaughan & Grajewski (2001). Next, it was necessary to select the locations where to conduct the counts, covering not only the Eixo Central sections but also control locations. Several factors were considered for selecting the counting locations, namely:

- **Variability of the street environment:** A starting option was to randomly select the street segments. However this procedure could hinder the sample representativeness, as each street serves a particular function within its surrounding street network and urban context, and eventually exclude some street "types". In accordance to Vaughan & Grajewski (2001), a range of well-used, moderately-used and poorly-used locations should be considered in the pedestrian count. For this it a stratified sampling method was used, based on the findings of previous research (Cambra *et al.*, 2017b). This allowed to tentatively classify the study area streets into 4 distinct types, similarly to a functional hierarchical classification of the street network (i.e. main streets, secondary streets, local streets). In the specific case of the study area setting - Avenidas Novas - the street environment is rather similar. This area resulted from a planned urban intervention in the late 19th century. It is at present a mixed-uses area formed by medium rise buildings with a significant office occupation. The street design incorporated the French boulevard style, being characterized by a regular grid of large avenues with tree alignments in the medians. The individual street environment presented slight variability, as most physical elements could be found in repetition across and along each street. To attain variability the counting locations were to cover both sides of the Eixo Central streets, and to be as spatially distributed as possible;

- **Expectations before-after:** This factor dealt with the public communication and promotion of the project. A series of images containing a before-after comparison of various Eixo Central locations was published on the media and on outdoor signs. The images used real and recent pictures of the street environment side by side with computer generated images, creating a certain expectation on the result of the project. Some of these images are presented in Figure 3.12 (refer also to Figures 3.5, 3.6 and 3.7). It is interesting to note that most of the images suggested an increase in pedestrian activity - more people walking, more people sitting, more people meeting and socializing - although being not clear if this was purposeful or a marketing strategy. The locations that reflected the before-after expectations of the project were identified and considered central for the sample;

- **Existence of previous observations:** Given the scarcity of pedestrian count data for the city of Lisbon and given the time proximity of the pedestrian counts conducted for the IAAPE project, the possibility to build on the previous data was considered an opportunity for further research. Hence the locations in the Eixo Central area for which there was previous count data were also considered essential to include in the sample;

- **Proximity to transit:** The study area is served by subway and by train. In order to control for the attraction effect of the transit stations it was considered necessary to include segments that were close to main transit but also further away;

- **Highly correlated locations:** A series of pilot pedestrian counts was made in the Eixo Central and surrouding area in order to screen out highly correlated locations, namely contiguous segments of the same street;

- **Operational concerns:** Finally the potential locations were fine-tuned according to the number of available auditors and the operational concerns of the counting procedure, (e.g. displacement time between counting locations).

Regarding the control locations, two control groups were considered: one “adjacent group” consisting of neighbouring locations, i.e. parallel and perpendicular streets; and one “external group” consisting of street sections with comparable urban characteristics located in another neighbourhood. Such control areas should match the characteristics of the area where the intervention takes place, or, in practical terms, they should be at least “broadly comparable” as each area of a city is unique to some extent (Ogilvie *et al.*, 2006). Another necessary condition was that during the implementation of the Eixo Central project, no other environmental interventions would be occurring in the control locations.

The “adjacent” group comprised all parallel and crossing street segments, similar to a 150 m buffer around the Eixo Central. The “external” control area comprised two major streets (Av.Almirante Reis and R.Morais Soares) linked by a round plaza –Praça do Chile- with an average pedestrian volume similar to the one of Eixo Central. The nodes of the “external” area and of the Eixo Central area are located at a straight line distance of 900 m, which correspond to a walking distance of 1.2 km and 16 min (using Google Maps online routing service). The “external” area was considered to be sufficiently similar in terms of urban characteristics to the Eixo Central but also to be sufficiently far apart (other considered options included Rua Braamcamp/Rua Alexandre Herculano and Avenida de Roma/Avenida João XXI). Likewise the "adjacent" control area was considered to be comparable in terms of population and urban characteristics.


(a)


(b)

Figure 3.12: Expectations: Example of the Eixo Central project communication. (Source: Expresso online newspaper, 05/09/2015)

### 3.4.1 Count data collection

Prior to the counts it was necessary to recruit and train the observers. The recruitment was made from "word of mouth" from fellow researchers to their connections. The training comprised a briefing session (1 hour) in a classroom from Técnico Lisboa followed by a on-site pilot count using the paper entry sheet (refer to Figures 3.10 and 3.11) made by all team members simultaneously. A number of repeated counts was usually necessary until the results from the observers met adequate similarity. A file containing the schedule, the map area and detailed maps of each counting section was provided as well as a number of paper copies of the entry sheet. Each observer would perform 20 counts per day for five days plus a Saturday, which required around 140 entry sheets.

An online digital entry sheet was created on a Google Drive ™ platform allowing for the recruited observers to upload their individual count data. They were requested to upload their data daily and to deliver the paper entry sheets upon completion of the counting event. A quality control was later performed by randomly selecting entry sheets and compare the tallied values on paper with the uploaded values.

The observers were paid (for the record, the event of counting pedestrians in 24 locations over a week had an associated cost of around 4.000€), which required additional funding. The Mobility Observatory of the Portuguese Auto Club (Automóvel Clube Português - ACP) kindly agreed to fund the pedestrian counts at baseline (2016). Follow-up counts were kindly supported by the Municipality of Lisbon.

The pedestrian count at baseline took place in the first week of July, from Monday to Friday, between the 4th and the July 8, 2016. The pedestrian count at follow-up took place one year after, between the 3rd and 7th July. Weather conditions were stable and similar in both occasions, consistent of Mediterranean summer: mostly warm (mean average daily temperature = 20 °C; SD = 1.78 °C), dry and sunny days. The choice of July was "imposed" by the sudden beginning of the construction work. There are some implications relating to performing the pedestrian counts in this time of the year. First, it is a month of school and summer holidays - many residents go out of Lisbon on holiday on this time of the year. The pedestrian counts do not therefore relate to a "typical" day. Second, high temperatures may prevent some people of walking, although the literature points for only a moderate variation in walking due to weather related factors (Zhao *et al.*, 2019). Third, the demand of tourists and visitors grows during summer months in Lisbon and a number of hotels is located in the Eixo Central area.

In 2017 the follow up pedestrian count was set up. It followed the methodology used for the baseline counts but certain adaptations were needed. These were due to budgetary constraints and to lack of interested participants, which limited the size of the observer team from 6 to 4 elements. Recalling that an observer would be able to audit 4 segments per 1h30 counting period, this would result in auditing 16 of the 24 initial locations. In order to retain as much comparable data as possible, the sizing and location of the audited segments was reviewed, namely by reducing the observation time from 15 minutes to 10 minutes and by screening contiguous audited segments for high correlation in pedestrian flow. This way, a single observer would be able to audit 5 segments within the 1h30 counting period, resulting in a total of 20 segments for a team of 4 observers (see Annex 2). The 4 street segments to be discontinued from the audit were one of two contiguous segment with high correlation.

Each counting location was observed for 5 consecutive working days, at 5 counting periods: 1) Morning peak period – 8:00 to 9:30 am; 2) Morning off-peak – 10:00 to 11:30 am; 3) Lunch peak period – 12:30 to 14:00 pm; 4) Afternoon off-peak – 15:00 to 16:30 pm and 5) Afternoon peak period – 17:00 to 18:30 pm. Counts were also performed Saturday for 2 counting periods: morning off-peak (10:00-11:30 am) and lunch peak (12:30 to 14:00 pm). Given the area´s functional characteristics, comparable to a central business district, only the work day flows were used in the analysis. The duration of the counting was determined by the pedestrian flow characteristics, where a period of 10 minutes was found to provide stable observations (Cambra *et al.*, 2017a).

The average values for each daily period for each location were used in the statistical analysis, yielding a total of 100 observations (20 locations; 5 time periods). The pedestrian count at baseline took place in the first week of July, from Monday to Friday, between the 4th and the 8th July 2016. The pedestrian count at follow-up took place one year after, between the 3rd and 7th July. Weather conditions were stable and similar in both occasions, consistent of Mediterranean summer: mostly warm (mean average daily temperature =20ºC; SD= 1.78ºC), dry and sunny days. The observed pedestrian flows (pedestrians/10 minutes) were converted to an hourly estimation of pedestrian volumes (pedestrians/hour) using the average flow per counting period (Hillier & Iida, 2005). Hence the 25 observed flows per location (5 days, 5 periods) resulted in 5 estimations of pedestrian volume -hourly average of each counting period during the week- per location. The rounded hourly average volumes were then used in the before-after analysis.

The results from the pedestrian counts are summarised as follows: Figure 3.13 shows the location of the pedestrian counts; Tables 3.4 and 3.5 show the mean pedestrian flow per 10 minutes per location and per counting period; the daily average of the pedestrian flow was mapped out in Figure 3.14 and 3.15. The variety of demand curves plotting the

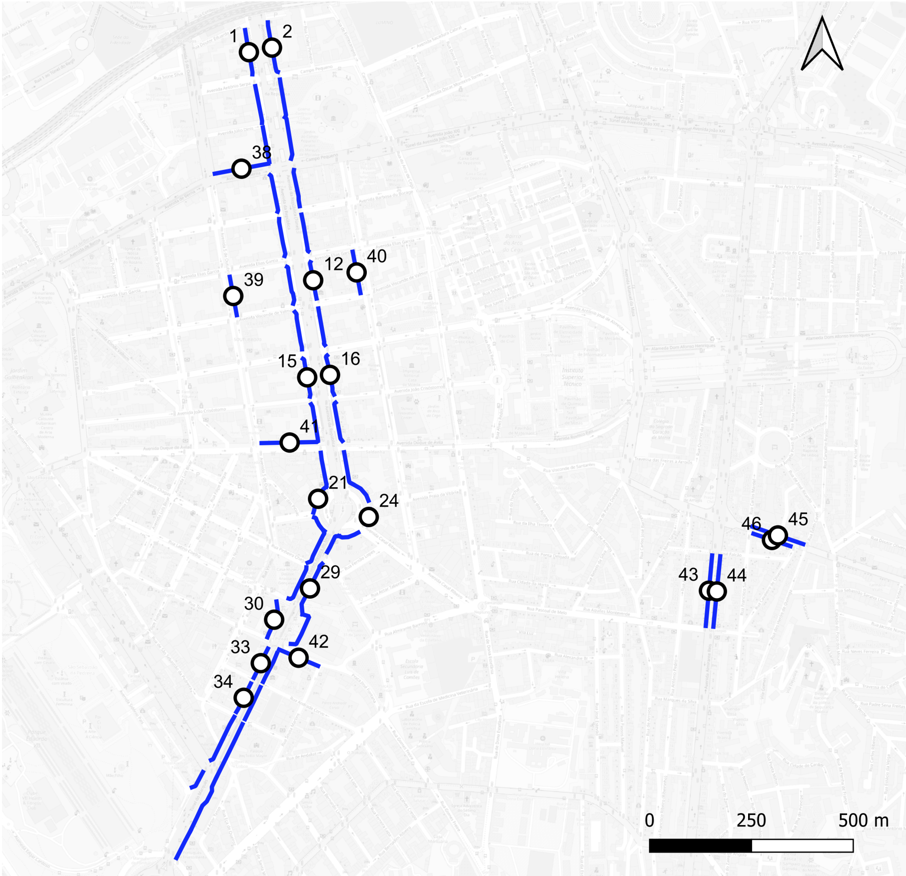



Figure 3.13: Pedestrian count locations

pedestrian flow per time period can be observed in Figure 3.20. In a similar approach, Tables 3.6 and 3.7 show the mean count of sojourning pedestrians per location and per counting period; which is mapped out in Figures 3.16 and 3.17. Figures 3.18 and 3.19 distinguish between observed sojourning activities in 2016 and 2017.

The mapped pedestrian flows show that some of the highest volumes were observed on the north side (locations n.1 and n.2), close to the railway line, where Entrecampos train station is located. The highest pedestrian volume in the Eixo Area was observed in Saldanha (location n.24) consistently in 2016 and 2017. However in 2016 the busiest sidewalks of all studied area were located in the External control streets, in Rua Morais Soares (location n.46). Regarding sojourning pedestrians, the majority of observed still people in the streets were standing up in most locations. The exception to this was found in the adjacent area, where more than 50% of the stationary people were sitting. This was notable in Av. Duque de Ávila (location n.41) and R. Tomás Ribeiro (location n.42) which host a considerable number of esplanades that were in high demand during the warm days of July when the counting was performed. In general terms a higher number of stationary people was observed in the external and adjacent streets in comparison

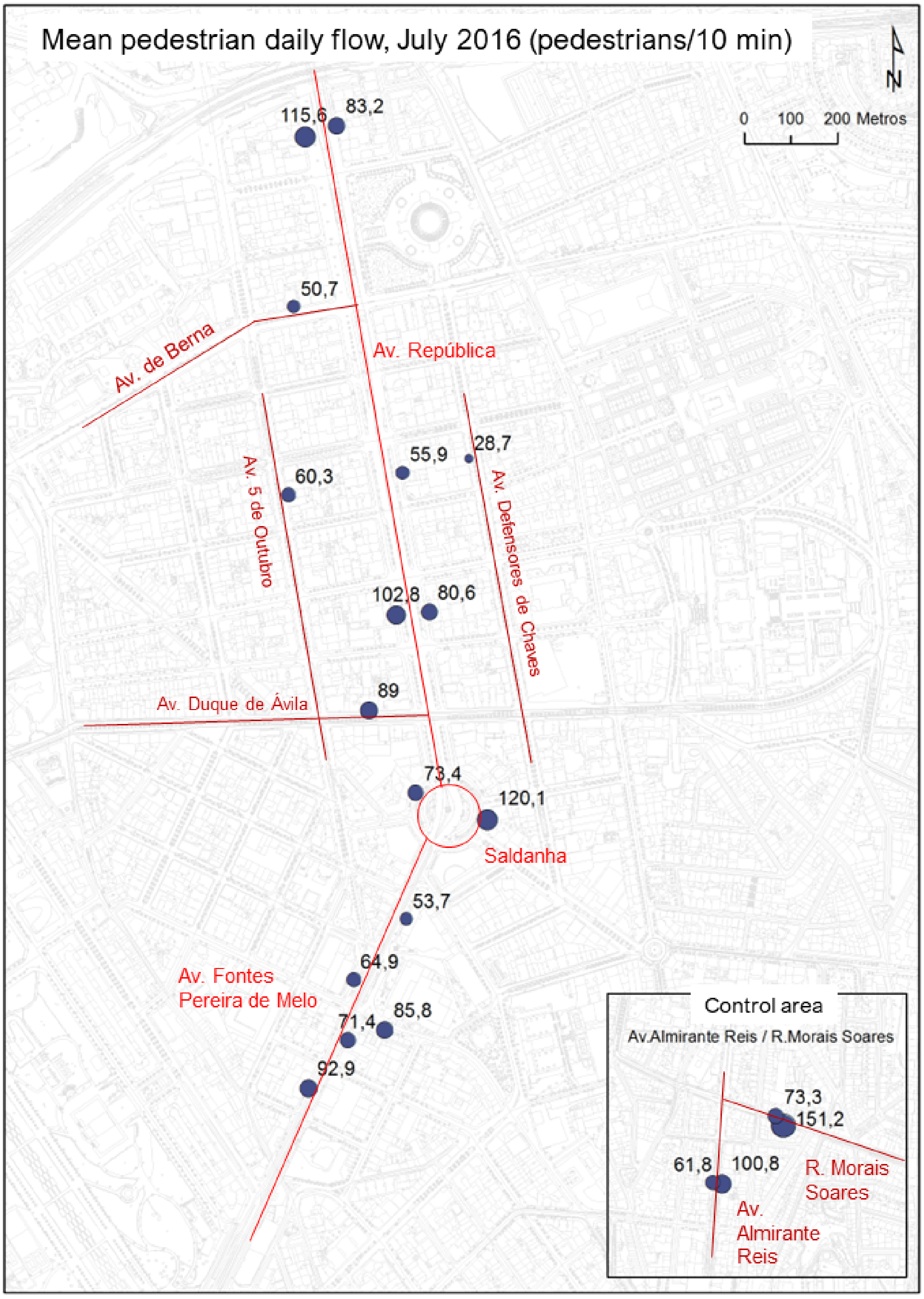



Figure 3.14: Pedestrian Flow, 2016

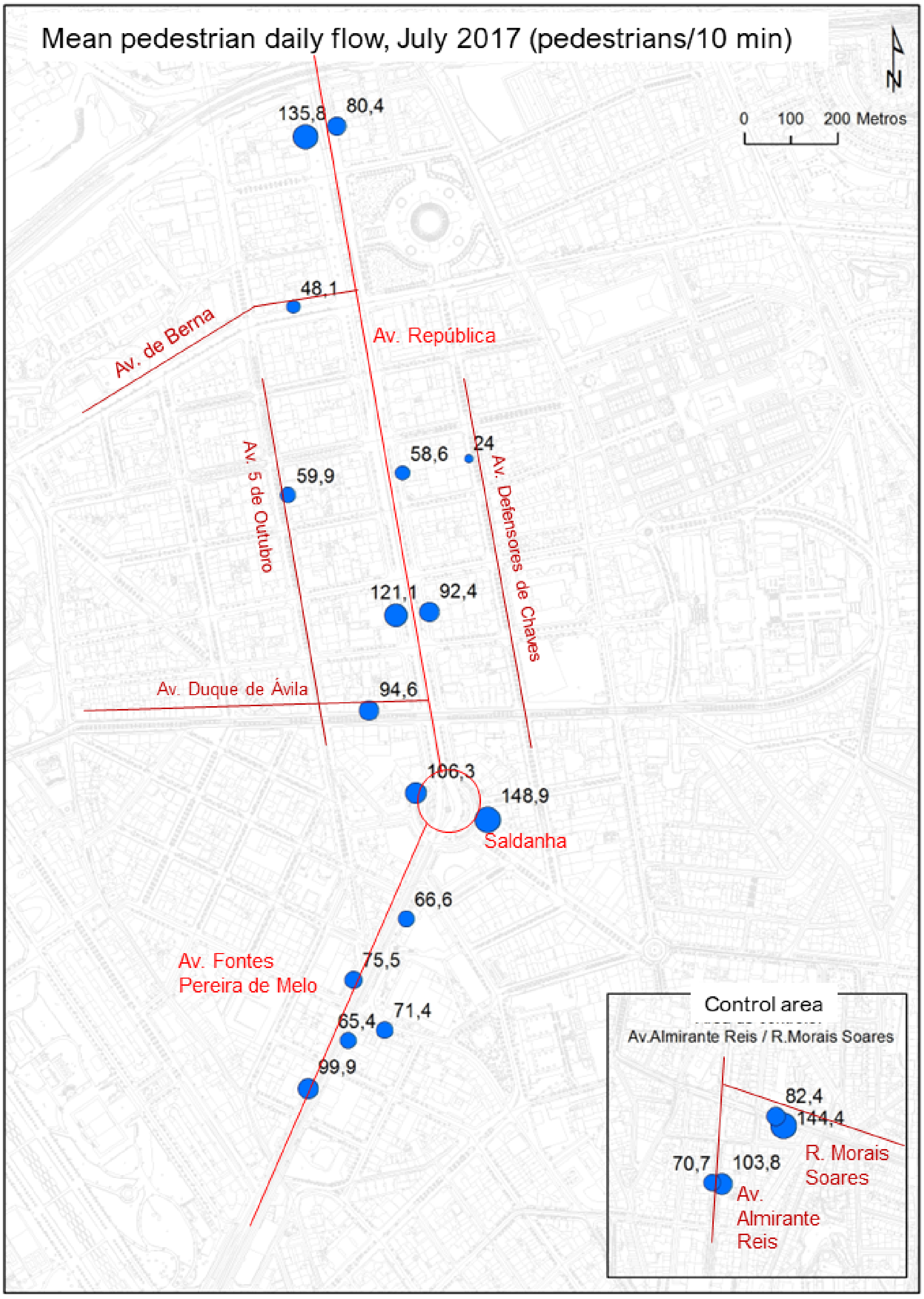



Figure 3.15: Pedestrian Flow, 2017

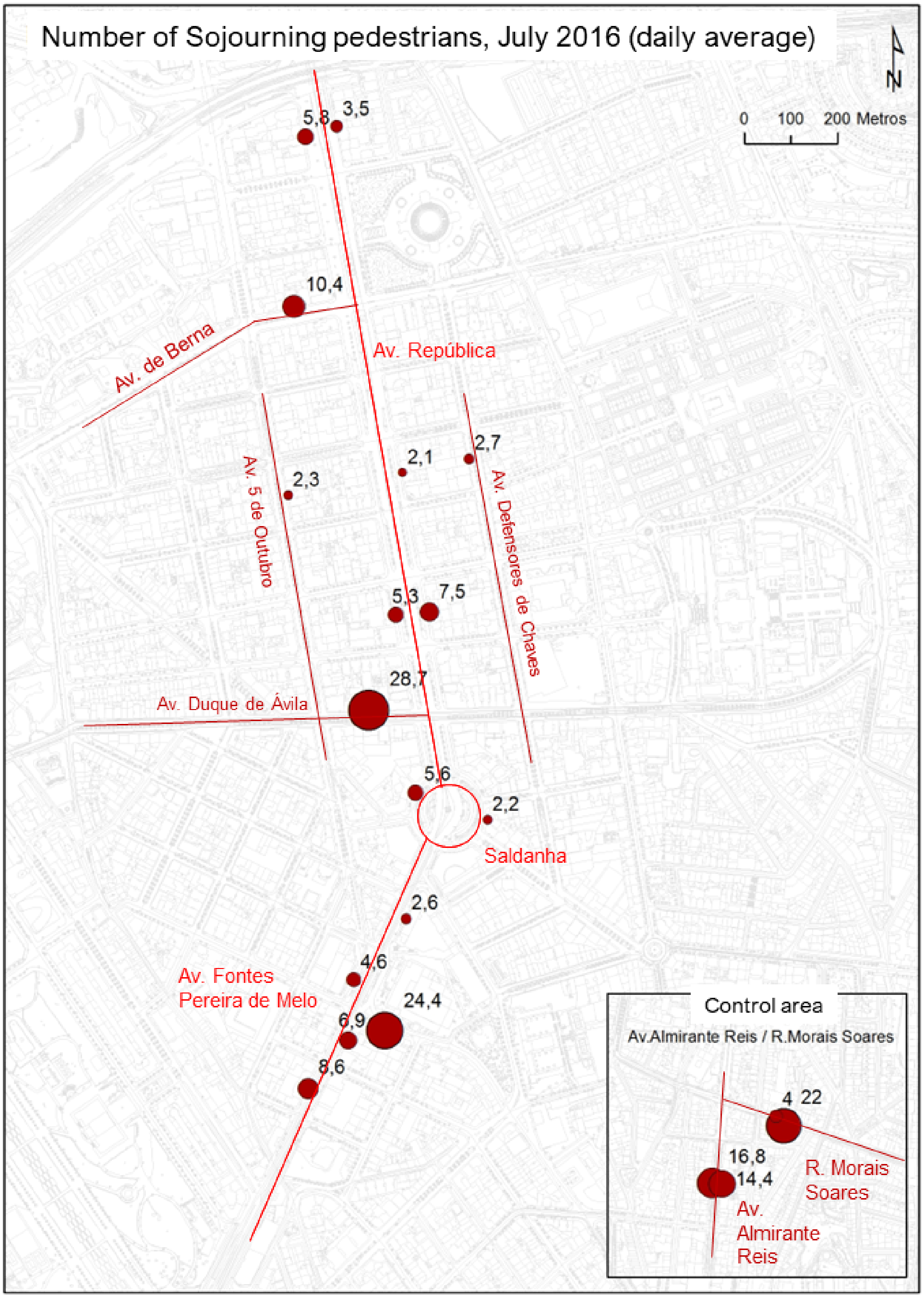



Figure 3.16: Sojourning pedestrians, 2016

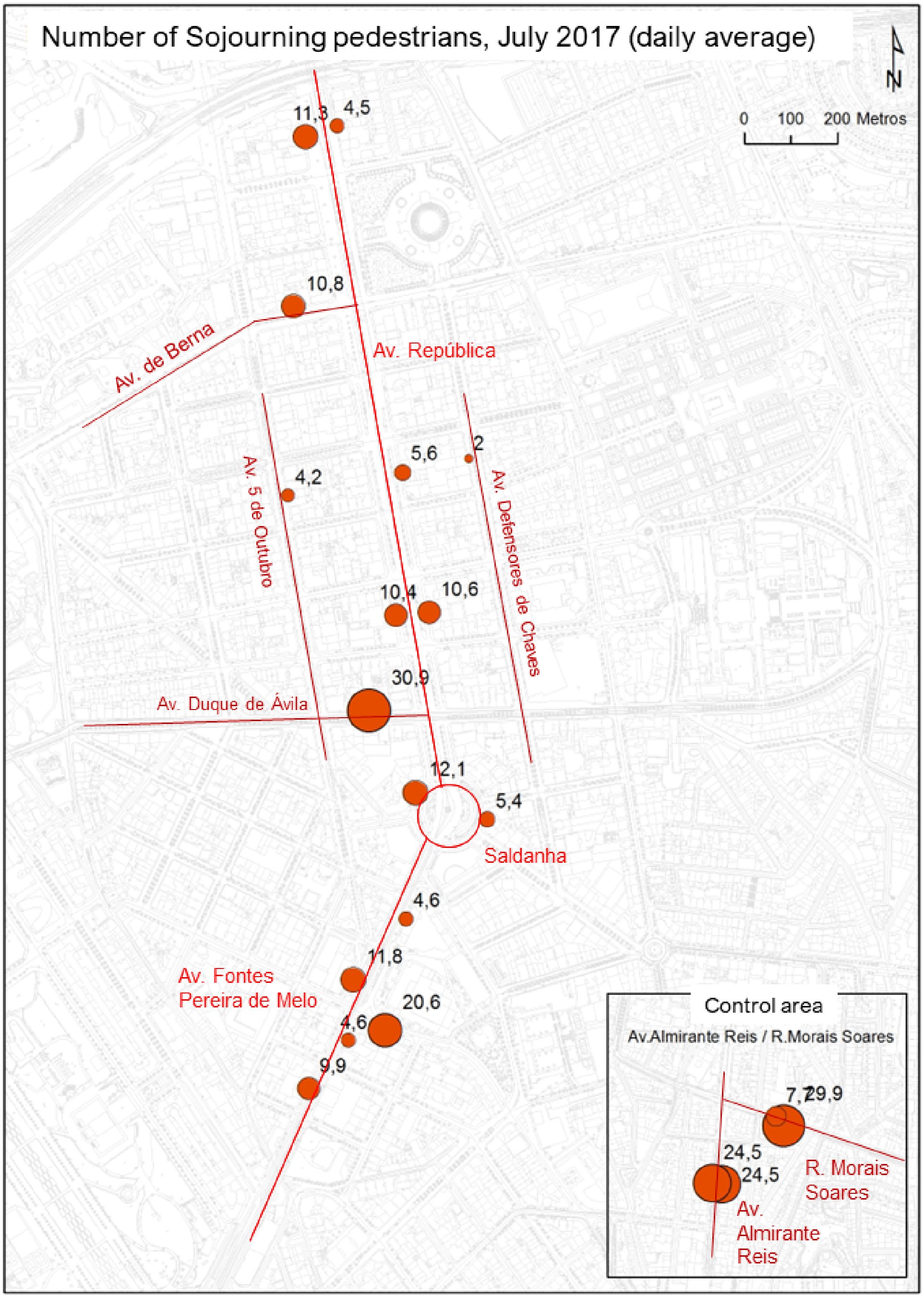



Figure 3.17: Sojourning pedestrians, 2017

Table 3.4: Pedestrian Flow 2016, average per 10 minutes and counting period

| Section | Counting Location | P1 (08h-09h30) | P2 (10h-11h30) | P3 (12h30-14h00) | P4 (15h-16h30) | P5 (17h-18h30) | Mean | *SD* |
|---|---|---|---|---|---|---|---|---|
| Eixo 1: Av. Republica | 1 | 162 | 77 | 103 | 94 | 151 | 117 | *37.1* |
| | 2 | 128 | 48 | 89 | 47 | 105 | 84 | *35.4* |
| | 12 | 64 | 51 | 69 | 37 | 56 | 56 | *12.6* |
| | 15 | 116 | 73 | 120 | 81 | 124 | 103 | *24.0* |
| | 16 | 88 | 62 | 111 | 48 | 93 | 81 | *25.3* |
| Eixo 2: Saldanha | 21 | 61 | 54 | 106 | 69 | 77 | 74 | *19.9* |
| | 24 | 134 | 87 | 159 | 81 | 139 | 120 | *34.1* |
| Eixo 3: Av. Fontes P. Melo | 29 | 43 | 41 | 112 | 36 | 37 | 54 | *32.6* |
| | 30 | 42 | 61 | 76 | 66 | 79 | 65 | *15.0* |
| | 33 | 60 | 71 | 111 | 49 | 65 | 71 | *23.5* |
| | 34 | 92 | 82 | 115 | 81 | 94 | 93 | *13.6* |
| Control 4: Adjacent streets | 38 | 47 | 41 | 54 | 38 | 73 | 51 | *14.0* |
| | 39 | 65 | 55 | 74 | 40 | 64 | 60 | *12.8* |
| | 40 | 16 | 20 | 34 | 35 | 44 | 30 | *11.4* |
| | 41 | 91 | 71 | 143 | 60 | 81 | 89 | *32.3* |
| | 42 | 88 | 76 | 118 | 65 | 81 | 86 | *19.9* |
| Control 5: External area | 43 | 51 | 56 | 54 | 67 | 81 | 62 | *12.2* |
| | 44 | 65 | 119 | 115 | 87 | 125 | 102 | *25.5* |
| | 45 | 89 | 86 | 59 | 55 | 77 | 73 | *15.5* |
| | 46 | 129 | 139 | 156 | 138 | 194 | 151 | *25.9* |

Table 3.5: Pedestrian Flow 2017, average per 10 minutes and counting period

| Section | Counting Location | P1 (08h-09h30) | P2 (10h-11h30) | P3 (12h30-14h00) | P4 (15h-16h30) | P5 (17h-18h30) | Mean | *SD* |
|---|---|---|---|---|---|---|---|---|
| Eixo 1: Av. Republica | 1 | 191 | 73 | 122 | 112 | 181 | 136 | *49.7* |
| | 2 | 104 | 53 | 94 | 47 | 104 | 80 | *28.3* |
| | 12 | 69 | 59 | 73 | 39 | 53 | 59 | *13.5* |
| | 15 | 142 | 89 | 146 | 96 | 131 | 121 | *26.6* |
| | 16 | 120 | 74 | 121 | 66 | 83 | 93 | *25.9* |
| Eixo 2: Saldanha | 21 | 64 | 91 | 144 | 108 | 114 | 104 | *29.4* |
| | 24 | 111 | 118 | 190 | 124 | 202 | 149 | *43.4* |
| Eixo 3: Av. Fontes P. Melo | 29 | 42 | 49 | 142 | 39 | 62 | 67 | *42.8* |
| | 30 | 76 | 69 | 93 | 65 | 74 | 76 | *10.8* |
| | 33 | 65 | 56 | 99 | 40 | 68 | 65 | *21.6* |
| | 34 | 88 | 94 | 125 | 99 | 93 | 100 | *14.4* |
| Control 4: Adjacent streets | 38 | 64 | 29 | 53 | 33 | 62 | 48 | *16.4* |
| | 39 | 50 | 60 | 77 | 35 | 77 | 60 | *17.9* |
| | 40 | 20 | 16 | 30 | 28 | 26 | 24 | *5.9* |
| | 41 | 95 | 77 | 127 | 74 | 97 | 94 | *21.3* |
| | 42 | 83 | 62 | 83 | 51 | 78 | 71 | *14.1* |
| Control 5: External area | 43 | 48 | 62 | 67 | 83 | 95 | 71 | *18.3* |
| | 44 | 82 | 127 | 107 | 88 | 115 | 104 | *18.8* |
| | 45 | 100 | 88 | 65 | 65 | 94 | 82 | *16.2* |
| | 46 | 105 | 138 | 134 | 139 | 206 | 144 | *37.0* |

to the Eixo Central streets. In the external area most stationary people were standing, socializing in spontaneous encounters and only a few were sitting as there were no benches nor esplanades in the observed segments of R. Morais Soares or Av. Almirante Reis.

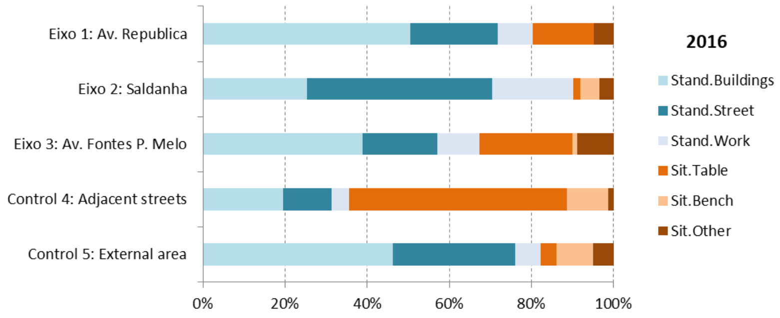



Figure 3.18: Share of pedestrian sojourning activites, 2016

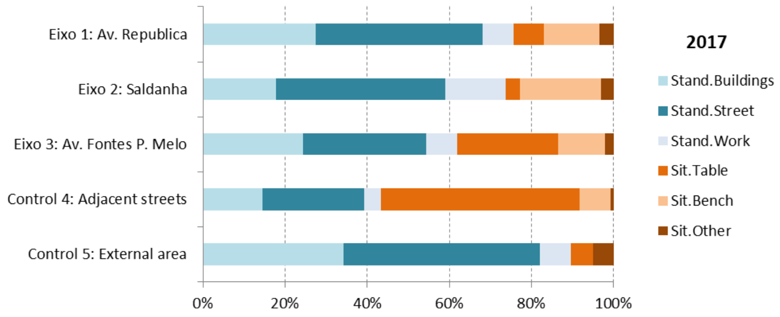



Figure 3.19: Share of pedestrian sojourning activites, 2017

Figure 3.20 depicts a very interesting variety of walking patterns. A first evident finding is that each street appears to have its own pattern which is maintained over time (2016 in blue colour, 2017 in red colour) sometimes with great accuracy (as in Figure 3.20 b)) . Another finding is that some patterns seem to be more unique than others. One of the classic patterns in traffic engineering studies is the "W" shape (as in Figure 3.20 a), b) and l)) associated to commuting - a high concentration of trips during the morning peak period and during the afternoon with a reduced number of trips during the day. A variation of the "W" can occur with a high number of lunch-time trips, suggesting a mid-day peak (as in Figure 3.20 d). It is interesting to notice that the classic "W" shape of motorized commuting is not the most frequent when dealing with pedestrian movement. In the analysed streets the lunch-time peak in pedestrian activity is notorious, either in terms of movement (see for instance Figure 3.20 h), j) and o)) and in terms of sojourning (see Tables 3.6 and 3.7).

