

UNDERSTANDING SPATIAL COGNITION FOR DESIGNING PEDESTRIAN WAYFINDING SYSTEMS: A CASE STUDY IN OPORTO CITY

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Aos meus.

O ponto de partida para o conhecimento, é a sensação, a experiência sensual imediata; os níveis seguintes, pela ordem, são percepção, consciência, atenção, reminiscência, imaginação, interpretação, memória e reflexão.

Winfried Nöth

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ABSTRACT

Wayfinding is an activity in people's daily lives that involves cognitive skills to collect and process spatial information from the surroundings, allowing them to navigate and find their way in different environments. This research intends to understand the senses and meanings attributed to urban spaces and the relationship of its inhabitants and visitors with them in the apprehension, appropriation, and construction of image representations of the city. The motivation for this work came from a request from the Oporto municipality to review the new integrated signage and information project proposed for the city and make suggestions for its improvement. Based on spatial cognition concepts, this study will analyze people's perceptions, emotions, decision-making, and actions towards the built environment in the wayfinding task. Furthermore, this dissertation will explore strategies of reference cases considered good practices for pedestrian wayfinding systems, their implementation in contemporary public spaces, and their particular visual and aesthetic forms of expression. That said, the main contribution of this research is developing a practical guide for a PWS design focused on helping the pedestrian navigate the spaces and the application of its criteria and principles in the case of Oporto. The goal is to understand how people perceive spatial clues and behave when traveling the city. The research was structured as follow: a) a literature review on the topic and some reading of other relevant documents in the perspective of this study; b) an analysis of reference cases in the development of wayfinding projects in different cities; c) the proposal of guidelines for designing a PWS; d) the assessment of tender specifications for the PISI (Projeto Integrado de Sinalização e Informação); and, e) a community and stakeholder engagement for co-designing the PWS through a mental mapping workshop. Finally, the research results and the internship experience at the Division of Requalification of Public Space of the municipality of Oporto (Portugal) aims to contribute with recommendations to improve the pedestrian navigation in the urban context and help decision-makers, designers, and urban planners potentially create better wayfinding systems in the future.

KEYWORDS: *Spatial Cognition; Mental Mapping; Human Behavior; Wayfinding Systems; Urban design and Planning.*

RESUMO

Se orientar pelos espaços é uma atividade do cotidiano das pessoas que envolve o uso de habilidades cognitivas na recolha e processamento de informações espaciais da envolvente, permitindo que elas naveguem e percorram seus caminhos em diferentes ambientes. Esta pesquisa pretende compreender os sentidos e significados atribuídos aos espaços urbanos e a relação de seus habitantes e visitantes com eles na apreensão, apropriação e construção de representações imagéticas da cidade. A motivação para este trabalho surgiu de um pedido da Câmara Municipal do Porto para rever o novo projeto integrado de sinalização e informação proposto para a cidade e apresentar sugestões para a sua melhoria. Com base nos conceitos de cognição espacial, este estudo investiga as percepções, emoções, tomadas de decisão e ações das pessoas em relação ao ambiente construído na tarefa de orientação. Em particular, esta dissertação explorará estratégias utilizadas em casos de referência considerados como boas práticas para sistemas de sinalização de pedestres, sua implementação em espaços públicos contemporâneos e suas formas particulares de expressão visual e estética. Posto isto, o principal contributo desta investigação é o desenvolvimento de um guia prático para um projeto de um PWS focado na ajuda ao pedestre na navegação pelos espaços e na aplicação dos seus critérios e princípios no caso do Porto. O objetivo é entender como as pessoas percebem as referências espaciais e se comportam ao percorrer a cidade. A pesquisa foi estruturada da seguinte forma: a) a revisão bibliográfica sobre o tema e leitura de outros documentos relevantes na perspetiva deste estudo; b) a análise de casos de referência no desenvolvimento de projetos de *wayfinding* em diferentes cidades; c) a proposta de orientações para a conceção de um PWS; d) a avaliação do caderno de encargos do PISI (Projeto Integrado de Sinalização e Informação); e, e) um envolvimento da comunidade e das partes interessadas para co-projetar o PWS por meio de um workshop de mapas mentais. Por fim, os resultados da investigação e da experiência de estágio na Divisão de Requalificação do Espaço Público do concelho do Porto (Portugal) pretendem contribuir com recomendações para melhorar a navegação pedonal em contexto urbano e ajudar decisores, designers e urbanistas a potencialmente criar melhores sistemas de orientação no futuro.

PALAVRAS-CHAVE: *Cognição Espacial; Mapeamento Mental; Comportamento Humano; Sistemas de orientação de pedestres; Planeamento e Projeto Urbano.*

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SYMBOLS, ACRONYMS AND ABBREVIATIONS

AIG – Applied Design Group

CITTA – Centro de Investigação do Território, Transportes e Ambiente

CLP – Central London Partnership

CMP – Câmara Municipal do Porto

MPPU – Mestrado em Planeamento e Projecto Urbano

PISI – Projeto Integrado de Sinalização e Informação

PWS – Pedestrian Wayfinding System

RST – Traffic Signaling Regulation

SDOT – Seattle Department of Transportation

STCP – Sociedade de Transportes Coletivos do Porto

TfL – Transport for London

1

INTRODUCTION

1.1. CONTEXT AND JUSTIFICATION

The images challenge and expose us to centers of significance, a dubious field between the real and the virtual. More than consuming information, people need to process it to make sense of their surrounding environment. The presence of images nowadays is increasingly strong, and it cannot be ignored. Therefore, exploring the points of view of city users, allowing them to share their experiences regarding the space they occupy, can show different realities of the same urban context.

Urban spaces are inherently related to the activities that people perform there, how they perceive and assimilate environmental signs, and build their existential territories. It is necessary to elucidate this knowledge, transcribing individual and collective mental images into urban narratives, enabling a broader understanding of how this process constitutes the subject's relationship with the city and how the community appropriates the places they live.

The tight relationship between urbanism and the processes of social subjectivation also opens the door to critical analysis. This skill is essential for the generations growing up in a world where digital media and technology (spaces of flow) are increasingly the way for individuals to participate in community issues. When the population's role in the urban planning process is successful, the result of actions in the city expresses the uniqueness of the place, promoting integration among its inhabitants.

On this subject, Madden et al., (2000) argues that the current disciplinary and project-oriented approach to public space planning should be replaced by an alternative, location-oriented and community-based perspective. This inversion of ideas would allow the active and continuous participation of the population in urban projects, adding to them the immeasurable value of existing local knowledge. Thus, the agents responsible for urban design and planning, such as planners and municipal authorities, start to support and engage the population in creating and transforming their own spaces.

When it comes to developing and shaping places, urbanism strategies focused on sustainability, social inclusion, and democracy have become the priority of development agendas in several cities around the world. In this scenario, walking as a mode of transport is seen as an alternative for the qualification of public spaces once it is pleasant, free, and accessible to everyone. From this, pedestrian wayfinding systems emerge as a new global trend in terms of active mobility, and aspects such as urban form, people's spatial behavior, and cognitive mapping (Couclelis et al., 1987) become essential study tools for the definition of environmental components that facilitate the orientation process.

In this panorama, this research is a response to a demand from the Oporto municipality to evaluate the PISI and propose practical recommendations to better it from the perspective of spatial cognition. Furthermore, the application of mental mapping knowledge for creating pedestrian wayfinding systems has turned diverse cities into references worldwide regarding the conception of strategies to improve the quality of public spaces, especially in terms of innovative solutions for mobility in the built environment. In addition, although this dissertation addresses aspects related to the design of PWS, this work is focused on urban planning studies within the scope of a project in development by the local authorities of the municipality for the subsequent opening of public tender.

1.2. METHODOLOGY AND OBJECTIVES

This dissertation aims to investigate how people perceive and translate elements of the urban realm into mental images using their cognition abilities to navigate through the city based on representations of space. Understanding how the human mind generates mental maps is fundamental for the definition of wayfinding strategies focused on improving pedestrian traffic in the built environment. The goal is to encourage active pedestrian mobility in public spaces.

Due to socio-cultural structures imposed by the dominant power and individual existential constructions, each person has a unique personality, and therefore their ideas and emotions are different. These factors make them perceive the world in different ways. Through literature review, analysis of case studies, and a combination of research methodologies, this dissertation aims to clarify how the user interprets the information obtained in the urban space and converts this knowledge into images and mental maps using their cognitive abilities.

The study of spatial cognition provides better insight concerning the subject's capacity to grasp clues from the outside world and learn from their surroundings. This understanding can be applied in the areas of urban design and planning, encouraging individuals to become not only passive recipients but actors involved directly in decision-making in the public domain. In this context, the analysis of the subjective

and material dimensions that influence people's actions towards the city can help the development of navigation tools for pedestrians and improve their wayfinding performance.

The practical component of this dissertation is the result of a collaboration with the Division of Requalification of Public Space of the municipality of Oporto, where an internship took place during six months. The activities programmed for the internship were as follows: make recommendations and suggestions to the presentation of the signage and information project with a new strategy; develop a proposal for pedestrian signage in terms of mapping and product design; and review tender documents (tender specifications and procedure program). In addition, to pursue a better understanding of the topic, collect data, and involve the community in decisions about the project, a mental mapping workshop was prepared, which took place in May 2021 at the Faculty of Engineering of the University of Porto.

1.3. STRUCTURE OF THE THESIS

This dissertation consists of six chapters comprising the theoretical and practical parts. This document includes, besides the literature review, the description of reference cases, the data collection and processing process, and conclusions and recommendations.

After this Introduction, **Chapter 2** provides a theoretical background regarding spatial cognition and pedestrian wayfinding systems. It also connects different concepts related to urban form, environmental knowledge acquisition, mental mapping, and human behavior.

Chapter 3 presents reference cases and exemplifies the Pedestrian Wayfinding Systems (PWS) benefits. It covers the implementation of PWS in different urban contexts. The cities chosen for this investigation are Lisbon (Portugal), Brisbane (Australia), London (United Kingdom), Dublin (Ireland), and Seattle (United States of America).

Chapter 4 proposes best practice guidelines based on the reference cases described in chapter 3 and other pertinent documents to design a successful pedestrian wayfinding system.

Chapter 5 describes the Integrated Signaling and Information Project of Oporto, analyzes its specifications, and applies the knowledge obtained in the previous sections of this study to suggest strategic recommendations to refine the project and deliver a differentiated product design, improving its legibility for pedestrian mobility, either of residents or visitors of the city. It also defines the study area

and research tasks for the mental mapping workshop and discusses its results from the perspective of spatial cognition.

Chapter 6 finalizes the document with conclusions and recommendations related to the main topics of this research: spatial cognition, pedestrian wayfinding systems, and community and stakeholder engagement for co-design in planning urban spaces. Finally, it synthesizes how the interconnection of these themes can allow end-users to better explore the city, through the new signage project of Oporto, in addition to serving as a basis for future investigations in the areas of urban design and planning.