Considering that a concentration of trips during the morning and afternoon peak periods can be associated to a more utilitarian travel motivation (such as going to work or school) and that a distribution of trips in other periods of the day can be associated to other motivations more recreational or leisure oriented (e.g. shopping, meeting people) then it is possible to estimate the utilitarian/recreational character of each street segment from


Figure 3.20: Pedestrian flow street specific shapes: average flow per period, week days

Table 3.6: Pedestrian Sojourning 2016, standing and sitting, average per counting period

| Section | Counting Location | P1 (08h-09h30) | P2 (10h-11h30) | P3 (12h30-14h00) | P4 (15h-16h30) | P5 (17h-18h30) | Mean | *SD* |
|---|---|---|---|---|---|---|---|---|
| Eixo 1: Av. Republica | 1 | 9 | 5 | 5 | 6 | 5 | 6 | *1.5* |
| | 2 | 4 | 5 | 5 | 2 | 1 | 3 | *1.7* |
| | 12 | 2 | 3 | 4 | 0 | 0 | 2 | *1.9* |
| | 15 | 3 | 3 | 6 | 6 | 5 | 5 | *1.5* |
| | 16 | 5 | 6 | 18 | 4 | 3 | 7 | *6.0* |
| Eixo 2: Saldanha | 21 | 7 | 5 | 2 | 5 | 7 | 5 | *1.7* |
| | 24 | 1 | 3 | 3 | 2 | 1 | 2 | *1.1* |
| Eixo 3: Av. Fontes P. Melo | 29 | 1 | 2 | 3 | 4 | 3 | 3 | *0.9* |
| | 30 | 4 | 4 | 6 | 3 | 6 | 5 | *1.2* |
| | 33 | 8 | 4 | 5 | 3 | 4 | 5 | *1.7* |
| | 34 | 9 | 9 | 14 | 5 | 6 | 8 | *3.5* |
| Control 4: Adjacent streets | 38 | 4 | 3 | 4 | 3 | 3 | 3 | *0.6* |
| | 39 | 2 | 1 | 5 | 2 | 2 | 2 | *1.4* |
| | 40 | 1 | 2 | 5 | 4 | 2 | 3 | *1.6* |
| | 41 | 9 | 12 | 65 | 31 | 24 | 28 | *22.4* |
| | 42 | 15 | 22 | 42 | 22 | 21 | 24 | *10.1* |
| Control 5: External area | 43 | 12 | 17 | 14 | 12 | 16 | 14 | *2.3* |
| | 44 | 7 | 20 | 17 | 12 | 12 | 13 | *5.3* |
| | 45 | 3 | 3 | 4 | 1 | 3 | 3 | *0.9* |
| | 46 | 10 | 15 | 12 | 10 | 13 | 12 | *2.2* |

Table 3.7: Pedestrian Sojourning 2017, standing and sitting, average per counting period

| Section | Counting Location | P1 (08h-09h30) | P2 (10h-11h30) | P3 (12h30-14h00) | P4 (15h-16h30) | P5 (17h-18h30) | Mean | *SD* |
|---|---|---|---|---|---|---|---|---|
| Eixo 1: Av. Republica | 1 | 8 | 6 | 9 | 15 | 9 | 10 | *3.4* |
| | 2 | 4 | 5 | 8 | 3 | 1 | 4 | *2.6* |
| | 12 | 5 | 5 | 4 | 2 | 2 | 4 | *1.6* |
| | 15 | 11 | 11 | 18 | 8 | 5 | 10 | *4.7* |
| | 16 | 15 | 10 | 19 | 5 | 5 | 11 | *6.0* |
| Eixo 2: Saldanha | 21 | 8 | 13 | 11 | 12 | 14 | 12 | *2.2* |
| | 24 | 7 | 8 | 7 | 3 | 1 | 5 | *2.9* |
| Eixo 3: Av. Fontes P. Melo | 29 | 6 | 5 | 11 | 1 | 1 | 5 | *3.9* |
| | 30 | 4 | 11 | 6 | 3 | 9 | 7 | *3.3* |
| | 33 | 3 | 4 | 11 | 2 | 2 | 5 | *3.6* |
| | 34 | 3 | 14 | 16 | 6 | 10 | 10 | *5.3* |
| Control 4: Adjacent streets | 38 | 2 | 5 | 7 | 2 | 2 | 3 | *2.1* |
| | 39 | 4 | 7 | 7 | 1 | 2 | 4 | *2.7* |
| | 40 | 2 | 2 | 4 | 1 | 0 | 2 | *1.5* |
| | 41 | 16 | 24 | 52 | 29 | 29 | 30 | *13.2* |
| | 42 | 18 | 17 | 37 | 12 | 17 | 20 | *9.9* |
| Control 5: External area | 43 | 22 | 29 | 19 | 21 | 14 | 21 | *5.5* |
| | 44 | 24 | 31 | 27 | 13 | 8 | 21 | *9.4* |
| | 45 | 5 | 7 | 3 | 1 | 3 | 4 | *2.2* |
| | 46 | 7 | 23 | 16 | 8 | 8 | 12 | *6.9* |

the pedestrian point of view. For instance, the patterns of the counting locations 43, 44, 45 and 46 (Figure 3.20 q), r), s) and t)) which refer to the external control area - Av.Almirante Reis and Av.Morais Soares - suggest a concentration of people in the afternoon peak which can be explained by daily shopping in the local commerce.

Further research could enrich the understanding of pedestrian activity within the street network. The analysis of pedestrian movement and sojourning from the adopted pedestrian count methodology could further inform street design and management. One example in practice is the Street Types Matrix, proposed by Transport for London's Roads Task Force with the objective of classifying streets according to their movement and place functions (e.g. High Street, City Street, Local Street, etc) (Force, 2015). This outlook points to a shift from a more traditional network efficiency model where streets are regarded as movement corridors that facilitate the passing of traffic to a more user centric model in which streets are viewed as places of complex social and economic exchange besides a corridor for movement (Carmona *et al.*, 2018).

Lastly, table 3.8 shows the composition of the pedestrian flow in terms of main pedestrian groups. As observed, adults form 90% of the observed pedestrian composition in Eixo Central. The adult specification for the walkability analysis and the age group representativeness in the survey could therefore be considered appropriate.

Table 3.8: Pedestrian flow composition 2017: observed number of adults, senior and pedestrians with mobility impairments

| Section | Counting Location | Adults (n) | Seniors (n) | Mobility impaired (n) | Total (n) | Adults (%) | Seniors (%) | Mobility impaired(%) |
|---|---|---|---|---|---|---|---|---|
| Eixo 1: Av. Republica | 1 | 3396 | 228 | 21 | 3645 | 93.2% | 6.3% | 0.6% |
| | 2 | 2009 | 102 | 7 | 2118 | 94.9% | 4.8% | 0.3% |
| | 12 | 1465 | 103 | 12 | 1580 | 92.7% | 6.5% | 0.8% |
| | 15 | 2786 | 244 | 27 | 3057 | 91.1% | 8.0% | 0.9% |
| | 16 | 2125 | 210 | 11 | 2346 | 90.6% | 9.0% | 0.5% |
| Eixo 2: Saldanha | 21 | 2444 | 241 | 22 | 2707 | 90.3% | 8.9% | 0.8% |
| | 24 | 3722 | 277 | 24 | 4023 | 92.5% | 6.9% | 0.6% |
| Eixo 3: Av. Fontes P. Melo | 29 | 1666 | 112 | 7 | 1785 | 93.3% | 6.3% | 0.4% |
| | 30 | 1888 | 150 | 18 | 2056 | 91.8% | 7.3% | 0.9% |
| | 33 | 1635 | 134 | 6 | 1775 | 92.1% | 7.5% | 0.3% |
| | 34 | 2398 | 202 | 20 | 2620 | 91.5% | 7.7% | 0.8% |
| Control 4: Adjacent streets | 38 | 1202 | 74 | 11 | 1287 | 93.4% | 5.7% | 0.9% |
| | 39 | 1378 | 100 | 10 | 1488 | 92.6% | 6.7% | 0.7% |
| | 40 | 600 | 53 | 5 | 658 | 91.2% | 8.1% | 0.8% |
| | 41 | 2175 | 227 | 20 | 2422 | 89.8% | 9.4% | 0.8% |
| | 42 | 1786 | 153 | 13 | 1952 | 91.5% | 7.8% | 0.7% |
| Control 5: External area | 43 | 1768 | 309 | 22 | 2099 | 84.2% | 14.7% | 1.0% |
| | 44 | 2595 | 450 | 36 | 3081 | 84.2% | 14.6% | 1.2% |
| | 45 | 2060 | 366 | 38 | 2464 | 83.6% | 14.9% | 1.5% |
| | 46 | 3611 | 545 | 39 | 4195 | 86.1% | 13.0% | 0.9% |

All in all, in the Eixo Central case study the observation of pedestrian flows and sojourning pedestrians revealed a mismatch between demand and supply, or at least a inconsistent level-of-service delivered to the actual demand. Several observations support this statement: 1) the corridor (considering both sides of the street) with the highest pedestrian flow was located in R.Morais Soares which shows a relative low walkability and, to the best of our knowledge, no plans for improvement of the pedestrian environment; 2) likewise, the Eixo Central intervention provided more amenities and opportunities for people to sit despite having no evident demand whereas in R. Morais Soares and Av. Almirante Reis a high number of sojourning people (namely seniors) was observed but no sitting facilities existed to provide for them; and 3) even in the Eixo Central sections, the corridor with the highest pedestrian volume was related to the Entrecampos train station, which was just outside the intervention area. That is to say, the most notorious pedestrian activity generator and its nearest links were not included in the project to improve pedestrian conditions.

These findings highlight the benefits of data-driven decision support, where urban planners and policy makers can be informed by real world data analysis in order to assist and improve environmental interventions or management operations (Xie & Wang, 2018). Of course, data-driven decision support does not rely only in big data and extensive counting. As referred in Gehl *et al.* (2013), a comprehensive toolbox of methods to observe pedestrians can be used, ranging from simple counting to more complex tracking, tracing and mapping individual activities through time and space. To conclude, more consideration should be given to the approach **to observe - to understand - to act** .

## 3.5 Pedestrian survey

A pedestrian survey was developed on order to collect additional data regarding walking behaviour. The survey had several goals: first, to capture two main variables of interest for the study - walking experience before and after and changes in walking frequency for different travel purposes; second, to collect the necessary data to test the proposed conceptual relations; and third, to obtain a general characterization of the population walking behaviour (e.g. number of walking trips, walking distances, preferences).

Regarding the latter, and similarly to the case of pedestrian count data, only little information on walking behaviour existed at the time. The main variable systematically collected at national level was the modal share of walking trips for work or study, which only considered trips done exclusively on foot, and was only collected every 10 years by the National Census.

The target population of the survey were the users of the Eixo Central area, although responses from the "external" population were also collected for the purpose of characterization of general walking behaviour. The users of the Eixo Central area included residents, workers, students and visitors. Various related studies have used household surveys (e.g. Keall *et al.* 2015), travel diaries (e.g. Panter & Ogilvie 2017) or telephone questionnaires (e.g. Evenson *et al.* 2005), which are mainly directed at residents of the studied area, overlooking workers and visitors. Another approach is the use of intercept surveys, inquiring pedestrians passing by (e.g. Jung *et al.* 2017), which covers all users. A drawback of this approach is the associated cost of performing the survey if a large sample is desired. In order to obtain a cost-effective data collection, the survey followed a online format, using the Google Forms ™ platform.

The survey structure was formed by 9 question blocks in accordance to the conceptual model, as presented in Figure 3.21:

1. Effect (behaviour change) block: this block addressed the self reported change in walking trips for different purposes (utilitarian; recreation; public transportation; exercise; route change). A 5 point ordinal scale was used (1. a lot less; 2. a bit less; 3. the same; 4. a bit more; 5. a lot more) for the responses;

2. Walking experience block: addressed the before-and-after walking experience of the Eixo Central users. People were asked to rate their walking experience in a Likert type item using a 9 point scale, assuming equidistant rating intervals. The lowest score, 1, represented an unpleasant experience, i.e., a street to avoid. Conversely, a

score of 9 represented a very pleasant walk;

3. Exposure block: addressed the proximity of the person to the intervention site. This was done by asking the location of residence and workplace;

4. Perceptions: addressed how the users of the area evaluated the change in various environmental factors related to walkability (pedestrian space; pavement comfort; greenery; sidewalk obstacles; crossing safety; crossing opportunities; land use mix; sidewalk accessibility; meeting points; and amenities). A 5 point ordinal scale was used to rate the perception of environmental change (1. significant change, is worse now; 2. slight change, is worse now; 3. the same; 4. slight change, is better now; 5. significant change, is better now);

5. Preferences block: addressed general walking preferences by asking which factors from a defined list were considered to have a positive influence on the person's walking experience and which were considered to have a negative influence;

6. Attitudes block: addressed attitudes towards active travel by means of 5 attitudinal questions relating to a preference for active travel (and allocated space for it) or for motorized modes (and allocated space for it). The attitudes were collected in a Likert-type scale with 5 levels of agreement, varying from "1)totally disagree" to "5)totally agree", having a "3)neutral" mid-scale classification;

7. Life changing events block: addressed if significant routine changing events had taken place. People were asked to indicate all of the events experienced within the past year time frame related to relocation (residential, work or school), retirement, parenthood or injury;

8. Travel patterns block: addressed the characterization of travel behaviour, accounting for several general variables (main transport mode, number of trips made on the previous day, average duration of daily commute) and also walking specific variables (number of walking trips done the previous day, considered feasible walking distance);

9. Socio-Demographic block: dealing with the person's characteristics, collecting standard data such as age, gender, education and occupation.

The survey questions were elaborated in Portuguese language. Prior to the launch a pilot survey was conducted to test if the questions were clear and to correct eventual faults. The pilot survey was presented to fellow researchers and students from the U-Shift research group [3]. The survey was then formatted as a web form, compatible with smartphone

[3] https://ushift.tecnico.ulisboa.pt

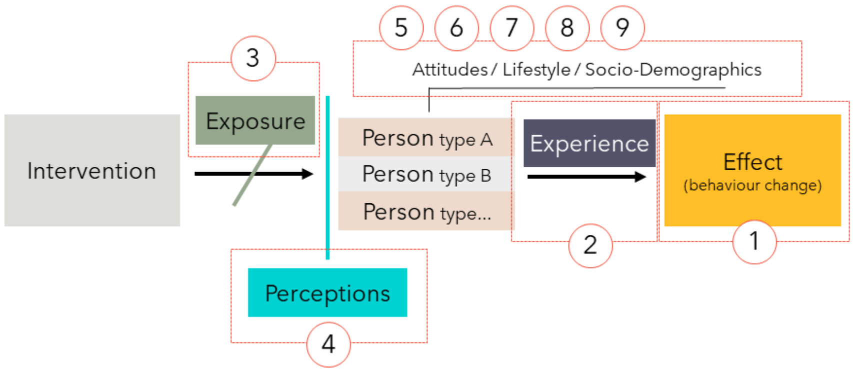



Figure 3.21: Survey question blocks

use. Finally, the survey was submitted for appreciation and approved by the Board of Administration of Instituto Superior Tecnico.

### 3.5.1 Survey data collection

The online survey was launched at the end of autumn 2017, allowing an experimental period of 6 months after the official inauguration/opening of the retrofitted Eixo Central but before harsher weather conditions that could bias the experience rating. In order to reach the target population of residents, workers and visitors of the Eixo Central, several local entities were asked to spread the survey through their mailing lists. These included major company offices, two universities located in the area, local governments, residents associations and social network forums dedicated to the discussion of local urban issues. Of these, Técnico Lisboa, ISCAL (Instituto Superior de Contabilidade e Administração de Lisboa), ACAM (Associação dos Cidadãos Auto-Mobilizados) and Forum Cidadania LX (a social network discussion group) were found to be the main referrals. All survey respondents were required to grant permission to the use of their data for academic purposes, being warranted anonymity. The survey can be found in Annex 4.

A population sample check was performed when the online survey reached 1.000 responses. This revealed a sub-representation of the senior population group (probably related to the use of an online survey). An additional dissemination strategy was then implemented: target advertisements were signed up with the Facebook ™ platform; the parish of Avenidas Novas was asked to help in conducting paper based surveys in senior facilities; and acquaintances were asked to pass the survey to their senior relatives.

The survey data collection ended in March 2018, totalling 1400 responses. A summary of the survey data is presented in Table 3.9. The survey sample was mainly composed of adult respondents with higher education, mostly workers and visitors. The sample is representative of the users of this city area, being a prime office location, hosting two tertiary education campuses and also being a high-end residential location. However, the senior population was under-represented in the survey, probably relating to the use of a web-based survey.

#### Walking behavior characterization

The results from the survey allowed to characterize the walking behaviour of the sampled population to a broader level than the available datasets in Portugal, presented in Table 3.10. Although there is a lack of standardized travel survey data to allow international comparisons (Bassett *et al.*, 2008), walking behaviour data was collected from the literature for the purpose of benchmarking, as presented in Table 3.11.

In brief, people in Lisbon like to walk. Only 7% of the surveyed population reported not to like walking. Most people are willing to walk up to 30 minutes (86%), but the majority only considers walking up to 20 minutes (59%). In practice, the mean trip duration was 36 minutes (median=30.0) but only a part of it was done walking - 12,8 minutes in average with a median value of 10 minutes. The part of the journey done walking was very significant - almost half of the trip duration in average values (43.5%) and more than a third in median values (33%). People reported having made an average of 4.6 trips the day before (median=4), of which 2 were done exclusively walking, and longer than 10 minutes.

In comparison to other studies, people in Madrid were found to be more devoted pedestrians, walking an average of 22,5 minutes per trip (Lamíquiz & López-domínguez, 2015) while in China utilitarian walking (commuting and or to reach destinations) sum less than 10 minutes per day (Alfonzo *et al.*, 2014). In a more directed comparison, De Bourdeaudhuij *et al.* (2005) compared the time people spent walking in Portugal and in Belgium, finding that people in Portugal walked more for transportation (168 minutes/week vs. 89 minutes/week) and for leisure (86 minutes/week vs. 62 minutes/week). Remarkably, the time spent walking for transportation was higher than the time devoted to walk for recreation or exercise both in Portugal and Belgium while in other geographies it was the other way around (e.g. Canada and China).

An interesting finding relating to the prevailing walking conditions in Portugal was that a non-trivial share of the surveyed population reported being injured due to falling on the sidewalk (106 cases, 7,6%) the year before (see Table 3.9).

Table 3.9: Survey sample characterization

| Socio demographic variables | n | % total | n obs |
|---|---|---|---|
| **Gender** | | | 1400 |
| Male | 711 | 50.8% | |
| Female | 689 | 49.2% | |
| **Age group** | | | 1400 |
| 15 to 19 years old | 165 | 11.8% | |
| 20 to 24 years old | 383 | 27.4% | |
| 25 to 34 years old | 255 | 18.2% | |
| 35 to 44 years old | 263 | 18.8% | |
| 45 to 54 years old | 153 | 10.9% | |
| 55 to 64 years old | 116 | 8.3% | |
| 65 to 79 years old | 65 | 4.6% | |
| 80 years old or older | | | |
| **Education** | | | 1393 |
| Elementary | 9 | 0.6% | |
| Secondary (high school) | 279 | 20.0% | |
| Professional | 64 | 4.6% | |
| Tertiary (university) | 1041 | 74.7% | |
| **Work class** | | | 1400 |
| Worker | 693 | 49.5% | |
| Student | 603 | 43.1% | |
| Retired | 63 | 4.5% | |
| Unemployed | 17 | 1.2% | |
| Other | 24 | 1.7% | |
| **Household** | | | |
| No kids | 1082 | 78.1% | 1385 |
| Has Kids, age of youngest: | 303 | 21.9% | |
| Less than 1 year old | 22 | 1.6% | |
| 1 to 5 years old | 135 | 9.7% | |
| 6 to 10 years old | 65 | 4.7% | |
| 11 to 15 years old | 0 | 0.0% | |
| 16 years old or older | 81 | 5.8% | |
| **Life changing events, year before** | | | 1400 |
| Need to use walking aids | 45 | 3.2% | |
| Need to use wheelchair | 9 | 0.6% | |
| Pedestrian fall injury | 106 | 7.6% | |
| Parenthood | 28 | 2.0% | |
| School change | 91 | 6.5% | |
| House change | 184 | 13.1% | |
| Work change | 191 | 13.6% | |
| Retirement | 13 | 0.9% | |
| **Population subgroup** | | | 1400 |
| Residents | 174 | 12.4% | |
| Workers | 568 | 40.6% | |
| Visitors | 424 | 30.3% | |
| External | 234 | 16.7% | |

Table 3.10: Walking behavior characterization

| Walking behaviour variables | n | % total | | | n obs. |
|---|---|---|---|---|---|
| **Like to walk?** | | | | | 1395 |
| Yes, both for transport and for leisure | 809 | 58% | | | |
| Yes, more for transport than leisure | 253 | 18% | | | |
| Yes, more for leisure than transport | 225 | 16% | | | |
| Neutral | 79 | 6% | | | |
| Don't like walking | 20 | 1% | | | |
| Unable to walk | 9 | 1% | | | |
| | n | % total | | cum.% | n obs. |
| **Willingness to walk** | | | | | 1393 |
| up to 5 min. | 82 | 6% | | 6% | |
| up to 10 min. | 140 | 10% | | 16% | |
| up to 15 min. | 258 | 19% | | 34% | |
| up to 20 min. | 336 | 24% | | 59% | |
| up to 30 min. | 377 | 27% | | 86% | |
| up to 45 min. | 90 | 6% | | 92% | |
| up to 60 min. | 85 | 6% | | 98% | |
| more than 60 min. | 25 | 2% | | 100% | |
| | Q1 | Median | Mean | Q3 | n obs. |
| **Daily travel pattern** | | | | | 1135 |
| Average trip duration (min.) | 20.0 | 30.0 | 36.6 | 50.0 | |
| Average trip duration done walking (min.) | 5.0 | 10.0 | 12.8 | 20.0 | |
| Share of walking time in trip duration (%) | 20.0 | 33.0 | 43.5 | 60.0 | |
| Number of daily trips (n) | 2.0 | 4.0 | 4.6 | 6.0 | |
| Number of daily trips done walking (n) | 0.0 | 2.0 | 2.1 | 3.0 | |
| Share of trips done walking(%) | 0.0 | 40.0 | 41.0 | 67.0 | |
| Number of walking trips > 10 min (n) | 0.0 | 2.0 | 2.1 | 2.0 | |
| Share of walking trips > 10 min (%) | 20.0 | 33.0 | 43.5 | 60.0 | |
| | n | % total | | | n obs. |
| **Main travel mode** | | | | | 1400 |
| Car, as driver | 324 | 23% | | | |
| Car, as passenger | 32 | 2% | | | |
| Public transportation: train or subway | 478 | 34% | | | |
| Public transportation: bus | 185 | 13% | | | |
| Walking | 286 | 20% | | | |
| Cycling | 42 | 3% | | | |
| Other | 53 | 4% | | | |

Table 3.11: Walking behaviour variables found in the literature

| WB outcome | Measured Variable | unit | Mean | SD | Location | Source |
|---|---|---|---|---|---|---|
| | Mean walking trip lenght | minutes | 22,50 | | Spain (Madrid) | Lamíquiz & López-domínguez (2015) |
| | Median distance of single walking trip | km | 0,87 | | USA (Portland) | Boarnet *et al.* (2008) |
| | Median distance walked in 2 days | km | 2,17 | | USA (Portland) | Boarnet *et al.* (2008) |
| Distance related | Walking for leisure | km | 1,02 | | Canada | Millward *et al.* (2013) |
| | Walking for transportation | km | 0,67 | | Canada | Millward *et al.* (2013) |
| | Number of walking trips on the surveyed day | Number | 0,80 | 1,48 | USA | Targa & Clifton (2005) |
| | Number of Walking trips per person per day | N.trips/day | 0,19 | | USA (S.Francisco) | Boarnet *et al.* (2011) |
| Frequency related | Walking for recreation | N.trips/day | 1,40 | 0,70 | Canada | Spinney *et al.* (2012) |
| | Walking for transportation | N.trips/day | 3,10 | 2,10 | Canada | Spinney *et al.* (2012) |
| Modal share related | Share walking: Proportion walking trips with respect to all trips made on the survey day | % | 19 | 34 | USA | Targa & Clifton (2005) |
| | Total walk time/day | minutes/day | 45,87 | | China (Shanghai) | Alfonzo *et al.* (2014) |
| | Total walk time/day | minutes/day | 18,69 | | China (Hangzhou) | Alfonzo *et al.* (2014) |
| | Walk commute | minutes/day | 7,13 | | China (Shanghai) | Alfonzo *et al.* (2014) |
| | Walk commute | minutes/day | 2,59 | | China (Hangzhou) | Alfonzo *et al.* (2014) |
| | Walk destinations | minutes/day | 9,85 | | China (Shanghai) | Alfonzo *et al.* (2014) |
| | Walk destinations | minutes/day | 3,99 | | China (Hangzhou) | Alfonzo *et al.* (2014) |
| | Walk exercise | minutes/day | 28,89 | | China (Shanghai) | Alfonzo *et al.* (2014) |
| | Walk exercise | minutes/day | 12,11 | | China (Hangzhou) | Alfonzo *et al.* (2014) |
| | Walking for leisure | minutes | 17,30 | | Canada | Millward *et al.* (2013) |
| | Walking for recreation | minutes/day | 50,60 | 35,20 | Canada | Spinney *et al.* (2012) |
| Time related | Walking for recreation | minutes/trip | 39,10 | 26,10 | Canada | Spinney *et al.* (2012) |
| | Walking for transportation | minutes | 9,00 | | Canada | Millward *et al.* (2013) |
| | Walking for transportation | minutes/week | 89,00 | 152,00 | Belgium | De Bourdeaudhuij *et al.* (2005) |
| | Walking for transportation | minutes/trip | 7,70 | 13,30 | Canada | Spinney *et al.* (2012) |
| | Walking for transportation | minutes/day | 23,30 | 30,90 | Canada | Spinney *et al.* (2012) |
| | Walking for transportation | minutes/week | 168,00 | 228,00 | Portugal | De Bourdeaudhuij *et al.* (2005) |
| | Walking in leisure time | minutes/week | 86,00 | 187,00 | Portugal | De Bourdeaudhuij *et al.* (2005) |
| | Walking in leisure time | minutes/week | 62,00 | 124,00 | Belgium | De Bourdeaudhuij *et al.* (2005) |

## 3.6 Concluding remarks

This chapter presented the methodology and datasets used in the research project. The main datasets used were presented and briefly discussed in this chapter: walkability data; pedestrian count data and pedestrian survey data. A positive point was the use of a micro scale walkability assessment framework that was able to evaluate most of the environmental change. At present most walkability assessment tools are aimed at cross sectional studies. Further refinements are needed to develop a more robust longitudinal walkability assessment. Also, it would be interesting for future studies to compare other walkability tools and realize if there were differences in the obtained results.

On the other hand, the application of the IAAPE method showed some limitations. In particular, estimating the walkability of a single street segment required calculating at least 3 other complementary street segments if not more, which constituted a serious burden. Hence, another development would be to improve the walkability assessment method in order to be able more easily evaluate a single segment, and, concurrently, calibrate the street audit parameters to be able to capture most environmental changes occurring in the context of street improvements.

# Chapter 4

# Examining intervention effects

The research goal of understanding the effects of a walkability change following an environmental intervention in walking behaviour necessarily required four main components. One was the realization of an environmental intervention, another was the capability to characterize the built environment in terms of its walkability before and after the intervention, another one was the capability to collect walking behaviour data relative to the before and after situations and lastly the capability to process and analyse the data in order to infer results, and, desirably, to provide supportive evidence to the research questions.

As presented in the previous chapter, walking behaviour data was collected through pedestrian counts and by a online survey. The complete sample comprised 1.400 surveys, of which were screened out people who were not familiar with the intervention area; did not recall the street environment prior to the intervention; or did not visit the area after the intervention. The final valid sample for the current analysis comprised 802 individuals who lived, worked or visited the area. The survey sample characteristics are presented in Table 4.1.

**Perceived changes by user group**

The first question addressed was is if the environmental changes were perceived by all user groups as improvements. To answer that question a 10 item likert-type scale was set up in the survey addressing distinct BE factors. People were asked to rank their perception of change in each factor in a 1 to 5 scale.

The measuring scale showed good internal reliability with a value for Cronbach's

Table 4.1: Characteristics of the survey sample

| Variable | n | % |
|---|---|---|
| **Sex** | | |
| Female | 384 | 48 |
| Male | 418 | 52 |
| **Age group** | | |
| $< 20$ | 21 | 3 |
| 20-34 | 331 | 41 |
| 35-65 | 404 | 50 |
| $> 65$ | 46 | 6 |
| **Education** | | |
| missing | 3 | 0.4 |
| Less than high school | 3 | 0.4 |
| High School | 90 | 11 |
| Technical school | 39 | 5 |
| University or higher | 667 | 84 |
| **Activity in the area** | | |
| Resident | 144 | 18 |
| Worker / Student | 362 | 45 |
| Visitor | 296 | 37 |
| **Employment status** | | |
| Worker | 513 | 64 |
| Student | 221 | 28 |
| Retired | 44 | 6 |
| Family caretaker | 2 | 0.2 |
| Unemployed | 8 | 1 |
| Other | 14 | 2 |

Alpha = 0.872. The 10 items [1] were summarized in a single variable (BEchangeEixo) whose values were in the range of 10 to 50. The results showed there was a generalized perception of a BE improvement: Mean = 39,59; SD = 5,38; N=777.

A sequent question was related to a potential difference in the perceptions of residents, workers and visitors. Vale & Pereira (2016) have pointed that the BE can influence walking at different levels, namely origins and destinations, the areas surrounding them, and the characteristics of the routes connecting them. Following this rationale it could be presumed that residents are sensitive to some particular factors relating to the "origin walkability"; workers to factors related to the "destination walkability" and visitors more sensitive to factors related to the "route walkability". To evaluate this hypothesis three "exposure" groups were considered: residents (n=133), workers (n=369) e visitors (n=275). The proportion of HM was balanced between groups (Chi squared 2 = 4.68, p=.096). Age groups were not proportionally distributed between groups (Chi 2 = 43.57,

[1] Amenities; CrossOp; CrossSafe; GreenSp; LandUse; MeetPoint; NoObstacles; PavComfort; PedAccess; and PedSpace

Table 4.2: Perceived environmental change

| Item | Mean | SD | Chi 2 | p |
|---|---|---|---|---|
| BEChg_PedSpace | 4,45 | ,702 | 3130 | ,207 |
| BEChg_PavComfort | 4,36 | ,767 | 4359 | ,111 |
| BEChg_GreenSp | 4,15 | ,790 | 1590 | ,460 |
| BEChg_NoObstacles | 3,90 | ,849 | 2032 | ,362 |
| BEChg_CrossSafe | 3,68 | ,927 | 5715 | ,055 |
| BEChg_LandUse | 3,32 | ,609 | 1490 | ,471 |
| BEChg_PedAccess | 4,10 | ,737 | 9747 | **,007** |
| BEChg_MeetPoint | 3,99 | ,788 | 5401 | ,068 |
| BEChg_Amenities | 3,94 | ,796 | 6486 | **,039** |
| BEChg_CrossOp | 3,69 | ,880 | 12159 | **,003** |

$p<0.01$). This is acceptable considering that 1) workers are typically adults and 2) Lisbon residents have a very high proportion of seniors. Also the survey diffusion method – web survey – may have been less effective in reaching younger and older participants. A one way ANOVA was used to check if there was a significant difference in the perception of built environment change. The BEchangeEixo variable was tested for normality (Skewness and Kurtosis) and for homogeneity of variances (Levene test). The results showed that there was not a significant difference between groups as determined by one-way anova: ANOVA ($F(2,776) = 2.59$, $p= .07$), hence refuting the hypothesis that residents, workers and visitors perceived the environmental changes differently.

Next it was realized if there were particular items of the built environment that were perceived differently by the same 3 groups. In general terms, the objective change in BE was perceived accordingly by the users of the space. Major changes in the area were related to the enlargement of the sidewalks (Pedestrian space) and replacement of Portuguese pavement (cobble stones) with smooth concrete paving (Pavement Comfort). There was practically no change in land use during the analysis period. Mean scores for these items show that perceived change in pedestrian space (M=4,45, SD=0.70) and pavement comfort (M=4.36, SD=0.76) were the highest whilst perceived change in land use (M=3.32, SD=0.60) was the lowest (see Table 4.2).

The Kruskall-Wallis test was used to check if there was a difference in perception between the groups. There were some statistically significant differences between groups as determined by the test results, in particular showing that Pedestrian Accessibility ($H(2) = 9.75$, $p= .007$), Amenities ($H(2) = 6.49$, $p= .039$) and Crossing Opportunities ($H(2) = 12.16$, $p= .003$) were significantly different between exposure groups.

Post-hoc comparisons using the Mann-Whitney U-test with a Bonferroni correction indicated that within exposure groups, Workers reported the lowest perception to change whereas visitors showed the highest change perception, higher than residents. This can perhaps be related to visitors' route options, over a wider spatial range.

Finally, it also analysed if there were differences in the way these three groups expressed their walking experience. Recalling, the walking experience variable for each street was obtained using a likert-type item ranging from 1 to 9, showing suitable skewness and kurtosis values for the application of parametric tests. A one way ANOVA test was used, showing that there was not a statistically significant difference between groups: ANOVA Av.Republica ($F(2,776) = 0.97$, $p= .38$); ANOVA Saldanha ($F(2,776) = 0.11$, $p= .89$); ANOVA Fontes Pereira de Melo ($F(2,776) = 0.97$, $p= .38$).

At this stage it was found that exposure groups, as determined by individual-space activity type – resident / worker / visitor , have perceived the change in the built environment in a similar manner and have improved their walking experience in a similar manner.

## 4.1 Association of walkability change to pedestrian activity

Paired sample t-tests were used in order to compare the before and after situation, assessing the changes in average values of walkability, pedestrian volumes and walking experience between baseline and follow up. The variables of interest were prior analysed for their suitability of application of parametric tests, setting a valid threshold for skewness and kurtosis values between -2 and +2, having met the required assumptions. The statistical analyses were executed in IBM SPSS version 22, using a significance level of 5%.

### 4.1.1 Walkability

Average walkability scores show that initial conditions were very similar in the 3 sites, with a score around 71 points. This is a relatively high score when compared to average values of other streets in Lisbon, considering Cambra *et al.* (2017a) who reported an average walkability score of 64 for a comprehensive sample of streets in the same neighbourhood. While the increase in walkability scores was primarily related to the improvement of pavement quality and comfort, the distinction between each site can be related to the sojourning opportunities introduced, providing a more convivial environment (as presented earlier in section 3.9).

On average, it was found the difference in before-after walkability to be higher in Saldanha (M=10.21, SE=2.48), t(4)=4.11, p<.05, r=0.90; followed by Av. República (M=6.57, SE=1.36), t(19)=4.83, p<.001, r=0.74. The change in overall walkability of Av. Fontes Pereira de Melo was positive but not significant (M=3.82, SE=3.01), t(11)=1.27, p=.23, r=0.36 (see Table 4.3).

Regarding walkability in a recreational perspective, the results showed a higher final walkability score compared to utilitarian walkability. In this case, the change in recreational walkability was positive and significant of all Eixo sections (see Table 4.4).

The surrounding area (adjacent and parallel streets) was surveyed for noticeable environment and land use changes. As there were no evident changes in the pedestrian environment, walkability scores were assumed constant between the baseline and follow-up period.

Table 4.3: Comparison of before-after walkability scores

| | **Walkability Score** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1-Before | | T2-After | | Paired samples test | | | | | |
| Intervention site | *Mean* | *SD* | *Mean* | *SD* | *Mean T2-T1* | *SE* | *t* | *df* | *r* | *p* |
| Av.República | 71.86 | 7.95 | 78.43 | 6.23 | 6.57 | 1.36 | 4.83 | 19 | 0.74 | **0.000** |
| Saldanha | 71.03 | 7.05 | 81.24 | 6.21 | 10.21 | 2.48 | 4.11 | 4 | 0.90 | **0.015** |
| Av.Fontes Pereira de Melo | 71.22 | 9.99 | 75.04 | 6.85 | 3.82 | 3.01 | 1.27 | 11 | 0.36 | 0.232 |

Table 4.4: Comparison of before-after recreational walkability scores

| | **Walkability Score - Recreational** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 - Before | | T2 - After | | Paired samples test | | | | | |
| Intervention site | *Mean* | *SD* | *Mean* | *SD* | *Mean T2 - T1* | *SE* | *t* | *df* | *r* | *p* |
| Av.Republica | 75.4 | 7.4 | 81.0 | 8.5 | 4.3 | 1.3 | 4.26 | 19 | 0.70 | **0.000** |
| Saldanha | 72.0 | 6.1 | 82.7 | 6.7 | 10.7 | 3.9 | 2.77 | 4 | 0.81 | **0.050** |
| Av.Fontes Pereira de Melo | 70.0 | 14.5 | 78.3 | 9.7 | 8.3 | 3.6 | 2.32 | 11 | 0.57 | **0.040** |

### 4.1.2 Pedestrian flow

The average number of pedestrians walking in the Eixo Central increased between baseline and follow up (Table 4.5). A significant increase was observed in Saldanha (M=178, SE=45, t(9)=3.98, p<.01, r=0.80); and in Av. República (M=58, SE=16, t(24)=3.56, p<.01, r=0.59); and a positive but less significant change was observed in Av. Fontes Pereira de Melo (M=37, SE=18, t(19)=2.03, p=.056, r=0.42) (see Table 4.5).

In the control locations the variation in the average pedestrian volume was not significant. In the adjacent streets there was a slight decrease (M=-14, SE=14, t(24)=-0.98, p=.335, r=0.20); whereas in the external area there was a slight increase (M=19, SE=16, t(19)=1.21, p=.242, r=0.27). We found evidence of an increase in the pedestrian volumes of the intervention area following the street renovation. The increase was significant in the Av. República (11.4%; p<.001) and Saldanha (29.9%; p<.001) sections and marginally significant in Av. Fontes Pereira de Melo section (8.5%; p=.056). There was no significant change of the pedestrian volumes in the control streets, either located in the vicinity of the Eixo Central (-3.2%; p=.335) or located in a different neighbourhood (3.1%; p=.242).