2

LITERATURE OVERVIEW

2.1. MENTAL REPRESENTATIONS OF URBAN ENVIRONMENT: FROM PERCEPTION TO MEANING

The importance of the book *Image of the city* (Kevin Lynch, 1960) in the literature of urbanism is undeniable. In this piece, Lynch proposes an innovative method for addressing research questions related to city form and cognitive mapping, impacting different disciplines such as architecture, psychology, social geography, urban design and planning. Lynch's work has become a reference for research and intervention practices in public space, as it objectively explores the complex interaction between individuals and their immediate surroundings. Besides, it promotes a specific understanding of how people perceive and assimilate the components of the built environment where they live, transforming them into imagery representations full of senses and meanings.

The content of Kevin Lynch's book derives from a five-year study in which the author analyzed three American cities: Boston, Massachusetts; Jersey City, New Jersey; and Los Angeles, California. In his research, he identified spatial features of the urban landscape that people use to structure their mental maps and classified them into five groups: paths, edges, districts, nodes, and landmarks. According to him, for a city to be considered legible, these elements must be easily recognizable, both separately and as a set in a coherent pattern.

Lynch (1960) defined "paths" as channels of movement (streets and roads, for example), and many people consider them to be the most relevant feature in their mental images of the city. The junction of paths configures "nodes" (or focal points), and they are spaces that people can access freely, such as squares and intersections. Sometimes, these places are considered landmarks because of their symbolic meaning or the activities that might happen there.

However, "landmarks" are generally distinctive and unique elements in the built environment. In other words, they are reference points that stand out in the landscape and that people have a predominantly

visual experience from the outside. The "edges" are dividing and continuous elements in the city, like viaducts and rivers, and they don't have the same use as the paths. Finally, the set of entities mentioned before constitutes the "district" structure (sections of the urban fabric recognized for having characteristics in common), thus forming the skeleton of the city's image.

Kevin Lynch (1960) also concluded that It's impossible to apprehend the entire city at once, and its perception is made over time, little by little. After all, nothing is experienced individually but related to its surroundings. Additionally, similar entities located in different contexts can acquire different meanings. That happens because each person has unique experiences in the urban context, and based on associations made with parts of it, they create mental images overgrown with memories and significances. This way, the elements of a given urban environment can be perceived as a whole or in parts, and they are always present through totality and in continuous movement. For example, people can walk around a street and discover a list of objects (urban furniture, trees, lights, advertisements) that acquire an immediate meaning that no one has built for them.

Each person has different thoughts and emotions due to social and individual constructions that compose their unique personality. Because of that, they have distinct perceptions of the world around them. When the dynamic of urban spaces is readable, people don't need much effort to identify and interact with environmental elements. In this way, the successful relationship between the physical form and the activity patterns developed in the city is essential to guarantee the quality of its spaces, thus increasing its legibility.

According to Madden et al., (2000) four factors promote the effective functioning of public space and its sustainable development: accessibility, uses and activities, comfort and image, and sociability. For this, the form that a building has must reflect its function (Bentley et al., 1996). When the urban layout is legible, it becomes easy to read, allowing people to construct a more accurate mental image of the real world. It is important to note that, in the contemporary city, public and private buildings have a similar appearance (in contrast to the traditional city), making spatial differentiation more complicated for the user, which may have negative impacts on their orientation, for example.

For people to inhabit public places, they need to be accessible and offer some interface with private spaces since these two domains work interdependently (Madden et al., 2000). In this sense, physical and visual permeability promotes a greater perception of the immediate surroundings and offers choices in route planning. However, the current trend of cities to build gated developments reduces people awareness of available paths for their journeys, undermining the navigation task. Another aspect that

affects traveler's movement is the unequal separation between pedestrians and vehicles, where the last one often has more priority, making pedestrian routes confusing and full of obstacles.

As well as permeability, the variety of forms and functions of public space also enriches the urban experience (Bentley et al., 1996). Land use characteristics and access to transport modes can attract different people with different interests at different times of the day. Thus, investing in the diversification of activities (work, housing, commerce and leisure) at the local level, where it is possible to carry out daily tasks on foot, can benefit financially disadvantaged groups with reduced mobility.

The concept of imageability is directly linked to the physical qualities of the environment, such as structure and identity. These two components must have the power to create strong mental images in the viewer (Lynch, 1960). Powerful images increase the likelihood of the user building a clear and cohesive representation of the urban realm in their minds. The image's capacity to awaken the senses and generate meaning (practical or emotional) is essential to guide the movement of people through the built environment, allowing a more complete and intense experience in the city. A well-formed city is memorable because it is legible or visible (Lynch, 1960).

The quality of environmental elements has the potential to evoke attention through the sensory system, increasing the user's spatial awareness and knowledge acquisition. Furthermore, it invites the subject to leave the position of a mere spectator and become an actor who transforms his surroundings. In this case, perception can be understood as the act of capturing sensory stimuli from the external environment. Based on this concept, Appleyard (1973) classified three methods for generating mental images (Table 1), in which the characteristics of spatial cues shape perception.

Table 1 Classification of methods for mental image generation
Source: adapted from Eslami (2019).

Perception method	Spatial cues	Mental image generation process
Operational	Ordinary features / city elements used repetitively	People become familiar with them and their role within the urban form and build a mental image of them
Responsive	Unique and unusual buildings	Distinct elements become more memorable to observers, creating responses beyond mere operational
Interferential	Repetition of concepts and relationships among urban elements	People develop a personal urban model based on their experience to make sense of the environment

With that said, the city must have unique and ordinary physical features at the same time to support imagery constructions in people's minds, helping them to make sense of their surroundings. These personal representations of the urban fabric are fundamental for the navigation task. In this regard, Eslami (2019) argued that measures of urban layout, such as integration, connectivity, visibility, and choice, can predict the movement patterns of individuals and improve their experience within the built environment, whether in daily activities performed by its residents or in the first contact of visitors with the place.

2.2. SPATIAL COGNITION

The word cognition can be described as the mental capacity to process and transform information into knowledge through personal and collective experiences and the senses (Angus, & Oxford University Press, 2010). Cognitive skills involve imagining, observing, feeling, thinking, remembering, perceiving, etc. (Gold, 2004). Each individual has a different cognitive process due to material and subjective factors that affect how they interact with the world.

Perception is an ability of the cognitive system. Its function is to capture enough social and physical information from the environment so the human brain can organize it, enabling the subject to make sense of his surroundings. Thus, the term “spatial cognition” emerges as a set of human cognitive skills linked to the acquisition and processing of spatial knowledge. This capacity involves the generation, storage, and retrieval of mental images, which, combined with motor and sensory systems, help people in the task of recognizing and finding their way around (Montello, 2001).

That is to say, the terms cognition and perception, although distinct in meaning (the first one being much broader than the second), are both related to the human's ability to acquire knowledge of the physical environment surrounding them (Eslami, 2019). Regarding spatial knowledge acquisition, mental mapping, and navigation, these two words have been used together in many studies since the late '70s, with the increase of publications and citations in the social and environmental sciences since then (Thorndyke & Hayes-Roth, 1982; Ishikawa, & Montello, 2006; Chrastil & Warren, 2013).

As far as spatial cognition is concerned, environmental information is perceived (encoded by the human mind) and then processed by cognitive abilities, stored in long-term memory, and eventually retrieved and applied for a specific purpose (Vandenberg, 2016). This relationship between human beings and their surroundings is representative, based on mental images formed in individual subjectivity and not

in reality itself. This behavior helps us understand people's interests and choices about the city and its impacts on urban design and planning.

Outside the image, the subject's position as a spectator in contemporary processes of interactivity with the environment determines its perception. The individual's location in space is then articulated with his identity, that is, with his social and physical constructions of the macro in which he finds himself. This phenomenon is essentially subjective, impregnated with cognitive transits such as memory-presence, symbol-imagination, reason-emotion, etc.

In this regard, the sensory experience is an essential step for people to learn from the urban context, assimilate its information and understand mental images, giving them meanings. In this line of thought (Figure 1), the environmental components become able to communicate with the user, establishing with them relationships that propose ideas and create emotions.

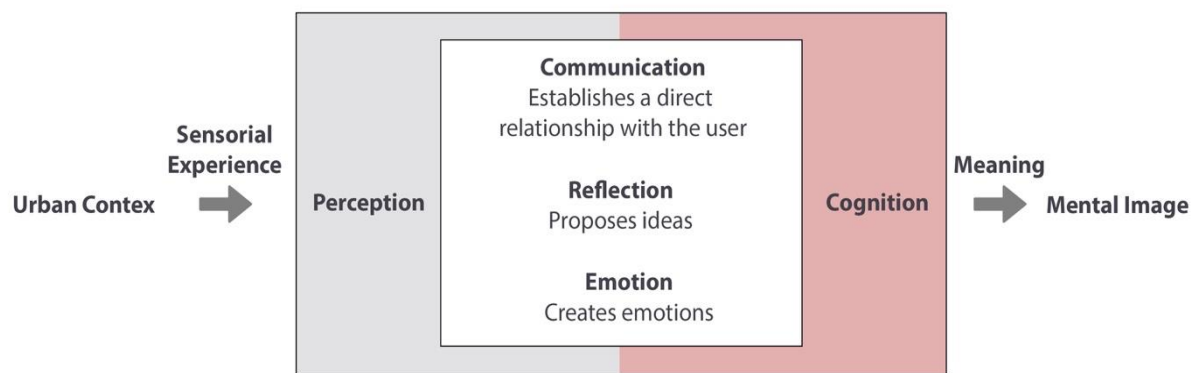


Figure 1 Process of creating mental images through sensorial experience in the urban context
Source: author of this work.

The environmental layout shapes human behavior at the cognitive level, thus influencing how one performs daily activities, for example, choosing a route to a familiar place (Hölscher et al., 2011). In this case, the tangible and intangible dimensions of the world intertwine (Figure 2), and the subject, through physiological perception, enters a subjective territory in which his cognitive abilities organize the interacting elements and understand them as if he were contemplating a map, composed of a range of mental images. This way, the decisions and actions taken in relation to objects present in the environment are the result of the emotions and meanings attributed to them.

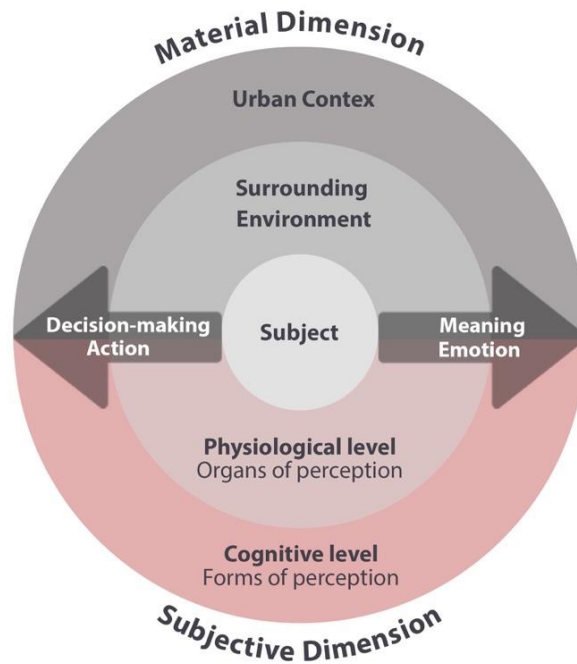


Figure 2 The interaction of the material and subjective dimensions and their influence in cognitive responses and choice behavior
Source: author of this work.