Table 4.5: Comparison of before-after pedestrian flow volumes

| | Pedestrian Volume (pedestrians/hour) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 -Before | | T2 -After | | Paired samples test | | | | | |
| Intervention site | *Mean* | *SD* | *Mean* | *SD* | *Mean T2-T1* | *SE* | *t* | *df* | *r* | *p* |
| Av.República | 528 | 202 | 586 | 240 | 58 | 16 | 3.56 | 24 | 0.59 | **0.002** |
| Saldanha | 581 | 253 | 758 | 216 | 178 | 45 | 3.98 | 9 | 0.8 | **0.003** |
| Av.Fontes Pereira de Melo | 424 | 165 | 461 | 152 | 37 | 18 | 2.03 | 19 | 0.42 | 0.056 |
| Controls | | | | | | | | | | |
| Adjacent streets | 377 | 174 | 363 | 161 | -14 | 14 | -0.98 | 24 | 0.2 | 0.335 |
| External area | 583 | 241 | 602 | 218 | 19 | 16 | 1.21 | 19 | 0.27 | 0.242 |

### 4.1.3 Pedestrian sojourning

Regarding sojourning pedestrians, i.e. the "instant recording" of people sitting or standing on the street, there was also a noticeable change following the public space improvements (Table 4.6). This was more evident in Saldanha square, with a twofold significant increase (from 3.5 to 8.4, t(9)=5.08, p<.000, r=0.86), and also in Av.República (M=3.2, SE=0.7, t(24)=4.79, p<.000, r=0.70). Surprisingly, the mean observed number of pedestrians sojourning was higher in Av.Fontes Pereira de Melo at. baseline compared to the other Eixo sections but the intervention did not seem to contribute to a significant increase of this behaviour (M=1.3, SE=0.8, t(19)=0.34, p=.130, r=0.34) (see Table 4.6).

There were no observable changes in the adjacent streets, but in the external control area there was a significant increase in sojourning pedestrians between baseline and follow-up (M=3.7, SE=1.4, t(19)=2.67, p=.015, r=0.52). It is worth mentioning that the streets included in the control areas were already places with a high number of sojourning pedestrians. Contributing to this figures there is Av.Duque de Ávila (adjacent street) which offers plenty opportunities for sojourning with a large sidewalk hosting restaurants with outdoor sitting and Av.Almirante Reis and Av.Morais Soares with an affluent number of brief social encounters amongst residents (i.e. the occasional chit-chat of people that meet while doing their errands).

However the t-test effect size was higher in the Eixo Sections than in the External Area. Both Av. República and Saldanha showed a large effect (r value close to 0.8) while the External area showed a moderate effect (r close to 0.5).

Table 4.6: Comparison of before-after pedestrian sojouring

| | Sojourning Pedestrians (average standing and sitting per observation) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 - Before | | T2 - After | | Paired samples test | | | | | |
| Intervention site | *Mean* | *SD* | *Mean* | *SD* | *Mean T2 - T1* | *SE* | *t* | *df* | *r* | *p* |
| Av.Republica | 4.6 | 3.4 | 7.8 | 4.8 | 3.2 | 0.7 | 4.79 | 24 | 0.70 | **0.000** |
| Saldanha | 3.5 | 2.1 | 8.4 | 4.2 | 4.9 | 1.0 | 5.08 | 9 | 0.86 | **0.000** |
| Av.Fontes Pereira de Melo | 5.1 | 2.9 | 6.4 | 4.3 | 1.3 | 0.8 | 1.58 | 19 | 0.34 | 0.130 |
| Controls | | | | | | | | | | |
| Adjacent streets | 12.1 | 15.5 | 12.0 | 13.4 | -0.1 | 1.0 | -0.15 | 24 | 0.03 | 0.884 |
| External area | 10.7 | 5.5 | 14.4 | 9.4 | 3.7 | 1.4 | 2.67 | 19 | 0.52 | **0.015** |

### 4.1.4 Walking experience

Walking experience was addressed upon completion of the street intervention. The interest was in capturing a self-assessment of the before-and-after experience of people that used the Eixo Central area. A survey was launched at the end of autumn 2017, allowing an experimental period of 6 months after the official inauguration/opening but before harsher weather conditions that could bias the experience rating.

The survey followed a quasi-longitudinal design. People were asked to provide their opinion on the present experience of walking in the streets of Eixo Central as well as to recall their past experience, relating to baseline walking conditions. The walking experience was rated in a 9 point scale, assuming equidistant rating intervals. The lowest score, 1, represented an unpleasant experience, i.e., a street to avoid. Conversely, a score of 9 represented a very pleasant walk.

The self-reported walking experience was similar for the 3 sites at baseline (see Table 4.7). In the 9-levels Likert scale used for assessing walking experience, scores for the initial conditions were slightly above the mean scale value. People reported an increase in their walking experience following the intervention in the 3 studied locations. The difference in walking experience was significantly higher in Saldanha (M=2.37; p<.001), followed by Av. República (M=2.15; p<.001) and Av. FPM (M=1.92; p<.001).

Table 4.7: Comparison of before-after rating of walking experience

| | **Walking Experience** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre | | Post | | Paired samples test | | | | | |
| Intervention site | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SEM* | *t* | *df* | *r* | *p* |
| Av.República | 4.84 | 1.57 | 6.99 | 1.57 | 2.16 | 0.07 | 29.85 | 801 | 0.73 | **.000** |
| Saldanha | 4.83 | 1.67 | 7.21 | 1.58 | 2.37 | 0.08 | 28.39 | 800 | 0.71 | **.000** |
| Av.Fontes Pereira de Melo | 4.63 | 1.7 | 6.56 | 1.7 | 1.92 | 0.08 | 24.87 | 800 | 0.66 | **.000** |

### 4.1.5 Relating walkability to walking behaviour

The potential relation between the variables was then analysed from the obtained results. This was done by calculating Spearman's rank correlation coefficient s for all pairs of measures. Walkability scores and walking experience were found to be the most correlated (rho=.943; p<.01) whilst the other associations showed no statistical significance.

Figure 4.1 shows the values for before-after pedestrian volumes in relation to before-after walkability scores. Before the intervention, the walkability scores were relatively similar with an apparent low correlation to pedestrian volumes. The highest pedestrian volumes were found in Saldanha (M=581, SD=254), despite having the lowest average walkability score (M=71.03, SD=7.05). After the intervention the values of walkability scores and pedestrian volumes suggest an ordered arrangement.

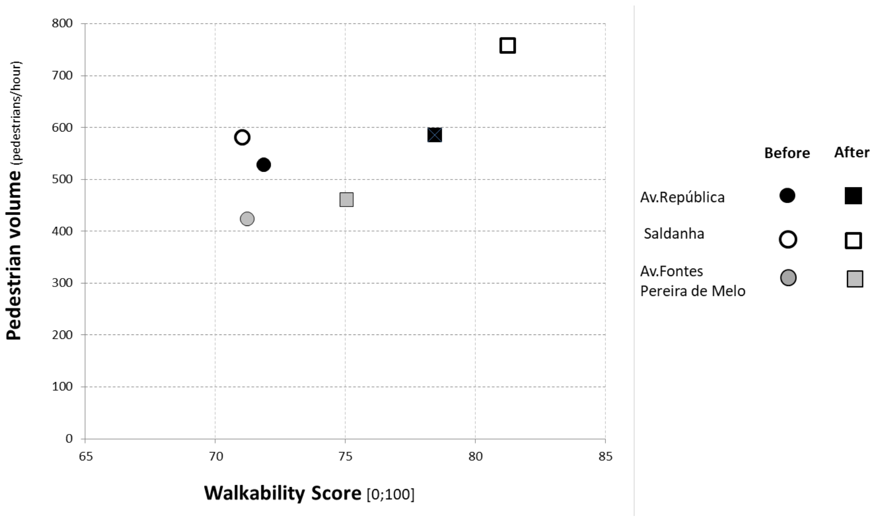



Figure 4.1: Graphical evaluation of the Before-After changes in the pedestrian volume in relation to measured walkability at each intervention site

Figure 4.2 presents the values for before-after walking experience in relation to before-after walkability scores. Walking experience was found to be very similar in the three sections prior to the intervention, being clustered with the walkability scores. The appreciation of the walking experience after the renovations increased in line with the increase in average walkability score, suggesting also an ordered arrangement. On the other hand the arrangement of the pedestrian volume and walking experience values was maintained, suggesting a somewhat inelastic relation (Figure 4.3).

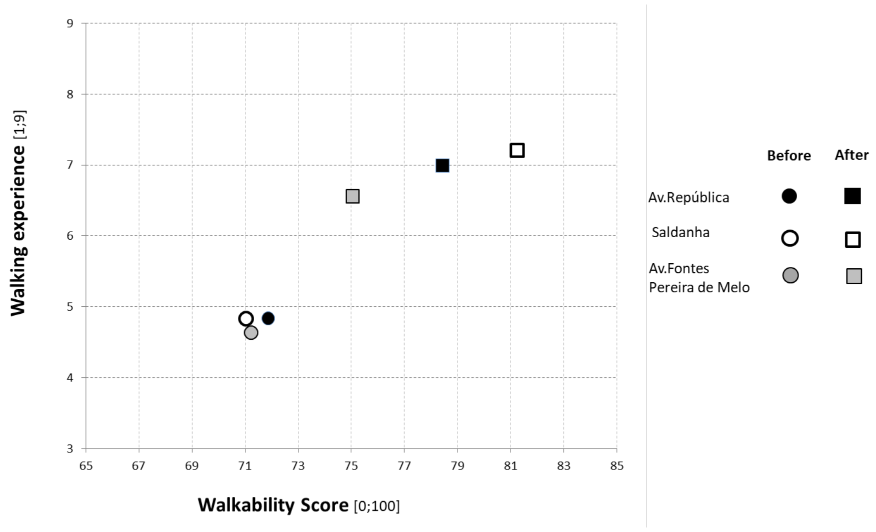



Figure 4.2: Graphical evaluation of the Before-After changes in surveyed walking experience in relation to measured walkability at each intervention site.

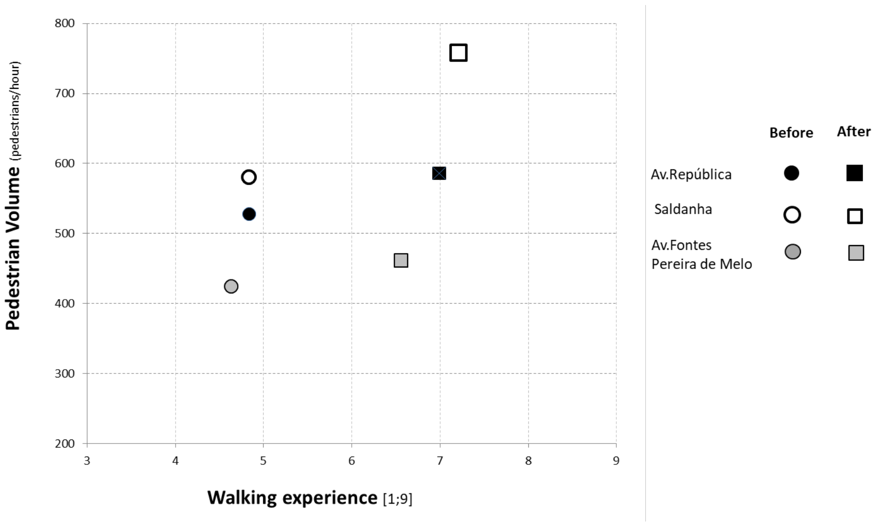



Figure 4.3: Graphical evaluation of the Before-After changes in the pedestrian volume in relation to surveyed walking experience at each intervention site.

## 4.2 Chapter discussion

This chapter evaluated the relations of walkability, pedestrian volume and walking experience before and after a street improvement intervention in three connected but distinct sections. A longitudinal study design was used to examine walkability and pedestrian volume, and a quasi-longitudinal design to evaluate the walking experience. The walkability score increased at different levels within each section. The pedestrian volume increased in the intervention sites, while in the control areas no significant change was observed. In addition, people reported a more satisfying walking experience following the intervention. Finally, positive relationship was found between the magnitude of change in walkability and the changes in pedestrian volume and walking experience.

The results suggest that walkability, walking experience, and pedestrian flows are related and that the observed change in the pedestrian volumes and walking experience are associated with the change in walkability. This relation highlights the fact that a higher improvement in walkability can be associated with a higher improvement in walking experience as well as to higher pedestrian activity. This was particularly noticeable in the Saldanha section where the change in the pedestrian environment was more intense - the mean pedestrian volume increased from 581 pedestrians/hour to 758 pedestrians/hour and the average number of sojourning pedestrians increased from 3.5 to 8.4, while the walkability score increased from 71.03 to 81.24. Likewise, a more contentious environmental change was associated with less significant changes in walking experience and pedestrian volumes. This was the case of the Av. Fontes Pereira de Melo section, where the difference in walkability scores before and after the intervention was not significant. Here, the mean pedestrian volume had a non significant increase from 424 pedestrians/hour to 461 pedestrians/hour, and, similarly, the walkability score had a non significant increase from 71.22 to 75.04.

According to these data, it can be inferred that using a unidimensional before-after scale to interpret the behaviour effects would have provided mixed or contradictory findings. The mixed findings would be related to having observed an increase in pedestrian volume following a BE intervention in one section whilst observing no increase of pedestrian volume in another area with the same intervention. By using a walkability score to measure the extent and importance of the BE intervention we were able to differentiate between levels of walkability change obtaining a more consistent interpretation of the results. Figures 4.1, 4.2 and 4.3 illustrate these findings, showing how the observed changes in pedestrian volume and walking experience relate to the measured changes in walkability at each intervention section.

Another relevant finding is that the average pedestrian volume increased only in the intervened area while remaining stable in the adjacent streets and in the external control area. Other studies have reported an increase in pedestrian volumes in retrofitted streets (e.g., Shu *et al.*, 2014; Jensen *et al.*, 2017a) but not all studies have included a control area in their observations (Stappers *et al.*, 2018). In comparison, Jung *et al.* (2017) addressed a comprehensive street intervention program finding that the pedestrian volumes increased not only in the intervention areas but also in control areas, and approximately at the same rate.

In contrast to existing studies, the present study was able to observe located and confined effects, thus supporting the hypothesis that a causal link of some extent may exist between walkability improvement and pedestrian activity. However, the present results meet only partially the conditions to establish causality, namely association; time precedence; plausibility and non- spuriousness (van de Coevering *et al.*, 2015). While time precedence and plausibility conditions can be claimed here, the statistical association and non-spuriousness conditions are less clear. There may be spurious relations to unobserved variables. In particular, tourism has been growing in the city of Lisbon, and the flow of tourists and visitors is noticeable in several parts of the city. Although the studied area is not part of the touristic routes it is possible that some of the increase in the number of people walking is due to tourism.

The present study did not find evidence to support a causal relationship between the increase in walkability and the increase in pedestrian activity. However, the evidence that the increase in pedestrian activity occurred only in the locations where there was a significant change in walkability cannot rule out the hypothesis of a causal relation.

Another interesting finding is that the walking experience increased in all sections, regardless of less significant changes in walkability and pedestrian flow. There are several possible explanations for this result. The first, consistent with Jung *et al.* (2017), is that smaller scale environmental interventions may be effective in improving the satisfaction of pedestrians whilst being less effective in triggering behaviour change. The second is that improving satisfaction with the walking environment is not a determinant per se to affect pedestrian flow numbers. In accordance, previous studies have demonstrated a decrease in pedestrian volume despite an increase in walking experience (Jung *et al.*, 2017). It is possible that walking trip purpose plays a pivotal role in the relation between experience and activity. On one hand, utilitarian walking trips, occurring as a result of necessity could be less responsive to environmental quality (Lindelöw *et al.*, 2014). On the other hand, recreational walking trips, essentially voluntary, could be more sensitive to a satisfactory pedestrian environment (Kim *et al.*, 2014).

Concomitantly, providing a more pleasurable experience may be a prerequisite in shaping a specific walking behaviour, in particular in recreational or non-transportation bouts. The prominent physical factors influencing walking experience seem to be related to the aesthetic quality of the built environment (Dadpour *et al.*, 2016), its imageability (Ameli *et al.*, 2015) , the available space to walk, and presence of green elements, such as trees (Kim *et al.*, 2014). The Eixo Central project enhanced the public space thus affecting the aesthetic and imagistic qualities of the environment, as well as increasing the pedestrian space. It is interesting to note that while the aesthetic factors believed to influence walking experience are not addressed by the 7 C layout of the walkability assessment model, still a positive and significant correlation was found between the walkability score and the reported experience. Hence, some of the 7 C layout factors seem to be also relevant in influencing walking experience.

There are however limitations that should be considered when interpreting the results, namely relating to the assessment of walkability and walking experience. There were noticeable environmental changes that were not fully captured by the walkability model, relating to design qualities such as imageability, enclosure and human scale (Ewing & Handy, 2009; Ameli *et al.*, 2015) and to the provision of amenities and greenery. For instance, in Av. República, the sidewalks were enlarged by more than 2m (taking up a parking lane) doubling their width, consequently changing the centreline perspective of the street. In Saldanha, the plaza layout provided more open public space for walking and sojourning. In Av. Fontes Pereira de Melo, there was also a plaza created but the majority of the street kept the original design. The enlargement of the sidewalks changed the perspective of the pedestrian in relation to the street, providing a different reading of the human scale in comparison to the motorized traffic space. Also, replacing traffic lanes by pedestrian space led to fewer nuisances from close traffic.

New amenities were installed in all Eixo Central sites, namely benches, LED lighting oriented to the sidewalk, greenery, and trees. Some of these factors are often considered relevant in other walkability assessment models. The IAAPE walkability assessment framework was developed using a participatory method for selecting and ranking relevant factors, involving local stakeholders (Moura *et al.*, 2017). None of the panels who participated in the selection and ranking of walkability factors regarded indicators as greenery or lighting as being meaningful in their perception of a walking friendly environment, contrasting to other studies. A study by Dauden *et al.* (2009) found that greenery was one of the most important factors for pedestrians in Spanish cites, whose built and social environments share some similarities to the ones found in Lisbon. Perhaps in the local context of Lisbon other factors are perceived as more relevant by people at present. In accordance to Alfonzo's model of hierarchy of walking needs (2005) it could be expected that upon satisfaction of basic concerns (e.g. pavement quality) other concerns gain more relevance (e.g. greenery).

Also, it may be that what people consider to be pedestrian friendly is somewhat different of what people consider to be a pleasurable walking experience. The former concept may be more related to the physical interaction with the environment while the latter may be more related to the sensorial and emotional interaction. Refining the methods for assessing walking experience will be a necessary step to further investigate the role of environmental change in providing a more pleasurable experience which in turn may favour walking. Recent research has addressed the development of travel satisfaction scales (Ettema *et al.*, 2011; De Vos *et al.*, 2015), also with a focus in measuring walking experience (Johansson *et al.*, 2017; De Vos *et al.*, 2018). For instance, Johansson *et al.* (2017) used on-site, walking along, questionnaires based on a 15 item Likert scale to address walking experience, finding that the affective experience of walking mediated the effect of perceived urban design qualities in the intention to walk. Multiple measurement scales may provide stronger report measures than single-item questions used in the present study and similar ones (Jung *et al.*, 2017). Future studies should consider controlling for factors such as seasonal variation and attachment to the study area amongst others.

As argued by Jacobs (1993) it is possible that the social environment plays a bigger role in attracting people to a street than the physical environment, and therefore the results of this study may not be generalized to other urban contexts. Other prospective studies are encouraged to assemble a catalogue of before-after assessment studies in different urban contexts and geographies and to consolidate walkability measures that can provide a solid basis for benchmarking. More comprehensive longitudinal evaluations of environmental changes will require improved walkability scoring tools that are sensitive to change in micro-scale factors and to urban design qualities.

# Chapter 5

# Exploring behaviour change triggers

Behavioural change was reported to some extent by users of the Eixo Central area in relation to its qualification. According to the performed survey, the majority of people did not change their daily walking routines, but a fair deal of people reported some degree of change. This chapter explores the factors that could be associated with triggering change in walking behaviour. The first half of the chapter analyses the walking behaviour change for five distinct purposes - utilitarian, recreational, walking for public transport, walking for exercise and route changing. Next, it explores and tests the hypothesis derived from the conceptual diagram where exposure, perception and walking experience are influential factors in achieving walking behaviour change. The second half explores if distinct pedestrians groups show different appreciations of the walking behaviour, testing market segmentation techniques in finding pedestrian groups. Next it explores the potential directions of influence between walking experience, perceptions and attitudes using structural equation modelling. A brief discussion on the findings closes the chapter.

## 5.1 Behaviour change triggers per walking purpose

This section analyses the walking behaviour change for five distinct purposes - utilitarian, recreational, walking for public transport, walking for exercise and route changing. Next, it explores and tests the hypothesis derived from the conceptual diagram where exposure, perception and walking experience are influential factors in achieving walking behaviour change.

### 5.1.1 Change in walking frequency per walking purpose

The variable of interest is the change in walking frequency per walking purpose, which includes walking for five different purposes. Several authors have backed to analyse walking in accordance to its purpose. One of the main distinctions is made between utilitarian walking and recreational walking (Krizek *et al.*, 2009a; Cambra, 2012). Kim & Yang (2017) have proposed to differentiate between three types: overall walking, shopping walking and leisure walking. Humpel *et al.* (2004) amongst others included the study of walking for exercise. It is plausible that some factors influence different walking purposes at different levels as it plausible that some purposes show a strong correlation in the meaningful factors, such as walking for leisure and walking for exercise (Owen *et al.*, 2004). In the present study, five distinct purposes were considered:

- Utilitarian walking - when walking is a mean of getting to an activity, with moving around;
- Recreational walking - when walking is associated to sojourning, spend some time in the public space;
- Walking for transport - when walking is derived from the main transport mode choice;
- Walking for exercise - when walking is a mean of physical activity;
- Route change - to control if the change in ped flow was associated with people changing their routes more than behaviour.

Although several studies address these different walking purposes, only few have provided a comparative analysis. Morevoer, the present study found an increase in the pedestrian volume which induced the question of which kind of walking purpose could be associated to the increase in the number of pedestrians.

The dependent variable(s) were obtained from the pedestrian survey. Residents, workers and visitors of the Eixo Central area were asked to self report their change in walking for the different purposes between the before (2016) and after (2017) situation, consisting in a quasi-longitudinal approach. The question was formulated as follows (in portuguese [1]) -

[1] Considere a situação antes das obras (2016) e a situação depois das obras (2017). Recorde-se da sua rotina habitual, por exemplo, a dos últimos 3 meses - Setembro, Outubro e Novembro - e compare-a com a rotina que tinha no mesmo período do ano passado (Setembro a Novembro de 2016). Actualmente, e em relação ao ano passado, vai mais vezes, a pé, ao Eixo Central...

*Consider the original conditions before intervention (2016) and the conditions after the intervention. Recall your usual routine, for instance from the last 3 months - September, October and November - and compare it to the usual routine you had in the same period last year (September to November 2016). Nowadays, comparing to last year, do you walk more often to the Eixo Central area:*

- To deal with personal affairs, shopping, have lunch, meet people. This formed the Utilitarian walking variable;
- To spend some time outside, sit, stay in the esplanades. This was considered the Recreational walking variable;
- To use public transport. This produced the transportation variable;
- For exercise, go for a walking jog. This produced the exercise variable;
- Just passing bye, on my way somewhere else. This produced the route selection, variable;

There were 5 answer classes to this question: 1) a lot less; 2) a bit less; 3) no change, the same; 4) a bit more; 5) a lot more. The collected variables were mainly subjective, hence without a specific and constant interval between levels. However given its intrinsically ordinal nature - given that there is a clear rank between the alternatives - the variable was considered as ordinal. Table 5.1 provides the distribution of the change in walking frequency variable per walking purpose.

According to Table 5.1, the majority of the respondents did not alter their walking behaviour following the Eixo Central intervention. About a third of the people reported some kind of increase in walking and contrastingly, 5% reported walking less after the intervention.

Walking for utilitarian and recreational purposes had a similar reported increase (30% and 28% respectively), considering the joint levels "a bit more" and "a lot more". Walking to use public transport and for exercise were the most rigid factors to change, as only about 16% of people reported walking more for these purposes. Choosing the Eixo Central as a route was the purpose with the most reported increase in frequency (32%). This result suggests that people may be opting to adapt their routes to use the Eixo Central area instead of alternative routes. In this case, the observed increase in pedestrian flows could be related to people changing their usual walking routes.

Table 5.1: Walking behavior change outcomes

| | Walking trip purpose | | | | |
|---|---|---|---|---|---|
| Frequency of walking trips | Utilitarian | Recreation | Pub.Trans. | Exercise | Route Change |
| 1 - A lot less | 21 | 34 | 26 | 45 | 16 |
| 2 - A bit less | 23 | 19 | 29 | 13 | 18 |
| 3- Same | 730 | 732 | 859 | 842 | 708 |
| 4- A bit more | 265 | 241 | 128 | 135 | 271 |
| 5- A lot more | 67 | 60 | 41 | 51 | 91 |
| *valid n* | *1106* | *1086* | *1083* | *1086* | *1104* |
| *NA* | *60* | *80* | *83* | *80* | *62* |
| *total* | *1166* | *1166* | *1166* | *1166* | *1166* |

| | Walking trip purpose | | | | |
|---|---|---|---|---|---|
| Frequency of walking trips | Utilitarian | Recreation | Pub.Trans. | Exercise | Route Change |
| 1 - A lot less | 2% | 3% | 2% | 4% | 1% |
| 2 - A bit less | 2% | 2% | 3% | 1% | 2% |
| 3- Same | 66% | 67% | 79% | 78% | 64% |
| 4- A bit more | 24% | 22% | 12% | 12% | 25% |
| 5- A lot more | 6% | 6% | 4% | 5% | 8% |
| total | 100% | 100% | 100% | 100% | 100% |

Despite their differences the results for change in walking frequency follow a similar general distribution, expressing some correlation. It could be that people reported a behaviour change where the purpose of the trip was disregarded, that is to say the trip purposes were not independent from each other. Spearman's correlation tests showed evidence of moderate correlation between the 5 variables, with the lowest correlation level being found between walking for public transport and walking for exercise (r=0.31) and the highest correlation being found between utilitarian and recreational walking (r=0.52), which meet a priori considerations. In order to test if the variables were independent, the Kruskal-Wallis test was used. The Kruskal-Wallis test by rank is a non-parametric alternative to one-way ANOVA test, that is suitable when the assumptions of one-way ANOVA test are not met (as in this case with 5 level ordinal variables) (Field, 2013). The Kruskal-Wallis test showed there were significant differences between the outcome of each variable, that is to say, the individuals reported distinct behavioural change in regard to walking purpose (Kruskal-Wallis chi-squared = 131.93, df = 4, p-value $< 2.2e-16$).

To model the change in frequency per walking purpose two approaches were considered suitable: a logistic regression and an ordinal regression model. According to Harrell (2015), it is intended that the model uses the data efficiently, therefore the selection of the modelling approach should consider the overall structures present in the data. Given the distribution of the DV by the 5 categories, concentrated in two categories "No change" and "Some change" the choice was to perform a binary logistic regression model. This required changing changing the variable outcome to "any change", obtaining a dichotomous variable.

Logistic regression is a type of multiple regression with an outcome variable that is a categorical variable and predictor variables that are continuous or categorical. When the goal is to predict membership of only two categorical outcomes the analysis is known as binary logistic regression. (Field, 2013). Accordingly, in logistic regression, instead of predicting the value of a variable Y from a predictor variable X1 or several predictor variables (Xs), we predict the probability of Y occurring given known values of X1 (or Xs), according to:

$$P(Y) = \frac{1}{1 + e^{-b_0 + b_1 x_1 + b_2 x_2 + \ldots b_n x_n}}$$

Where P(Y) is the probability of Y occurring, e is the base of natural logarithms, and the other coefficients form a linear combination as in the case of in simple regression, with a constant (b0), a predictor variable (X1) and a coefficient (or weight) attached to that predictor (b1).

Table 5.2: Outcome of dependent variables

| Walking trip purpose | Any increase in frequency of walking trips | % | n |
|---|---|---|---|
| Utilitarian | 332 | 30.0% | 1106 |
| Recreation | 301 | 27.7% | 1086 |
| Pub.Trans. | 169 | 15.6% | 1083 |
| Exercise | 186 | 17.1% | 1086 |
| Route Change | 362 | 32.8% | 1104 |

### 5.1.2 Covariates: Exposure, Perception and Experience

According to the conceptual relational diagram, it is hypothesized that people may be more or less exposed to the intervention, the BE changes are perceived by the individual, the walking environment provokes an experience and a satisfactory experience triggers the outcome - walking behaviour change (see Figure 5.1).

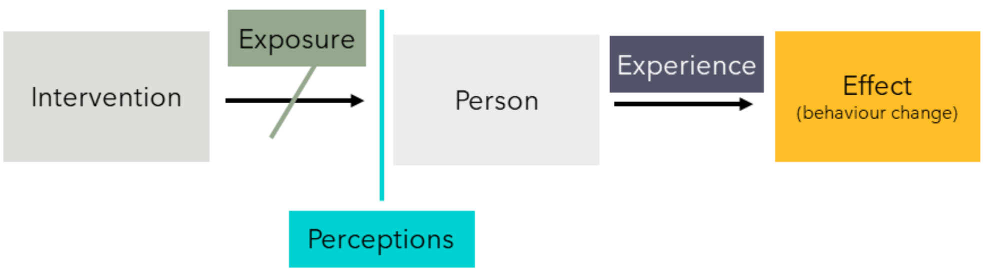



Figure 5.1: Conceptual relational diagram - Exposure, perceptions and experience

**Exposure**

Exposure is a concept closely related to the public health literature, regarding city as preventive medicine. In this perspective, a person who is exposed to a treatment would more likely bear an outcome related to the effect of the treatment than a person who is not exposed. In the case of environmental interventions, the improvement of the walking conditions can be considered the treatment that is supposed to have a positive effect on the person, resulting in an increase of walking levels and therefore in physical activity and in its associated benefits.

Exposure has been defined and measured in several ways in the literature. The most common approach is to define exposure by the proximity of residence to the intervention, often relying on household surveys. For instance, Heinen *et al.* (2017) derived an exposure measure based on the distance from survey respondents' home postcode to a new pathay. Pazin *et al.* (2016) defined exposure groups based on the distance from respondent's home a new walking and cycling route ( 0–500 m, 501–1000 m and 1001–1500 m).

A variation of the linear distance is the use of buffers around the place of residence. For instance, Stewart *et al.* (2018) used two exposure measures to assess the relation of park proximity to PA. First, a 833m sausage buffer was defined from the road network segments around each study participant's home. One exposure measure - park count - consisted in counting the number of distinct parks that intersected the buffer area. The other one - park area - was measured as the sum of the areas of the parks that intersected the buffer area (including the area outside the buffer). A network buffer around the study participants' residence was also used by Knell *et al.* (2018) to examine changes in PA associated with living near recently improved sidewalks. The exposure was measured by counting the number of improved sidewalks ordered by the number of improvements (0,1,2, and 3 or more).

Song *et al.* (2017) tested two types of exposure measures to examine if infrastructure provision was associated to modal shift from private car use to walking and cycling. One was a measure of potential usage, which was obtained by the distance between the intervention site and respondents' homes. The other consisted in the actual usage of the infrastructure, given by the self reported use of the new infrastructure as a dummy variable, representing actual exposure.

Hence two main exposure types can be considered: active exposure, relating to the actual use of the infrastructure; and passive exposure, relating to the potential influence of the infrastructure, accredited to be higher in subjects living nearby. Although passive exposure is a more commonly used measure it addresses only residents' behaviour, disregarding other users. In the case of recreational trails it can be admitted that most users will be people living nearby. But in the case of interventions in urban streets, such as in central areas, the composition of the users is broader, such as people who work in the area or visitors who use the area for various activities.

In this study, both exposure types - passive and active - were considered in the model. In order to overcome the gap of focusing only in residents, the survey used in this study addressed also people who worked or studied in the Eixo Central area

#### Passive Exposure: Distance to intervention

Passive exposure was defined by the least distance from the respondent's home or workplace to the Eixo Central site. This was performed using the following method: 1) In the online survey people were asked to provide their home and work/study locations, either by entering the 7 digit Portuguese postal code or by providing a reference point. It was found that the respondent's were more likely to provide the postal code of their residence and more prone to provide a reference location for their workplace. This may be related to people being used to provide their home postal address more often than their workplace postal address. The broad use od reference points implied the manual screening of the survey, by finding the reference points in the map and finding the respective postal code. 2) The second step was to map the survey's home and postal codes as point features. The postal codes refer to an area, and in the case of the Portuguese postal codes the respective geometry data (polygons) is not publicly available. This limitation has been dealt earlier by Rosa Félix, who developed a method to find the postal codes' centroids [2]. 3) At this stage, each survey entry provided two locations - home and workplace. The distance between each location and the Eixo Central was found by using QGis minimum distance function. The Eixo Central was represented by a polyline which included the three sections - Av.Republica, Av.Fontes Pereira de Melo and Saldanha Sq. Consequently, the calculated distance was the minimum straight line distance between residential and work locations to the closest section of Eixo Central. 4) Following, the shortest distance between home-Eixo Central and work-Eixo Central was defined as the "distance to intervention" variable. 5) Finally, the distribution of the resulting values was analysed. The histogram revealed extreme values signalling the presence of outliers. Some of these cases were found to be related to geolocation errors (for instance, a typo in the postal code). The outliers were

[2] https://fenix.tecnico.ulisboa.pt/homepage/ist155593/gis

corrected using the method proposed by Field (2013), replacing them by the immediately inferior value plus one unit. A second outlier screening consisted in standardizing the distance variable, finding the cases whose values were higher than three times the standard deviation, and replacing the value by the average distance value plus two times the standard deviation (12 cases were replaced by a distance of 41.752m).

Table 5.3 summarizes the results. It was found that half of the population sample lived or worked at less than 600m from the Eixo Central and 75% lived or worked up to a 1000m distance. Walking distances are somewhat better perceived in terms of duration. In order to have a better reading of the distance to the intervention, the metric distance was converted to a corresponding travel time assuming a constant speed of 1,2 m/s for all pedestrian types (Cambra, 2012). Accordingly it was found that most people worked or lived up to 10 mins away of Eixo Central and 75% worked or lived up to 20 mins walking distance from Eixo.

Table 5.3: Walking distance to Eixo Central

| | Mean | SD | Min | Q1 | Q2 | Q3 | Max | n |
|---|---|---|---|---|---|---|---|---|
| Distance to Eixo Central (m) | 1843.00 | 4966.30 | 8.67 | 563.10 | 585.30 | 996.70 | 41752.00 | 1166 |
| Distance to Eixo Central (min) | 25.60 | 68.90 | 1.00 | 7.82 | 8.13 | 13.84 | 579.89 | |

| Distance classes | up to 5 min | 10 min | 15 min | 20 min | 25 min | 30 min | >30 min | n |
|---|---|---|---|---|---|---|---|---|
| Distance to Eixo Central (n) | 115 | 681 | 86 | 62 | 37 | 44 | 141 | 1166 |
| Proportion | 10% | 58% | 7% | 5% | 3% | 4% | 12% | |

### Active Exposure: Frequency of usage

Another way of portraying exposure is using active exposure, hereby defined by the frequency of use of the intervention site. To obtain this data, people were asked in the survey to report how frequently they walked in each of the three Eixo Central sections (Av.Republica, Av.Fontes Pereira de Melo and Saldanha Sq.). Data was collected by means of a closed answer, consisting in a categorical variable arranged in an ordinal scale:

1. Almost never (less than once a month)
2. Rarely (+- once a month)
3. Occasionally (more than once a month but less than once a week)
4. Habitually (at least once a week)

5. Frequently (more than once a week but not daily)
6. Daily (or almost daily)

From the three Eixo sections, Saldanha Sq. showed the higher frequency of use, with a median value of 4 (mean = 3.62, between occasional and habitual use), followed by Av.Republica with a median value of 3 (mean = 3.52, also between occasional and habitual use) and by Av.Fontes Pereira de Melo with a median value of 3 (mean = 2.74, between rare and occasional use).

As in the case of passive exposure where the Eixo Central was considered as a whole, in this case it was necessary to formulate a single exposure variable from the three sections' frequency of use. The option was to select the maximum frequency value of the three sections (median = 4; mean = 3.98). The frequency of use (i.e. active exposure) was further analysed by user group - residents, workers and visitors, as shown in Table 5.4.