According to the book *History of bourgeois perception* by Donald Lowe (1982), the act of perception connects human beings with the environment. In his words, “this connection includes the subjective as the perceiver, the act of perceiving, and the content of the perceived”. The result of these three aspects of perception, when linked to change in time and the hierarchy of sensing (Lowe, 1982), affects how the subject positions himself in the world. The experiences that people have in their everyday lives are a reflection of this positioning. After all, the organs of perception, through which physical stimuli reach the brain, are directly linked to the cognitive phenomena responsible for representing the world and adapting to its continuous process of change.

The mental image is a representation of reality, constructed in human cognition through the perception of stimuli from the place where the subject is. Through this image, they become aware of their relationship with their surroundings. As people move through the city, they attach importance to the spatial elements they encounter within the urban context. This hierarchy changes due to the parameters of the perceived object in relation to the observer: its proximity and vice versa, its size, color, shape, function, etc.

Perception is a raw material of spatial cognition. People need to observe the urban realm and explore it (Ishikawa, 2016). As the navigator changes his position in space through bodily movements, he perceives the objects from different perspectives. It allows him to acquire more knowledge about his

surroundings, such as locations, directions, and distances (Rapoport, 1977). This information is stored in the human mind as memories and used in the configuration of mental maps. Therefore, the more detailed the content extracted from the environment, the more accurate and coherent the cognitive maps will be in relation to reality.

Although mental maps are simplified constructions of the physical environment, they play an imperative role in spatial cognition. (Eslami, 2019). In this sense, certain aspects of urban layout, analyzed from the understandings of the Gestalt school of psychology, help us discover obvious meanings and create new ones (Trancik 1986). Gestalt theory contemplated ten aspects to analyze how people process visual information, and five of them stand out in the areas of urban planning and design (Figure 3). In summary, in the early 20th century, the German term *ge-shatlt*, which translation means form, pattern, or configuration (Elshater, 2015), emerged as a crucial concept in comprehending spatial signs and how they can change dramatically over time.

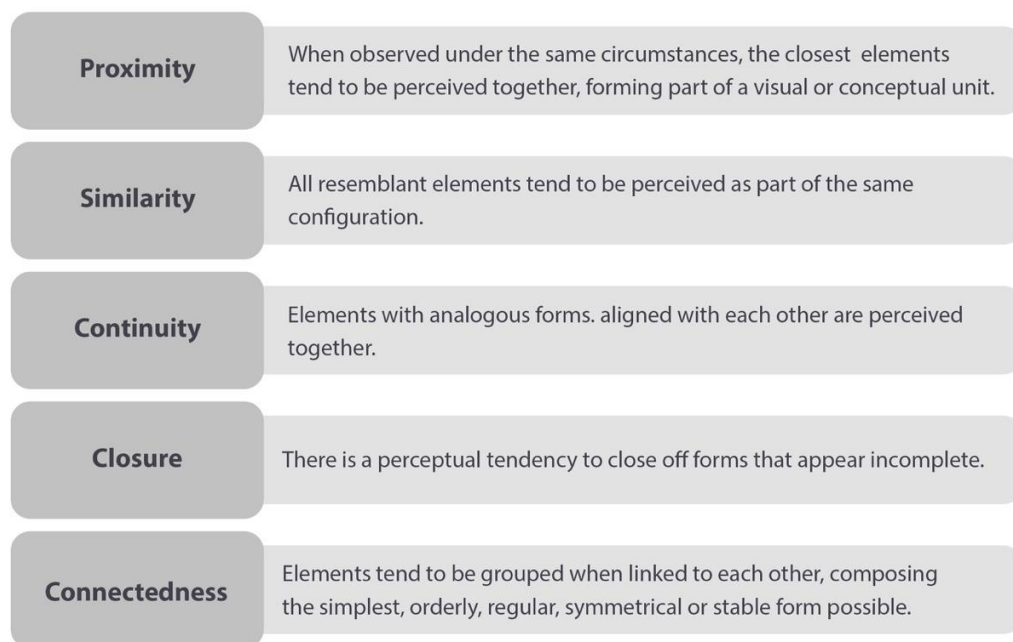


Figure 3 Gestalt laws applied in the configuration of urban elements

Source: author of this work.

2.2.1. GENERAL CONCEPTS

The existential territory of each individual or collectivity (family, school, college, work, etc.) as a sedimented and dynamic construction is where creativity happens. As we escape the macro thinking (what is real, possible, objective, and controlled by society), we start to create our own concepts and

knowledge. Images exist everywhere, and the mind produces a particular significance about them. The power of the thing-image provokes feelings and emotions, and through them, we penetrate the innermost part of our being into the shadows of our unconscious. Understanding the world as a set of symbols is a way of getting out of certain specular positions and advancing in richer ways of representing, implicating a plural interpretation of the cognition process.

Images are complex places where the real, the imaginary, the symbolic, and the ideological intertwine, and in which, therefore, constellations of meanings begin. It is the prerogative of all images to awaken some emotion in the viewer. Nowadays, the image occupies a considerable space in contemporary society, becoming as important as other languages that are part of our daily lives. The image has the capacity to testify and expose the city.

In general, vision is not only related to the eyes. It can be said that it is also possible to see through the other senses, as environmental experiences derive from stimuli that the subject perceives through the body as a whole. When reading spaces, the individual becomes capable of transforming elements such as shape, volume, and perspective into raw material for subjectivity. The representation of architecture and urbanism, even visual and symbolic, exposes how people relate aesthetically to their surroundings.

Table 2 addresses the most relevant material and subjective factors cited in the literature on spatial cognition. They directly influence people's behavior in the navigation task in the built environment, from how things are perceived and assimilated to the stage of choosing a route to reach a destination. It is noteworthy that among these variables, only environmental complexity was considered as a material factor, as the others depend on affective dimensions and local particularities that are not measurable or cannot be applied in the same way in different urban contexts.

Table 2 Subjective and material factors (perception and personal experience: how people relate and interact with their surrounds)

Source: author of this work.

Factors	Description	Author/Year
Environment familiarity	Spatial cues, memories, daily activities	Dai & Zheng, 2021; Iftikhar et al., 2021; Lynch, 1960; Stea, 2017; Hölscher et al., 2011; Eslami, 2019; Golledge, 1992; Xia, Arrowsmith et al., 2008.
Cultural and individual differences	Social structure, emotions, ideas, history, personality	Iftikhar et al., 2021; Ishikawa & Montello, 2006; Mark & Frank, 1996; Symonds et al., 2017.

Sensorial experience	Visual, touch, sound, smell and taste	Dai & Zheng, 2021; Wankhede & Wahurwagh, 2016; Bohme, 2013; Hasse, 2016; Mark & Frank, 1996.
Environment complexity	Morphology, local particularities, organization and relationship of urban elements in the space, hierarchy and scale	Iftikhar et al., 2021; Lynch, 1960; Hegarty et al., 2006; Devlin, 2001; Miller, 1956; Raubal & Egenhofer, 1998.
Socio-demographic characteristics	Income, ethnicity, gender, age, occupation, housing status, and level of education	Dai & Zheng, 2021; Lynch, 1960; Montello., et al., 1999; Hannes et al., 2006; Tournier et al., 2016.

2.2.1.1. Environment Familiarity

In the context of this study, familiarity refers to the dynamic of daily activities performed in urban space, the arrangement of spatial elements, and the memories and meanings attached to them based on the perception of local inhabitants and visitors when traveling through the city. People become familiar with a given environment by exploring them through the senses. The exploration stage is essential for the user to acquire spatial knowledge. Searching strategies and cognitive mapping abilities are fundamental to achieving environmental familiarity. Therefore, the affective image of the city has a high influence on the behavior and intentions of people towards a city (Dai & Zheng, 2021).

To navigate through the city, people identify its elements and learn about the relationships among them. Mental mapping strategies help travelers orient themselves in familiar and unfamiliar territories. They can remember the location of landmarks or other environmental cues and their organization as a network. This knowledge serves as a guide for route planning and decision-making. The mental map is a collection of spatial images grasped by the user as they move around places, combined with feelings and memories associated with them. This representation of the space does not correspond accurately with reality but with individual physical and cognitive needs.

When a person goes to a different city, they rely on the cognitive mapping skills developed in a familiar environment to learn their way in a strange locality. They use the parts of the old mental map that remain pertinent to create the new one. Although it is not possible to reuse the previous reference frame in its entirety (due to the distinct characteristics of each space), it is essential to strengthen the sense of direction. By searching for environmental clues, the subject already has an idea about the probable connection between them. This way, people can update and adjust their maps according to what they perceive as they navigate in an unfamiliar urban context.

The process of apprehending and assimilating urban scenes depends on the capacity for personal learning. In this sense, Stea (2017, p. 299) stated that “active participation demands attention and facilitates learning”. The subject develops his orientation ability better when he can find the places in the city independently. To move from one location to another, travelers structure images of their surroundings into a connected system. In other words, the sequence of images memorized forms a path that makes sense in their mind and is likely to remain in long-term memory.

Feelings of security and comfort that a legible city provides are also associated with the practical and emotional significance of the places. One person can recognize a street based on a small sign, while others will remember the same space by the presence of a coffee shop, for example. On the other hand, when the environment is incorrectly organized, it fails to provide the necessary information or stimulate people’s senses, making them experience fear of being lost and emotions of distress caused by disorientation.

Daily activities can also increase environmental familiarity. People’s routine or seasonal events makes the city a vivid environment and create shared memories for its residents and visitors. Some places have the potential to generate more traffic than others. For example, a city center can have a greater movement due to its commercial activity and, in some cases, truistic points, attracting different groups of people with distinct interests, in contrast to a residential area, where only its residents circulate. The diverse dynamics of everyday life activities delimitate areas within the city, giving them meaning, creating bounds in the community, and increasing affection for the place, thus reinforcing the feeling of belonging.

Concerning spatial cognition and the five elements that structure the city defined by Lynch (1960), the “path” stands out from the point of view of environment familiarity. The navigator learns about landmarks, nodes, edges, and districts by following paths. Through exploration and recognition of spaces, people begin to develop more assertive cognitive maps. Once they visit a place frequently and spend more time there, the acquisition of spatial knowledge increases, and the environment becomes familiar (Eslami, 2019).

2.2.1.2. Cultural and Individual Differences

The image is composed of a series of cultural parameters and individual differences. Barthes (1980) proposed in his research multiple mechanisms that intervene in the formation of the images: social, subjective, aesthetic, anthropological, technological, etc. On the other hand, Umberto Eco (1984)

considers that the imagery construction process is already socially determined and, therefore, we cannot see if not through a culturally constructed filter. Both statements can explain the existence of distinct mental maps and people's behaviors in general. Finally, Rénaud (1990) adds that the image is the representation of the visible: it shows cultural visibility.

Most of the time, perceptual processes are a direct exchange between the subject and the world through eye contact. However, the vision is culturally conditioned and socially formatted to act in a certain way. Therefore, the perceived reality does not coincide with the totality of the world. According to the book *Foucault: a critical reader* (David, 1986), “each historical formation sees and let be seen everything it can, depending on its conditions of visibility”. Ergo, visible is what is seen, what society allows to be seen, and institutes what is seen.

It is the prerogative of all images to arouse some reaction in the viewer. However, the meaning associated with the imagery representations of the world is sensible to mental states of an emotional, social and cultural nature, and these aspects change from one person to another. Thus, due to individual particularities, people's cognitive maps and spatial behavior will always be different at some level. That is why the same object can be perceived differently once its value judgment is relative to a personal point of view that involves principles, beliefs, priorities, etc. (Rapoport, 1977).

The person's existential territory is a construction manufactured by outside influences, assimilated by subjective processes, combination of individual and social identity mechanisms (Guattari, 1995). In this way, the structure of a mental image is formed in people's subjectivity through different cultural and community knowledge. It belongs both to the subject in the act of perception and to the socio-spatial context that embraces him. In other words, images are not static but shaped over time by dynamic urban environments and ever-changing personal perceptions (Stea, 2017).

For Balandier (1999), the imaginary is composed of all the images that each person builds from their body, desire, immediate surroundings, and relationship with the other through cultural references and shared experiences that provoke a projection of the future. The imaginary comprises the idea of the individual or a collectivity that attributes meanings and values to the perceived objects, later enabling interventions in the space to transform it or adapt it to the mental images created by them. These processes of apprehension and appropriation of spaces serve as guides for concrete, necessary, and desired changes in the urban environment.

2.2.1.3. Sensory Experience

People's perceptions of the environment are bonded to their senses: visual, touch, sound, olfactory and gustatory. Therefore, it is necessary to explore the interactions of individuals with their surroundings with tangible elements, such as man-made or natural features of urban space, and intangible components, such as culture and art. Sensory experience is imperative for creating identity, meaning, and memory, strengthening the connection between people and urban areas while shaping public space (Wankhede & Wahurwagh, 2016).

The quality of public space is related to its physical form, designated meanings, and daily life activities. When these three aspects are combined successfully, people feel comfortable and develop a sense of place or belongingness. Using their sensorial abilities, a person perceives the urban space and then navigates within it. Spatial information extracted from the environment is subjective, gathered by the senses, and organized in the human mind to build mental images. After the knowledge acquired is processed, the perceived external elements gain significance and context in the form of a mental map that relates to the city itself.

The clues about the world around us stimulate the senses, especially vision. According to Wankhede & Wahurwagh (2016), the urban landscape can be seen in terms of a “viewscape” through the configuration of the built environment (such as district, edge, path, nodes, and landmarks) and its properties (such as legibility, shape, color, volume, size, order, diversity, etc.). Thus, the degree and quality of the sensory experience of a given urban space would be predominantly visual. In addition, unique areas of the city, with a stronger cultural identity and territorial structure, would be able to stimulate the senses more intensely.

Multi-sensory spatial experiences promote meaningful spatial quality, improving knowledge acquisition and choice behavior (Dai & Zheng, 2021). Each sense may be subjectively experienced singularly but not separately, revealing the overall emotional impression that people have towards a place (Böhme, 2013), which feelings are attached to it, and the influences of affective mental image of the city on the user's mind (Hasse, 2016). With that said, it is necessary to apply urban design and planning strategies focused on the city's configuration and capacity to communicate environmental information to shape personal affection for a place.

Visual factors, such as scale, form, and configuration of the public realm should be perceived not only as points of reference, but as living spaces in which their vitality composes the meaning of the place. In

their research, Dai & Zeng (2021) explored how the sensorial dimension of bodily experience through serial scenes across the space impacts the affective city image and people's intentions. According to them, the perception by static visual observation of the physical space alone is not enough to build up the reflective social space in one's mind, being necessary motion visual confrontations through bodily movements derived from multi-sensory experiences: "physical presence, the constant changes of perspectives and focal points, that can convey an impression of space, including its size and physical boundary, measured by the moving body" (Dai & Zheng, 2021).

Vision and hearing have more spatial range in the environment in terms of distance, while the stimulation of smell, touch, and taste depends on the subject's proximity in the urban context. A person can see a landmark even if it is far from his location or hear a sound without realizing precisely its source. However, for someone to touch, smell, and taste, they need to be close to the objects and have direct contact with them. Hence, Figure 4 presents a way of identifying and relating the components that influence perception through the human sensory system in urban space.

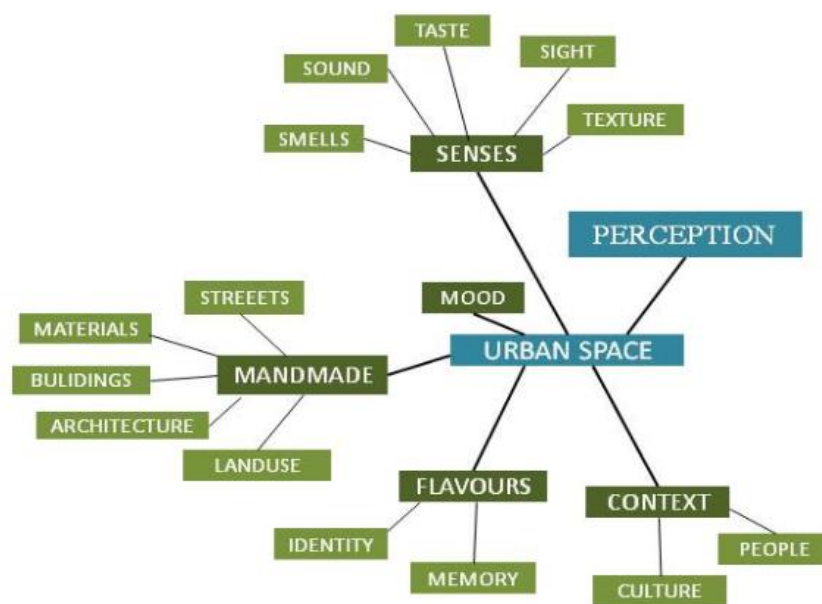


Figure 4 Systems approach to the sensory experience and urban space
Source: Stephen, 2013.

2.2.1.4. Environment Complexity

This topic aims to clarify the influences of the physical space in urban navigation from the perspective of spatial cognition. Environmental complexity has to do with morphology, local particularities, scale, organization and articulation between urban features, and characteristics of the displayed elements

(proximity, size, shape, and location). Thus, it's essential to understand the role of this material factor in spatial decision-making.

To move from one place to another, the person has to know where they are and gather spatial information from their immediate surroundings before choosing a route for their journey. It's impossible to perceive the entire space at once, with just one point of view. Exploration through bodily movements in the environment is required so the navigator can gain and store spatial knowledge kinesthetically and complete the travel itinerary (Hegarty et al., 2006).

The complexity of a city refers to its dynamic network of relationships and its ability to provide clear and usable information to people, ensuring sufficient subjective material for them to represent their surroundings in terms of mental images. A complex environment is often a rich and diverse urban fabric, a mixture of places and flows. When these interactions are not well organized, or the spatial distribution of the urban elements does not make sense to the user, the space becomes unreadable (or visually incomprehensible). In other words, if the web of relationships in an urban area is not apparent because it is too confusing or foreign to the navigator's knowledge, it compromises his cognitive ability to learn from the space.

A legible city has well-structured urban elements, combines form and function, and offers spatial choices for its inhabitants and visitors (Devlin, 2001). Hierarchy, scale, and logic in the layout of streets, landmarks, nodes, intersections, etc., promote the quality of places, provide comfort to their users, and facilitate the orientation process. Although repetition and standardization are fundamental for the maintenance of memory, people need to be able to distinguish the components of urban space. Thus, environmental complexity can be a positive aspect, as differentiation in the city is necessary to avoid confusion and lack of identity.

The city is a complex system that directly affects the lives of its users, especially their movement. As the scale of the city grows, the need for contrasting landscape components and defined unities increases. In other words, dividing the urban fabric into groups such as neighborhoods enhances its legibility. Furthermore, the hierarchy of visual cues is crucial for building meaningful relationships between the urban landscape and individual and collective mental representations, contributing to the information storage and creation of long-term memory structures (Miller, 1956).

2.2.1.5. Socio-Demographic Characteristics

Socio-demographic variables such as income, ethnicity, gender, age, and occupation status affect people's preferences towards the aesthetic characteristics of the built environment. This way, decision-making regarding architectural/urban design and planning and effective management strategies can shape the city's image and target specific groups with different motivations (Dai & Zheng, 2021). Lynch (1960) argued that although each individual perceives and interprets the surroundings in a particular way, members of the same classes produce consensual mental pictures once they interact with the same reality or culture.

The environment presents the same overall picture for everyone. Nonetheless, the navigator's needs influence the comprehension and absorption of its cues. Hannes et al. (2006) recognized the importance of socio-demographic factors in spatial behavior, explaining the relationships between travel and mental maps (Figure 5). He concluded that this aspect is related to the individual demands of travelers, such as accessibility and the type of environmental information available for the construction of mental maps. In this way, the user would have the opportunity to learn from their experience in space over time, becoming aware of their location and available routes to the desired destination

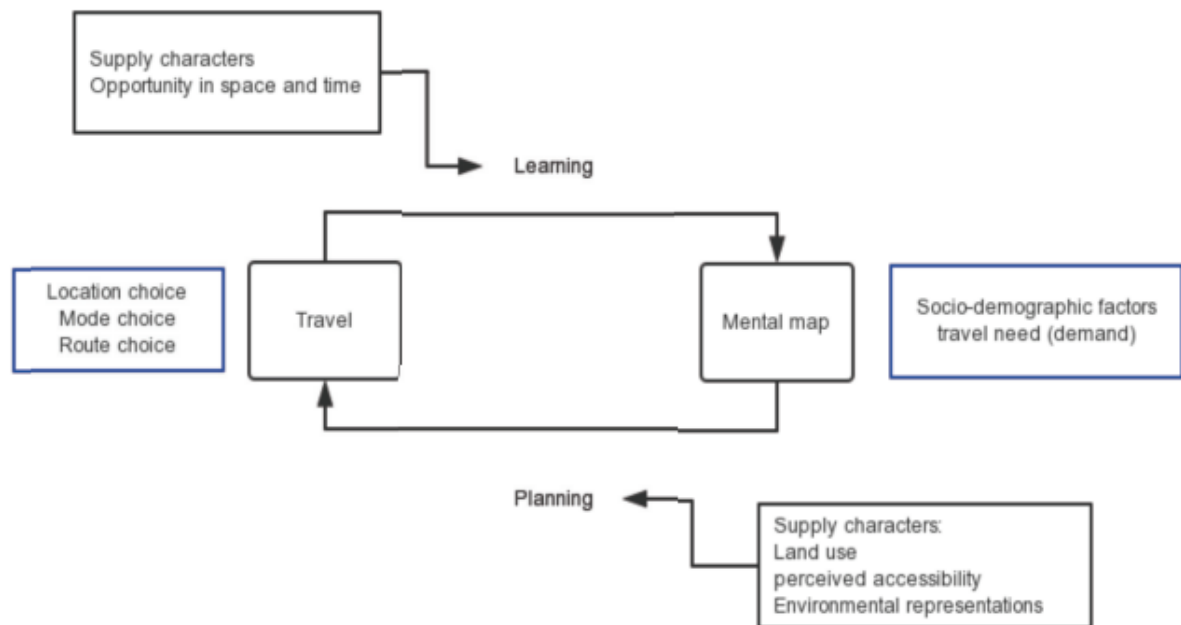


Figure 5 Relationship between travel and mental maps.