Table 5.4: Exposure:Frequency of use

| Eixo Central | 1) Less than 1 trip/ month | 2) Around 1 trip/month | 3)More than 1 trip/month, less than 1 trip/week | 4)At least 1 trip/week | 5)More than 1 trip/week | 6)Daily | total | mean) |
|---|---|---|---|---|---|---|---|---|
| Residents | 8 | 2 | 24 | 27 | 49 | 64 | 174 | 4.72 |
| Workers | 44 | 34 | 105 | 95 | 133 | 157 | 568 | 4.25 |
| Visitors | 47 | 66 | 141 | 82 | 54 | 34 | 424 | 3.31 |
| Total | 99 | 102 | 270 | 204 | 236 | 255 | 1166 | 3.98 |

### Perceptions

The built environment is perceived by the individual through the primary sensory systems (visual, auditory, olfactory, gustatory and tactile). Moreover perceptions of the environment reflect an individual's interaction with the actual environment (Ma & Cao, 2017), and a mix of past experiences, one's culture and the interpretations of the perceived (Ewing & Handy, 2009). Therefore, different people belonging to similar socio-demographic segments may perceive the same built environment in a different manner, which in turn may trigger different behavioural responses (Ewing & Handy, 2009).

In other words, an environmental improvement can be objectively considered as a relevant improvement from the viewpoint of trained auditors but it may not be perceived as an improvement from the viewpoint of the population. Accordingly, lacking to perceive an environmental change may not bear any effect on the individual. As stated by Lynch (1960), behaviour is based on the perception of what reality is, not on reality itself.

The present study addressed the perception of change in 10 environmental factors: 1) Pedestrian space; 2) Pavement comfort; 3) Greenery; 4) Sidewalk obstacles (absence of);

5) Crossing safety; 6) Crossing opportunities; 7) Land Use mix; 8) Sidewalk accessibility; 9) Meeting points; 10) Amenities.

Survey respondents were asked to rate the degree of environmental change for each of the 10 factors. The rating scale attempted to rank the intensity of the change and also its direction - if an improvement, if a deterioration - using a likert type item ranging from 1 to 5 with the following values:

1. Notorious change, for worse;
2. Small change, for worse;
3. No change;
4. Small change, for better;
5. Notorious change, for better.

Table 5.5: Perceived change in built environment factors

| BE factor | 1) Notorious change, for worse | 2) Small change, for worse | 3) No change | 4) Small change, for better | 5) Notorious change, for better | Mean | Missing (NA) | n |
|---|---|---|---|---|---|---|---|---|
| Land use mix | 9 | 21 | 703 | 306 | 48 | 3.33 | 79 | 1087 |
| Crossing safety | 24 | 46 | 400 | 405 | 209 | 3.67 | 82 | 1084 |
| Crossing opportunities | 22 | 56 | 336 | 492 | 177 | 3.69 | 83 | 1083 |
| Sidewalk obstacles (absence of) | 13 | 40 | 237 | 556 | 236 | 3.89 | 84 | 1082 |
| Meeting points | 7 | 20 | 271 | 522 | 264 | 3.94 | 82 | 1084 |
| Amenities | 10 | 25 | 265 | 542 | 236 | 3.99 | 88 | 1078 |
| Sidewalk accessibility | 10 | 10 | 175 | 576 | 297 | 4.07 | 98 | 1068 |
| Pavement comfort | 4 | 20 | 100 | 450 | 517 | 4.34 | 75 | 1091 |
| Pedestrian space | 5 | 14 | 63 | 433 | 577 | 4.43 | 74 | 1092 |
| Greenery | 9 | 22 | 131 | 557 | 366 | 4.45 | 81 | 1085 |

Table 5.5 show how people perceived the changes in the Eixo built environment. The results show that from all factors land use was considered the one to have undergone the least change, which is in line with the objective walkability audit. On the other hand, greenery was the factor pointed to have improved the most. In fact, grassy medians were implemented along the Eixo which provided a distinctive image, in Saldanha square new landscaping complemented the existing trees, and the enlargement of the sidewalks allowed to be closer to the existing tree alignments, hence perceiving them in a different manner. The enlargement of the sidewalks was also pointed in the change of "pedestrian space", which scored the most full ratings (577). The sidewalks were enlarged but also improved, with more regular and smoother pavement being installed. This change was perceived also as a "notorious change, for better" for almost half of the respondents (517). Interestingly, some people reported having perceived a negative change (for worse), namely relating to crossing opportunities and safety. The consistency of the perceptions scoring scale was

checked using Cronbach's Alpha. The alpha coefficient found was 0.86, suggesting that the items have relatively high internal consistency.

**Experience**

Walking provides an internal, individual experience of the environment, but often delivers also a social experience, by means of sharing the environment with other people (Darker *et al.*, 2007). Such experiences and interactions influence a person's walking behaviour, where a past positive journey is more likely to increase the chance of walking again and a negative experience would have an opposite influence, refraining from walking again (Park *et al.*, 2014). Hence, several researchers have been addressing how pedestrians feel about their walking environments (Dadpour *et al.*, 2016). This has been done by interviews or focus groups (e.g.Johansson *et al.* (2017)) or by intercept surveys (e.g.Jung *et al.* (2017)). In the present study, the before-after walking experience was obtained using a retrospective approach. Survey respondents were asked to rate their walking experience in the present and comparatively to rate their walking experience one year before, considering the same time of the year (the survey was launched in winter). Walking experience was rated using a 9 point likert item, where the minimum vale corresponded to a "place to avoid walking" and the maximum value to a "very pleasant walk". People were instructed to assume an identical interval between the scale levels. Walking experience was rated for each of the three Eixo sections, resulting in a 6 likert items scale.

The walking experience ratings allowed several readings which could have different effects in behaviour change. As in the case of walkability research, most studies focusing in walking experience have been cross sectional rather than longitudinal. Hence, in the face of an environmental change, there is not sufficient evidence to understand if the final walking experience is more relevant to influence behaviour, or if it is the average experience that matters or even if it is the difference between before and after experience that is more influential. To test these alternatives, two different walking experience variables were drawn from the survey responses - satisfaction and final experience - presented in Table 5.6.

### Satisfaction

Satisfaction was considered to be the amount of increase in walking experience, being the difference between the after and before walking experience rating. In this case, the initial walking conditions matter. The result for the Eixo was obtained from the mean of the three sections' satisfaction score. Table 5.6 shows a number of missing values relating to satisfaction. This has to do with people not familiar with the walking conditions of the Eixo prior to the intervention (namely in Av.Fontes Pereira de Melo).

### Final walking experience

Final walking experience refers to the rating of the "after" walking experience, following the rationale that the last impression is more relevant in influencing behaviour. Given that over time many people will not recall the original conditions, and more importantly, new users will experience this environment, initial conditions dot not matter. The result for the Eixo was obtained from the mean of the three sections' final rating.

Table 5.6: Walking experience descriptive statistics

| | Mean | SD | Min | Q1 | Q2 | Q3 | Max | n | Missing (NA) |
|---|---|---|---|---|---|---|---|---|---|
| Satisfaction (difference before-after) | 2.42 | 2.03 | -6.67 | 1.00 | 2.33 | 3.66 | 9.00 | 975 | 191 |
| Final walking experience (after) | 6.86 | 1.39 | 1.00 | 6.00 | 7.00 | 7.67 | 9.00 | 1166 | 0 |

## Additional covariates

In addition to the main covariates -Exposure, Perceptions and Experience- that are hypothesized to influence walking behaviour change, several additional covariates were considered to be included in the model, namely life changing events, travel behaviour variables and socio-demographic variables.

### Life changing events

Several studies have addressed the importance of "life changing events" in changing mobility patterns. Such events include relocation - residential, work or school - that change origins and destinations , or events like retirement or parenthood that change daily routines (Giles-corti *et al.*, 2013; Kesten *et al.*, 2015; McCarthy *et al.*, 2019; Chakrabarti & Joh, 2019). Other cases relate to injury that restrain ability to move (Methorst *et al.*, 2017). The survey respondents were asked to indicate if they had experienced such events within the past year time-frame. Table 5.7 presents the considered life changing events. Relocation was the most frequent event reported by the sampled population (around 12% of the respondents had changed their workplace or residential location in the previous year).

Table 5.7: Life changing events

| Life changing events (n=1166) | Freq. | % |
|---|---|---|
| Used walking aids (cane, crutches, walkers, etc.) | 41 | 3.5% |
| Used wheelchair | 7 | 0.6% |
| Injury due to a sidewalk fall | 94 | 8.1% |
| Parenthood | 21 | 1.8% |
| Change in children's school location | 78 | 6.7% |
| Change in residential location | 138 | 11.8% |
| Change in workplace location | 144 | 12.3% |
| Retired from work | 9 | 0.8% |

#### Willingness to walk

Some people are willing to walk more than others. The distance that people are willing to walk to reach a certain destination or activity has been a somehow understudied subject (Millward *et al.*, 2013; Weinstein Agrawal *et al.*, 2008). In the case of transportation studies for instance, it is common to find "standard" walking distances to reach the public transportation system, such as 400m to reach a bus station or 800m to reach a train station. It can be hypothesized that people that are willing to walk more, or walk further distances are more prone to increase their walking activity following an environmental intervention. In the present study, survey respondents were asked to state how much they were willing to walk in a regular journey to reach their destination. Table 5.8 shows that in average the sampled population was willing to engage in a 24 minute walk, but half of the population was not willing to walk more than 20 minutes. These values are in line with those found in neighbouring Spain (22.5 minutes) (Lamíquiz & López-domínguez, 2015).

Table 5.8: Willingness to walk (trip duration

| | Mean | SD | Min | Q1 | Q2 | Q3 | Max | n |
|---|---|---|---|---|---|---|---|---|
| Willingness to walk (minutes) | 24.29 | 14.76 | 0.00 | 15.00 | 20.00 | 30.00 | 70.00 | 1160 |

## 5.2 Modeling behavior change by trip purpose

A critical step in setting up the binary logistic regression model is the selection of variables. In this case the model falls within the scope of confirmatory research, that is to say hypothesis testing. It aims to confirm if the theoretical behavioural diagram is supported by the collected data. Hence most of the variables to test in the model have been selected, and presented in the previous section. As stated by Hosmer Jr *et al.* (2013), model building should seek to find the "most parsimonious model that still accurately reflects the true outcome experience of the data". Reducing the number of variables in the model not only provides numerical stability but also fosters a wider use of the model: the more variables included in the model the more dependent the model is on observed data.

Hosmer Jr *et al.* (2013); Zhang (2016) and Harrell (2015) provide guidance for the "purposeful selection of variables" in logistic regression model building, comprising the following steps:

**Step 1:** The first step in the purposeful selection method is to perform a univariate analysis of each independent variable. Hosmer Jr *et al.* (2013) recommends the use of independent samples t-tests for interval variables and the use of contingency tables for categorical variables. When analysing the contingency tables one should check for empty cells or cells with less than 5 cases, as the model may become unstable or fail to run. A possible way around this issue is to merge categories. Zhang (2016) suggests using a cut-off point of 0.25 in the Wald test coefficient (p-value) to select which variables should be initially included.

**Step 2:** The variables identified for inclusion at Step 1 form the base model. The base model should be fit and the relative importance of each variable assessed using the respective p-value (Wald test coefficient). Following the base model fit, variables that are below the usual statistical significance level (e.g. $p<.05$) should be identified and removed from the model. The remaining, significant, variables form the reduced model. Hosmer Jr *et al.* (2013) advises to ensure that at this stage the samples used to fit the base model and the reduced model are the same, which can be an issue if in the presence of missing data.

**Step 3:** The next step is to compare the values of the estimated coefficients (the beta values) between the base and the reduced model, screening for high changes - above 20%. In these cases the excluded variable should be added back into the (reduced) model.

**Step 4:** At step 4, the variables originally excluded in step 1 should be added one at the time to the model, checking its significance. This is necessary to identify variables that alone have a low relation to the outcome but can make a significant contribution in the presence of other variables. Significant variables should be added, forming the preliminary main effects model.

**Step 5:** In this step the assumption of linearity of the regression model should be, where continuous covariates should be linearly related to the log of the model outcome. This can be performed by visual inspection of scatterplots (Zhang, 2016), as presented in Figure 7.2 in the annexes. If the assumption is met, the model can be denominated the main effects model.

**Step 6:** Having the main effects model, the next step is to check for interactions among the variables in the model. An interaction between two variables implies that the effect of one variable each variable is not constant over levels of the other variable, that is to say, the effect of a covariate is dependent on another covariate. Interaction pairs should be meaningful, being its inclusion based on previous research considerations.

**Step 7:** The final step is to assess the model adequacy and its fit. This can be performed using several measures of goodness of fit, including deviance, pseudo R2, the Hosmer-Lemeshow test (HL) and the receiver operating characteristic curve (ROC). The present study used the HL test and the ROC curve to assess the GOF of the final model. In brief, the HL test calculates if there is a significant difference between observed and predicted values (a significant result means that the model does not have a good fit). The ROC curve reflects the discrimination power of the model by showing the trade-off between sensitivity and specificity. Sensitivity is given by the true positive rate (TPR) of the model outcome whilst specificity is given by the false positive rate (FPR). The ROC curve can be generated by plotting the cumulative distribution function of TPR versus the cumulative distribution function of FPR. The calculation of the area under the ROC curve provides the GOF value, which can be interpreted as follows (Hosmer Jr *et al.*, 2013):

- ROC = 0.5: This suggests no discrimination, so we might as well flip a coin.
- ROC between 0.5 and 0.7: poor discrimination, not much better than a coin toss.
- ROC between 0.7 and 0.8: acceptable discrimination.
- ROC between 0.8 and 0.9: excellent discrimination.
- ROC higher than 0.9: outstanding discrimination.

### 5.2.1 Results

Tables 5.9, 5.10, 5.11, 5.12 and 5.13 present the results of the binary logistic models which predict the propensity that the respondents reported an increase in the walking frequency for the five considered purposes in the Eixo Central area: utilitarian walking; recreational walking; walking for public transport; walking for exercise and adopting alternative walking routes. Annex 5 presents the ROC curves and the assumption of linearity plots.

#### Utilitarian walking

The model fit indices indicate an increase in the model fit from the base model to the main effects -final- model. McFadden's adjusted pseudo R2 value indicated a modest fit, with the final model being able to explain only about 13% of the variation in the dependent variable. However this modest explanatory power is in line with similar regression models applied to walking behaviour (Burbidge, 2008). The ROC curve area value denoted acceptable discrimination.

The hypothesis that exposure, perceptions and walking experience were significant predictors of increasing the frequency of utilitarian walking trips was confirmed. The actual use of the streets was found as a significant exposure factor. Notably, the occasional use showed a positive association ($B=0.570$, $p<.01$) but a more frequent use was negatively associated with change in utilitarian walking ($B=-0.317$, $p<.05$). Exposure given by the distance from the residence or workplace to the intervention area was non-significant. In terms of perceived environmental changes, the perception of some improvements in land use mix ($B=0.948$, $p<.01$), meeting points ($B=0.273$, $p<.05$) and pedestrian space ($B=1.097$, $p<.05$) were found to be significant. Conversely, the perception of big improvements in these factors was found to have a negative yet non-significant association. Satisfaction, considered as the difference between the final and initial reported walking experience was found to be a significant factor ($B=0.149$, $p<.01$), contrary to the final walking experience. No socio-demographic variables were found to significant in explaining the variance in utilitarian walking behaviour change. An interesting result is the counter-intuitive negative association from the perceptions of larger scale improvements and behaviour change in some factors whilst the perception of just some improvements results in a positive association (seen in crossing opportunities, meeting points and pedestrian space).

The most influential factors were found to be the perception of improvement in the pedestrian space (Odds Ratio -OR=2.996) and in the land use mix (OR=2.579), meaning that a person who perceived some improvement in the pedestrian space of the Eixo Central was almost 3 times more likely to increase the frequency of utilitarian walking than a person who had not perceived such change.

### Recreational walking

The final model of change in recreational walking show various similarities to the one of utilitarian walking. The goodness of fit indices of this model were in line to the utilitarian model, where McFadden's adjusted pseudo R2 value shows also a modest fit of about 14%. The ROC curve area value denoted acceptable discrimination.

For recreational walking, the hypothesis of exposure, perceptions and walking experience being significant predictors was also confirmed. The results of this model also showed the actual use of the streets to be a significant exposure factor ($B=0.607$, $p<.01$) but not the distance from the residence or workplace to the intervention area. In terms of perceived environmental changes, significant associations were found regarding the perception of some positive change in the land use mix ($B=0.769$, $p<.01$) and the existence of meeting points (1.028, $p<.01$). Counter-intuitively, perceiving a big improvement in pedestrian accessibility was negatively associated to increasing recreational walking ($B=-0.417$, $p<.01$). In terms of walking experience, satisfaction was also found to be a significant factor ($B=0.805$, $p<.01$), but not the final walking experience. As in the previous model, no socio-demographic variables were found to significant in explaining the variance in recreational walking behaviour change.

In this model, the most influential factors were found to be the perception of improvement in the provision of meeting places (OR=2.797) and in the land use mix (OR=2.158). Again, a person who perceived some improvement in the provision of meeting places in the Eixo Central was almost 3 times more likely to increase the frequency of recreational walking than a person who had not perceived such change.

### Walking for public transport

The model fit indices model were in line with the previous ones, being able to explain 17% of the variation in making public transportation walking bouts. Walking for transportation was the purpose with the least reported change (15% of reported increase), possibly meaning that people make their travel decisions with only a little influence of environmental factors, of walking experience and of exposure to a street improvement intervention. The ROC curve area value denoted acceptable discrimination.

Table 5.9: Change in utilitarian walking - logit model results

| | Utilitarian Walking | | | | |
|---|---|---|---|---|---|
| | Increase in frequency | | Odds Ratio | Conf. Interval | |
| | Base model | Final | | 5% | 95% |
| Exposure ref.: rarely used | | | 1 | | |
| Exposure: occasional use | 0.645*** (0.195) | 0.570*** (0.190) | 1.769 | 1.304 | 2.439 |
| Exposure: frequent use | -0.353** (0.150) | -0.317** (0.147) | 0.728 | 0.57 | 0.926 |
| B.Env.Factor ref.: no improvement | | | 1 | | |
| Amenities: some improv. | -0.055 (0.206) | | | | |
| Amenities: big improv. | 0.075 (0.142) | | | | |
| Crossing opp.: some improv. | 0.041 (0.210) | 0.225 (0.177) | 1.252 | 0.936 | 1.673 |
| Crossing opp.: big improv. | -0.310** (0.142) | -0.337*** (0.131) | 0.714 | 0.575 | 0.884 |
| Crossing safety: some improv. | 0.379** (0.188) | | | | |
| Crossing safety: big improv. | 0.001 (0.142) | | | | |
| Green spaces: some improv. | 0.064 (0.218) | | | | |
| Green spaces: big improv. | 0.052 (0.150) | | | | |
| Land use: some improv. | 1.005*** (0.300) | 0.948*** (0.289) | 2.579 | 1.623 | 4.215 |
| Land use: big improv. | 0.137 (0.200) | 0.107 (0.195) | 1.113 | 0.811 | 1.546 |
| Meeting Points: some improv. | 0.405** (0.204) | 0.407** (0.180) | 1.502 | 1.119 | 2.024 |
| Meeting Points: big improv. | -0.023 (0.141) | -0.045 (0.132) | 0.956 | 0.768 | 1.188 |
| Obstacle free: some improv. | -0.220 (0.208) | | | | |
| Obstacle free: big improv. | -0.012 (0.140) | | | | |
| Pav.Comfort: some improv. | 0.396 (0.303) | | | | |
| Pav.Comfort: big improv. | -0.035 (0.197) | | | | |
| Ped.Accessibility: some improv. | 0.076 (0.220) | | | | |
| Ped.Accessibility: big improv. | -0.263* (0.149) | | | | |
| Ped.Space: some improv. | 0.955** (0.478) | 1.097** (0.445) | 2.996 | 1.551 | 6.948 |
| Ped.Space: big improv. | -0.223 (0.285) | -0.260 (0.275) | 0.771 | 0.464 | 1.169 |
| Walk Experience: satisfaction | 0.170*** (0.054) | 0.149*** (0.048) | 1.161 | 1.073 | 1.258 |
| Walk Experience: final | -0.099 (0.086) | | | | |
| Age group | 0.036 (0.082) | | | | |
| Work activity ref.: Worker | | | | | |
| Work activity: Student | -0.119 (0.245) | | | | |
| Work activity: Retired | -0.310 (0.430) | | | | |
| Work activity: Other | 0.568 (0.461) | | | | |
| Intercept | -1.038 (0.684) | -1.484*** (0.261) | 0.227 | 0.142 | 0.34 |
| Observations | 906 | 906 | | | |
| Log Likelihood | -479.486 | -486.554 | | | |
| Akaike Inf. Crit. | 1,016.97 | 997.108 | | | |
| McFadden adjusted R2 | 0.14 | 0.13 | | | |
| Hosmer and Lemeshow GOF test | p=0.979 | | | | |
| ROC curve area | 0.748: Acceptable discrimination | | | | |

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5.10: Change in recreational walking - logit model results

| | Recreational Walking | | | | |
|---|---|---|---|---|---|
| | Increase in frequency | | Odds Ratio | Conf. Interval | |
| | Base model | Final | | 5% | 95% |
| Exposure: min. distance | 0.000 (0.000) | | | | |
| Exposure ref.: rarely used | | | 1 | | |
| Exposure: occasional use | 0.625*** (0.207) | 0.607*** (0.198) | 1.835 | 1.336 | 2.565 |
| Exposure: frequent use | -0.216 (0.158) | -0.178 (0.154) | 0.837 | 0.648 | 1.076 |
| B.Env.Factor ref.: no improvement | | | 1 | | |
| Amenities: some improv. | 0.252 (0.218) | | | | |
| Amenities: big improv. | -0.075 (0.150) | | | | |
| Crossing opp.: some improv. | -0.194 (0.219) | | | | |
| Crossing opp.: big improv. | -0.179 (0.149) | | | | |
| Crossing safety: some improv. | 0.337* (0.197) | | | | |
| Crossing safety: big improv. | -0.175 (0.148) | | | | |
| Green spaces: some improv. | 0.155 (0.241) | | | | |
| Green spaces: big improv. | -0.298* (0.162) | | | | |
| Land use: some improv. | 0.815*** (0.304) | 0.769*** (0.285) | 2.158 | 1.363 | 3.496 |
| Land use: big improv. | 0.326 (0.204) | 0.268 (0.196) | 1.307 | 0.95 | 1.816 |
| Meeting Points: some improv. | 0.974*** (0.219) | 1.028*** (0.195) | 2.797 | 2.037 | 3.878 |
| Meeting Points: big improv. | -0.005 (0.149) | -0.029 (0.140) | 0.972 | 0.771 | 1.222 |
| Obstacle free: some improv. | -0.084 (0.213) | | | | |
| Obstacle free: big improv. | 0.203 (0.146) | | | | |
| Pav.Comfort: some improv. | 0.036 (0.302) | | | | |
| Pav.Comfort: big improv. | 0.033 (0.199) | | | | |
| Ped.Accessibility: some improv. | 0.159 (0.239) | 0.273 (0.225) | 1.314 | 0.913 | 1.919 |
| Ped.Accessibility: big improv. | -0.421*** (0.160) | -0.417*** (0.152) | 0.659 | 0.511 | 0.842 |
| Ped.Space: some improv. | 0.149 (0.444) | | | | |
| Ped.Space: big improv. | -0.155 (0.265) | | | | |
| Walk Experience: satisfaction | 0.246*** (0.056) | 0.271*** (0.047) | 1.312 | 1.214 | 1.42 |
| Walk Experience: final | 0.026 (0.091) | | | | |
| Gender ref: Male | | | | | |
| Gender Female | 0.179 (0.169) | | | | |
| Work activity ref.: Worker | | | | | |
| Work activity: Student | -0.052 (0.186) | | | | |
| Work activity: Retired | -0.416 (0.400) | | | | |
| Work activity: Other | 0.386 (0.498) | | | | |
| Acceptable walk distance | 0.005 (0.005) | | | | |
| Intercept | -2.165*** (0.627) | -1.707*** (0.219) | 0.181 | 0.126 | 0.259 |
| Observations | 890 | 890 | | | |
| Log Likelihood | -449.423 | -458.914 | | | |
| Akaike Inf. Crit. | 960.847 | 937.829 | | | |
| McFadden adjusted R2 | 0.16 | 0.14 | | | |
| Hosmer and Lemeshow GOF test | p=0.989 | | | | |
| ROC curve area | 0.754: Acceptable discrimination | | | | |

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5.11: Change in walking for public transportation - logit model results

| | Walking for public transport | | | | |
|---|---|---|---|---|---|
| | Increase in frequency | | Odds Ratio | Conf. Interval | |
| | Base model | Final | | 5% | 95% |
| Exposure: Origin distance | -0.0001*** (0.00005) | -0.0001** (0.00003) | 1.000 | 1.000 | 1.000 |
| Exposure: Destination distance | -0.000 (0.000) | | | | |
| Exposure: min. distance | 0.00002 (0.0001) | | | | |
| Exposure ref.: rarely used | | | | | |
| Exposure: occasional use | 0.059 (0.475) | | | | |
| Exposure: frequent use | 0.192 (0.380) | | | | |
| B.Env.Factor ref.: no improvement | | | 1 | | |
| Amenities: some improv. | 1.226** (0.549) | 1.229*** (0.442) | 3.417 | 1.701 | 7.371 |
| Amenities: big improv. | -0.353 (0.353) | -0.211 (0.303) | 0.81 | 0.485 | 1.322 |
| Crossing opp.: some improv. | 0.013 (0.583) | | | | |
| Crossing opp.: big improv. | -0.115 (0.366) | | | | |
| Crossinf safety: some improv. | -0.438 (0.568) | | | | |
| Crossinf safety: big improv. | -0.523 (0.356) | | | | |
| Green spaces: some improv. | -0.427 (0.571) | | | | |
| Green spaces: big improv. | 0.248 (0.378) | | | | |
| Land use: some improv. | 0.307 (0.636) | | | | |
| Land use: big improv. | 0.218 (0.448) | | | | |
| Meeting Points: some improv. | 0.913* (0.552) | | | | |
| Meeting Points: big improv. | 0.102 (0.360) | | | | |
| Obstacle free: some improv. | -0.836 (0.546) | | | | |
| Obstacle free: big improv. | -0.194 (0.364) | | | | |
| Pav.Comfort: some improv. | -0.129 (0.732) | | | | |
| Pav.Comfort: big improv. | -0.161 (0.462) | | | | |
| Ped.Accessibility: some improv. | 1.531** (0.686) | 1.232** (0.592) | 3.43 | 1.412 | 10.543 |
| Ped.Accessibility: big improv. | -0.523 (0.426) | -0.449 (0.374) | 0.638 | 0.321 | 1.132 |
| Ped.Space: some improv. | 0.578 (0.913) | | | | |
| Ped.Space: big improv. | 0.082 (0.598) | | | | |
| Walk Experience: satisfaction | 0.422*** (0.139) | 0.323*** (0.111) | 1.381 | 1.151 | 1.663 |
| Walk Experience: final | -0.529** (0.227) | -0.343* (0.187) | 0.71 | 0.521 | 0.968 |
| AgeGroup | -0.335 (0.235) | | | | |
| Work activity ref.: Worker | | | | | |
| Work activity: Student | 0.582 (0.586) | | | | |
| Work activity: Retired | 0.238 (1.330) | | | | |
| Work activity: Other | -16.736 (1547) | | | | |
| Education ref.: No university degree | | | | | |
| Education: Has univ. degree | 0.478 (0.539) | | | | |
| Average Trip duration | 0.008 (0.005) | | | | |
| Average Trip done walking | 0.053* (0.028) | | | | |
| Main transport mode ref.: Car | | | 1 | | |
| Main transport mode: Public transport | -0.042 (0.649) | 1.120** (0.456) | 3.065 | 1.496 | 6.772 |
| Main transport mode: Walking | -1.320 (0.861) | -0.010 (0.610) | 0.99 | 0.354 | 2.693 |
| Main transport mode: Other | -17.534 (1322) | -15.363 (891.5) | 0.000 | 0.000 | 9.32E6 |
| Intercept | 0.410 (1.853) | -0.927 (1.248) | | | |
| Observations | 327 | 327 | | | |
| Log Likelihood | -93.863 | -107.316 | | | |
| Akaike Inf. Crit. | 263.725 | 236.631 | | | |
| McFadden adjusted R2 | 0.27 | 0.17 | | | |
| Hosmer and Lemeshow GOF test | p=0.800 | | | | |
| ROC curve area | 0.781: Acceptable discrimination | | | | |

Note: *p<0.1; **p<0.05; ***p<0.01

The results of this model showed that the distance from the residence to the intervention area to have a significant yet low contribution (B=-0.0001, $p<.05$), while the actual use of the Eixo area did not contribute significantly, as opposite to the previously presented models.

In terms of perceived environmental changes, the perception of a positive change in amenities (B=1.229, $p<.01$) and accessibility (B=1.232, $p<.01$) were found to be significant. In terms of walking experience, satisfaction was again found to be a significant factor (B=0.323, $p<.01$), but also the final walking experience although with a weak and negative association (B=-0.343, $p<0.1$). Once again, there were no significant socio-demographic variables.

The model also showed the influence of usual transportation mode. Public transport users were 3 times more likely to report an increase in walking for public transport than car users (B=1.120, $p<.05$, OR=3.065). Other highly influential factors were the perception of improvement in pedestrian accessibility (OR=3.43) and in the provision of amenities (OR=3.417).

**Walking for exercise**

An increase in the frequency of walking for exercise in the Eixo Central area was reported by 17% of the survey respondents. The model fit indices were not higher than the previous models, with McFadden's adjusted pseudo R2 value showing a modest fit of 15% and acceptable discrimination values given by the ROC curve area.

Consistent to the previous models, the actual use of the streets was found to be a significant exposure factor (B=1.574, $p<.01$), but not proximity to the intervention area. In terms of perceived environmental changes, the perception of improved pavement comfort (B=0.786, $p<.05$) and pedestrian accessibility (B=0.598, $p<.05$) were found to be significant factors in explaining an increase in walking for exercise.

Contrasting to the previous models, walking experience expressed as satisfaction was not a significant factor, but, instead, the final walking experience was found to be a significant term for this walking purpose (B=0.364, $p<.001$). Also contrasting to the previous models, two socio-demographic factors revealed a significant association to walking behaviour change. One was the age group, with a positive association showing that older people were slightly more likely to change their walking behaviour (B=0.245, $p<.01$, OR=1.278). The other one was gender, with marginally significant association showing that females were less likely to engage in walking for exercise than male users (B=-0.35.

Table 5.12: Change in walking for exercise - logit model results

| | Walking for exercise | | | | |
|---|---|---|---|---|---|
| | Increase in frequency | | Odds Ratio | Conf. Interval | |
| | Base model | Final | | 5% | 95% |
| Exposure: min. distance | 0.00002 (0.0001) | | | | |
| Exposure ref.: rarely used | | | 1 | | |
| Exposure: occasional use | 1.550*** (0.382) | 1.574*** (0.374) | 4.826 | 2.771 | 9.714 |
| Exposure: frequent use | -0.664*** (0.251) | -0.590** (0.246) | 0.554 | 0.356 | 0.81 |
| B.Env.Factor ref.: no improvement | | | 1 | | |
| Amenities: some improv. | 0.382 (0.268) | | | | |
| Amenities: big improv. | -0.227 (0.179) | | | | |
| Crossing opp.: some improv. | 0.090 (0.247) | | | | |
| Crossing opp.: big improv. | -0.119 (0.171) | | | | |
| Crossing safety: some improv. | 0.180 (0.227) | | | | |
| Crossing safety: big improv. | 0.039 (0.172) | | | | |
| Green spaces: some improv. | 0.204 (0.294) | | | | |
| Green spaces: big improv. | -0.266 (0.196) | | | | |
| Land use: some improv. | 0.365 (0.306) | | | | |
| Land use: big improv. | 0.005 (0.210) | | | | |
| Meeting Points: some improv. | -0.129 (0.251) | | | | |
| Meeting Points: big improv. | -0.014 (0.173) | | | | |
| Obstacle free: some improv. | -0.092 (0.255) | | | | |
| Obstacle free: big improv. | 0.078 (0.172) | | | | |
| Pav.Comfort: some improv. | 0.498 (0.406) | 0.786** (0.357) | 2.195 | 1.273 | 4.185 |
| Pav.Comfort: big improv. | -0.225 (0.261) | -0.245 (0.244) | 0.783 | 0.511 | 1.151 |
| Ped.Accessibility: some improv. | 0.414 (0.269) | 0.598** (0.253) | 1.818 | 1.215 | 2.809 |
| Ped.Accessibility: big improv. | 0.118 (0.188) | 0.128 (0.180) | 1.137 | 0.841 | 1.521 |
| Ped.Space: some improv. | 0.298 (0.587) | | | | |
| Ped.Space: big improv. | 0.016 (0.350) | | | | |
| Walk Experience: satisfaction | 0.045 (0.065) | | | | |
| Walk Experience: final | 0.258** (0.110) | 0.364*** (0.093) | 1.439 | 1.238 | 1.682 |
| AgeGroup | 0.129 (0.097) | 0.245*** (0.058) | 1.278 | 1.162 | 1.407 |
| Gender ref.: Male | | | 1 | | |
| Gender: Female | -0.364* (0.197) | -0.35* (0.19) | 0.704 | 0.515 | 0.961 |
| Work activity ref.: Worker | | | | | |
| Work activity: Student | -0.552* (0.307) | | | | |
| Work activity: Retired | -0.022 (0.466) | | | | |
| Work activity: Other | 0.362 (0.600) | | | | |
| Education ref.: No university degree | | | | | |
| Education: Has univ. degree | -0.109 (0.268) | | | | |
| Acceptable walk distance | 0.008 (0.006) | | | | |
| Intercept | -4.632*** (0.934) | -5.789*** (0.738) | 0.003 | 0.001 | 0.01 |
| Observations | 918 | 918 | | | |
| Log Likelihood | -354.407 | -363.847 | | | |
| Akaike Inf. Crit. | 774.814 | 747.693 | | | |
| McFadden adjusted R2 | 0.17 | 0.15 | | | |
| Hosmer and Lemeshow GOF test | p=0.741 | | | | |
| ROC curve area | 0.768: Acceptable discrimination | | | | |

Note: *p<0.1; **p<0.05; ***p<0.01

p<0.1, OR=0.704).

### Walking route selection

The model fit indices of this model revealed the lowest explanatory power, being able to explain less than 10% of the variation in choosing the Eixo Central streets as an alternative route. Likewise the ROC curve area indicated a borderline value, close to a poor discrimination value ("not much better than a coin toss"). Nevertheless, several significant associations were found, much in line with the previous models: exposure, expressed by the use of the streets (B=0.394, p<.05); perception of improvements in crossing safety (B=0.325, p<.05); and satisfaction (B=0.202, p<0.01). The age group of respondents was marginally significant (B=-0.086, p<.10) as well as the perceptions of improvements in pedestrian space (B=0.642, p<.10).

Table 5.13: Change in walking route - logit model results

| | Walking route selection | | | | |
|---|---|---|---|---|---|
| | Increase in frequency | | Odds Ratio | Conf. Interval | |
| | Base model | Final | | 5% | 95% |
| Exposure ref.: rarely used | | | 1 | | |
| Exposure: occasional use | 0.415** (0.173) | 0.394** (0.168) | 1.483 | 1.13 | 1.967 |
| Exposure: frequent use | -0.219 (0.137) | -0.188 (0.134) | 0.829 | 0.663 | 1.033 |
| B.Env.Factor ref.: no improvement | | | 1 | | |
| Amenities: some improv. | -0.020 (0.194) | | | | |
| Amenities: big improv. | 0.079 (0.133) | | | | |
| Crossing opp.: some improv. | 0.123 (0.195) | | | | |
| Crossing opp.: big improv. | -0.024 (0.135) | | | | |
| Crossing safety: some improv. | 0.210 (0.182) | 0.325** (0.149) | 1.384 | 1.084 | 1.768 |
| Crossing safety: big improv. | -0.307** (0.135) | -0.273** (0.124) | 0.761 | 0.621 | 0.934 |
| Green spaces: some improv. | 0.258 (0.206) | | | | |
| Green spaces: big improv. | -0.003 (0.142) | | | | |
| Land use: some improv. | 0.333 (0.272) | | | | |
| Land use: big improv. | -0.054 (0.185) | | | | |
| Meeting Points: some improv. | 0.019 (0.192) | | | | |
| Meeting Points: big improv. | -0.114 (0.133) | | | | |
| Obstacle free: some improv. | -0.108 (0.196) | | | | |
| Obstacle free: big improv. | 0.101 (0.133) | | | | |
| Pav.Comfort: some improv. | 0.336 (0.271) | | | | |
| Pav.Comfort: big improv. | 0.010 (0.178) | | | | |
| Ped.Accessibility: some improv. | 0.157 (0.198) | | | | |
| Ped.Accessibility: big improv. | 0.086 (0.136) | | | | |
| Ped.Space: some improv. | 0.571 (0.373) | 0.642* (0.333) | 1.900 | 1.135 | 3.441 |
| Ped.Space: big improv. | -0.094 (0.224) | 0.009 (0.212) | 1.009 | 0.697 | 1.41 |
| Walk Experience: satisfaction | 0.213*** (0.051) | 0.202*** (0.046) | 1.224 | 1.136 | 1.32 |
| Walk Experience: final | -0.151* (0.08) | | | | |
| AgeGroup | -0.121** (0.050) | -0.086* (0.047) | 0.918 | 0.848 | 0.992 |
| Acceptable walk distance | 0.006 (0.005) | | | | |
| Intercept | -0.245 (0.572) | -1.280*** (0.254) | 0.278 | 0.181 | 0.419 |
| Observations | 921 | 921 | | | |
| Log Likelihood | -524.985 | -534.522 | | | |
| Akaike Inf. Crit. | 1,103.97 | 1,087.05 | | | |
| McFadden adjusted R2 | 0.10 | 0.09 | | | |
| Hosmer and Lemeshow GOF test | p=0.402 | | | | |
| ROC curve area | 0.695: Acceptable discrimination | | | | |

Note: *p<0.1; **p<0.05; ***p<0.01

### 5.2.2 Overall discussion

It was tested whether exposure, perceptions and walking experience were associated to walking behaviour change for distinct purposes.