Source: Hannes et al., 2006.

The choice of routes, mode of locomotion, and frequency of trips change according to housing status, family income, age, etc. In addition, factors such as land use also modify travel behaviors (Zhang, 2015).

Different means of transport influence the quality of urban cognitive constructions. Therefore, socio-demographic characteristics are a relevant factor for spatial cognition, especially regarding the formation of mental maps of the city. Previous studies on this topic have had different results because they are related to specific urban contexts and the uniqueness of the groups of people analyzed. Finally, this topic remains inconclusive, and the lack of information available in the literature raises the need for further investigation.

2.3. PEDESTRIAN WAYFINDING SYSTEMS

This section aims to explain what wayfinding is and explore how active mobility can offer interconnected benefits to the life and economy in the urban space. More than helping tourists find major destinations, high-quality navigation tools change the behavior of users, promoting walkability for the city's residents and visitors. Therefore, the modal shift improves sustainability and public health, encouraging exploration, longer stays in public spaces, and pedestrian traffic. It also increases spatial knowledge and social interaction. These aspects contribute to building a more dynamic and livable environment.

In the last decade, pedestrian signage systems have been recognized in many cities around the world as an effective mechanism to encourage walkability. When implemented consistently in an urban context, it can increase the number of journeys made on foot as well as the time people stay in places, potentially spending more money and boosting local businesses. Clear and friendly information improves the navigator's experience in urban space and the spatial knowledge acquired. Mental images well established in the human mind contribute to the generation of more effective cognitive maps, ensuring greater freedom of movement due to the gain of environmental familiarity.

Wayfinding strategies help locals and tourists enjoy the most of what the city has to offer. In addition, a well-connected system that facilitates modal shift during a journey (from walking to public transportation, for example) becomes inclusive as it enables all users to explore the city, improving its image as a whole and its reputation. In summary, Figure 6 demonstrates the links between the direct and indirect benefits that wayfinding can provide.

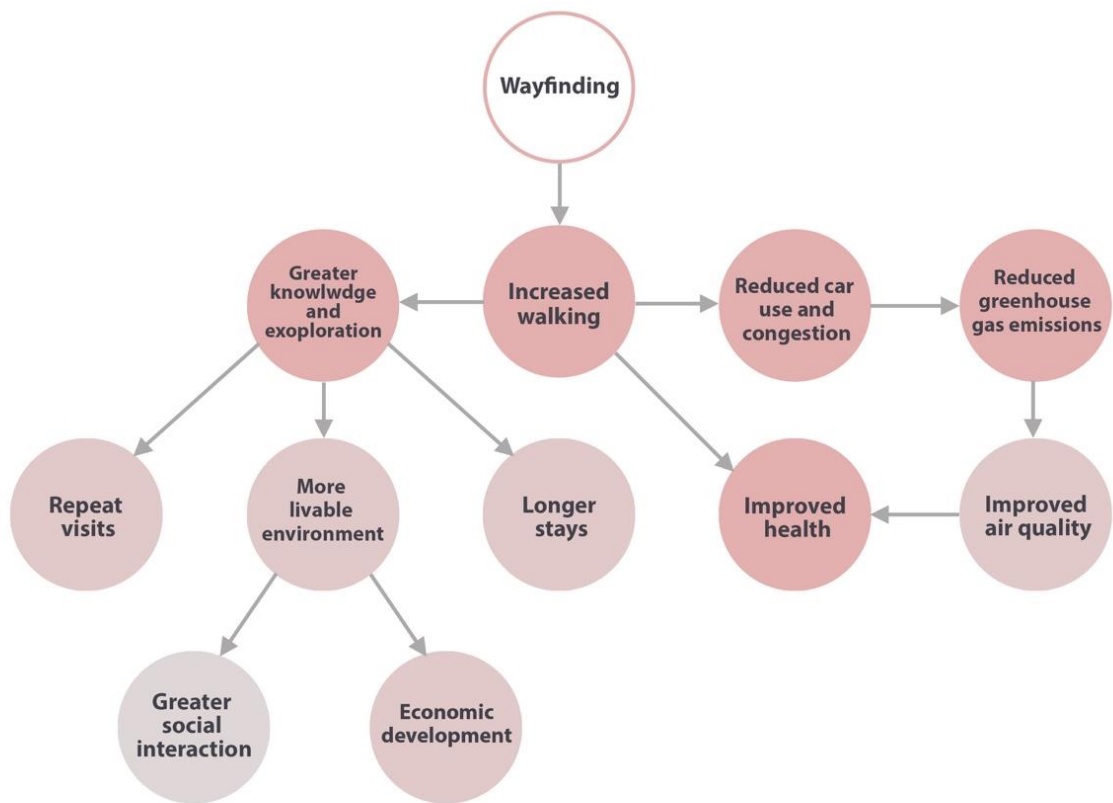


Figure 6 Benefits of implementing pedestrian wayfinding systems
Source: author of this work.

2.3.1. HISTORIC AND CONCEPTUAL REVIEW

Kevin Lynch was the first author to use the term “wayfinding” in his book *Image of the city* (Lynch 1960), and ever since, it has been used in different areas of research and gained various definitions. It can be described as “a generic navigation task of traveling from one location to a specific destination” (Iftikhar et al., 2021). According to Montello (2005), the navigation task in an urban space is not easy, involving bodily movements around the immediate surroundings through the motor and sensory systems and a planned action towards a desirable destination.

Wayfinding is either the practical action of traveling to a familiar/unfamiliar destination or just exploratory navigation (Allen, 1999). It is the result of information processing (environment perception and cognitive mapping), decision-making (selection of reference points and path integration based on social aspects and spatial quality), and decision execution (behavioral action – movement toward a

destination) (Hunter et al., 2016; Passini, 1984). In other words, wayfinding is the interrelationship between “seeing” and “going” (Hillier, 2003).

The pedestrian wayfinding system encompasses the set of signs placed in the urban environment to guide the movement of people on foot. Such programs consider all elements that constitute the city in terms of architecture, natural assets, private and public spaces distribution, configuration and quality of urban entities, etc. Even sensory cues such as lighting and sounds play an essential role in the project of consistent and functional signage schemes.

PWS (Pedestrian Wayfinding System) is a combination of coordinated signage systems (heads-up maps, directional signage, hand-held maps, etc.) with similar design and strategically located in the city, focused on encouraging people to walk. This approach was first developed in 2001 in Bristol – United Kingdom as part of the Building Legible Cities project (Kelly, 2001). Since then, it has been improved and applied by several cities in different countries such as the United States, Australia, Ireland, etc. This phenomenon became standard practice for the benefit of pedestrians, recognizing their importance as indicators of a good quality public environment.

In March 2006, a study called Legible London, conducted by the Applied Information Group under the supervision of a Steering Group established by the Central London Partnership (CLP), evaluated the benefits of implementing user-friendly guidance systems to improve walkability in the city. The wayfinding system performance report tested during the London Olympics (2012) pointed out that although most routes were suitable for pedestrians, they needed persuasion to walk. Hence to increase pedestrian flow, it was necessary to deliver better information to users. It also concluded the following:

A study by Research Business International (2002) found that 66% of travelers said they would consider walking instead, after being shown a walking map. (Among tourists it's as high as 80%, and even among citywise commuters the figure was 60%.) [...] improved signage would be the best way of encouraging people to walk more. These findings are supported by a MORI study for the London Borough of Islington, which reported in 2005 that 49% of respondents had seen and used mapbased signs, and of these 83% were satisfied that the signs had helped them find their way. Maps had assisted 66% with their journey, with 47% saying that the maps had ‘encouraged’ them to walk. Only 5% said that they did not find them useful. What this suggests is that an integrated signage and information strategy to support the needs of walkers can be expected to deliver substantial dividends. (Transport for London [TfL] & Applied Information Group [AIG], 2007).

Data presented in the Legible London report confirms that a well-planned signage system encourages visitors to explore the city on foot. It also increases the number of residents choosing walking routes in

their daily tasks, visiting places more often, and discovering new ones. In addition, using signage increases physical activity, improving people's health, environmental quality, and economic growth.

2.3.2. STRATEGIES OF PWS

It is essential to deliver relevant information to travelers where it is needed. Therefore, providing accessible, effective, and connected navigation aids to other modes of transport can improve the user experience in the city, making tourist itineraries more attractive and facilitating displacements related to the daily life of the local population. Wayfinding systems seek to ensure the comfort and safety of these journeys, as traveling in complex environments such as dense urban areas is not easy and requires some knowledge about the space.

Mental mapping is considered an internal tool for wayfinding (Vandenberg, 2016). It is an individual and essential cognitive exercise that can lead to multiple interpretations of the same place (Gardony et al., 2013). As presented in Table 3, people use different navigation strategies to locate and orient themselves in the city, generally combining more than one tool in the wayfinding task (Chang, 2015; Eslami, 2019; Iftikhar et al., 2021). The effectiveness of these tools is also a reflection of urban configuration, once people's route planning depends on the quality of urban elements and the assimilation of information from the surrounding environment through cognitive abilities.

Table 3 Most used navigation aids in wayfinding

Source: author of this work.

Navigation Tools	
Types	Description
Physical maps	People can plan the route that best suits their needs based on the knowledge acquired by reading a map
Social navigation	People ask for directions and learn about the urban environment from other people
Global Positioning Systems (GPS)	People guide themselves through virtual representations of space provided by technological devices such as smartphones equipped with navigation software
Signage Systems	People use signs placed in the urban space in the navigation task

The city images and the scene sequences created and stored in people's minds are crucial for defining route strategies. Hence, the repetition of elements in the urban space can optimize long-term memory

facilitating the wayfinding performance (Garling et al.1981). When tools such as physical maps, social navigation, GPS, and signage systems are familiar and consistent, the user interprets them quickly and comfortably, enhancing environmental knowledge. Also, the frequency of visits made by the users to the same places leads to the construction of more accurate cognitive maps.

In this regard, a pedestrian wayfinding system is essential to encourage movement through active mobility. Thus, it is necessary to pay attention to the design and implementation of signage in the urban fabric and the relevancy of the information communicated, such as directions, language, identification of landmarks, the distance between places, travel time, etc. This content must be focused on the user to increase pedestrian traffic in the city.

The layout design of urban navigation aids should contain textual and symbolic information, so the person can orient themselves along the chosen route, recognizing the elements and connecting them in the space. In this matter, the standardization of signage in terms of colors, shapes, style, etc., is substantial for wayfinding as people will look for the next sign by association with the first one they had contact with and so on until they reach their destination. Finally, it is possible to improve walkability within the built environment, providing better active assistance (Lakehal et al., 2021).