Exposure was expressed by two descriptors - active exposure (the actual use of the space) and passive exposure (living or working close to the intervention area). Exposure was found to be a significant predictor of reported change in walking behaviour for all considered walking purposes. While exposure to an environmental intervention has been consistently found as an influential factor (Pazin *et al.*, 2016), most studies have considered exposure as the distance from the place of residence to the intervention site. For instance Pazin *et al.* (2016) found that people living up to 500m from a new recreation path were more likely to increase their walking levels that people living further away. Likewise, Heinen *et al.* (2017) tested whether exposure measured by proximity from home was associated to mode choice, finding that individuals who were more exposed to the intervention were not more likely to have a full or partial modal shift. Stewart *et al.* (2018) found that living close to parks was not associated to the individuals total physical activity but it did account for a small proportion of total activity. Knell *et al.* (2018) found that living near sidewalk improvements was not associated to transport related walking or physical activity. Similarly,Song *et al.* (2017) found that residential proximity to BE interventions was not associated to modal shift towards active travel. These findings suggest that passive or potential exposure may not be sufficient to influence behaviour change. Only a few studies have considered the actual use of the infrastructure as exposure, finding it a significant factor (Ogilvie *et al.*, 2006). The study of Song *et al.* (2017) found that actual exposure, given by the self reported use of new walking and cycling infrastructure, was positively associated with a modal shift from the private car towards walking and cycling.

The contrast in the findings whereas considering active or passive exposure may be related to an issue of awareness. It may happens that even people living close by to a new or improved infrastructure are not aware of its existence and therefore the potential effects of the environmental improvements can only be significant if people actually use the infrastructure. Also, most studies only addressed exposure to residents, which is probably related to the use of household surveys and phone interviews. This data collection methods leave out other users of the urban environment, namely workers and visitors. To overcome this gap, the present study performed a survey which addressed residents, workers and visitors and evaluated four distinct exposure measures: the distance from residence to the intervention site, the distance from workplace to the intervention site, the least distance from residence/workplace and the reported frequency of walking trips in the Eixo Central sections. Exposure measured by distance from residence to the intervention site was found significant only for walking for transportation, and only with a very low contribution. The results from the five developed models showed that the actual use of the infrastructure was a significant factor.

The perception of environmental changes was found to play a role in shaping behaviour change. Interestingly, some factors were found to be more relevant to a determined walking behaviour outcome than others, and no single perception factor was found to be significant across all walking purposes.

The results show a logical accordance between the significant perceived factors and corresponding behavioural outcome: pedestrian space and land use mix were the most relevant perceived factor for utilitarian walking; the existence of meeting places and land use diversity were found to be the most relevant perceived factor for recreational walking; sidewalk accessibility and amenities were relevant for walking to public transportation; and pavement comfort and accessibility were relevant for walking for exercise; whilst perceived changes in pavement comfort and land uses were relevant for preferring to walk in the Eixo Central streets. A perceived increase in crossing safety was associated to choose the Eixo streets instead of other routes.

The variation in the direction of association of perception of change in environmental factors when reporting "some improvements" and "big improvements" (i.e. the level "some improvements" have been shown to have a positive association to behaviour change whilst the level "big improvements" have been shown to have a negative association) can be related to a self-report issue in surveys known as response-style effect or scale perception bias (Araña & León, 2013). This issue reflects that in various surveys a non-trivial portion of respondents recurs to the extreme values of the measuring scale to all the surveyed items.

Walking experience is a significant predictor of walking behaviour change. In particular, satisfaction (the before-after variation in walking experience) was found to be determinant for four of the five considered walking purposes. Only in the case of walking for exercise the final walking experience mattered more than the relative increase in walking experience.

A major contribution of the present analysis is the confirmation that exposure, perception and walking experience are influential in shaping walking behaviour change. Satisfaction with environmental quality and the experience of walking have long been recognized as influential factors in attracting people to the streets and to encourage walking (Gehl, 2010; Jacobs, 1961, 1993; Lynch, 1960) and also as key factors in sustaining behavioural change (Isaacs, 2010; Ettema *et al.*, 2011; Kim *et al.*, 2014). However, alternative model specifications should be tested given the skewed distribution of the dependent variable outcome, with a much higher proportion of people not reporting any change in walking behaviour.

## 5.3 Pedestrian segmentation and influential relations

This section deals with exploring pedestrian segmentation and the relation of behaviour triggers in walking behavior change. Pedestrian segmentation is related to classifying the population into meaningful groups of walking behaviour and response to environmental interventions. Exploring the mediation of triggers is related to the previous findings whereas walking experience and perceptions were found to be significant explanatory factors of behaviour change for all trip purposes. In this sense, the aim is to analyse possible mediation roles between walking experience, perceptions and pedestrian types.

### 5.3.1 Pedestrian segmentation

Market segmentation is a process used to identify relatively independent groups from a heterogeneous population sharing similar preferences and characteristics, for instance towards travel and transit (Krizek & El-Geneidy, 2007; Chia *et al.*, 2016). Different segments are likely to react differently to policy measures and interventions, hence matching policies to segments could be a key element to achieve more effective solutions (Félix *et al.*, 2017). Likewise, impacts of environmental interventions are not likely to be homogenous across different sociodemographic groups (Chang *et al.*, 2017).

The concept of "pedestrian type" consists of a tentative categorization of the pedestrian population by a number of attributes. Examples of pedestrian categorization found in the literature include age groups (Cambra, 2012), walking ability/mobility impairments (Moura *et al.*, 2017) and socio-demographic profile (Yang & Diez-Roux, 2012; Chang *et al.*, 2017) but specific classification methods or typologies are limited.

An interesting parallel is found in cycling related research. As stated by Félix *et al.* (2017), urban cyclists are not all the same; they do not travel for the same reason or with the same frequency, or have the same needs. In their work, they have proposed to identify different groups of cyclists according to experience level, risk perception, attitudes, and behavior. In another study, Dill & Mcneil (2013) have discussed and validated the classification of cyclists in 4 typologies: 1) "the strong and the fearless" ; 2) "the enthused and confident" 3) "the interested but concerned" and 4)"no way, no how". The categorization was in part determined by a person's comfort level with cycling on various types of streets.

Two main goals are presented: 1. to identify independent groups sharing similar preferences and characteristics towards travel and walking specifically; and 2. to examine if belonging to any of these "pedestrian groups" plays a role in behaviour change.

Following the conceptual diagram that frames the present study, it is hypothesised that the individual socio-demographic characteristics together with his attitudes, preferences and actual travel behaviour play a role in the way the environment is perceived and also influence the walking experience. Moreover it is hypothesised that individuals may share some of these attributes and therefore can be grouped into independent pedestrian groups.

In order to find such classification various statistical methods can be used. These belong to the realm of dimension reduction, where it is desired to retain the most of variance accounted for using a more reduced set of variables. Such tools include principal component analysis, factor analysis, and cluster analysis. Following Pestana & Gageiro (2008), principal component analysis is an exploratory technique that transforms a set of quantitative variables that have some correlation in a smaller, uncorrelated (orthogonal) set of variables; similarly, factor analysis is a technique that reduces a larger set of variables in a smaller set of factors, being more flexible than the former in determining the number of necessary factors; cluster analysis detects homogenous groups based on the differences of a set of quantitative or binary variables. These general tools are adequate to deal with numeric/interval variables but not so to deal with categorical variables.

To overcome this limitation specific data dimension tools have been developed, namely Categorical principal components analysis (CATPCA), Two-step cluster and Hierarchical Clusters of Principal Components (HCPC). In brief, CATPCA is considered appropriate for data reduction when variables are categorical (e.g. ordinal) and the researcher is concerned with identifying the underlying components of a set of variables (or items) while maximizing the amount of variance accounted for in those items (by the principal components); the two-step cluster is a hierarchical clustering process that can deal with categorical and continuous variables; while HCPC performs an agglomerative hierarchical clustering on results from a factor analysis (Husson *et al.*, 2010; Shukla *et al.*, 2019). An example of application of these techniques for segmentation can be found in Félix (2012), who used a combination of CATPCA and two-step clusters to define segments of cyclists based on 5 categorical variables (gender, cycling experience, commuting frequency, helmet use and frequency of doing sport) and one ordinal variable (age group), finding 3 different groups: the "beginners", the "commuters" and the "weekenders".

An exploratory pedestrian segmentation analysis was performed applying each of the three techniques to a common dataset. The dataset, drawn from the pedestrian survey, comprised the following variables:

### Socio-Demographic Variables

- Gender - dichotomous variable for male and female;
- Age Group - ordinal variable with 7 levels corresponding to the standard age intervals used by the national statistics office: 15 to 19 years old; 20 to 24 years old; 25 to 34 years old; 35 to 44 years old; 45 to 54 years old; 55 to 64 years old; over 65 years old;
- Education - nominal variable with an underlying ordinal structure of 4 levels, whereas the first level corresponds to elementary school, the second one to high school, the third to professional education (a degree of education possible upon completion of high school but not conductive to a degree such as in an university) and the fourth to university degree. The survey was unclear on considering education levels as complete or as "in progress";
- Workclass - nominal variable with 5 classes: Worker; Student; Retired; Unemployed and Other (e.g. housekeeping, family support)

As presented in Table 5.14

### Travel behaviour

Transport alternatives are considered to influence walking behaviour. For some walking may be an option, a choice of travel mode whilst for others walking may be the only available transport mode. Travel behaviour was characterized by the following variables ( see Table 5.15):

- Main transport mode - a nominal variable comprising 3 main classes: motorized;public transportation and active travel. People were asked to report on their main transport mode used in daily commute (work/school), having a choice of 8 alternatives (private car, as driver; private car, as passenger; train or subway; bus; walking; bicycle; motorcycle; other).

Table 5.14: Socio-demographic variables

| **Socio demographic variables** | n | % total | n obs |
|---|---|---|---|
| **Gender** | | | 1166 |
| Male | 575 | 49.3% | |
| Female | 591 | 50.7% | |
| **Age group** | | | 1166 |
| 15 to 19 years old | 111 | 9.5% | |
| 20 to 24 years old | 322 | 27.6% | |
| 25 to 34 years old | 221 | 19.0% | |
| 35 to 44 years old | 228 | 19.6% | |
| 45 to 54 years old | 138 | 11.8% | |
| 55 to 64 years old | 92 | 7.9% | |
| over 65 years old | 54 | 4.6% | |
| **Education** | | | 1159 |
| Elementary | 5 | 0.4% | |
| Secondary (high school) | 203 | 17.5% | |
| Professional | 53 | 4.6% | |
| Tertiary (university) | 898 | 77.5% | |
| **Work class** | | | 1166 |
| Worker | 606 | 52.0% | |
| Student | 477 | 40.9% | |
| Retired | 51 | 4.4% | |
| Unemployed | 10 | 0.9% | |
| Other | 22 | 1.9% | |

- Number of trips - people were asked to report on the number of trips taken on the previous day.
- Duration - people were asked to report on the average duration (in minutes) of their daily commute, considering a door to door journey .

Table 5.15: Travel behavior variables

| **Travel behavior variables** | n | % total | n obs |
|---|---|---|---|
| Main transport mode | | | 1166 |
| *Motorized travel:* | *315* | | |
| Private car, as driver | 267 | 22.9% | |
| Private car, as passenger | 27 | 2.3% | |
| Motorcycle | 21 | 1.8% | |
| *Public transport:* | *572* | | |
| Train or subway | 398 | 34.1% | |
| Bus | 156 | 13.4% | |
| other | 18 | 1.5% | |
| *Active travel:* | *279* | | |
| Walking | 241 | 20.7% | |
| Bycicle | 38 | 3.3% | |
| | Mean | SD | n obs |
| Number of trips | 4.54 | 3.38 | 1157 |
| Average trip duration (min.) | 36.09 | 26.98 | 1029 |

**Attitudes**

There were 5 attitudinal questions relating to a preference for active travel (and allocated space for it) or for motorized modes (and allocated space for it). The attitudes were collected in a Likert-type scale with 5 levels of agreement, varying from "1)totally disagree" to "5)totally agree", having a "3)neutral" mid-scale classification. The surveyed attitudes were as following:

- Att1."It is important to build more roads to reduce traffic and congestion"
- Att2."I would like there were less cars in the city"
- Att3."Investing in cycling infrastructure is unnecessary because people won't ride bicycles"
- Att4."I would like there were more parking places than better public space"
- Att5."Walking in everyday trips cannot be considered physical exercise"

As presented in Table 5.16

Table 5.16: Attitudes judgement towards car use and active travel

| Attitudes | 1) Totally disagree | 2) Disagree | 3) Neutral | 4) Agree | 5) Totally agree | n obs. |
|---|---|---|---|---|---|---|
| Att1: Need More roads | 236 | 334 | 253 | 219 | 110 | 1152 |
| Att2: Want less cars in cities | 18 | 39 | 185 | 412 | 498 | 1152 |
| Att3: No Investment in Bike | 483 | 357 | 159 | 116 | 37 | 1152 |
| Att4: More parking than public space | 264 | 292 | 234 | 214 | 147 | 1151 |
| Att5: Walk not proper Physical Activity | 121 | 392 | 181 | 359 | 101 | 1154 |
| *Cronbach Alpha= 0.62 (using reversed classification in Att2)* | | | | | | |

### Preferences

What people like and dislike about walking play an important role in shaping behavior, acting as barriers or motivators. Walking preferences were addressed by the following factors (Table 5.17):

- Positive Preferences: this factor was composed by 10 dummy variables representing different environmental factors. People were asked to choose up to 3 environment factors that they considered to contribute positively to their walking experience. The positive preferences were composed of:

  1. PosPref1:To encounter other people on the street
  2. PosPref2:No encounter with other people on the street
  3. PosPref3:Existence of meeting places
  4. PosPref4:Display windows
  5. PosPref5:Architectural quality of building façades
  6. PosPref6:Greenery (trees, parks, planters)
  7. PosPref7:Wide space to walk without detouring from obstacles
  8. PosPref8:Comfortable and well maintained sidewalks
  9. PosPref9:No disturbance from traffic
  10. PosPref10:Pedestrian priority at road crossings

- Negative Preferences: likewise, this factor was composed by 10 dummy variables representing different environmental factors from which up to 3 environment factors considered to contribute negatively to the walking experience could be selected. The negative preferences were composed of:

  1. NegPref1:Low air quality (odours, exhaust emissions)
  2. NegPref2:Noise
  3. NegPref3:Detouring from obstacles on sidewalk
  4. NegPref4:Narrow or missing sidewalk links
  5. NegPref5:Inacessible sidewalks, raised curbs
  6. NegPref6:Insufficient pedestrian space
  7. NegPref7:Cars parked on the sidewalk
  8. NegPref8:Traffic
  9. NegPref9:Untidy streets
  10. NegPref10: Poorly maintained sidewalks (potholes, irregularities)

- Preferred walking purpose:people were if they liked to walk regardless of purpose or if they preferred to walk specifically for utilitarian purposes or for recreational purposes; or eventually if they were neutral about walking or did not like to walk at all. Hence, this was a nominal variable with 5 classes.

Table 5.17: Walking preferences

| Walking Preferences (n=1166) | Freq. | % |
|---|---|---|
| *Positive influence items* | | |
| To encounter other people on the street | 113 | 9.7% |
| No encounter with other people on the street | 75 | 6.4% |
| Existence of meeting places | 223 | 19.1% |
| Display windows | 201 | 17.2% |
| Architectural quality of building façades | 317 | 27.2% |
| Greenery (trees, parks, planters) | 760 | 65.2% |
| Wide space to walk without detouring from obstacles | 484 | 41.5% |
| Comfortable and well maintained sidewalks | 509 | 43.7% |
| No disturbance from traffic | 386 | 33.1% |
| Pedestrian priority at road crossings | 154 | 13.2% |
| *Negative influence items* | | |
| Low air quality (odours, exhaust emissions) | 433 | 37.1% |
| Noise | 178 | 15.3% |
| Detouring from obstacles on sidewalk | 168 | 14.4% |
| Narrow or missing sidewalk links | 466 | 40.0% |
| Inacessible sidewalks, raised curbs | 58 | 5.0% |
| Insufficient pedestrian space | 280 | 24.0% |
| Cars parked on the sidewalk | 481 | 41.3% |
| Traffic | 217 | 18.6% |
| Untidy streets | 347 | 29.8% |
| Poorly maintained sidewalks (potholes, irregularities) | 542 | 46.5% |
| *Walking purpose* | | |
| Like to walk both for utilitarian and for recreational purposes | 698 | 59.9% |
| Like to walk for utilitarian purposes, not so much for recreation | 195 | 16.7% |
| Like to walk for recreation, not so much for utilitarian purposes | 187 | 16.0% |
| Not fond of walking | 86 | 7.4% |

### Cluster analysis

According to the rationale of the conceptual model, the presented variables could be combined in some manner leading to the formation of pedestrian segments, that could in turn show similar behaviour responses to environmental interventions. A tentative pedestrian segmentation was performed using different techniques: Two-step clustering; Categorical Principal Components Analysis (CATPCA), and Hierarchical Clusters of Principal Components (HCPC).

The results were shy. The 2 step cluster analysis was performed in IBM SPSS. The clusters showed an internal consistency measure (Silhouette) inferior to 0.4, which can be considered as a fair cluster consistency (IBM SPSS suggests that a Silhouette value lower than 0.2 reveals poor consistency whilst values higher than 0.5 reveal a good solution). The CATPCA analysis was performed in R using the package PRCR, whereas the process failed to converge.

Lastly, the HCPC analysis was performed in R using the package FactoMiner. This procedure resulted in two main clusters - Cluster 1) with 518 members and Cluster 2) with 855 members - whose members shared the following main characteristics (see Table 5.18).

Table 5.18: Cluster characteristics

| **Cluster 1) 518 members** | % of individuals that selected this statement and belong to Cluster 1 | % of Cluster 1 members that selected this statement | % of surveyed individuals that selected this statement |
|---|---|---|---|
| Absolutely disagree on providing more car parking in the cities. | 91% | 63% | 21% |
| Absolutely disagree that is necessary to provide more roads to decrease traffic jams. | 87% | 56% | 20% |
| Absolutely disagree that investing in cycling infrastructure is unnecessary. | 57% | 76% | 40% |
| Like to walk both for transport (from A to B) and for leisure. | 52% | 81% | 40% |
| Agree on having less cars in the city. | 37% | 95% | 78% |
| Dislike to encounter cars parked in the sidewalks. | 43% | 59% | 41% |

| **Cluster 2) 855 members** | % of individuals that selected this statement and belong to Cluster 2 | % of Cluster 2 members that selected this statement | % of surveyed individuals that selected this statement |
|---|---|---|---|
| Agree on providing more car parking in the cities. | 92% | 43% | 32% |
| Neutral on having less cars in the city. | 96% | 23% | 17% |
| Agree that is necessary to provide more roads to decrease traffic jams. | 90% | 37% | 28% |
| Disagree that investing in cycling infrastructure is unnecessary. | 86% | 40% | 32% |
| Dislike poorly maintained sidewalks. | 77% | 52% | 46% |
| Agree that everyday walking cannot be considered physical exercise. | 75% | 48% | 39% |

The main component contributing to the membership classification is related to the attitudes towards car vs. active travel. Almost all individuals that are not favourable to having more car parking in the cities nor providing more roads were grouped into Cluster 1) whilst almost all individuals that were favourable to provide more car parking and more roads were grouped into Cluster 2). The results show a great polarization between the population who is pro-active travel and desire less cars and the ones who are pro-car who are less sensitive to public space qualities. Interestingly, it seems that attitudes account for more variation than preferences and socio-demographic characteristics of the individual.

These results however should be interpreted with caution. The variable structure used in the analysis, consisting mostly of categorical and dichotomous variables did not produced stable nor consistent results using concurrent statistical methods, namely the two-step cluster or the CATPCA. The produced results using the hierarchical clustering on principal components method lack a goodness of fit measure in order to evaluate its consistency.

Pedestrian segmentation is still an understudied topic. Contrary to segmentation attempts proposed for cyclists (Félix *et al.*, 2017), for public transport users (Kuppam *et al.*, 2007; Shiftan *et al.*, 2008) or for general travel decisions (Beirão & Cabral, 2008), only few attempts have been made in the case of pedestrians (Moura *et al.*, 2017; Yang & Diez-Roux, 2012).

A comprehensive attempt to define pedestrian segments was made in the present study, using socio-demographic, preferences, attitudes and travel behaviour factors. The results showed that various limitations need to be overcome in order to obtain consistent pedestrian segmentation. The results suggested that attitudes alone (towards the use of car vs. active travel) may be a relevant classifier for the definition of pedestrian groups, which, in turn, may play a significant role in influencing the way the individual perceives and experiences the environment.

Hence, it can be suggested that the persons' mindset influences how the person sees and perceives from the built environment that then translates into the person's walking experience which has influence on the behaviour; or that the person's mindset influences not the environmental perception but the experience that the person gets from it; or both. This finding sets ground for the next section.

### 5.3.2 Structural relation of behavioural triggers

According to the present study findings, exposure to the environment, perception of environmental improvements and walking experience are significant predictors of walking behaviour change. Walking experience in particular deserves a more thorough investigation. Only few studies have addressed walking experience in relation to environmental improvements to promote walking finding that the walking experience following an intervention was generally more positive than before despite in some cases no other behavioural outcome was observed (Jung *et al.*, 2017).

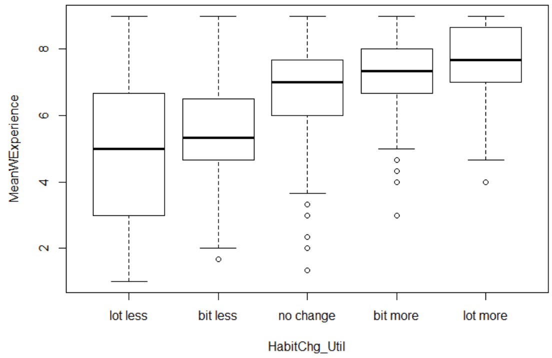
In this regard improving walking experience could be considered as a "quick win", that is to say an achievable goal that benefits the policy makers. But improving walking experience can have other positive implications. One is related to the formation of habits, which are enforced in our brain by positive feedback following an action (Duhigg, 2012). A negative experience following an action, such as walking in a new path, may refrain the person of repeating the behaviour whilst a positive experience may, if sustained, contribute to re-enforce the behaviour.

Just how much satisfactory should the walking experience be in order to have an effect in actual behaviour makes an interesting question. In the present study, data on walking experience was collected on a 9 point scale, asking people about their experience in Eixo Central before and after. As reported earlier in this section, satisfaction (or the difference after-before) was found to be a more significant predictor than the mean final walking experience for various behaviour outcomes. Considering now the mean final walking experience in relation to the five walking behaviour outcomes (see Figure 5.2), it can be observed a positive association between the mean value of walking experience and the ordered self-reported change in walking frequency for distinct purposes. Noteworthy, the values of walking experience from which some behaviour change is observed are quite similar across the different walking purposes, around a score of 7 (out of 9, corresponding to a 77%). What is also interesting to note is the variation in the minimum value of walking experience that corresponds to a change in walking behaviour: no behaviour changes are found when the minimum walking experience is under the score of 4 (44%), which is a borderline value for a positive evaluation.

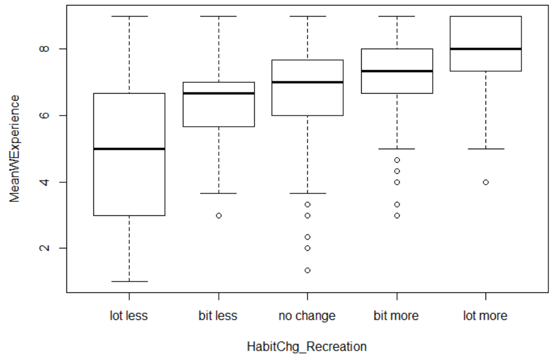
In order to address the potential mediation role of the identified triggers, a Structural Equation Model was developed. Structural Equation Models (SEM) can illustrate direct effects between variables and indirect effects through mediating variables and allows to evaluate the effects of variables simultaneously (Marôco, 2014). A number of travel studies have recurred to SEMs to investigate the underlying relation of variables (Talavera-Garcia & Soria-Lara, 2015; Coogan *et al.*, 2012), namely perceptions (Ma & Cao, 2017), lifestyle (Etminani-ghasrodashti & Ardeshiri, 2015), attitudes (Shiftan *et al.*, 2008).

A series of SEMs was tested. A preliminary test model included another take on pedestrian segmentation following Section 5.3 with no sound results. Focusing in the aim of analysing the relations between behavioural triggers, 5 models were produced, as illustrated in Figure 5.3.

The first model tested the role of Attitudes in influencing Walking Experience (WE). Model 2) tested if Perceptions were also influential in the resulting WE. Model 3) tested




(a)

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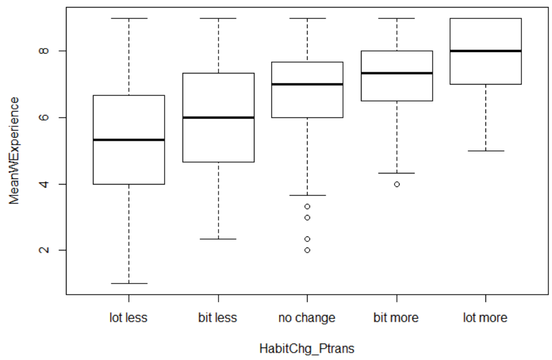


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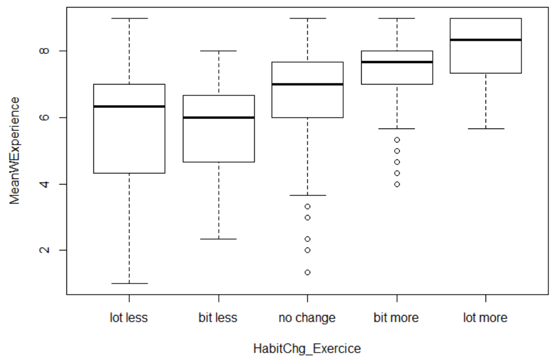


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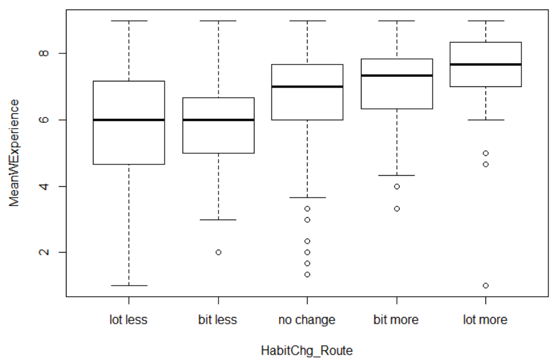


(e)

Figure 5.2: Walking experience x Walking purposes

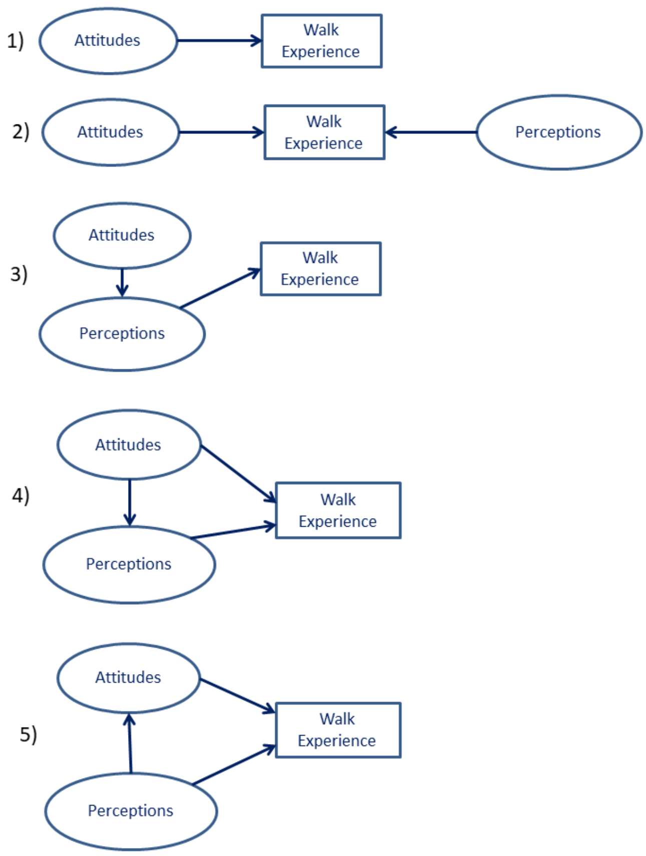


Figure 5.3: Structural Equation Model specifications

whether the persons' mindset - Attitudes - influenced how people perceived the environment - Perceptions - and subsequent WE. Model 4) tested if Attitudes influenced WE directly or indirectly, mediated by Perceptions. Model 5) tested the mediating role of Attitudes.

SEM analysis was performed in R using the package Lavaan (Rosseel, 2012). The obtained models were compared using common goodness of fit measures for SEMs, namely the comparative fit index (CFI, desirably higher than 0.90); goodness of fit index (GFI, desirably higher than 0.95); and root-mean square error of approximation (RMSEA, desirably lower than 0.5) (Marôco, 2014; Rosseel, 2012). From the aforementioned specifications, model 4) presented the relatively most satisfactory fit indices: CFI=0.871; GFI=0.914; and RMSEA=0.077. Figure 5.4 illustrates the selected final model (based on Figure 5.3.(4)).

The results from the structural equation model analysis show that the person's attitudes did not have a significant influence in the way they experienced walking. However, the persons' standpoint on statements related to the presence of cars and the use of public space did have a significant influence on the individual perception of environmental change. According to the results, a more favourable attitude towards the presence of cars and parking led to a lower, or less positive, appreciation of environmental changes towards pedestrian space. The way people perceive the environment also showed a positive and significant association with walking experience - the more an individual values the environmental change, the higher walking experience is attained.

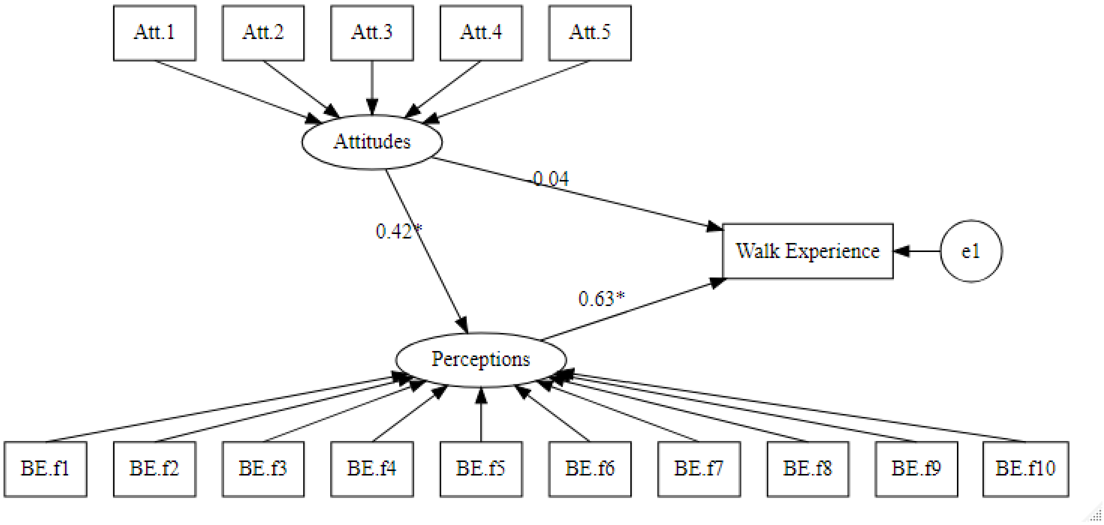


Figure 5.4: SEM final model

## 5.4 Concluding remarks

The analysis presented in this chapter followed in a mix of exploratory and confirmatory research. Confirmatory because we knew what was the hypothesis we wanted to test. Exploratory because in some cases we did not know which factors to be more relevant given the relative literature gap in the subject. This was the case of the exposure, perceptions and experience.

It was found that these three factors contribute in triggering behaviour change, confirming the test hypothesis. The models presented only modest explanatory power (Pseudo rho squared) but a satisfactory fit (ROC indice), which is in line with the argument of Harrell (2015) that it should be preferable to obtain a good fit over a less explanatory model than a marginal fit over a more explanatory model. Moreover, the obtained model fit indices are in line with other studies (Burbidge, 2008).

Some limitations were identified in the present study. First, the question that addressed the dependent variable was not sufficiently clear in separating utilitarian walking from recreational walking. Such limitation has a relation to the multi-purpose nature of walking, making it a challenge to distinguish between motivations to walk (Kang *et al.*, 2017), resulting in inconsistencies in classifying walking activity found across studies Kang *et al.* (2013). Another limitation was the considerable number of missing answers, reducing the model sample. Often datasets have missing data, which can be of various nature. In the conducted survey several questions were not responded, for instance the evaluation of before-after walking experience in the Av.Fontes Pereira de Melo section of the Eixo Central. In the obtained dataset there were 1166 valid observations, but due to missing values in some of the considered variables for analysis, the complete cases sum up to 609, that is to say 52,2% roughly half of the initial dataset. While the use of complete cases is advisable when developing a model, discarding otherwise valid observations due to a less represented single variable does affect the sample size and may affect model fit. One of the options is to accept the reduction in sample size and use only complete observations. Another option is to impute data over missing values, which can be performed by using several methods, from using average values to regression imputation.

A refinement of the study could gain from using a variable imputation method - as stated by Harrell (2015), even using a modest variable imputation could be more beneficial than having no data at all. A further development of this work would be to elaborate a full dataset comprising imputed data and to test the binary logistic models with this new dataset.

# Chapter 6

# Evaluating intervention success

This section deals with the evaluation of the success of an environmental intervention such as the comprehensive street improvement performed by the Eixo Central project. Recalling the main outcomes related to walking, the implementation Eixo Central project increased the overall walkability of its street sections, which was associated with a significant increase in the levels of pedestrian activity, i.e. pedestrian flow and sojourning. It was also found that some people reported having increased their walking frequency for different purposes following the Eixo Central intervention, which was associated to a higher level of satisfaction related to the walking experience and to the perception of a more accomplished walking environment.

Given these findings one could consider the Eixo Central project to be a successful intervention. However none of the Eixo Central goals was related to increase pedestrian flow, satisfaction or number of walking trips. Also, as in other cases, the promotion of the pedestrian environment was made possible by the reallocation of street space, which in turn has implications for other users, namely car users.

This issues set the base for this section, which is structured as follows: First, the intervention success is argued on a multimodal perspective. Next, the evaluation of success is addressed in relation to goal setting, discussing policy implications and overviewing the positive and negative effects related to promoting the walking environment.

## 6.1 Evaluating Eixo Central intervention on a multimodal perspective

It was found that the perception of having more pedestrian space allocated to the pedestrian had a significant effect in increasing the probability of engaging in more utilitarian walking trips and in increasing the probability of people changing their routes thus increasing the pedestrian use of the retrofitted streets. The amount of street space allocated to the pedestrian in relation to other transport modes has long been recognized as an important walkability factor, translated in variables such as "enclosure" and "human scale" (Ewing & Handy, 2009). Given its potential benefits, providing more space to the pedestrian could trigger more people to walk and to walk more, scaling up the benefits associated with walking, covering all the environmental, societal and public health positive effects.