2.3.3. GENERAL METHODS OF WAYFINDING ANALYSIS

Various studies measured wayfinding performance in terms of time taken to reach a destination, distance traveled (m), speed (m/s), sense of direction, number of stops made, pointing error, difficulty level, etc. (Eslami, 2019; Khan & Kolay, 2017). In this context, researchers developed techniques to qualify and quantify the user's performance in the wayfinding task, such as GPS tracking, think-aloud records, sketch mapping, questionnaires, cognitive tests, post-test interviews, and environment analysis using space syntax, for example.

According to the nature of the intended results, the investigator can combine two or more methods to obtain more accurate data. Realizing what people express when they think and speak during the proposed task can help the researcher identify, in a more spontaneous way, which aspects of the urban space people pay more attention to when walking a path. Likewise, through sketch mapping exercises, people can illustrate which environmental characteristics remain in their memory and become mental images of the city. In addition, investigation techniques through immersion in Virtual Reality (VR) have gained prominence as an innovative way to evaluate strategies and performance in wayfinding systems.

The use of technology to understand spatial cognition and assess wayfinding systems allows urban designers and planners to adjust the project in the virtual environment (VE) before implementing it in the real environment (RE). Although the participants' behavior is different in the two domains, the results in terms of data collection are practically the same. Recent studies have shown that visual information acquired by people is better processed in RE, as they are more attentive. Nonetheless, spatial cues are identified by the user more easily in VR, estimating distance, direction, and time more accurately (Dong et al. al., 2022).

2.3.4. VIRTUAL DIMENSION AND WAYFINDING

The human-environment relationship is a complex interaction, both in real and virtual spaces. These days, it is clear that people are increasingly directing their lives based on digital connectivity data and the entire infrastructure of social networks. The rise and proliferation of mobile apps have revolutionized the way people interact and collaborate with each other. Through this virtual space, users create online communities to share information, ideas, personal messages, and other content. In the virtual dimension of the world, people transmit urban narratives, written or visual, dynamically, spontaneously, and in real-time.

With digital equipment, people enter the globalizing aspect of contemporary images. In the 1990s, virtual reality revolutionized visual representation, allowing a complete immersion in virtual spaces through technology. Thus, the interactivity is total since the observer himself becomes an actor in changing. The images provided by virtual reality pave the way for a new aesthetic. This range of interpretations of the built environment is an opportunity to design new solutions for the city, looking to the future and contemplating the past.

Digital maps and smartphone navigators provide virtual representations of the real world. The way people (residents and visitors) wayfinding in the digital era is questionably affecting social and spatial interactions. Although the advent of technological equipment to assist urban navigation with detailed trip instructions make it easy for pedestrians to move around the city quickly, they do not allow people to memorize the journey or create meaningful relationships with others or the surroundings. Users tend to pay more attention to the changes in directions and routes defined in digital applications instead of observing and learning about the place where they are.

Passive assistance methods of navigation such as GPS, available in the palm of the hand through smartphone software, for example, are practical and help the user find and orient themselves in the urban

space. However, because people remain focused on their devices for most of their travel, they do not pay appropriate attention to the surroundings, missing important environmental cues they could memorize and use as material for their mental maps of the city. Thus, the lack of spatial knowledge and adaptive behavior resulting from blind navigation negatively affects the wayfinding task.

2.3.5. COMMUNITY PARTICIPATION IN DEFINING WAYFINDING SYSTEMS

It is necessary to improve the flow of pedestrians through active navigation so they can better learn about the places where they live or visit. This awareness promotes the local economy, the sense of belongingness, the feeling of security and comfort, and maintains the vitality of spaces in the city. Built environments are dynamic and constantly change. Thus, popular participation in urban design and planning decisions represents an essential strategy for creating spaces meant to be used by people.

The design of urban spaces should meet the unique needs of the community members and potential visitors. No matter how well planned and executed the wayfinding system is, it will only work if it makes sense to the people who walk around the city. The community needs to have an active voice in the changes made in their surroundings, so they can relate to them and incorporate new urban elements into their mental images and maps.

Therefore, encouraging popular participation in the design phase of future interventions in the city increases the probability of its success. It is an opportunity for locals to express their opinion on the transformation of public space along with professionals. In this way, they learn about government procedures, budgeting, environmental issues, etc., thus reinforcing previous bonds with the places and creating new emotional connections with them.

Public engagement in making an environment is an inclusive and democratic approach to co-design the city. According to Hester, (1990), when people participate in the design process, the spaces created gain special meaning and are better cared-for, increasing the sense of place and identity among insiders and outsiders. That said, it is far-reaching to add community knowledge to the planning and management of urban environments. People who live in the city must always play an essential role in its development, not being just another variable in decisions made by city councils, urban planners, and stakeholders in general. In other words, the planning department should be able to interpret people's needs and apply them to actual projects.

One of the best ways to present information and understand social demands is by exchanging ideas at public hearings. These events can provide productive insights for projects. Holding community meetings helps to comprehend the impacts caused by the implementation of urban projects. This methodology is essential for a broader understanding of the dynamics of each place.

In addition, it allows the urbanist to observe and map people's behavior through interviews, surveys, photographs, films, etc. This data collection is fundamental for defining strategies and refining recommendations for further actions. Finally, the agents responsible for the decisions concerning the city must keep in mind that people give value to space and not the other way around.

2.4. CONCEPTUAL FRAMEWORK / REVIEW OF STUDIES

Based on the literature review explained in this chapter, Figure 7 represents the conclusion of the author of this work about the relationships between urban form, navigation aids, spatial cognition, and the role of environmental information in the wayfinding behavior. This general framework shows the subjective and material factors and their impact on users' perception of their surroundings.

The following image is a summary of the research and reading stages, developed systematically and interactively, bringing together the main theoretical concepts in three groups that are directly influenced by each other. This cycle, in turn, converges into social and spatial interaction, from the act of perceiving to the wayfinding performance, the central objects of this study.

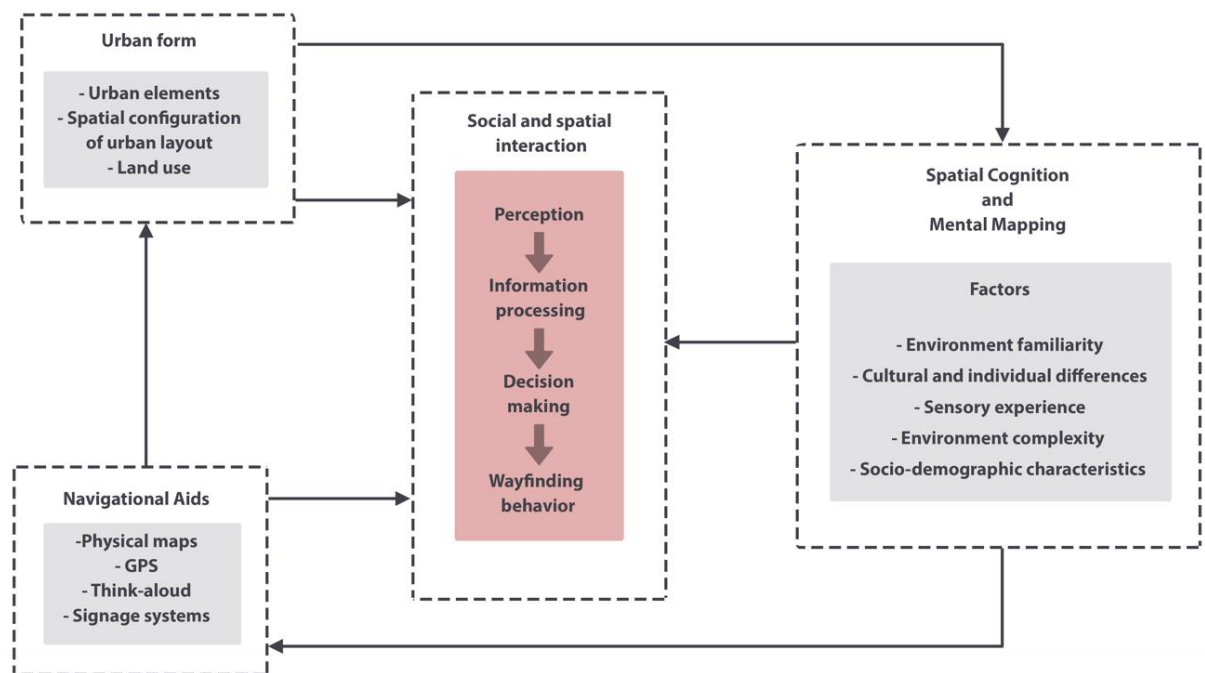


Figure 7 General framework of studies

Source: author of this work.

For this research, a bibliometric analysis was conducted with the following keywords: wayfinding, perception, cognition, and urban. Scopus platform revealed an increase in the number of publications investigating these themes grew considerably from 2017 to 2021 (Figure 8). This fact demonstrates that the application of understandings related to spatial cognition in the development of pedestrian wayfinding systems has been promising and is gaining more prominence in the areas of urban design and planning.

This analysis also indicated that the social and environmental sciences have a significant presence in the number of documents available, encompassing disciplines such as psychology, geography, and computer science. In addition, the database provided the most cited authors and their contributions to the study in question (Figure 9).

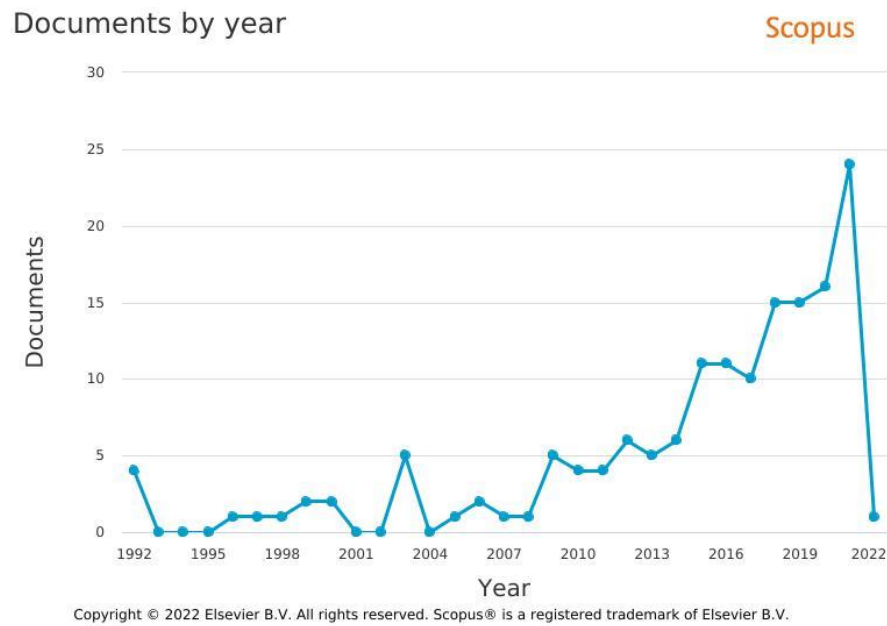


Figure 8 Documents published by year based on the combinations of the main keywords
Source: author of this work (using Scopus).