However, in order to provide more street space for the pedestrians (or generally for active travel) some space has to be reclaimed from other uses, namely from the motorized transport infrastructure, i.e. from the road space. The reallocation of road space has been subject to a lively debate in the civil society and in the academy. Those in favour of reallocation of road space from traffic to more sustainable mobility solutions argue that cities were firstly made for people and then later conquered by the car. Reclaiming back the space taken for the car would be a natural evolution for cities. Those against the reallocation of space allege that the current layout of the urban system could not subsist with a reduction of car accessibility (Cairns *et al.*, 2002).

Given the present climate crisis and public health crisis various actors have claimed for a shift in the urban mobility paradigm (Banister, 2008), namely through the inversion of the transport pyramid, that is to say, to go from considering first the private car and lastly the pedestrian to considering the pedestrian first, as illustrated in Figure 6.1:

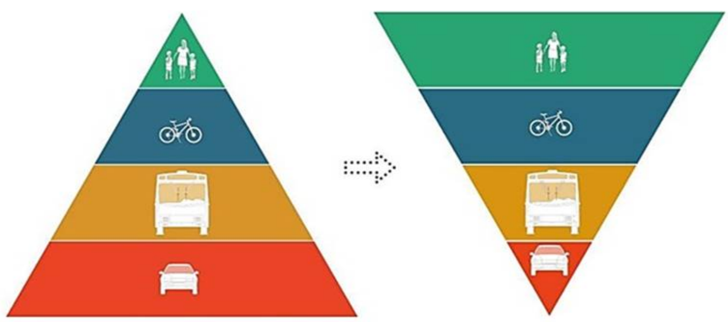

Figure 6.1: The inversion of the transport pyramid. Source:https://www.urbanizehub.com

Space-wise, the reallocation of space for private car circulation and parking to active travel and public transportation has given way to the concept of "road diet". Several studies have addressed "road diet" schemes, finding positive associations between reducing car capacity and the improvement in air quality (Shu *et al.*, 2014), in the reduction of road accidents and subsequentially the improvement in road safety conditions (Stout *et al.*, 2006), and in increasing the flow of pedestrians and cyclists (Brown *et al.*, 2016). However the effects of a "road diet" intervention on broader mobility patterns -including various transport modes- have not been sufficiently addressed in the literature. To overcome this gap, a study of the effects of the Eixo Central intervention on a multimodal perspective is proposed. For this, an analysis of the before-after usage of various transport means is performed, which includes pedestrians, cyclists, private car and public transportation. This analysis draws from various sources, as at present only little data is publicly available in Lisbon on traffic flow, public transport rides and pedestrians and cyclists counts. These sources included previous work done by the researcher, such as a report on the Eixo Central impact on traffic commissioned by Automóvel Clube de Portugal (ACP, the portuguese drivers' association) or a report on pedestrian and cyclists counts commissioned by the Municipality of Lisbon.

**Private car use**

The "before" conditions of private car use in the Eixo Central area were drawn from a 2015 traffic study. [1] This document presented the results from a traffic model made to estimate the future demand given the physical alterations in the road environment. The estimated variation in traffic volumes allowed to calculate the baseline values. In order to obtain comparison values upon completion of the Eixo Central intervention, traffic counts were performed between 21th of February and the 9th of March 2018 considering only work days and two counting periods - the morning peak (8 a.m. to 10 a.m.) and the afternoon peak (17 p.m. to 19 p.m.). There were 20 counting locations, of which 6 were distributed along the Eixo Central: 4 locations in Av. da República; 2 in Av. Fontes Pereira de Melo; and also in control locations. Another 11 locations were located in streets adjacent to Av. da República and 3 other locations in Av. Fontes Pereira de Melo adjacent streets. The traffic volume was observed in continuous two hour periods, using a standard conversion rate to PCU - Passenger Car Units.

**Public transportation**

The Eixo Central area is served by bus (33 stops, mainly from Carris, the city operator), subway (blue line, red line and yellow line of Metropolitano de Lisboa) and train (one

[1] TIS e Câmara Municipal de Lisboa, "Estudo de Tráfego do Eixo Central," 2015.

station with suburban and regional services). Data for public transportation use was kindly provided by Otlis - the transport operator association of the greater Lisbon area. The shared data comprised ticket validations performed in Carris buses (on board validation) and in the Marquês de Pombal, Picoas, Saldanha, Campo Pequeno and Entrecampos subway stations. The data referred to a single day's observation - the 1st of March - collected in 2016 (before) and 2018 (after), from 7 a.m. to 11 a.m. and from 17 p.m. to 21 p.m. A two hour morning peak period was considered from 8 a.m to 10 a.m. and a two hour afternoon peak period was considered from 17 p.m. to 19 p.m.

**Active travel: cycling**

Active travel observation comprised pedestrian and cyclists counts. The pedestrian count dataset was presented and discussed earlier (refer to Sections 3.4 and 4 ). The cyclist count dataset was provided by Técnico Lisboa (U-Shift group). It comprised data from 2016 (before) and 2017 (after) collected in 5 counting locations in the Eixo Central area: 1) Av. da República (Campo Pequeno); 2) Av. da República (Av. Elias Garcia/Av. Visconde de Valmor); 3) Av. Fontes Pereira de Melo; 4) Av. Duque de Ávila and 5) Av. 5 de Outubro.

A series of pairwise t-tests was performed using these datasets in order to find if there was a significant difference between the before and after situations. The statistical analyses were executed in SPSS v.22 using a significance level of 5%.

### 6.1.1 Results and Discussion

**Private car use**

The estimates done in the planning stage of the Eixo Central pointed to similar traffic levels before and after the intervention. When comparing the mean traffic levels of 2018 ($M = 970$; $SD = 665$) with the reference situation ($M = 1285$; $DP = 778$), a significantly difference was found, corresponding to a decrease of 315 PCU/h (-24,5%, p.value $<.001$) in the mean flow vales (see Table 6.1). The reduction in traffic was observed in the whole study area, that is to say in the Eixo Central as well as in the control locations adjacent to the Eixo Central. It is important to mention that this analysis only considered the morning peak period as no valid baseline values were found for the afternoon peak period.

The overall reduction in traffic volume was considerable (-25%), and was mainly observed in the adjacent streets (-31,3%), where no reallocation of road space occurred, than in the Eixo Central streets (-17,4%) where road capacity was reduced. In order to control for possible traffic congestion situations that could be masking the lower volumes,

Table 6.1: Before-after analysis of traffic volume

| Traffic volume (PCU/h) morning peak period | N | **Before T1** M (SD) | **After T2** M (SD) | T2 - T1 | **Variation** | ***p value*** |
|---|---|---|---|---|---|---|
| Eixo Central | | | | | | |
| Av.Republica | 15 | 1090.5 (506.3) | 896.7 (731.5) | -193.8 | -17.8% | .132 |
| Av.Fontes Pereira de Melo | 4 | 2129.8 (298.4) | 1776.0 (136.7) | -353.8 | -16.6% | .181 |
| *total Eixo Central* | *19* | 1309.3 (635.4) | *1081.8 (745.0)* | -227.5 | *-17.4%* | *.041* |
| Adjacent streets | | | | | | |
| Adjacent to Av.Republica | 17 | 1320.9 (988.2) | 939.8 (615.3) | -381.2 | -28.9% | .044 |
| Adjacent to Av.Fontes Pereira de Melo | 4 | 1017.8 (364.4) | 564.5 (309.3) | -453.3 | -44.5% | .033 |
| *total Adjacent streets* | *21* | *1263.2 (903.3)* | *868.3 (583.1)* | -394.9 | *-31.3%* | *.011* |
| **Total** | **40** | **1285.0 (778.0)** | **969.7 (664.9)** | **-315.3** | **-24.5%** | **.001** |

a number of intersections was observed. No situations of heavy congestion were found.

The results show that the traffic flow conditions improved following the intervention, suggesting that the reallocation of road space which reduced traffic capacity in this area did not have a negative effect, being in fact associated with a reduction in the traffic volumes. Such phenomenon has been coined as "evaporating traffic".

There are several possible reasons for these results. Some people may have shifted from car to public transport or to active travel. Some other people may have changed their activity patterns and adapted their travel schedule accordingly (only the morning peak period was analysed). Another reason is related to the adoption of alternative routes due to the disruption during the construction phase, where there were heavy traffic constraints.

The perception of the traffic constraints in the area could have triggered drivers to search for temporary alternative routes, which eventually became habitual even upon completion of the intervention. In this sense, the traffic volume may not have decreased but may have been distributed through the network.

It is possible that the observed reduction in the Eixo Central traffic is explained by a combination of the aforementioned factors. Of these, the redistribution traffic over the network seems to constitute the most plausible one. Cairns *et al.* (2002) inquired a panel of over 200 international transportation professionals on the possible reasons for the reduction in traffic volumes following a reduction in road capacity. The main reasons identified by the panel were the adoption of new routes (over 90% agreement); change in activity pattern (approx. 80% agreement) and modal shift (approx. 70% agreement). As pointed by Clegg (2007), the disruptive effect of a temporary road block has immediate effects in the choice of alternative routes, which, with time, can become the habitual routes. The study by Zhu & Levinson (2015) found that the most drivers do not use the fastest ways in their habitual routes, given the inherent cognitive limitations of knowing all alternative ways and being able to compute travel time between alternatives.

The growing use of navigation applications in smartphones with the capability of computing real time traffic conditions may have contributed to a swift adoption of alternative routes to using the Eixo Central area, some of which may have resulted to be faster than the original ones.

**Public transportation**

Regarding public transportation usage, it was found that the demand for subway was much higher than the demand for buses. For instance, on the reference day (1st of March 2018), the number of passengers entering the subway in the Eixo Central stations (39.930) was around 9 times higher than the number of passengers entering the buses in the same period and area (4.300). It can be seen in table 6.2 the equilibrium between trips stating and ending in the Eixo Central. In the morning period the number of passengers arriving in the area is higher that the ones entering the stations, whilst in the afternoon period the opposite occurs. This is consistent with the characteristics of the Eixo Central area as a "central business district" and also higher education pole. A positive and significant difference was found between the mean value per hour of passengers using the subway stations in the Eixo Central prior and after the intervention (M=57.1, p<.001), corresponding to a 6.1% increase.

Table 6.2: Use of public transport in Eixo Central

| Passengers by transport mode | Period | 2016 | 2018 | Variation 2016-2018 |
|---|---|---|---|---|
| Subway: check-in | Morning peak | 13,092 | 14,101 | 7.7% |
| | Afternoon peak | 25,105 | 25,829 | 2.9% |
| Subway: check-out | Morning peak | 27,589 | 28,177 | 2.1% |
| | Afternoon peak | 14,869 | 15,698 | 5.6% |
| Subway: total | Morning peak | 40,681 | 42,278 | 3.9% |
| | Afternoon peak | 39,974 | 41,527 | 3.9% |
| Carris Buses: Check-in | Morning peak | 616 | 2,132 | 246.1% |
| | Afternoon peak | 1,151 | 2,168 | 88.4% |

According to the "New Urbanism" and "Transport Oriented Development" principles, the observed increase in public transportation use could be related to the improvement of the walking conditions around the subway stations as a result of the Eixo Central intervention (Ryan & Frank, 2009; Cervero, 2002). However, such principles are more directed to projects with a more significant change in the land use mix and a larger temporal scale, while in the case of the Eixo Central there were mainly urban design changes over a short time period. Hence, other factors may be more adequate to explain the observed variation, such as the local dynamic of public transport demand. Passenger demand data

Table 6.3: Before-after analysis of subway passengers

| Passengers | N | Before T1 M (SD) | After T2 M (SD) | T2 - T1 | Variation | *p-value* |
|---|---|---|---|---|---|---|
| Entering the Eixo Central stations (check-in) | | | | | | |
| Morning Peak period | 14 | 935.1 (1049.2) | 1007.2 (1120.3) | 72.1 | 7.7% | .123 |
| Morning , off peak | 21 | 529.9 (463.2) | 602.0 (512.8) | 72.1 | 13.6% | .000 |
| Afternoon peak period | 14 | 1793.2 (614.7) | 1844.9 (689.2) | 51.7 | 2.9% | .222 |
| Afternoon off period | 21 | 706.6 (484.1) | 729.5 (494.1) | 23.0 | 3.2% | .217 |
| Exiting the Eixo Central stations (check-out) | | | | | | |
| Morning Peak period | 14 | 1970.6 (723.5) | 2012.6 (769.1) | 42.0 | 2.1% | .286 |
| Morning , off peak | 21 | 708.0 (249.1) | 793.8 (281.7) | 85.8 | 12.1% | .000 |
| Afternoon peak period | 14 | 1062.1 (840.3) | 1121.3 (878.4) | 59.2 | 5.6% | .182 |
| Afternoon off period | 21 | 436.7 (382.6) | 486.5 (422.4) | 49.8 | 11.4% | .007 |
| **Total** | **140** | **933.3 (780.8)** | **990.4 (810.7)** | **57.1** | **6.1%** | **.000** |

from Metropolitano de Lisboa showed a consistent increase in subway passengers since 2015 to 2017 (the most recent available data at the time of writing this study) of approx. 6%, which is consonant with the results obtained for the Eixo Central.

The results from the subway passenger analysis also help in clarifying the hypothesis of the reduction in traffic volume being related to a modal shift from car to public transport. The number of subway passengers directed to the Eixo Central area during the morning peak hour (typically commuting for work/study) was rather stable, showing a non significant difference (M=42, p-value = .286). Concomitantly, the trips originating in the Eixo Central area during the morning peak period did not show a significant difference (M=72.1, p=.123), hence suggesting no evidence of a modal shift from car to public transport of the users of the Eixo Central area (residents or workers). These results also provide additional support to the association of the traffic volume reduction to route changing and traffic redistribution over the network (see Table 6.3).

### Active travel: cycling

The physical environmental alterations were perhaps most significant for the promotion of bicycle use, where a new cycling infrastructure was installed providing safe and comfortable cycling conditions. The new cycling infrastructure was constituted by a bi-directional cycle lane from Campo Grande (north limit of Eixo Central) and Saldanha and two uni-directional cycle lanes in Av.Fontes Pereira de Melo, connecting Saldanha to Marquês de Pombal. The new infrastructure also performed connections to existing cycling infrastructure, namely in Av.Duque de Ávila, at the time one of the most used routes in Lisbon (average of 30 cyclists/hour during the peak periods. For comparison purposes, in Av.Fontes Pereira de Melo the average was 6 cyclists/hour).

Table 6.4: Before-after analysis of cycling volume

| Cyclist flow (cyclists/30 minutes) | N | Before T1 M (SD) | After T2 M (SD) | T2 - T1 | variation | t-test |
|---|---|---|---|---|---|---|
| Eixo Central | | | | | | |
| Av.Republica | 10 | 5.9 (2.8) | 40.1 (10.6) | 34.2 | 5.8 | .000 |
| Av.Fontes Pereira de Melo | 5 | 3.1 (0.8) | 22.2 (9.7) | 19.1 | 6.1 | .012 |
| total Eixo Central | 15 | 5.0 (2.7) | 34.1 (13.2) | 29.1 | 5.8 | .000 |
| Adjacent streets | | | | | | |
| Adjacents to Av.Republica | 10 | 9.5(5.5) | 9.0 (7.8) | -0.5 | -0.1 | .808 |
| **Total** | **25** | **6.8 (4.5)** | **24.1 (16.8)** | **17.3** | **2.5** | **.000** |

After the implementation of the new cycling infrastructure a notable fivefold increase in bicycle use was observed in the Eixo Central area (M=29,1; $p<.001$, corresponding to a 582.7% increase). Conversely, in the control street adjacent to Eixo Central no significant differences were found (M=-0.5; p=.808) suggesting that the observed increase in cycling levels was an effect of the provision of new cycling infrastructure (see Table 6.4).

From all transport modes - pedestrian included - cycling was the one with the most considerable growth associated to the Eixo Central intervention. In terms of absolute values, the number of cyclists is still modest (less than 100 cyclists per hour during peak periods) but provide a sound evidence on the effects of the provision of safe and attractive cycling infrastructure in inducting demand. This finding is in line with other studies (Dill & Carr, 1991; Pucher *et al.*, 2010).

In the case of cycling, the results show a higher concentration of use during peak periods, suggesting a commuting purpose (work/school). In this case, it is plausible to consider that the trips made in bicycle result from a modal shift from other modes rather than being new generated trips. It is worth mentioning that the present results refer to a moment prior to the implementation of the Gira shared bike system in Lisbon, which also had a very significant effect in the cycling levels in the Eixo Central area (Félix *et al.*, 2020).

**Overall findings**

Looking at the Eixo Central from a multimodal perspective, the before-after analysis showed multiple associations between the physical alteration of the street environment and the use of different transport modes. Hence, this study found evidence of association between a built environment change and modal choice, which in turn may be associated to a modal shift. This finding supports, but does not warrant, the existence of a direct cause-effect relation between the reallocation of street space from cars to active modes to the decrease of car use accompanied by the increase in transit use.

The fact that providing more space as well as improving the pedestrian and cycling infrastructure was followed by a significant increase of pedestrians has important policy consequences, as it suggests that such measures (alike road diets) do contribute to achieve sustainable mobility goals at the local scale.

However, at a larger scale, at the city scale, the potential intervention effects are less clear. It may be possible that the decrease in car traffic observed in the Eixo Area was a result of route change, hence traffic merely relocated to other areas. The ubiquitous use of rote planners that compute routes based on real time traffic conditions may have contributed to such alterations, with potential negative effects in the case traffic is diverted through residential areas.

Another negative impact that may contrast to the overall positive active travel outcomes in Eixo Central is related to a reduced car accessibility that may have an impact in the attractiveness of an area for visitors, thus harming local businesses and commerce. This has been a subject of long controversy and a major obstacle for the adoption of reallocation of road space from car use (lanes and parking) to pedestrian and cycling use. As put by Cairns *et al.* (2002), there is a growing understanding that reallocating street space from driving and parking cars to other modes and uses needs to be part of the solution but not in a way where reduced car accessibility results in less attractive and vibrant city centres.

More longitudinal studies are needed to monitor the long-term and wider-scale effects of infrastructural changes that span across various transport modes.

## 6.2 Successful interventions - Policy implications

Success is defined by the Oxford Learners online dictionary as *"the fact that you have achieved something that you want and have been trying to do or get"* and by the Merriam-Webster online dictionary as a *"degree or measure of succeeding" or a "favourable or desired outcome"*, whereas succeeding is *"to turn out well" or "to attain a desired object or end"*. There is a thought-provoking differentiating nuance to the two definitions. In the Oxford definition success implies the existence of a concrete goal ("something that you want") and an effort to accomplish it, which is closely related to the concept of efficacy *("the ability of something to produce the results that are wanted")* . In fact, the Oxford Learners online dictionary defines effectiveness as *the fact of producing the result that is wanted or intended; the fact of producing a successful result*, pointing "success" as a synonym for "effectiveness". On the other hand, the american Merriam-Webster dictionary relaxes the necessity of a goal, stating that a "favourable outcome" our "to turn out well" are also considered to be a "success". In this perspective it can be admitted an action to be considered successful if it produces favourable results even without reaching stated goals.

***What is a successful intervention? Was the Eixo Central a successful intervention?***

### 6.2.1 Street intervention goals

There are various types of street interventions related to the promotion of walking (or active travel in general). The most canonical is the one lead by a local authority, such as a municipality. These local government institutions usually have the legal authority and the resources to manage public space, which includes the street space (and road environment). In many cases these interventions are actually planned and follow/comply to a broader strategy. In many other cases the interventions are projected to solve or to address localized issues or as a reaction to some public pressure. Another type of street intervention is the one lead by an agency, namely a transport agency, for instance for the implementation of a new rapid transit. Street interventions can also be lead by private agents, as in the case of urban renewals or new developments. Finally, a new sort of street interventions has been gaining attention - the community lead interventions - which include temporary or more permanent environmental changes either made in accordance with local authorities or without an express consent, the latter being in the realm of "tactical urbanism".

In the present study the focus is on the "canonical" type of street interventions, which are programmed and implemented by the city's local government. Governments are, in democratic regimes, subject to public scrutiny. In order to remain in power, governments need to ensure public acceptance and votes. Given that urban mobility is something that affects if not all a very large part of the population, it is natural that street interventions can be a sensitive subject. This is even magnified when street interventions imply the reallocation of space from motorized traffic to active travel or public transport. In order to minimize negative reactions politicians often offer broader goals based on generically accepted values as a trade-off for reclaiming road space. An example of such generic goals it to "improve quality of life".

The Eixo Central project presented substantial and quite focused goals (a thoroughly description of the project is presented in Chapter 3). In brief, the project was firstly aimed to improve walking conditions providing accessibility for all, having evolved to a more comprehensive intervention. The intervention principles can be related to pedestrians/walking, general transport and urban design groups, although its classification in any of the groups is sometimes less clear (e.g. enlarging the sidewalks):

- Pedestrian/Walking
  - Create an accessible to all pedestrian pathway between Entrecampos and Marquês de Pombal.
  - Give back space to the pedestrian, by enlarging the sidewalks;
- Transport
  - Create a dedicated busway;
  - Reduce traffic speed whilst not reducing significantly traffic capacity;
  - Reduce car parking places in the Eixo Central street sections, balanced with an increase of parking in the surrounding area;
  - Balance the street space allocation, reducing the space allocated for automobiles;
  - Promote the use of active travel, in particular cycling;
- Urban design
  - Restore the original "boulevard" concept marked by tree alignments;
  - Improve the image of the Eixo Central, creating a strong sense of place;
  - Qualify all public space elements (e.g. paving, lighting, furniture);

Despite stating pedestrian oriented goals - accessible pathways and larger sidewalks - there were no specific goals relating to walking. Arguably the goal "Promote the use of active travel, in particular cycling" could be considered to be relating to the promotion of walking. However the remark "in particular cycling" sets a clear orientation of the target. In terms of achieving the stated goals, both of the pedestrian/walking oriented goals were achieved. In fact, most of the goals were generally achieved.

Given the observed results presented earlier on, the number of pedestrians and cyclists increased following the intervention along with pedestrian satisfaction. Hence, the Eixo Central was effective in the promotion of active travel, accomplishing as well the pedestrian/walking specific goals and the balancing of the street space allocation.

Goal setting is crucial to improvement strategies. These usually consist of the following cycle: 1) setting the goal; 2) measuring and evaluating current performance against the goal; 3) take actions to improve performance; 4) evaluate and revise the goal if necessary; and so on (Barlas & Yasarcan, 2006). From a managerial or organizational point of view, goals are ought to be SMART - Specific, Measurable, Attainable, Relevant and Time-bound (Rubin, 2002). The distinction between goals and objectives is often unclear. According to Young (1966), a goal is an ideal, "a value to be sought after, not an object to be achieved" - a goal "provides the traveller a direction, not a location", while on the other hand an objective is "the aim or end of action". Accordingly, goals should be "universal and lasting" while objectives can change under varying circumstances.

The sometimes unclear distinction between these concepts adds to the challenge of addressing the success of environmental interventions. One example of broader goals vs. specific objectives is the Seoul Design Project presented in Jung *et al.* (2017). In this case, an urban-policy project called "Design Seoul" was initiated by the mayor of Seoul in 2007 with the aim of creating a "pleasant Seoul urban life environment". Following, the Seoul Metropolitan Government planned a number of street interventions - the "Design Street Project" - with the aim of encouraging walking and social activities on streets by improving physical street environments. Upon completion, the study of Jung *et al.* (2017) showed that the walking levels had not increased (missing the "Design Street Project" goal) but the satisfaction with the environment had increased (meeting the "Design Seoul" policy goal).

Earlier in 2 it was referred the scarcity of studies addressing the effects of environmental interventions in walking behaviour. In terms of addressing successful case studies, the literature paucity is also notorious. As put by Risser & Šucha (2020), "In many cases, measures which have a potential to enhance walking (or cycling) were implemented, but because evaluation is lacking, we do not actually know if it is really a success story". Policy-wise, McConnell (2016) has suggested that even if successful in some respects, a policy can be considered to fail if it does not fundamentally achieve the goals that proponents set out to achieve, and opposition is great and/or support is virtually non-existent. This argument gives way to another challenge in addressing intervention success - public acceptance.

The Eixo Central intervention could then be considered to be a success in the promotion of walking. Yet, it faced fierce public opposition, namely from residents concerned with having less parking spaces and more congestion due to the reduction of traffic lanes.

A well-reported case study regarding fierce opposition to an eventually successful intervention is the pedestrianization of MariaHilfeStrasse in Vienna (Bartenberger & SzeŚciŁo, 2016; Risser & Šucha, 2020). Mariahilferstrasse is one of the most notorious streets of Vienna. It is a central shopping street that until 2010 was also a major traffic route through the city. Nowadays it is a pedestrianized and shared space zone. The pedestrian volumes increased significantly from 25.000 to 70.000 per day, reflecting the intervention's success. The transformation process started in 2010 following the city elections where the Green Party secured the office for urban planning for the first time in the city's history. The Mariahilfestrasse project was regarded as a hallmark of the new cabinet. In 2012 the results of the preliminary design stage led by urban planners with citizens and stakeholders contributions were presented. At this time the political opposition (the conservative Austrian People's Party) launched a poll for residents in the area finding that more than 60% preferred to keep the street as it was, not accepting traffic limitations. An interim redesign was implemented in August 2013, with the aim of testing the solution with minimum road works. As stated by Maria Vassilakou (then vice-mayor and chairman of the Green Party), "it is wise, especially when it comes to transport policy issues, that the population can experience the difference. If the change proves to be successful we can keep it and if it doesn't we should be also able to say «this wasn't a good idea» and change it back to the way it was" (Bartenberger & SzeŚciŁo, 2016). The test phase ran from August 2013 until February 2014, providing additional clues for improving the design. At the end of the test phase a final referendum was made asking residents if they supported the street redesign (as tested) or if it should be reverted to its original state. The results of the referendum revealed a shallow but sufficient support for the redesign - 53.3% in favour, with 46.8% opposing it. The construction works started in May 2014 and finished in July 2015. As a shopping street MariaHilfeStrasse turned out to be a success drawing an increased number of visitors. According to Risser & Šucha (2020), the general notion in Vienna is that MariaHilfeStrasse is now a complete success.

In brief, interventions to promote walking that imply reallocation of space have a political cost. At the same time the effects may not be tangible or have enough impact in terms of increasing walking levels. Moreover, the results of the present study suggest that a *de facto* walkability improvement is required to trigger behaviour change and even in this case the increase in walking levels is moderate.

If on one side of the equation there is a high political cost and in the other side only modest outcomes, the result may well be less action towards environmental change to promote walking. On the other hand, broader goals that relate to general improvement of the urban environment and quality of life may be accomplished to a certain degree at a lower political cost.

This rationale may support the relative lack of comprehensive urban interventions towards the promotion of walking compared to smaller, aesthetic environmental improvements. As put by Risser & Šucha (2020), "Unfortunately, while talk is universal, action is much harder to find".

### 6.2.2 Acceptance

Resistance to change from various interest groups, notably local shopkeepers and car user residents, can jeopardize pedestrian oriented interventions as fierce opposition is not a sign of success for local governments (Lambe *et al.*, 2017). Several approaches can contribute to overcome resistance to change from these interest groups, such as information campaigns, studies and preliminary tests (Davies, 2012).

Bertolini (2020) states that city streets are increasingly becoming spaces for experimentation, not just to "learn by doing" but even more to provide a more comprehensive understanding of the possibilities and constraints associated to change. Accordingly, experiencing the environmental change is expected to generate a more consensual and informed agreement by local communities, social movements and planning professionals. Another virtue of undergoing experimentation is the communication power. People passing by are drawn to the experiment, people talk about the experiment, attention is given in social media. Such "virtual awareness" can be considered on its own a success metric (Hipp *et al.*, 2017). Various street experiments with different functional complexity have been implemented and reported, which have been categorized by Bertolini (2020) as follows: simple street re-markings, alternative uses of parking spaces, reconversion of sections of streets, and the opening of entire streets to uses other than motorised traffic.

Besides environmental interventions that require reallocation of street space, increasing walking levels could be achieved using alternative actions. These are often in the realm of "soft measures", which include but are not limited to awareness campaigns, education, marketing and the promotion of public transportation.

Starting from the latter, the promotion of public transportation use has been regarded as an effective, yet indirect way, of promoting walking in particular from the public health perspective (Besser & Dannenberg, 2005; Wener & Evans, 2007; Morency *et al.*, 2011). In the USA, the study of Besser & Dannenberg (2005) showed that transit users spent a median of 19 minutes daily walking to and from transit, making a significant contribution to the recommended 30 minutes a day of moderate to vigorous physical activity, while Wener & Evans (2007) found that daily train commuters were found to walk 30% more during the day than car commuters. Morency *et al.* (2011) found that in average a transit trip in Montreal involves 1250 steps, including the required journey to access and egress the network as well as to transfer between routes or modes (accounting 2500 steps for a round trip, that is 25% of the recommended 10.000 steps per day). In the Eixo Central case, there was a significant increase in transit use (mostly subway use) of around 6%. The number of passengers entering the Eixo Central stations increased by an average of 60 per counting period (refer to Table 6.3). This value is the same range as the observed increase in hourly pedestrian volume (refer to Table 4.5), namely in Av. República (M=58) and Av. Fontes Pereira de Melo (M=37). It could be that some of the increase in the pedestrian volume is associated to an increase of subway use rather than being an effect of the street improvement intervention. On the other hand it should be noted that according to the performed survey only 15% of the Eixo Central users referred an increase in the frequency of walking trips to public transportation, which was the lowest reported change compared to other walking purposes (refer to Table 5.2). And, in the case of people who reported an increase in walking for transportation the results from the logistic model revealed the influence of improving amenities and providing an accessible pedestrian network (refer to Table 5.11).

Regarding awareness campaigns, education and marketing, the role such measures can play in promoting walking levels may be comparable to the one of hard measures, and often at a fraction of cost (Foster *et al.*, 2018; Davies, 2012). For instance, in the case of "soft measures" to promote walking to school, recent research has shown that even if the effects on modal shift are not evident, such measures are able to create awareness and intentions of change (Teixeira *et al.*, 2019) and more positive perceptions of walking both in children as in their caregivers (Humberto *et al.*, 2021). The possibility that social norms can be influenced by a variety of "soft measures" opens a potential field of action to complement more effectively the "hard measures".

As presented in Chapter 5.3, individual attitudes relating to the presence of cars and the use of public space were significantly influenced the person's perception of environmental change, which in turn significantly influenced walking experience, which in turn significantly influenced behaviour change. According to this rationale - that draws directly from Ajzen (1991) Theory of Planned Behaviour - awareness campaigns, education and marketing directed to younger generations could act as a medium to long term walking promotion policy, contributing to intergenerational learning, in a similar manner to environmental education (Duvall & Zint, 2007).

Acting on the prevailing social norm may be a *sine qua non*, as public acceptance is itself a prerequisite for the successful implementation of policies. In the words of Banister (2008), "sustainable mobility has a central role to play in the future of sustainable cities, but it is only through the understanding and acceptance by the people that it will succeed".

### 6.2.3 Urban planning implications

On the other hand, looking at "harder" measures, the improvement of public space quality and of the pedestrian realm is not at all fruitless. On the contrary, studies have shown that from the perspective of key stakeholders (for instance local authorities, land owners or everyday users) better urban design adds value in economic, social and environmental terms. For instance, Carmona *et al.* (2002) reviewed stakeholders views on value and urban design based on real case studies, finding that investors and land owners in particular favour the potential increase in market value, residents appreciated a reinforced sense of place, and planning authorities were motivated by meeting broad public interest and planning policies.

That the quality of public space affects walking experience seems to be consensual. Design has long been considered one of the 3 main drivers of travel demand (Density, Diversity and Design, as coined by Cervero & Kockelman (1997)), while the urban design literature has proposed various perceptual qualities that may affect the walking environment - these include, for instance, complexity, enclosure, imageability, rhythm and spaciousness (Ewing & Handy, 2009). Attractiveness is considered one of the main dimensions of walkability, not only relating to micro-scale factors and design but also to the capacity of a pedestrian to endure social interaction and participate in commercial and cultural activity along the street (Talavera-Garcia & Soria-Lara, 2015). Hence, the relationship between urban design and land use can create synergies that promote the attractiveness of places, potentiating pedestrian activity.

Public space design and land use regulations are in the realm of urban planning offices. Addressing these two key issues can contribute to promote walking in a cost-effective manner, somehow in between "soft" and "hard" measures. To the best of our knowledge, only few attempts of incorporating walkability concerns in urban planning (namely public space design and municipal land use regulations) have been successful. A notable case is "The Affordable Renting Program" led by the municipality of Lisbon (set to build 3.000 new residential units to rent out at controlled prices), which included a walkability assessment process in the project phase of the developments (Olaias and Vale de Santo António[2])

Regarding the relation between walkability and property values, Gilderbloom *et al.* (2015) found a positive association between walkability -as measured by WalkScore ™- and housing values in over 170 north-american neighbourhoods. A similar finding that was also commercially advertised by the company behind WalkScore, claiming that an increase of one WalkScore point could raise the property value by an average of USD$ 3.000. [3]

The increase of housing prices due to a built environment improvement and sequent walkability improvement can in turn result in an undesirable effect - gentrification. In this process, urban renewal or improvements create added value on the property prices, eventually displacing original poorer residents for an influx of more affluent people, becoming a driver of social injustice (Bockarjova *et al.*, 2020). The gentrification process is not exclusive to residents. Commercial gentrification can also occur following pedestrianization schemes. The study by Özdemir & Selçuk (2017) showed that a pedestrianisation scheme in Istanbul, Turkey, was associated to an increase in shop rents resulting in the replacement of local small businesses by international chain-stores and hospitality facilities (eating and drinking). The diverse mixture of shops gave way to a homogenous mix, found in many other cities, with consequences to the sense of place and social justice.

Utterly the success of pedestrian oriented environmental interventions may have bitter consequences. In order to minimize this dilemma and to overcome the expected negative outcomes, planning authorities should adopt preventive measures to protect less affluent residents and shop keepers.

Importantly, walkability improvements should not be confined to city centres and to high streets. Pedestrian oriented improvements, such as pedestrianization schemes, often occur in central, historical, centres where they are more tolerated and accepted as they contribute to preserve historical heritage and contribute to local tourism economy. However when pedestrianization schemes are implemented in non-central locations, residents' satisfaction have been shown to increase as well as their walking frequency, particularly by the elderly population (Castillo-Manzano *et al.*, 2014).

[2] http://www.lisboarendaacessivel.pt/localizacoes/av-marechal-francisco-costa-gomes; http://www.lisboarendaacessivel.pt/localizacoes/vale-de-santo-antonio.html

[3] https://www.walkscore.com/professional/why-walkscore.php; https://www.redfin.com/news/how-much-is-a-point-of-walk-score-worth/

The findings of the present study also sustain the importance of walking experience, and in particular the variation of walking experience associated to walkability improvement. As discussed in Chapter 5, satisfaction (the before-after variation in walking experience) was found to be a significant predictor for walking behaviour change. Based on this finding, it can be induced that the places that have the most potential to succeed in increasing walking levels are the ones that already have a relative high usage (pedestrian flow) but a low walking experience, associated to lower walkability. One of such locations is Av. Morais Soares in the external control area of the Eixo Central study, where the pedestrian volume is higher than in some Eixo Central locations but walkability and reported walking experience is much lower.

On the other hand, the present study findings also sustained that a more expressive walkability improvement could be more effective in attaining the desired effects in increasing walking levels and that large scale developments require strong political backing. Some of these developments have been flagship projects from local governments, as in the case of Eixo Central.

Pedestrian oriented intervention projects should not just be flagship projects and certainly not confined to pedestrianization of the high street in city centres. The imperative to reduce social disparities (as well as reducing transport inequalities) calls for these interventions to be geographically broader (Su *et al.*, 2019). To overcome the political issue perhaps more policy should come in play, perhaps at national level -as in the case of national strategies to promote walking.

One interesting take on policy culture revealed that attitudes towards walking and sojourning tend to be more positive in health and public activity related institutions than in traffic and transportation institutions by (Methorst, 2021, p.460). Accordingly, such attitudes towards walking and sojourning (W+S) could be categorized in 6 levels:

1. **Denial:** Not my problem, pedestrians can fend for themselves;
2. **Pathological:** We do not feel responsible for W+S. It is unimportant. As long we are not summoned or sued and our public image stays unblemished, we do not feel the need to take action;
3. **Reactive:** W+S is important, but as long as we do not get complaints or clear signals from the outside, we do not concern ourselves with it; we do not have written policies on W+S but we follow central guidelines;
4. **Calculative:** W+S is important, we have signals that improvement is needed, we develop or have active policies.

5. **Pro-active:** W+S is important, we have improvement policies and we actively look for improvement opportunities;

6. **Generative:** W+S in a source of wealth and health and we treat it like that.

Local governments in Portugal -municipalities- tend to have a more representative traffic department than a physical activity department, suggesting that in order to climb the policy culture ladder, cabinets ought to acquire insights - and training - in active travel.

Various future developments come from this reflection. Dealing first with walkability assessment, the IAAPE framework should be refined to better express walking experience. This means a more thorough analysis of what influences walking experience. From here it could be compelling to address how to model walking experience. It is well established that pedestrians demonstrate more positive feelings about their means of transportations than other transport users - walking makes people happier (Montgomery, 2013). A better understanding of what raises the satisfaction of people walking could be a step forward towards the Happy City concept.

Regarding the issue of successful interventions, it would be of interest to develop a methodology to select locations based on the potential gains of increasing walking levels in order to prioritize interventions. This topic is straightly related to another potential development - the estimation of latent demand for walking. This could be done for distinct walking purposes and pedestrian groups, and used to inform policy in ex-ante evaluation of significant (i.e. costly) street interventions.

Finally, the role of play and recreation in the walking environment as a source of physical activity and social capital merits further research. The concept of "play streets" - a street that is reserved for children's safe play for a specific period during school vacations (D'Haese *et al.*, 2015) - also touches the emerging and stimulating research topic of dynamic allocation of street space.

All in all, increasing walking levels is a challenge. It could be questionable if increasing the walking levels should be considered as a measurable target or if the improvement of public space could be the target *per se*. **However a clear takeaway from this study was the need for more consistent monitoring to evaluate the outcomes and effects of measures, as a mean to learn, as a mean to achieve more people-centric, sustainable cities.**

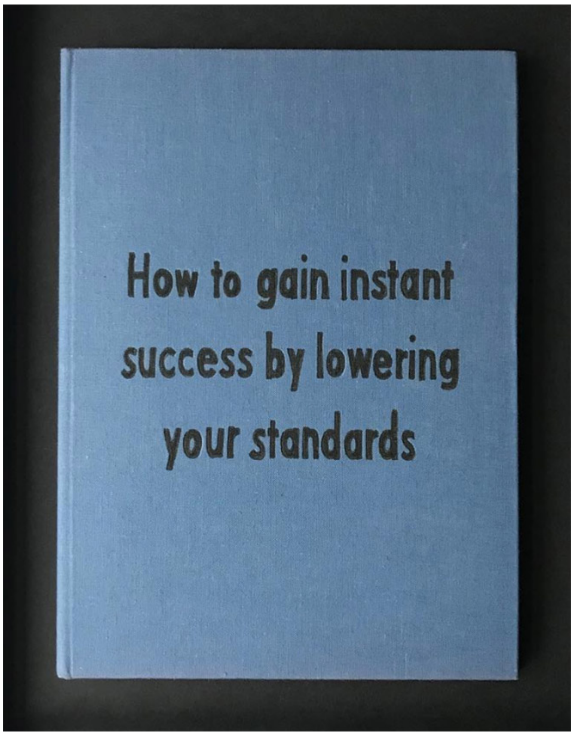


Figure 6.2: The artist's take on success - a fictional Self-Help Book by artist Johan Deckmann. Source:https://www.instagram.com/johandeckmann/

# Chapter 7

# Conclusion

This study explored the effects of changing the urban environment in walking behaviour, using a longitudinal design applied in a real world case - the Eixo Central project in Lisbon. It addressed the relation environment-walking behaviour in several ways: it has provided a systematic before-after evaluation of a street improvement intervention, assessing changes in walkability, pedestrian volumes and walking experience; it has analysed and modelled walking behaviour change for distinct trip purposes in relation to the intervention; and it has evaluated what could be considered to be a successful intervention from different perspectives. The study conclusions are presented in this chapter, covering the major findings -presented in the next section- and the significance and implications of these findings, ending with an overview of leads for future research.

## 7.1 Review of main findings

Table 7.1 summarises the study's research questions, the starting hypothesis and main findings. From the starting four sub-questions, the findings confirmed the four hypothesis, whereas one was considered to be only partilly confirmed.

Table 7.1: Research hypothsis confirmation

| Main research question: How does changing the Walking Environment relate to a change in Waking Behavior ? | | |
|---|---|---|
| **Research sub-questions** | **Hypothesis** | **Main findings** |
| How does a change in walkability affects pedestrian activity? | Positive association between walkability and pedestrian activity and walking experience | Confirmed |
| Which factors influence walking behaviour change? | Exposure, Perception and Experience are significant predictors | Confirmed |
| How do distinct pedestrian segments respond to environmental change? | Pedestrian segmentation via preferences and attitudes is associated to different outcomes | Partially confirmed |
| How can the success of a walking promotion intervention be evaluated? | Intervention results bear distinct "success" levels in relation to the type of walking behaviour of interest | Confirmed |

**Examining intervention effects:** Street interventions occur at different scales, ranging from isolated aesthetics enhancements to the provision of new infrastructure. This study evaluated the relations of walkability, pedestrian volumes and walking experience before and after a comprehensive street intervention. To the best of our knowledge no previous studies have provided a systematic evaluation of these three factors combined.

The evidence found suggests that the scale of environmental interventions matters for triggering effects in walking behaviour. A positive relationship was found between the magnitude of change in walkability and the changes in pedestrian volume and walking experience. The results suggest that walkability, walking experience, and pedestrian flows are related and that the observed change in the pedestrian volumes and walking experience are associated with the change in walkability.

This relation highlights the fact that a higher improvement in walkability could be associated with an increase in walking experience as well as in pedestrian activity (people moving and sojourning).

Smaller scale interventions, affecting single micro-factors may not be as effective in influencing walking behaviour as larger scale interventions where a change in walkability de facto takes place: making people walk more may require substantial environmental change. On the other hand smaller scale interventions seem to be effective in increasing the pedestrian satisfaction.

Another relevant finding is that the average pedestrian volume increased only in the intervention area while remaining stable in the adjacent streets and in the external control area, thus supporting the hypothesis that a causal link of some extent may exist between walkability improvement and pedestrian activity. Given the increase in tourism in Lisbon and associated flows of tourists moving around, the non-spuriousness condition for causal inference is unclear: it is possible that some of the increase in the number of people walking was due to tourism.

However, the evidence that the increase in pedestrian activity occurred only in the locations where there was a significant change in walkability cannot rule out the hypothesis of a causal relation.

**Exploring behaviour change triggers:**
Further research is needed also to better understand the role of experience as a mediator between the perceived environment and active travel behaviour and to discern which population groups may be more reactive to changes in the built environment. The understanding of which factors are more influential to whom and which synergies between the factors can provide more accomplished results are key to guide future urban interventions and policies aimed at increasing walking.

**Evaluating success:**
Another interesting finding is that the walking experience increased in all sections of the Eixo Central, regardless of less significant changes in walkability and pedestrian flow. Policy-wise, targeting the improvement of the population satisfaction can be a goal on its own hence smaller scale street improvements could be also considered to be successful.

However on a multimodal perspective the reallocation of road space may have produced not "evaporating traffic" but distribution of traffic to other streets, hence not resolving the problem but changing its place. In this regard, the understanding of what constitutes a successful intervention to promote walking requires further reflection.

In brief, the urban environment affects walking behaviour. Through behavioural mechanisms that relate perception, exposure and satisfaction with the urban environment, improving the walking conditions was found to be associated with positive outcomes in walking behaviour, namely:

- It is very likely that walking experience and satisfaction increases following a BE intervention, which in turn contributes to people's general satisfactions levels. This can be understood as a successful outcome for politics but is not usually considered as a policy goal;
- It is likely that improving the walking environment contributes to an increase in pedestrian activity (walking and sojourning) which contributes to strengthen the liveability and social capital of the urban environment, in turn making cities more

appealing;

- It is fairly likely that the increase in pedestrian activity is oriented more to recreational and leisure purposes. This could make people to walk more minutes or longer distances, or make more walking bouts, contributing to the public health goal of a more active population, fighting sedentary lifestyles ans obesity;
- It is less likely that the increase in pedestrian activity is due to a modal shift from motorized travel to active travel. In the scope of sustainable mobility goals, this is an underachieved outcome.

However, the findings of the study suggest that a BE intervention that simultaneously improves the walking environment, improves the conditions to the use of public transport and cycling and reduces the allocation of road space to private car use may lead to more people walking more.

In order to achieve that major goal, it is plausible to admit that adopting the "complete streets" model will not be sufficient if not accompanied by planning policies that incorporate the principles of TOD - Transport Oriented Development and Active Buildings. Improving the sidewalks is good but on its own it does not trigger behaviour change.

**A general conclusion of this study is that ex-post evaluations of street interventions remain a gap**. In continuum monitoring and evaluation are key factors to build up knowledge, learning from successful outcomes and from non accomplished projects.

**Overall strengths and limitations:**

Key strengths of this study include the use of a validated walkability assessment model to assess the extent of the environmental change and the application of a quasi-experimental study design to examine pedestrian volumes using two control areas to better isolate the potential effects in walking levels.

There are however limitations that should be considered when interpreting the results, namely relating to the assessment of walkability and walking experience. There were noticeable environmental changes that were not fully captured by the walkability model. The main variables used in the models were of very subjective nature. Multiple measurement scales may provide stronger report measures than single-item questions used in the present study and similar ones.

The data on public transport use refer to a single day. A more comprehensive dataset could have produced different results. It is expected that with time more open data on public transport use is made available thus allowing for more robust studies to be performed.

**Significance and implications:**

The understanding of the factors that determine the success of a BE intervention in triggering walking behaviour change is key to inform policy. We expect the results of this study to have significant implications for policy makers but also for urban planners and researchers. The findings of this study have significant implications, in particular relating to goal setting from the local government decision makers perspective.

It was found that the scale at which the environment is improved -and especially perceived- matters for alterations in walking behaviour. Hence larger scale investments are prone to be more effective in obtaining results concerning the promotion of walking. However larger investments come at a cost, not just monetary. Comprehensive street improvement projects favouring the pedestrian may require the reallocation of space used by motorized modes. This has often resulted in resistance from local stakeholders, namely residents and shop keepers concerned with a loss of accessibility. Fierce opposition to larger scale operations can lead to significant political costs.

In order to minimize the potential political costs, local government decision makers may opt to follow "quick win" strategies based on small, consensual interventions that improve local walking conditions but are not sufficient to make a significant improvement in walkability levels. Arguably, to protect BE intervention from scrutiny, goal setting may be vague and the characterization of the "before" conditions neglected.

## 7.2 Scientific contributions and further research

### 7.2.1 Scientific contributions

This research project produced several contributions to the state of knowledge, namely on:

1. Measuring walkability. The development and testing of a walkability assessment framework was a starting point of the present study, producing the journal article "Measuring Walkability for distinct pedestrian groups with a participatory assessment method: A case study in Lisbon (Moura *et al.*, 2017);

2. Testing the walkability model in relation to pedestrian activity. The association of the walkability scores to pedestrian activity - flows and sojourning - was tested in an early stage of the present study, producing the conference paper "On the correlation of pedestrian flows to urban environment measures: A Space Syntax and Walkability Analysis comparison case" (Cambra *et al.*, 2017a), presented in the Space Syntax international conference.

3. Modelling the digital pedestrian network. The digital pedestrian network is a robust refinement of the usual street centreline datasets that allows a more realistic evaluation of the pedestrian accessibility conditions and also acts as the geographic support of walkability data. The development of the digital pedestrian network concept produced the journal article "The digital pedestrian network in complex urban environments: a primer discussion on typological specifications" (Cambra *et al.*, 2019b).

4. Improving tools for sidewalk accessibility evaluation. The concern with inadequate walking conditions, the verification of regulatory accessibility parameters and the opportunity to do joint research with the signal processing department from Técnico resulted in the development of the WalkBot - a semi-automated sidewalk irregularity detection system, presented in (Cambra *et al.*, 2019c)

5. Before-After walking behaviour analysis. This was a core research subject, consisting of the before-after analysis of the walkability change in relation to changes in pedestrian flow and walking experience applied to the Eixo Central Case Study. It produced the journal article "How does walkability change relate to walking behaviour change ? Effects of a street improvement in pedestrian volumes and walking experience" (Cambra & Moura, 2020)

6. Before-after multimodal perspective. The study of the Eixo Central intervention in a multimodal perspective which included the analysis of changes in traffic, public

transportation use and cycling was produced a conference paper presented in the 9th Congresso Rodoviário Português (Cambra *et al.*, 2019a)

It worth mentioning also the outreach of this research in the participation of conferences, workshops and public debates, namely on the Walk21 international conferences (Munich 2012, Sidney 2014, Vienna 2016, Rotterdam 2018)[1].

### 7.2.2 Further research

A number of complementary research cues were identified during the thesis preparation.

First, at the application level, the present work set grounds to further refining the methods used to collect and model pedestrian data. In particular, the development of a **longitudinal walkability assessment tool** is devised, as most proposed tools focused in cross-sectional walkability assessment.

Eventually, comprehensive longitudinal evaluations of environmental changes will require improved walkability scoring tools that are sensitive to change in micro-scale factors and to urban design qualities. The development of these tools and the availability of open data (e.g. automated pedestrian counts) should also contribute to overcome the inherent challenges of documenting the effects of pedestrian interventions. But it is important to note, in accordance to Krizek *et al.* (2009a) that the body of intervention studies will only grow if policy makers, communities and researchers work together for rigorous and timely evaluations.

Prospective studies are encouraged to assemble a catalogue of before-after assessment studies in different urban contexts and geographies and to consolidate walkability measures that can provide a solid basis for benchmarking. Providing not only more but also using more robust study designs is key to establish the **causality** relation between walkability improvement and behaviour change.

Another refinement that could be introduced in walkability assessment has to do with the experiential dimension (walking experience). Refining the methods for assessing walking experience will be a necessary step to further investigate the role of environmental change in providing a more pleasurable experience which in turn may favour walking. Eventually evaluating and **modelling walking experience** could set a new venture, separated from walkability assessment.

[1]Conference materials (presentations and posters) available here: http://walk21.cedeus.cl/

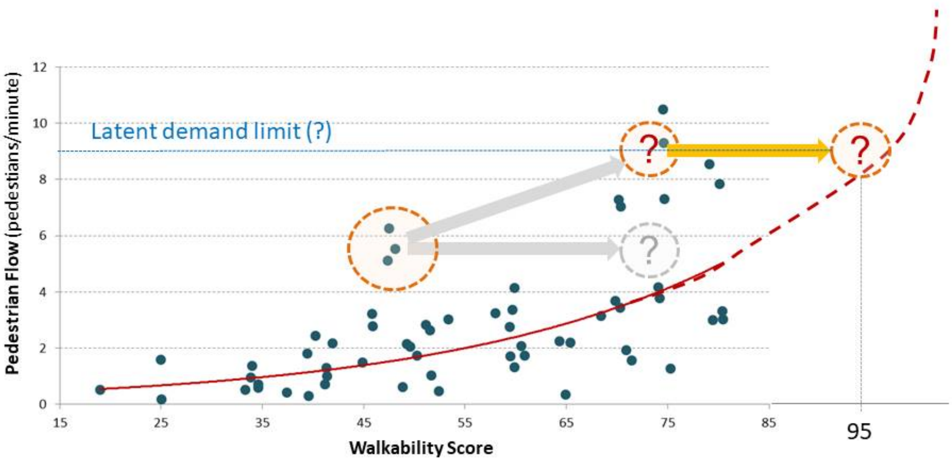


Figure 7.1: Latent demand - further research

The study results are expected to enable further **analysis and interpretation of pedestrian flows** in urban areas, making it possible to analyse the functional structure of the pedestrian network, based on supply (factors related to the pedestrian environment) and demand (the pedestrian activity). This could lead to the proposition of the **hierarchical pedestrian network**, contributing to inform policy in strategic mobility planning and in prioritizing built environment interventions.

Lastly, recalling one of the early questions that motivated this research, it was unclear what would the effect be in the pedestrian flow (demand side) if the walkability score increased (supply side). At this point, having found that an increase in walkability can be associated to an increase in pedestrian flow, the natural question that follows is up to how much pedestrian activity can be increased with an environmental intervention. In other words, how to **estimate latent demand** (see Figure 7.1).

Further research in this topic could have a significant implication for policy and planning as it would provide local governments a tool to identify places with a higher probability to achieve an effective and positive change in walking behaviour through an environmental intervention, thus contributing to meet the sustainable mobility goals, the public health goals and the justice/equity goals.

Given the political drawbacks of street space allocation temporary solutions ought to be tested. The implementation of temporary, intermittent or **dynamic allocation of the street space** for pedestrian usage in terms of feasibility and acceptance warrants further study.

Space may not be the final frontier.

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# Suplementary Materials

## Annex 1

Street auditing record page.

| Crossing | C61 | | | C14 |
|---|---|---|---|---|
| | Configurations | Conflicts | Visibility | Curb Drop and Tactile Aid |
| Evaluation | 1-4 | 1-3 | 1-3 | 0-2 |
| Reference | Aud_1 | Aud_2 | Aud_3 | Aud_4 |
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| Arcs | C53 | C32 | | C14 | C22 | C21 | C41 | C31 | C43 | C51 | C24 | C42 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Availability of Signals | Pavement Quality | No Presence of Tripping Hazards | No Presence of Steps | Walking Width (m) | Land Use Mix | Public Meeting Places | Vigilance Effect | Service Hours | Sense of Place and reference Elements | Everyday Use Commercial Activities | Existence of Attractor Destinations |
| Evaluation | 0-3 | 0-4 | 0-1 | 0-1 | Measure | 0-4 | 0-2 | E-A | 0-1 | 0-2 | Count | Count |
| Reference | Aud_5 | Aud_6 | Aud_7 | Aud_8 | Aud_9 | Aud_10 | Aud_11 | Aud_12 | Aud_12 | Aud_13 | Aud_14 | Aud_15 |
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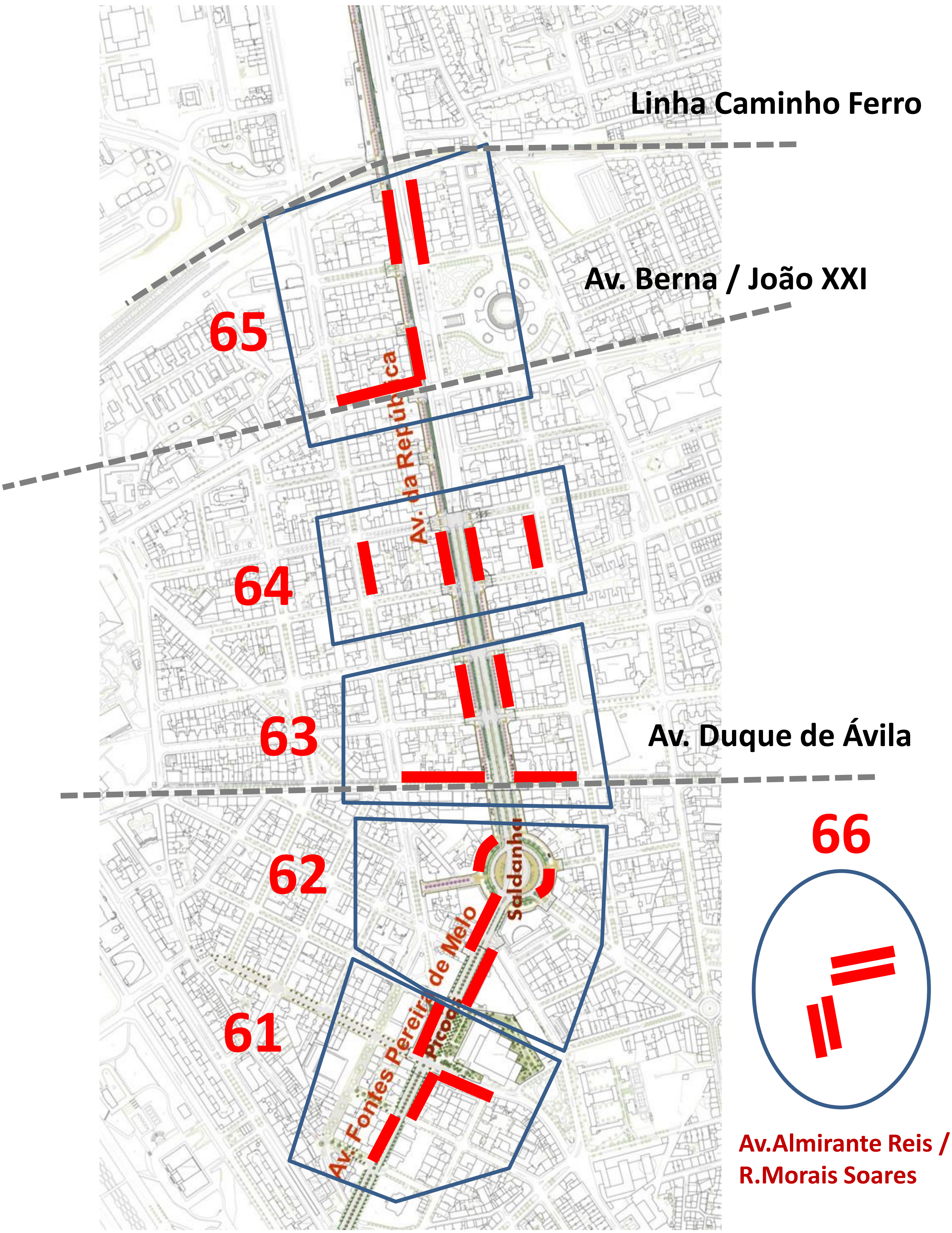
# Annex 2

Auditor counting circuits.

# Mapa Geral: circuitos



# Annex 3

Walkability scores, before and after.

| Study area | Street | Location ref. | C1: Connectivity | C2: Convenience | C3: Comfort | C4: Conviviality | C5: Conspicuousness | C6: Coexistence | C7: Commitment | Walkability Score Utilitarian **T1** | Walkability Score Recreation **T1** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | **T1 - Before** | | | | |
| Eixo Central, section 1 | Av.Republica | 1 | 59.4 | 75.0 | 50.0 | 100.0 | 100.0 | 72.7 | 100.0 | 78.1 | 83.5 |
| | | 2 | 59.4 | 75.0 | 37.5 | 50.0 | 100.0 | 68.1 | 100.0 | 66.5 | 69.8 |
| | | 3 | 65.7 | 75.0 | 50.0 | 100.0 | 100.0 | 63.2 | 45.5 | 71.1 | 78.0 |
| | | 4 | 59.4 | 75.0 | 37.5 | 100.0 | 100.0 | 65.3 | 100.0 | 74.3 | 80.9 |
| | | 5 | 65.7 | 100.0 | 37.5 | 50.0 | 100.0 | 63.2 | 45.5 | 62.0 | 69.7 |
| | | 6 | 59.4 | 75.0 | 37.5 | 100.0 | 100.0 | 65.3 | 100.0 | 74.3 | 80.9 |
| | | 7 | 65.7 | 50.0 | 87.5 | 50.0 | 100.0 | 63.2 | 45.5 | 67.5 | 66.2 |
| | | 8 | 59.4 | 100.0 | 87.5 | 50.0 | 100.0 | 65.3 | 100.0 | 75.8 | 80.2 |
| | | 9 | 65.7 | 50.0 | 87.5 | 50.0 | 50.0 | 74.8 | 37.5 | 63.6 | 57.8 |
| | | 10 | 59.4 | 75.0 | 100.0 | 100.0 | 100.0 | 65.3 | 100.0 | 85.0 | 88.4 |
| | | 11 | 65.7 | 75.0 | 100.0 | 100.0 | 100.0 | 74.8 | 37.5 | 81.3 | 85.1 |
| | | 12 | 59.4 | 75.0 | 87.5 | 50.0 | 100.0 | 76.5 | 100.0 | 76.8 | 77.1 |
| | | 13 | 65.7 | 75.0 | 87.5 | 50.0 | 100.0 | 65.8 | 25.0 | 67.3 | 69.7 |
| | | 14 | 59.4 | 75.0 | 50.0 | 50.0 | 100.0 | 73.2 | 100.0 | 69.7 | 72.1 |
| | | 15 | 66.7 | 75.0 | 25.0 | 50.0 | 100.0 | 67.8 | 66.7 | 61.8 | 65.9 |
| | | 16 | 65.7 | 75.0 | 87.5 | 50.0 | 100.0 | 60.0 | 100.0 | 74.2 | 74.9 |
| | | 17 | 68.8 | 75.0 | 25.0 | 100.0 | 100.0 | 67.1 | 100.0 | 74.2 | 80.1 |
| | | 18 | 64.8 | 75.0 | 37.5 | 100.0 | 100.0 | 67.8 | 66.7 | 72.1 | 78.8 |
| | | 19 | 57.9 | 75.0 | 12.5 | 100.0 | 100.0 | 65.1 | 75.0 | 67.0 | 75.8 |
| | | 20 | 53.5 | 50.0 | 87.5 | 50.0 | 100.0 | 78.4 | 100.0 | 74.7 | 72.4 |
| Eixo Central, section 2 | Saldanha | 21 | 57.9 | 75.0 | 25.0 | 50.0 | 100.0 | 65.1 | 75.0 | 60.7 | 65.8 |
| | | 22 | 57.9 | 50.0 | 75.0 | 50.0 | 100.0 | 65.1 | 75.0 | 67.7 | 67.1 |
| | | 23 | 57.9 | 50.0 | 50.0 | 100.0 | 50.0 | 79.5 | 100.0 | 72.3 | 70.2 |
| | | 24 | 57.9 | 50.0 | 50.0 | 100.0 | 100.0 | 78.4 | 100.0 | 77.6 | 79.6 |
| | | 25 | 57.9 | 75.0 | 87.5 | 50.0 | 100.0 | 78.4 | 100.0 | 77.0 | 77.3 |
| Eixo Central, section 3 | Av.Fontes Pereira Melo | 26 | 57.9 | 75.0 | 75.0 | 100.0 | 100.0 | 65.1 | 75.0 | 77.7 | 83.3 |
| | | 27 | 57.9 | 50.0 | 87.5 | 100.0 | 50.0 | 79.5 | 100.0 | 78.7 | 74.7 |
| | | 28 | 57.9 | 50.0 | 87.5 | 100.0 | 100.0 | 65.1 | 75.0 | 78.3 | 80.1 |
| | | 29 | 57.9 | 75.0 | 75.0 | 100.0 | 50.0 | 73.2 | 100.0 | 76.7 | 77.0 |
| | | 30 | 57.9 | 50.0 | 87.5 | 100.0 | 100.0 | 61.4 | 77.8 | 77.8 | 79.8 |
| | | 31 | 57.9 | 25.0 | 50.0 | 0.0 | 100.0 | 73.2 | 100.0 | 57.9 | 51.0 |
| | | 32 | 57.9 | 75.0 | 87.5 | 100.0 | 50.0 | 74.4 | 75.0 | 76.3 | 76.7 |
| | | 33 | 57.9 | 100.0 | 87.5 | 100.0 | 100.0 | 72.9 | 100.0 | 85.8 | 92.8 |
| | | 34 | 57.9 | 75.0 | 87.5 | 50.0 | 50.0 | 74.4 | 75.0 | 67.8 | 65.2 |
| | | 35 | 57.9 | 0.0 | 87.5 | 0.0 | 100.0 | 72.9 | 100.0 | 62.8 | 50.8 |
| | | 36 | 57.9 | 75.0 | 37.5 | 50.0 | 50.0 | 74.4 | 75.0 | 59.3 | 59.2 |
| | | 37 | 57.9 | 25.0 | 37.5 | 0.0 | 100.0 | 72.9 | 100.0 | 55.8 | 49.5 |
| Control Adjacent | Av.Berna | 38 | 64.6 | 75.0 | 100.0 | 50.0 | 50.0 | 60.6 | 71.4 | 67.7 | 64.6 |
| | Av. 5 Outubro | 39 | 62.4 | 50.0 | 100.0 | 50.0 | 0.0 | 75.5 | 75.0 | 64.0 | 52.8 |
| | Av.Defensores de Chaves | 40 | 62.4 | 75.0 | 50.0 | 100.0 | 0.0 | 83.3 | 66.7 | 66.3 | 63.6 |
| | Av.Duque de Ávila | 41 | 64.9 | 100.0 | 100.0 | 100.0 | 100.0 | 59.9 | 100.0 | 86.2 | 92.6 |
| | R.Tomás Ribeiro | 42 | 52.6 | 75.0 | 75.0 | 50.0 | 100.0 | 70.4 | 75.0 | 69.4 | 72.4 |
| Control External | Av.Almirante Reis | 43 | 50.1 | 100.0 | 50.0 | 100.0 | 100.0 | 69.5 | 58.3 | 72.7 | 84.1 |
| | Av.Almirante Reis | 44 | 50.1 | 100.0 | 50.0 | 100.0 | 100.0 | 60.3 | 75.0 | 72.5 | 84.0 |
| | R.Morais Soares | 45 | 50.1 | 100.0 | 37.5 | 100.0 | 50.0 | 70.4 | 58.3 | 65.3 | 73.2 |
| | R.Morais Soares | 46 | 50.1 | 100.0 | 37.5 | 100.0 | 50.0 | 60.9 | 58.3 | 63.2 | 71.8 |

| Study area | Street | T2 - After<br>Location reference | C1: Connectivity | C2: Convenience | C3: Comfort | C4: Conviviality | C5: Conspicuousness | C6: Coexistence | C7: Commitment | Walkability Score Utilitarian **T2** | Walkability Score Recreation **T2** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eixo Central, section 1 | Av.Republica | 1 | 59.4 | 75.0 | 100.0 | 100.0 | 100.0 | 72.7 | 100.0 | 86.6 | 89.5 |
| | | 2 | 67.2 | 75.0 | 37.5 | 50.0 | 100.0 | 68.1 | 100.0 | 67.8 | 70.2 |
| | | 3 | 65.0 | 75.0 | 100.0 | 100.0 | 100.0 | 63.2 | 45.5 | 79.5 | 84.0 |
| | | 4 | 67.2 | 75.0 | 87.5 | 100.0 | 100.0 | 65.3 | 100.0 | 84.2 | 87.2 |
| | | 5 | 65.0 | 75.0 | 100.0 | 50.0 | 100.0 | 63.2 | 45.5 | 71.0 | 72.5 |
| | | 6 | 67.2 | 75.0 | 87.5 | 100.0 | 100.0 | 65.3 | 100.0 | 84.2 | 87.2 |
| | | 7 | 65.0 | 50.0 | 37.5 | 50.0 | 100.0 | 63.2 | 45.5 | 58.8 | 60.2 |
| | | 8 | 67.2 | 75.0 | 25.0 | 100.0 | 100.0 | 65.3 | 100.0 | 73.5 | 79.7 |
| | | 9 | 61.7 | 75.0 | 100.0 | 50.0 | 100.0 | 74.8 | 37.5 | 72.1 | 73.4 |
| | | 10 | 67.2 | 75.0 | 100.0 | 100.0 | 100.0 | 65.3 | 100.0 | 86.3 | 88.7 |
| | | 11 | 61.7 | 75.0 | 100.0 | 100.0 | 100.0 | 74.8 | 37.5 | 80.6 | 84.9 |
| | | 12 | 67.2 | 75.0 | 100.0 | 100.0 | 100.0 | 76.5 | 100.0 | 88.8 | 90.4 |
| | | 13 | 63.8 | 75.0 | 100.0 | 50.0 | 100.0 | 65.8 | 25.0 | 69.1 | 71.2 |
| | | 14 | 67.2 | 75.0 | 100.0 | 50.0 | 100.0 | 73.2 | 100.0 | 79.5 | 78.4 |
| | | 15 | 64.8 | 75.0 | 100.0 | 50.0 | 100.0 | 67.8 | 66.7 | 74.3 | 74.8 |
| | | 16 | 63.8 | 75.0 | 100.0 | 50.0 | 100.0 | 60.0 | 100.0 | 76.0 | 76.3 |
| | | 17 | 68.8 | 75.0 | 100.0 | 100.0 | 100.0 | 67.1 | 100.0 | 87.0 | 89.1 |
| | | 18 | 64.8 | 75.0 | 100.0 | 100.0 | 100.0 | 67.8 | 66.7 | 82.8 | 86.3 |
| | | 19 | 60.4 | 75.0 | 87.5 | 100.0 | 100.0 | 65.1 | 75.0 | 80.2 | 84.9 |
| | | 20 | 53.5 | 75.0 | 100.0 | 100.0 | 100.0 | 78.4 | 100.0 | 86.8 | 90.2 |
| Eixo Central, section 2 | Saldanha | 21 | 60.4 | 75.0 | 87.5 | 50.0 | 100.0 | 65.1 | 75.0 | 71.7 | 73.4 |
| | | 22 | 60.4 | 75.0 | 100.0 | 100.0 | 100.0 | 65.1 | 75.0 | 82.3 | 86.4 |
| | | 23 | 60.4 | 75.0 | 100.0 | 100.0 | 100.0 | 79.5 | 100.0 | 88.3 | 90.6 |
| | | 24 | 60.4 | 50.0 | 87.5 | 100.0 | 100.0 | 78.4 | 100.0 | 84.4 | 84.2 |
| | | 25 | 60.4 | 75.0 | 100.0 | 50.0 | 100.0 | 78.4 | 100.0 | 79.5 | 78.9 |
| Eixo Central, section 3 | Av.Fontes Pereira Melo | 26 | 60.4 | 75.0 | 87.5 | 100.0 | 100.0 | 65.1 | 75.0 | 80.2 | 84.9 |
| | | 27 | 56.7 | 50.0 | 25.0 | 100.0 | 100.0 | 79.5 | 100.0 | 73.4 | 76.7 |
| | | 28 | 60.4 | 50.0 | 100.0 | 100.0 | 100.0 | 65.1 | 75.0 | 80.8 | 81.7 |
| | | 29 | 56.7 | 75.0 | 25.0 | 100.0 | 100.0 | 73.2 | 100.0 | 73.5 | 80.5 |
| | | 30 | 56.7 | 50.0 | 100.0 | 100.0 | 100.0 | 61.4 | 77.8 | 79.7 | 81.2 |
| | | 31 | 56.7 | 50.0 | 100.0 | 100.0 | 100.0 | 73.2 | 100.0 | 84.7 | 84.7 |
| | | 32 | 56.7 | 75.0 | 37.5 | 100.0 | 100.0 | 74.4 | 75.0 | 73.1 | 80.2 |
| | | 33 | 56.7 | 100.0 | 25.0 | 100.0 | 100.0 | 72.9 | 100.0 | 74.9 | 85.2 |
| | | 34 | 56.7 | 75.0 | 87.5 | 100.0 | 100.0 | 74.4 | 75.0 | 81.6 | 86.2 |
| | | 35 | 56.7 | 0.0 | 87.5 | 0.0 | 100.0 | 72.9 | 100.0 | 62.6 | 50.7 |
| | | 36 | 56.7 | 100.0 | 25.0 | 50.0 | 100.0 | 74.4 | 75.0 | 64.0 | 71.9 |
| | | 37 | 56.7 | 50.0 | 25.0 | 100.0 | 100.0 | 72.9 | 100.0 | 71.9 | 75.7 |
| Control Adjacent | Av.Berna | 38 | 64.6 | 75.0 | 100.0 | 50.0 | 50.0 | 60.6 | 71.4 | 67.7 | 64.6 |
| | Av. 5 Outubro | 39 | 62.4 | 50.0 | 100.0 | 50.0 | 0.0 | 75.5 | 75.0 | 64.0 | 52.8 |
| | Av.Defensores de Chaves | 40 | 62.4 | 75.0 | 50.0 | 100.0 | 0.0 | 83.3 | 66.7 | 66.3 | 63.6 |
| | Av.Duque de Ávila | 41 | 64.9 | 100.0 | 100.0 | 100.0 | 100.0 | 59.9 | 100.0 | 86.2 | 92.6 |
| | R.Tomás Ribeiro | 42 | 52.6 | 75.0 | 75.0 | 50.0 | 100.0 | 70.4 | 75.0 | 69.4 | 72.4 |
| Control External | Av.Almirante Reis | 43 | 50.1 | 100.0 | 50.0 | 100.0 | 100.0 | 69.5 | 58.3 | 72.7 | 84.1 |
| | Av.Almirante Reis | 44 | 50.1 | 100.0 | 50.0 | 100.0 | 100.0 | 60.3 | 75.0 | 72.5 | 84.0 |
| | R.Morais Soares | 45 | 50.1 | 100.0 | 37.5 | 100.0 | 50.0 | 70.4 | 58.3 | 65.3 | 73.2 |
| | R.Morais Soares | 46 | 50.1 | 100.0 | 37.5 | 100.0 | 50.0 | 60.9 | 58.3 | 63.2 | 71.8 |

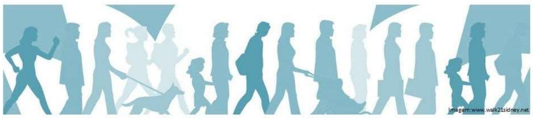
# Annex 4

Web Survey

## Inquérito Mobilidade Pedonal

*Required

### A requalificação do espaço urbano e o andar a pé



**Obrigado por participar neste inquérito.**
O objectivo deste inquérito é compreender melhor a relação da experiência dos peões nas suas deslocações habituais com as características do espaço urbano, focando-se, em particular, nos possíveis efeitos das intervenções de requalificação do espaço nos hábitos de mobilidade.