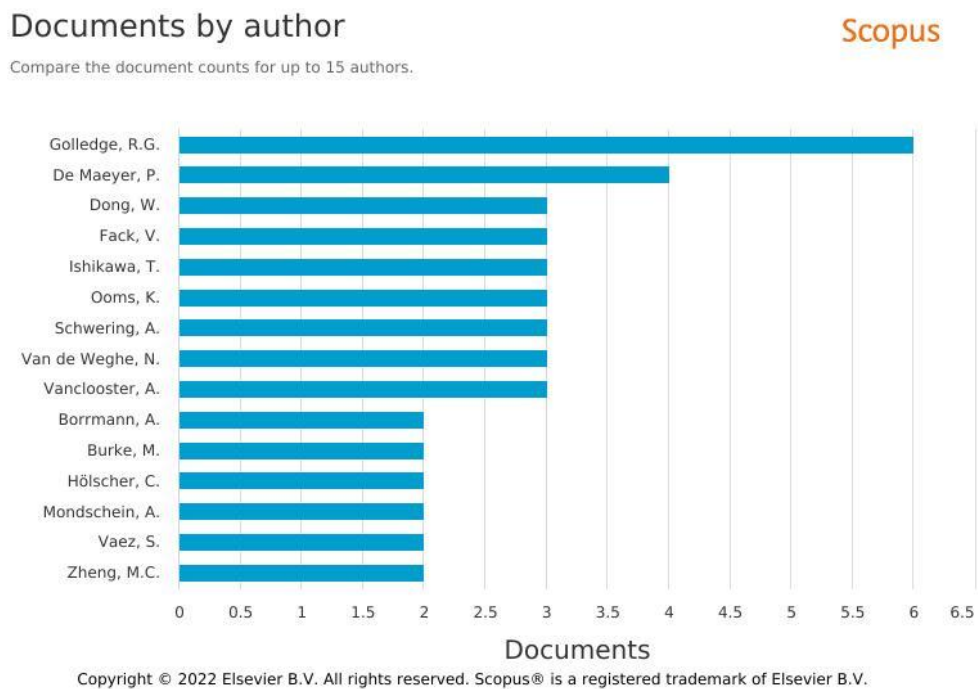


Figure 9 Documents published by author based on the combinations of the main keywords
Source: Author of this work (using Scopus).

The freedom of the brainstorming approach, combined with various search engines available on the internet, made it possible to test different keywords related to this study with further examination of the most relevant terms and their ramifications in the VOSviewer software (Bessa, 2021). One hundred and fifty-four articles were sorted out on the Scopus platform to obtain more assertive results. This data was

exported from the site in excel format to VOSviewer, allowing the creation of networks and relationships from the concurrence of words (Figure 10) and the overlapping and density visualization of their use over time (Figures 11). This methodology helped identify the final scientific papers to compose the literature review of this dissertation, understand concepts and define the cases of reference. The images below allow us to connect and contemplate the interaction of the literature review as a whole.

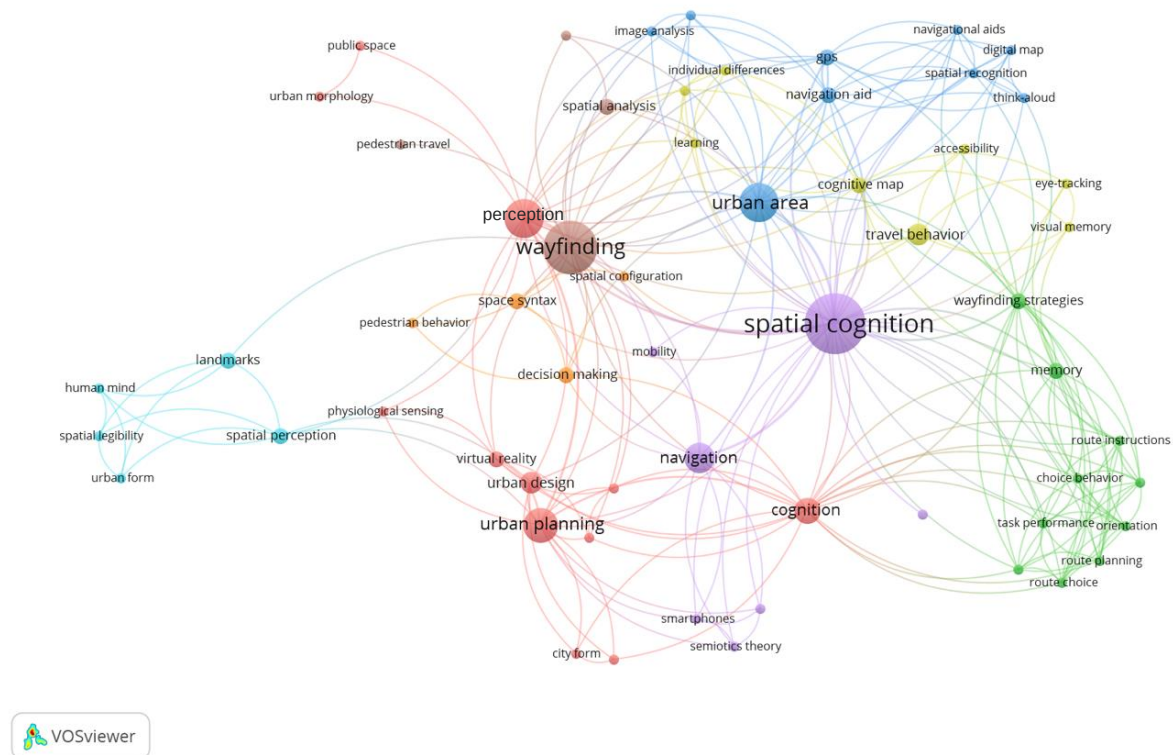


Figure 10 Network visualization of co-occurrence of words
Source: Author of this work (using VOSviewer).

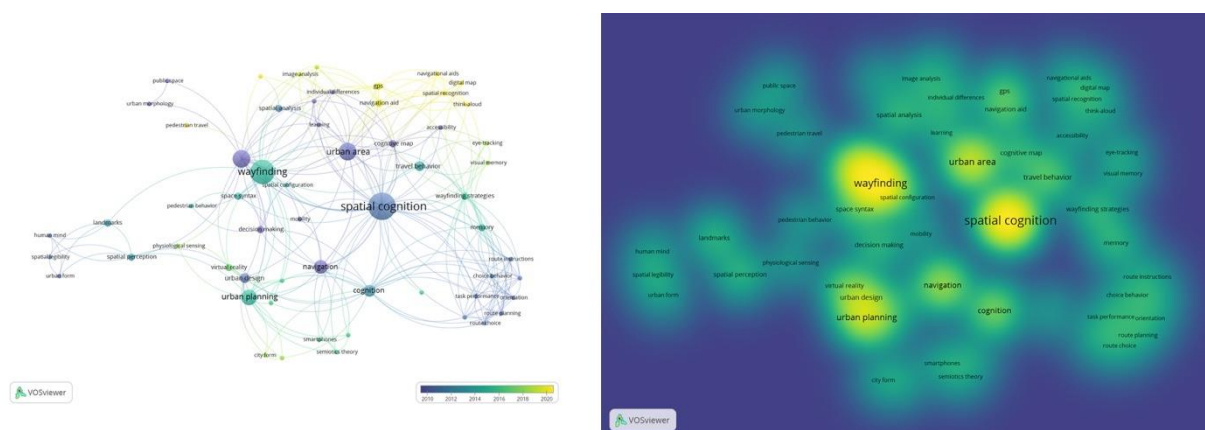


Figure 11 Overlay visualization of co-occurrence of words; density visualization of co-occurrence of words
Source: author of this work (using VOSviewer).

3

REFERENCE CASES

This chapter describes examples of different case studies considered as references for the design and implementation of the pedestrian wayfinding system. To enrich this work and understand the topic more broadly, five cities with programs recognized worldwide as good practices were selected: Lisbon - Portugal, Dublin - Ireland, Brisbane - Australia, London - United Kingdom, and Seattle - United States. The analysis of the context of the development of each program, the needs that led to the decision to adopt wayfinding strategies, and the process of planning and design of the signage systems, this section intends to identify the main aspects that turn these projects into successful cases.

When developing a new PWS, municipal authorities generally partner with private companies and consider the urban agendas, socio-demographic data, and past experiences from other cities. They also consider the factors that influence human response to their surroundings during the wayfinding task. Thus, it is necessary to understand the role played by each stakeholder in the design process and assess the impacts of the project on the community.

3.1. NATIONS PARK (PORTUGAL – 1998)

3.1.1. PROJECT CONTEXT

To celebrate the 500th anniversary of the Portuguese Discoveries, the city of Lisbon held an international exhibition called Expo'98. The exhibition took place in 1998 in the city's east end alongside the Tagus River, and its demands culminated in a strategic project for Portugal. The organizing committee had to build the entire Expo'98 from the ground up because the area chosen for the event used to be a polluted industrial park, with degraded structures and slaughterhouses abandoned over a decade. The site went through a massive urban, social, and environmental requalification that implied a complex planning process resulting in a vivid and multifunctional urban centrality on the waterfront for residents and visitors to enjoy.

With five main pavilions encompassed by the theme "The Oceans, a Heritage for the Future" and several others representing 146 countries, the exhibition received around 10 million people over four months. Expo'98 left a legacy in Lisbon by transforming an obsolete terrain of the city into a thriving, modern, and stylish neighborhood through an integrated intervention that generated real-estate revenue and land valorization. Additionally, as a result of the program, the Portuguese capital inherited urban infrastructures such as the Vasco da Gama Bridge, a new line for the Lisbon Metro, and a new main multi-modal terminal designed by architect Santiago Calatrava. Later, the Nations Park territory became a new parish of Lisbon municipality.

3.1.2. DESIGN PROCESS AND MAIN FEATURES OF THE PROGRAM

The Nations Park signage system was born from the project for Expo'98. The directional signs and information equipment physiognomy elaborated by the architect Pierluigi Cerri has its pictograms signed by Shigeo Fukuda, a Japanese professional expert in communication design, and Henrique Cayatte, the Portuguese designer responsible for the lettering coordination (Figure 12). To meet the ideas and intentions of the proposed scheme, Larus Design (a global specialized company in urban furniture) had to come up with viable solutions within a short deadline.

The program's goal was to create an image that provided a clear and unique identity for Expo'98. For this, Larus Design developed a pole able to support and communicate intelligible information, in other words, to be comprehended by the intellect without much effort. The physical elements installed were also built to be easily maintained and facilitate replacement operations. The directional signs in blue, red, and yellow colors help the navigators find the objects in the urban environment. In addition, each local designation is written in Portuguese and English to facilitate the orientation of foreign visitors to the area.



Figure 12 Nations Park signage design

Source: Larus Design, 1998.

3.1.3. WAYFINDING SYSTEM PERFORMANCE ASSESSMENT

This project is an example of good practice in communication design for signage in terms of entities' location and system efficiency. Unfortunately, due to the lack of maintenance and abandonment over the years, the signage structure became degraded, with message gaps, and outdated, especially regarding the definition of limits of the new parish of Nations Park and the integration of neighborhoods (Junta de Freguesia do Parque das Nações, 2016).