Este inquérito é realizado no âmbito de uma tese doutoramento em Sistemas de Transportes, do Departamento de Engenharia Civil e Arquitectura do Instituto Superior Técnico (Universidade de Lisboa).

As respostas são anónimas, e serão alvo de análise de dados para fins académicos. Os dados recolhidos não serão partilhados com outras entidades.

Os resultados deste estudo poderão ser divulgados em conferências, publicações em livros e revistas, e nos meios de comunicação virtuais na esfera académica.

A sua participação neste inquérito é muito bem vinda e valorizada. Não existem respostas certas nem erradas, apenas as suas.

Duração estimada de 10 a 15 minutos, questões de resposta simples [x].

1. *

*Tick all that apply.*

- [ ] Concordo em participar voluntariamente neste inquérito. Estou ciente do objectivo desta investigação, de que os resultados desta investigação poderão ser difundidos nos meios de comunicação académicos e de que este questionário é anónimo, não permitindo a identificação do/a participante.

Introdução

O inquérito está dividido em 5 grupos de questões que procuram caracterizar:
a) Hábitos de andar a pé;
b) Efeitos da requalificação do espaço urbano;
c) Experiência de andar a pé;
d) Padrões de mobilidade;
e) Características sócio-demográficas.

2. Para iniciar o inquérito por favor indique a sua idade: *

*Mark only one oval.*

- 14 anos ou menos
- 15 a 19 anos
- 20 a 24 anos
- 25 a 34 anos
- 35 a 44 anos
- 45 a 54 anos
- 55 a 64 anos
- 65 a 79 anos
- 80 anos ou mais

3. género: *

*Mark only one oval.*

- Feminino
- Masculino

4. e o dispositivo que está a utilizar para responder: *

*Mark only one oval.*

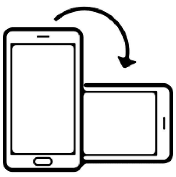
- Telemóvel (Smartphone)
- Tablet *Skip to question 5*
- Computador (PC, Laptop, Notebook, etc.) *Skip to question 5*

Nota para os utilizadores de telemóvel:

Algumas questões são apresentadas em tabela.

Nestas questões a leitura será mais clara se rodar o telemóvel para a posição horizontal, como indicado na figura:

A opção "Rodar"/"Rotate" do seu telemóvel deverá estar selecionada.



1. Andar a pé para si...

5. Gosta de andar a pé?

*Mark only one oval.*

- Sim, tanto em deslocações diárias como para recreio, lazer e exercício.
- Sim, mais para deslocações diárias do que para recreio, lazer e exercício.
- Sim, mais para recreio, lazer e exercício do que para deslocações diárias.
- É-me indiferente, não gosto nem desgosto.
- Não gosto de andar a pé.
- A minha condição física não me permite andar a pé.
- Other: ____________

6. Como considera a sua condição física para andar a pé?

*Mark only one oval.*

- Não tenho qualquer dificuldade em andar a pé.
- Estou temporariamente condicionado/a (p.ex. canadianas, muletas).
- Tenho alguma dificuldade em andar a pé.
- Tenho grandes dificuldades em andar a pé.
- Estou impossibilitado/a de andar a pé sem apoios.
- Other: ____________

Andar a pé para si...(ii)

7. Em que alturas do dia costuma andar mais a pé ?
Considere as viagens a pé habituais e de recreio e lazer, incluindo apanhar transportes, almoçar fora, fazer compras, passear, etc.

*Tick all that apply.*

- [ ] Amanhecer (antes das 8h)
- [ ] Manhã (8h - 10h)
- [ ] Meio da manhã (10h - 13h)
- [ ] Almoço (13h - 15h)
- [ ] Meio da tarde (15h-17h)
- [ ] Tarde (17h-19h)
- [ ] Anoitecer (depois das 19h)

8. Quanto tempo está normalmente disposto a andar a pé para chegar ao seu destino, sem considerar usar outro modo de transporte ? (minutos)
Ou seja, sem ponderar fazer essa viagem de automóvel, transporte público, bicicleta, táxi, etc. Considere que o tempo está bom e que não leva cargas pesadas.

________________________

**O que o/a DESAGRADA mais quando anda a pé ?**

Pensando nas suas deslocações habituais indique, por favor, os factores que afectam de forma mais negativa a sua experiência quotidiana de andar a pé.

9. Indique até 3 factores:

*Tick all that apply.*

- [ ] Má qualidade do ar - fumos, cheiros, escapes
- [ ] Ruído, barulho
- [ ] Desviar-me por causa de postes e esplanadas
- [ ] Passeios estreitos ou inexistentes
- [ ] Lancis altos, passeios não acessíveis a todos
- [ ] Pouco espaço livre para o peão
- [ ] Carros estacionados no passeio
- [ ] Trânsito intenso
- [ ] Falta de limpeza das ruas
- [ ] Passeio em mau estado - buracos, irregularidades

Other: [ ] ________________________

**O que o AGRADA mais quando anda a pé ?**

Pensando nas suas deslocações habituais indique, por favor, os factores que afectam de forma mais positiva a sua experiência quotidiana de andar a pé.

10. Indique até 3 factores:

*Tick all that apply.*

- [ ] Cruzar-me com muitas pessoas
- [ ] Não me cruzar com ninguém, haver poucas pessoas na rua
- [ ] Existirem pontos de encontro (bancos, esplanadas, praças)
- [ ] Montras, vitrines para olhar
- [ ] Qualidade arquitectonica das fachadas dos edifícios
- [ ] Proximidade de árvores, jardins, espaços verdes
- [ ] Haver espaço para circular sem me desviar de pessoas ou obstáculos
- [ ] Passeios confortáveis e bem mantidos
- [ ] Não me sentir incomodado(a) com o trânsito
- [ ] Ter prioridade a atravessar a rua

Other: [ ] ________________________

**2. A requalificação do espaço urbano**

O projeto Eixo Central consistiu numa intervenção de requalificação do espaço da Av.República, Saldanha e Av. Fontes Pereira de Melo em Lisboa.

**Caso de Estudo:**
**Intervenção no Eixo Central, obra concluída em Janeiro de 2017**
**Eixo Central: Avenida da República – Saldanha – Av.Fontes Pereira de Melo**

Fonte: Jornal Expresso online, 2015/09/05

11. Conhece a zona do Eixo Central? (Av. República - Saldanha - Av. Fontes Pereira de Melo e ruas adjacentes) *

*Mark only one oval.*

- ( ) Sim, resido nessa zona.
- ( ) Sim, trabalho ou estudo nessa zona.
- ( ) Sim, resido e trabalho/estudo nessa zona.
- ( ) Sim, costumo ir a essa zona para fazer compras ou tratar de assuntos.
- ( ) Sim, costumo passar nessa zona a caminho de outros sítios.
- ( ) Nem por isso. Conheço a zona mas não costumo passar nessas ruas. *Skip to question 36*
- ( ) Não, não conheço essas ruas. *Skip to question 36*

**Recorda-se do Eixo Central antes das obras?**

Recorda-se como era a Av.República, Saldanha e Av.Fontes Pereira de Melo antes da conclusão das obras de intervenção no Eixo Central que terminaram em 2017? Considere, por exemplo, o ano passado, Setembro-Novembro de 2016.

12. Recorda-se de como era a Av. República antes das obras?

*Mark only one oval.*

- ( ) Não conheci a Av.República antes da intervenção.
- ( ) Sinceramente não me recordo.
- ( ) Tenho uma ideia mas não me recordo bem.
- ( ) Recordo-me bem.
- ( ) Recordo-me muito bem da Av.República antes da intervenção.

13. Recorda-se de como era o Saldanha antes das obras?

*Mark only one oval.*

- ( ) Não conheci o Saldanha antes da intervenção.
- ( ) Sinceramente não me recordo.
- ( ) Tenho uma ideia mas não me recordo bem.
- ( ) Recordo-me bem.
- ( ) Recordo-me muito bem do Saldanha antes da intervenção.

14. Recorda-se de como era a Av.Fontes Pereira de Melo antes das obras?

*Mark only one oval.*

- Não conheci a Av. Fontes Pereira de Melo antes da intervenção.
- Sinceramente não me recordo.
- Tenho uma ideia mas não me recordo bem.
- Recordo-me bem.
- Recordo-me muito bem da Av. Fontes Pereira de Melo antes da intervenção.

Nos últimos três meses (Setembro a Novembro) com que frequência passou, a andar a pé, no Eixo Central:

15. Avenida da República

*Mark only one oval.*

- Quase nunca (menos do que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos do que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

16. Saldanha

*Mark only one oval.*

- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

17. Avenida Fontes Pereira de Melo

*Mark only one oval.*

- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

Como classifica a experiência de andar a pé nestas ruas?

Com base no que torna a sua experiência positiva ou negativa, por favor classifique os casos de 1 a 9, admitindo que:
1 - representa uma experiência desagradável - evitaria andar nesta rua.
5 - representa um ponto neutro.
9 - representa uma experiência muito agradável - é com muito prazer que anda nesta rua.

18. Av.República, actualmente *

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

19. Av.República, antes das obras (2016)

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

20. *Tick all that apply.*

- [ ] Não me recordo o suficiente para conseguir avaliar a experiência antes das obras.

21. Saldanha, actualmente *

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

22. Saldanha, antes das obras (2016)

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

23. *Tick all that apply.*

- [ ] Não me recordo o suficiente para conseguir avaliar a experiência antes das obras.

24. Av. Fontes Pereira de Melo, actualmente *

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

25. Av. Fontes Pereira de Melo, antes das obras (2016)

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

26. *Tick all that apply.*

- [ ] Não me recordo o suficiente para conseguir avaliar a experiência antes das obras.

Como classifica a experiência de andar a pé nestas outras ruas?

Tal como nos casos anteriores, com base no que torna a sua experiência positiva e negativa, por favor classifique os casos de 1 a 9, admitindo que:
1 - representa uma experiência desagradável - evitaria andar nesta rua.
5 - representa um ponto neutro.
9 - representa uma experiência muito agradável - é com muito prazer que anda nesta rua.

27. Avenida Duque de Ávila

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Muito agradável |

28.

*Tick all that apply.*

☐ Não ando a pé nesta rua.

29. Avenida da Liberdade

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | Muito agradável |

30.

*Tick all that apply.*

☐ Não ando a pé nesta rua.

Para si, como se alterou o Eixo Central?

Nota: Se está a utilizar o telemóvel sugerimos que o rode para a posição horizontal de forma a conseguir ler a tabela completa.

Se não se recorda o suficiente para comparar o antes e o depois da intervenção, por favor compare o Eixo Central com as ruas da área envolvente (p.ex. Av. 5 de Outubro, Av. Miguel Bombarda, etc.).

Na sua perspectiva, o que mudou no Eixo Central de como era antes das obras (2016) para o presente (2017):

31.

*Mark only one oval per row.*

| | Mudou muito, para pior | Mudou um pouco, para pior | Está na mesma | Mudou um pouco, para melhor | Mudou muito, para melhor |
|---|---|---|---|---|---|
| 1.Espaço para peões | ◯ | ◯ | ◯ | ◯ | ◯ |
| 2.Conforto dos passeios | ◯ | ◯ | ◯ | ◯ | ◯ |
| 3.Árvores, canteiros, espaços verdes | ◯ | ◯ | ◯ | ◯ | ◯ |
| 4.Obstáculos no passeio (existência de) | ◯ | ◯ | ◯ | ◯ | ◯ |
| 5.Segurança a atravessar a rua | ◯ | ◯ | ◯ | ◯ | ◯ |

32. (continuação)

*Mark only one oval per row.*

| | Mudou muito, para pior | Mudou um pouco, para pior | Está na mesma | Mudou um pouco, para melhor | Mudou muito, para melhor |
|---|---|---|---|---|---|
| 6.Lojas, comércio e serviços (presença de) | ◯ | ◯ | ◯ | ◯ | ◯ |
| 7.Acessibilidade a pessoas com mobilidade reduzida | ◯ | ◯ | ◯ | ◯ | ◯ |
| 8.Locais de encontro e estadia (p.ex. quiosques, esplanadas) | ◯ | ◯ | ◯ | ◯ | ◯ |
| 9.Mobiliário urbano (bancos, mesas, etc.) | ◯ | ◯ | ◯ | ◯ | ◯ |
| 10.Localização das passadeiras e semáforos | ◯ | ◯ | ◯ | ◯ | ◯ |

33. *

*Mark only one oval.*

◯ Comparei o antes e o depois das obras da intervenção no Eixo Central, como solicitado.

◯ Não me recordo o suficiente para comparar o antes e o depois da intervenção. Comparei o Eixo Central com as ruas da área envolvente.

Considera que alterou alguns dos seus hábitos?

Nota: Se está a utilizar o telemóvel sugerimos que o rode para a posição horizontal de forma a conseguir ler a tabela completa.

Considere a situação antes das obras (2016) e a situação depois das obras (2017).
Recorde-se da sua rotina habitual, por exemplo, a dos últimos 3 meses - Setembro, Outubro e Novembro - e compare-a com a rotina que tinha no mesmo período do ano passado (Setembro a Novembro de 2016).
Se não realizava habitualmente alguma destas actividades quer em 2016, quer em 2017, assinale a coluna "Na mesma"

34. Actualmente, e em relação ao ano passado, vai mais vezes, a pé, ao Eixo Central...

*Mark only one oval per row.*

| | Não, muito menos | Não, um pouco menos | Na mesma | Sim, um pouco mais | Sim, muito mais |
|---|---|---|---|---|---|
| para tratar de assuntos, compras, almoçar, encontrar pessoas. | ◯ | ◯ | ◯ | ◯ | ◯ |
| para apanhar transportes. | ◯ | ◯ | ◯ | ◯ | ◯ |
| para passar algum tempo, sentar, estar nas esplanadas. | ◯ | ◯ | ◯ | ◯ | ◯ |
| para fazer exercício físico ao ar livre (caminhar , correr) | ◯ | ◯ | ◯ | ◯ | ◯ |
| só de passagem, a caminho de outros locais | ◯ | ◯ | ◯ | ◯ | ◯ |

35. Considera que a requalificação do espaço urbano no Eixo Central influenciou de alguma forma os seus hábitos de mobilidade quotidianos? *
Tenha em conta os seus hábitos de mobilidade em geral, não limitados a andar a pé.

*Mark only one oval.*

- Não teve qualquer influência.
- Pouca influência.
- Alguma influência pontual.
- Influência significativa.
- Muita influência. Existe claramente um "antes" e um "depois".

*Skip to question 52*

Avaliação do espaço urbano

36. Qual considera ser a rua principal, que atrai mais pessoas, na sua área de residência/bairro? *
Se for difícil identificar uma rua em particular, indique por favor uma rua que conheça muito bem da sua área de residência.

_______________________________

37. Com que frequência passou a pé, nessa rua, nos últimos 3 meses?

*Mark only one oval.*

- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

O espaço urbano é amigo do peão?

Nota: Se está a utilizar o telemóvel sugerimos que o rode para a posição horizontal de forma a conseguir ler a tabela completa.

38. Na sua perspectiva, como classifica a rua que nos indicou face a estes atributos de caminhabilidade:

*Mark only one oval per row.*

| | Muito mau | Insatisfatório | Nem bom nem mau | Satisfatório | Muito bom |
|---|---|---|---|---|---|
| 1.Espaço para peões | | | | | |
| 2.Conforto dos passeios | | | | | |
| 3.Árvores, canteiros, espaços verdes | | | | | |
| 4.Obstáculos no passeio (existência de) | | | | | |
| 5.Segurança a atravessar a rua | | | | | |

39. (continuação)

*Mark only one oval per row.*

| | Muito mau | Insatisfatório | Nem bom nem mau | Satisfatório | Muito bom |
|---|---|---|---|---|---|
| 6.Lojas, comércio e serviços (presença de) | | | | | |
| 7.Acessibilidade a pessoas com mobilidade reduzida | | | | | |
| 8.Locais de encontro e estadia (quiosques, esplanadas) | | | | | |
| 9.Mobiliário urbano (bancos, mesas, etc.) | | | | | |
| 10.Localização das passadeiras e semáforos | | | | | |

40. Com base no que torna a sua experiência positiva e negativa, como considera a experiência de andar a pé nessa rua?
Por favor classifique de 1 a 9, admitindo que: 1) representa uma experiência desagradável - evitaria andar nesta rua; 5)- representa um ponto neutro; 9) representa uma experiência muito agradável - é com muito prazer que anda nesta rua.

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

Experiência de andar a pé noutras ruas de Lisboa.

Tal como fez na questão anterior, por favor classifique estes outros 5 casos: Avenida da Liberdade; Avenida Duque de Ávila; Rua Morais soares; Ribeira das Naus; Chiado.

Nos últimos 3 meses (Setembro, Outubro e Novembro), com que frequência andou a pé na:

41. Avenida da Liberdade

*Mark only one oval.*

- Não conheço esta rua (por favor passe para o caso seguinte)
- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

42. Como classifica a experiência de andar a pé na Av.da Liberdade?

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

43. Avenida Duque de Ávila

*Mark only one oval.*

- Não conheço esta rua (por favor passe para o caso seguinte)
- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

44. Como classifica a experiência de andar a pé na Av. Duque de Ávila?

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

45. Rua Morais Soares

*Mark only one oval.*

- Não conheço esta rua (por favor passe para o caso seguinte)
- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

46. Como classifica a experiência de andar a pé na Rua Morais Soares?

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

Continuação da questão anterior, com os 2 últimos casos: Ribeira das Naus e Chiado.

Nos últimos 3 meses (Setembro, Outubro e Novembro), com que frequência andou a pé na:

47. Ribeira das Naus (Cais do Sodré - Praça Comércio)

*Mark only one oval.*

- Não conheço esta rua (por favor passe para o caso seguinte)
- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

48. Como classifica a experiência de andar a pé na Ribeira das Naus?

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

49. Chiado (R.Garret / Rua do Carmo)

*Mark only one oval.*

- Não conheço esta rua (por favor passe para o caso seguinte)
- Quase nunca (menos que 1 vez por mês)
- Raramente (+- 1 vez por mês)
- Ocasionalmente (mais do que 1 vez por mês, mas menos que 1 vez por semana)
- Habitualmente (pelo menos 1 vez por semana)
- Frequentemente (mais do que 1 vez por semana mas não todos os dias)
- Quase sempre (todos os dias da semana)

50. Como classifica a experiência de andar a pé no Chiado?

*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Desagradável | | | | | | | | | | Muito agradável |

Considera que alterou alguns dos seus hábitos?

Nota: Se está a utilizar o telemóvel sugerimos que o rode para a posição horizontal de forma a conseguir ler a tabela completa.

Recorde-se da sua rotina habitual, por exemplo dos últimos 3 meses - Setembro, Outubro e Novembro, e compare-a com a rotina que tinha o ano passado no mesmo período (Setembro a Novembro de 2016).

Se não realizava habitualmente alguma destas actividades quer em 2016, quer em 2017, assinale a coluna "Na mesma"

51. Do ano passado (2016) para o presente (2017) e em relação ao mesmo período, como classifica estas afirmações? Actualmente...

*Mark only one oval per row.*

| | Não, muito menos | Não, um pouco menos | Na mesma | Sim, um pouco mais | Sim, muito mais |
|---|---|---|---|---|---|
| Faz mais viagens a pé para tratar de assuntos, compras, almoçar, encontrar pessoas | | | | | |
| Faz mais viagens a pé para apanhar transportes | | | | | |
| Sai mais vezes à rua para passar algum tempo, passear | | | | | |
| Passa mais tempo ao ar livre sentado nos bancos ou nas esplanadas | | | | | |
| Sai mais vezes à rua para fazer exercício físico ao ar livre (caminhar, correr) | | | | | |

Obrigado. Estamos quase a acabar as questões...

Nota: Se está a utilizar o telemóvel sugerimos que o rode para a posição horizontal de forma a conseguir ler a tabela completa.

52. No geral, em que medida concorda com estas afirmações?

*Mark only one oval per row.*

| | Discordo absolutamente | Discordo | Nem sim nem não | Concordo | Concordo plenamente |
|---|---|---|---|---|---|
| É importante construir mais estradas para reduzir o trânsito e o congestionamento | ◯ | ◯ | ◯ | ◯ | ◯ |
| Gostava que houvesse menos carros na cidade | ◯ | ◯ | ◯ | ◯ | ◯ |
| O investimento em ciclovias é desnecessário porque ninguém vai andar de bicicleta | ◯ | ◯ | ◯ | ◯ | ◯ |
| Preferia que houvesse mais estacionamento a melhor espaço público | ◯ | ◯ | ◯ | ◯ | ◯ |
| Andar a pé no dia-a-dia não é suficiente para ser considerado exercício físico | ◯ | ◯ | ◯ | ◯ | ◯ |
| Faço exercício físico suficiente para me manter em boa forma | ◯ | ◯ | ◯ | ◯ | ◯ |

Hábitos de transporte. Já completou 75% do inquérito.

57. De todas as viagens que fez ontem, em quantas andou a pé mais do que 10 minutos? (nº)

______________________________

58. De todas as viagens que fez ontem, quantas foram feitas exclusivamente a pé? (nº)

Neste caso não deverá incluir as viagens a pé efectuadas para utilizar outro tipo de transporte (p. ex. ir a pé para paragens de transporte ou estacionamento não contam)

______________________________

Consegue indicar o local de origem e destino da sua viagem diária principal?

Indique por favor o concelho, a freguesia e o código postal (CP).

53. Quanto tempo costuma demorar a sua viagem entre casa e trabalho/estudo? Tenha em conta toda a viagem, desde o momento em que sai de casa até chegar ao seu destino. (minutos)

Caso não trabalhe nem estude, refira-se à sua viagem diária mais frequente.

______________________________

54. Qual considera o seu principal meio de transporte, no seu trajecto casa - trabalho/estudo ?

Considere como meio principal o transporte utilizado para percorrer a maior distância da viagem. No caso de ser diferente na ida e na volta, considere o meio de transporte de ida. Caso não trabalhe nem estude, refira-se à sua viagem diária mais frequente.

*Mark only one oval.*

- ◯ Automóvel, como condutor
- ◯ Automóvel, como passageiro
- ◯ Comboio / Metropolitano
- ◯ Autocarro
- ◯ A pé
- ◯ Bicicleta
- ◯ Motociclo
- ◯ Other: ____________________

55. Em média, quanto desse trajecto é feito a andar a pé? (em minutos)

Deve incluir o tempo de/para o local de estacionamento, paragens de transporte ou pequenos desvios. Por exemplo: sai de casa e anda 5 minutos até ao seu transporte. Quando sai do transporte anda 10 minutos até ao seu destino. No total fez 15 minutos a andar.

______________________________

Por favor recorde a sua rotina de ontem e todas as deslocações que realizou.

Considere também as viagens curtas como ir ao café, ir almoçar, ir à loja da esquina, ir ao multibanco, ir ao ginásio, deixar filhos na escola, etc.
Uma deslocação de ida e volta conta como 2 viagens.

56. Quantas viagens fez ontem? (nº)

______________________________

59. Origem: Concelho de residência

*Mark only one oval.*

- ◯ Alcochete
- ◯ Almada
- ◯ Amadora
- ◯ Barreiro
- ◯ Cascais
- ◯ Lisboa
- ◯ Loures
- ◯ Mafra
- ◯ Moita
- ◯ Montijo
- ◯ Odivelas
- ◯ Oeiras
- ◯ Palmela
- ◯ Seixal
- ◯ Sesimbra
- ◯ Sintra
- ◯ Setúbal
- ◯ Vila Franca de Xira
- ◯ Outro

60. Se reside em Lisboa, por favor indique também a freguesia:

*Mark only one oval.*

- Não resido em Lisboa
- Ajuda
- Alcântara
- Alvalade
- Areeiro
- Arroios
- Avenidas Novas
- Beato
- Belém
- Benfica
- Campo de Ourique
- Campolide
- Carnide
- Estrela
- Lumiar
- Marvila
- Misericórdia
- Olivais
- Parque das Nações
- Penha de França
- Santa Clara
- Santa Maria Maior
- Santo António
- São Domingos de Benfica
- São Vicente

61. Código postal da área de residência

Se souber o código postal da sua área de residência indique aqui, por favor. Se não souber os 7 dígitos do seu CP coloque apenas os 4 primeiros dígitos ou indique a morada.

Destino da viagem diária principal

Se não trabalha nem estuda por favor considere a sua viagem mais frequente.

62. Concelho de trabalho/estudo/destino principal

Por favor seleccione o concelho:

*Mark only one oval.*

- Alcochete
- Almada
- Amadora
- Barreiro
- Cascais
- Lisboa
- Loures
- Mafra
- Moita
- Montijo
- Odivelas
- Oeiras
- Palmela
- Seixal
- Sesimbra
- Sintra
- Setúbal
- Vila Franca de Xira
- Outro

63. Se o seu principal destino é em Lisboa, por favor indique também a freguesia:

*Mark only one oval.*

- Ajuda
- Alcântara
- Alvalade
- Areeiro
- Arroios
- Avenidas Novas
- Beato
- Belém
- Benfica
- Campo de Ourique
- Campolide
- Carnide
- Estrela
- Lumiar
- Marvila
- Misericórdia
- Olivais
- Parque das Nações
- Penha de França
- Santa Clara
- Santa Maria Maior
- Santo António
- São Domingos de Benfica
- São Vicente

64. Código postal do local de Trabalho/Estudo

Se souber o código postal do seu local de trabalho/estudo/destino principal indique aqui, por favor. Se não souber os 7 dígitos do CP coloque apenas os 4 primeiros dígitos, indique a morada, o nome do local ou um ponto de referência.

Último bloco: Caracterização Sócio-Demográfica.

Neste bloco vamos colocar questões gerais sobre si e o seu agregado familiar para caracterizar a amostra do estudo.

65. Quantas pessoas residem na sua habitação? (inclua-se a si próprio)

66. Tem filhos ou dependentes menores a seu cargo? Qual a idade do seu dependente mais novo?

*Mark only one oval.*

- Não tenho filhos ou dependentes menores a meu cargo.
- Sim tenho, com menos de 1 ano.
- Sim, 1 a 5 anos.
- Sim, 6 a 10 anos.
- Sim, 11 a 15 anos.
- Sim, 16 anos ou mais.

67. Em que andar reside?

*Mark only one oval.*

- Pisos térreos (R/C, cave, moradia)
- 1º andar
- 2º andar
- 3º andar
- 4º andar
- 5º andar ou superior

68. O prédio onde reside tem elevador?

*Mark only one oval.*

- ( ) Sim
- ( ) Não

69. Qual a sua situação laboral?

*Mark only one oval.*

- ( ) Trabalhador
- ( ) Estudante
- ( ) Pensionista / Reformado
- ( ) Doméstico / Apoio familiar
- ( ) Desempregado
- ( ) Other: ____________

70. Qual a sua formação escolar?

*Mark only one oval.*

- ( ) Ensino básico (até ao 9º ano)
- ( ) Ensino secundário (até ao 12ºano)
- ( ) Ensino profissional (pós 12º ano)
- ( ) Ensino superior

71. Onde enquadra o seu escalão de rendimentos ?

Se não tiver rendimento próprio, considere as fontes de subsistência aplicáveis (p. ex. apoio familiar, subsídios, etc. )

*Mark only one oval.*

- ( ) Menos de 800 € mensais *Skip to question 73*
- ( ) Entre 800 € e 1.600 € mensais *Skip to question 73*
- ( ) Mais de 1.600 € mensais *Skip to question 73*
- ( ) Prefiro não dizer valores, obrigado/a

Fim do inquérito. Obrigado pela sua ajuda! Agora é só carregar no botão "enviar".

Caso queira receber os resultados e conclusões deste estudo, ou tenha alguns comentários ou questões que queira colocar, pode-nos enviar um email para:

Paulo Cambra

inquerito.pedonal.ist@gmail.com



Último bloco: Caracterização Sócio-Demográfica.

72. Em alternativa, pode indicar se:

*Mark only one oval.*

- ( ) Os seus rendimentos permitem-lhe viver sem dificuldades.
- ( ) Os seus rendimentos permitem-lhe viver com moderada facilidade.
- ( ) Vive com dificuldades financeiras.

A terminar...

73. Assinale, por favor, se alguma destas condições ocorreram consigo em 2017 (todas as que se aplicarem)

*Tick all that apply.*

- [ ] Utilizei bengala, canadiana ou andarilho
- [ ] Utilizei cadeira de rodas
- [ ] Caí no passeio, tendo ficado magoado ou lesionado
- [ ] Fui mãe/pai (os nossos sinceros parabéns e votos de felicidades!)
- [ ] Pelo menos um dos meus filhos entrou para ou mudou de escola/creche/infantário
- [ ] Mudei de casa (área de residência)
- [ ] Mudei de local de trabalho
- [ ] Aposentei-me

74. E se fosse o presidente da câmara por um dia, que medida tomaria?

Esta questão é aberta e opcional. Se pretender finalizar aqui o seu inquérito, pode passar à pagina seguinte para submeter as suas respostas.

# Annex 5

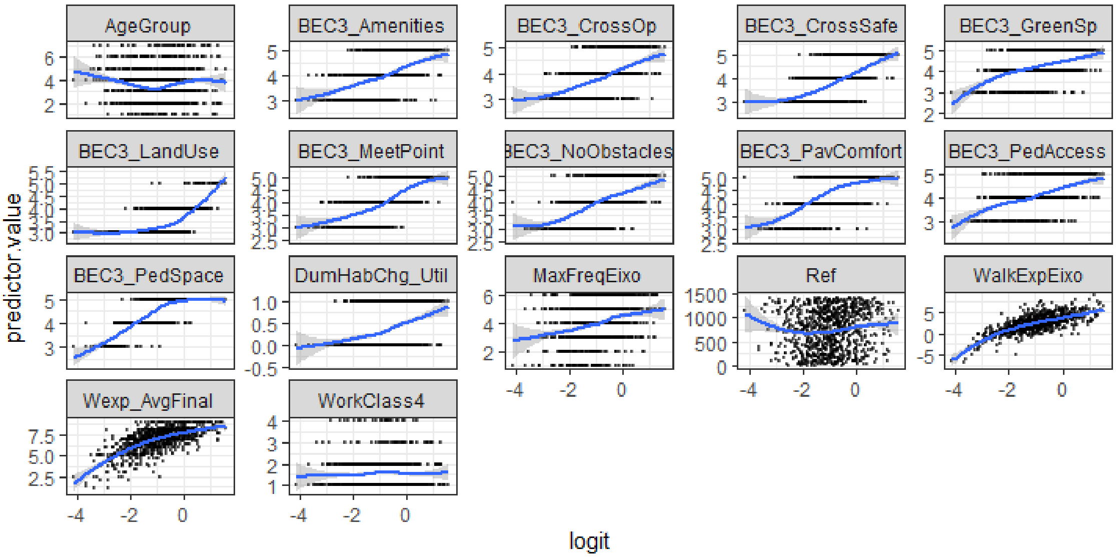
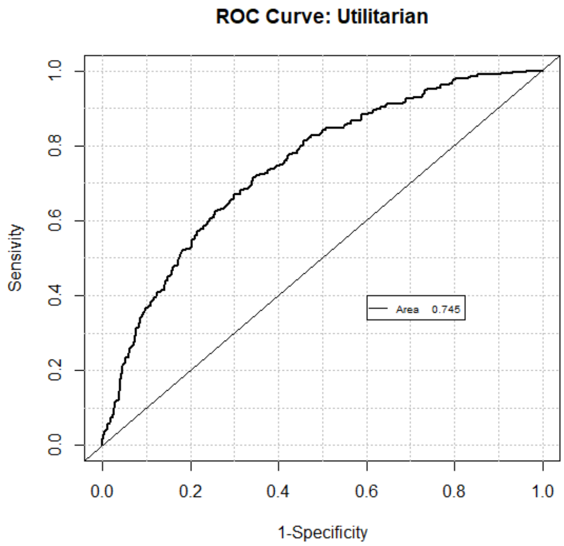
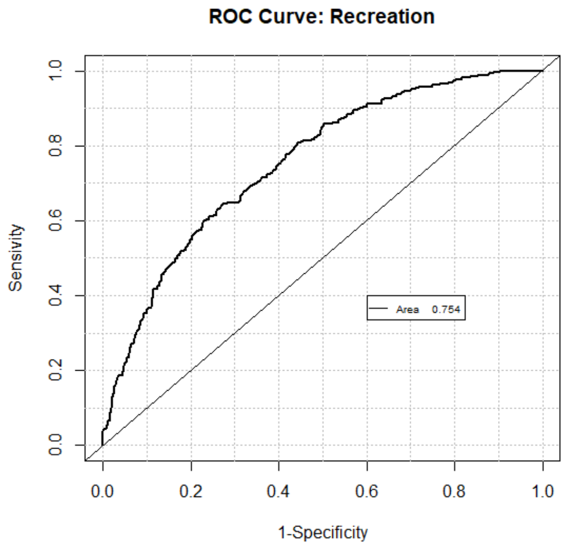


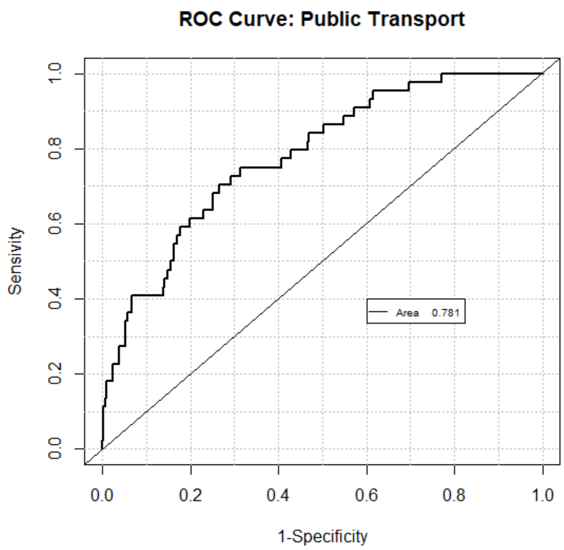

Figure 7.2: Log-linear assumption check



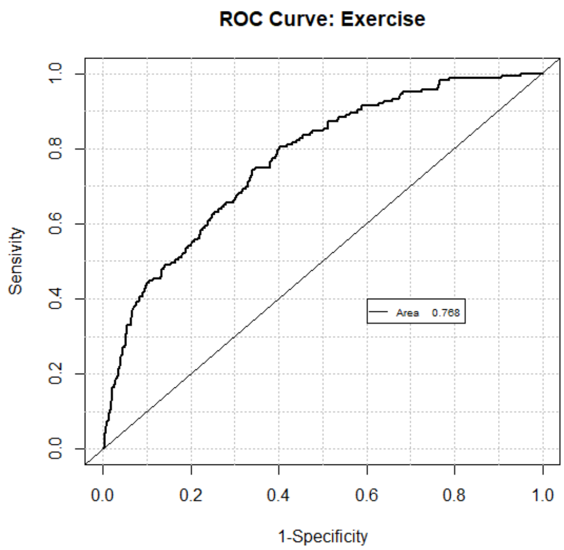

(a)



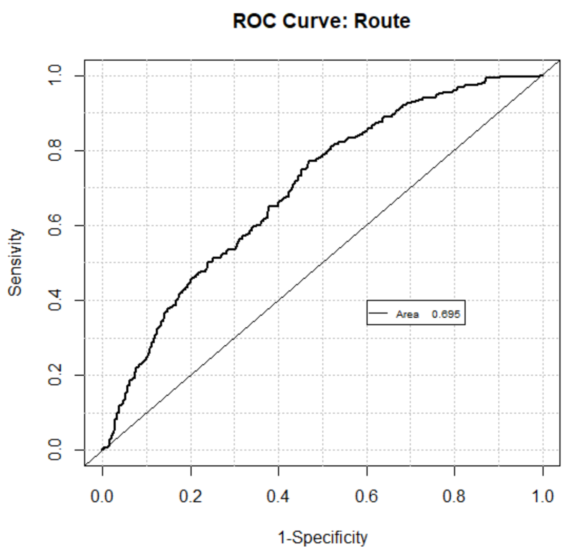

(b)




(c)




(d)




(e)

Figure 7.3: ROC plots for binary logistic regression models