In face of this situation, the municipality of Lisbon, in collaboration with the parish's Communication and Image office and the Mobility and Urban Management division, started a plan in 2016 to update the signs to give them a universal language across the whole territory, guarantying the uniqueness of the set and respect the Expo'98 heritage. For this intervention, the institutions involved investigated the needs of the area through survey application before defining a signage model for the parish, including new plates and urban maps/charts.

3.2. DUBLIN – IRELAND (2011)

3.2.1. PROJECT CONTEXT

Dublin is an international destination due to its ability to attract people to live, shop, work, and visit. Nevertheless, the city did not keep up with the demands of the spatial structure generated by the new flows, making it an uncomfortable urban environment for navigators. The streets congested by cars and without adequate pedestrian routes fragmented their movement, reducing the quality of their experience in the urban spaces and compromising the mental mapping process. These aspects exacerbate the lack of connection between places, resulting in illegibility and loss of economic and social opportunities.

In this context, the study “Legible Dublin” (City ID & Dublin City Council, 2004) emerged as an innovative proposal, aiming to highlight the city as an example of good practices worldwide through a systematic improvement of the public realm structure, focused mainly on pedestrians and their needs. The goal was to reduce car use by 45% until 2030, with strategies to encourage walking, decrease street clutter, and avoid conflicts between pedestrians and other transportation modes.

According to the report (City ID & Dublin City Council, 2004), the existing signage was inconsistent in the delimitation and naming of some city areas. Also, its lack of logic, hierarchy and low quality of the set was confusing and uncomfortable for the users. Furthermore, the elements poorly positioned in the space and the directional plates in brown and white were causing visual pollution in the environment.

3.2.2. DESIGN PROCESS AND MAIN FEATURES OF THE PROGRAM

In 2005, the Dublin City Council partnered with JCDecaux and hired the company Fwdesign to develop an innovative wayfinding system with a unique identity for the city. The graphic material (printed maps, digital applications, signage elements, tourist guides, and advertising billboards) was designed to be inclusive, with a format for the visually impaired, and provide readable information to the user 24 hours a day with LED illumination panels. Also, the scheme was created to be efficient and connect to JCDecaux's bicycle system, public transport, and other interfaces. Finally, Dublin's new family of signs has an expected useful life of 25 years, reinforcing its sustainable aspect.

The program intended to help pedestrians locate and move effortlessly and safely around the city. Unlike other examples, this scheme did not focus on routes to commercial services but prioritized places of cultural, civic, and religious interest, fomenting content related to the heritage characteristics of the city.

The heads-up maps are master map cutouts installed on panels fixed on steel poles that increase the readability of the urban environment, allowing the traveler to explore the city with more confidence, enhancing their experience in the urban context.

To perceive people's movement to key locations in the city and how to improve the quality of the built environment, the agents involved in the project delimited a study area, which included the current Central Business District (CBD). The urban analysis made through digital mapping helped to understand the infrastructure and the layers of information of the city. In addition, the involvement of stakeholders and the conducting of semi-structured interviews with organizations identified by the City Council revealed aspects such as the flow of pedestrians and the most relevant streets, spaces, and destinations for visitors and residents.

After careful analysis of the Central District, the researchers traced a precise "axis of orientation" in the urban fabric (Figure 13), articulating important city spaces in 5-minute walks (approximately 400m in either direction). The delimitation of this "backbone" are points of latitude and longitude from O'Connell Bridge along the length of the Liffey River (City ID & Dublin City Council, 2004). As a result of several spatial examinations, public meetings, and prototype testing, the new bilingual signage system (English and Irish) with more than 100 individual elements, including information panels and directional plates, was installed by the JCDecaux across the Irish capital (Figure 14).

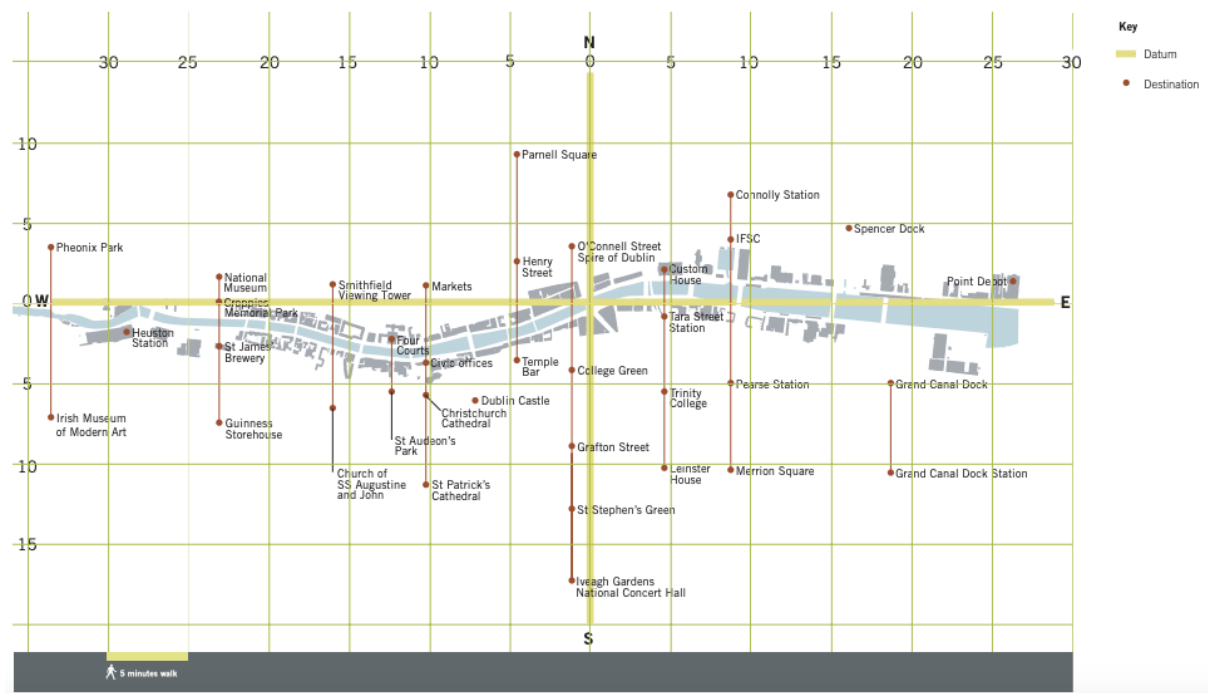


Figure 13 Spatial structure - axis of orientation
Source: City ID & Dublin City Council, 2004.



Figure 14 The Dublin Wayfinding Scheme
Source: Fwdesign, 2012.

3.2.3. WAYFINDING SYSTEM PERFORMANCE ASSESSMENT

Dublin's wayfinding system created a network of pedestrian paths that has improved the urban domain by making it friendly to walking travelers. Along with the requalification of public spaces (the regeneration of underlying areas such as the port zone, for example), the routes defined in the scheme promoted social interactivity, linking educational, recreational, and working destinations. Furthermore, the relocation of the road system favored the circulation of wayfinders, redirecting unnecessary vehicle traffic away from the center, thus relieving congestion and enhancing the quality of the environment.

The visual material of the project is part of the new image of the city, reinforcing the concept of originality by providing interconnected content that “combines graphic identity, cartography and product design that is unique to Dublin” (City ID & Dublin City Council, 2004). The program stands

out because of its sensitivity to the city center heritage and its ability to create pleasurable and efficient routes that reveal a series of recovered areas in a walkable sequence. The new wayfinding system has a significant impact on the built environment improving access to urban facilities and increasing pedestrian flow. It is also constantly monitored and updated to provide a service of excellence for the users.

3.3. BRISBANE – AUSTRALIA (2016)

3.3.1. PROJECT CONTEXT

Brisbane is one of Australia's larger urban centers, which concentrates two-thirds of the country's residents, and the city has been expanding with high density (about 2.2 million inhabitants), along with economic growth observed in the last decade. In addition to hosting world events, Brisbane has become an international meeting place for its business partnership with the United States, European and Pacific countries, attracting more tourists, students, and immigrants.

To prepare for the future, the municipality commissioned the report “Brisbane's Unique Window of Opportunity” (Brisbane City Council, 2011). which among other factors, revealed the need for visual communication that would establish a better connection with the demands of markets such as New Zealand, the United Kingdom, USA, Germany, China, Korea, Japan, and Singapore.

3.3.2. DESIGN PROCESS AND MAIN FEATURES OF THE PROGRAM

To address the multi-cultural aspect of the city and serve the communities born in other countries, the city council hired Dotdash, a company with 26 years of experience in wayfinding, through public tender. Dotdash was responsible for developing an innovative pedestrian wayfinding program in Brisbane's commercial center. The designers then adapted the old system according to the existing graphic standards manual, highlighting yellow as the dominant color in a softer golden tone. Based on a demographic study carried out in and around the city, municipal agencies and stakeholders decided that the new signage should be in English but incorporate Traditional Chinese, Japanese, Korean and Arabic.

Organizing five different languages and respecting the individual characteristics of each in a compact space was considered a challenge by the designers. Hence, they carefully selected the typography and made size adjustments, always seeking a visual balance between the information transmitted. Apart from the text, pictograms, arrows, and walking distances were added to the signs. The pictograms are mostly

universally recognized symbols. This standardization helps the traveler easily identify generic destinations and allows the plate's customization in specific locations.

Harlequin Signs and Plastics was the company responsible for the fingerpost fabrication. They considerably reduced project costs by taking advantage of part of the existing structure for the implementation of directional blades (1 cm thick) and posts, both in stainless steel. The system design allows easy removal and replacement of the panels, resisting the hot climate of the city, corrosion in a coastal environment, and the weight of the new signage. At the end of the design, a detail draws attention: the 6 mm thick laser-cut “walking man” acrylic pictogram.

The presence of circular maps is another essential aspect of the program. The local areas and context maps are heads-up maps, with geographic boundaries determined by walking distance and colors according to the city's brand identity. The content of the panels illustrates connections with other modes of locomotion such as bicycles and public transport and includes directions to shopping centers, tourist sites, urban spaces of collective interest, and relevant landmarks (Figure 15). Also, according to Driven X Design (2020), the project incorporated the following aspects

- Place name.
- Directional information to nearby services.
- Visitor orientation through mapping of immediate, local and broader areas.
- Regulatory information to advise visitor behavior, video monitoring, etc.
- Emergency contact information.
- Promotion of upcoming events in the precinct.
- Linkage to further digital information such as maps, Council's website, timetables and interpretation, through media such as QR codes and NFC.
- Step-Hear Navigation and Information system visually impaired users.
- BCC branding including tagline, logo and cleat integrated within the sign.



Figure 15 Brisbane Multilingual Pedestrian Wayfinding
Source: Driven X Design, 2020.

3.3.3. WAYFINDING SYSTEM PERFORMANCE ASSESSMENT

Brisbane's new wayfinding system became internationally recognized. This innovative program won design and planning awards and has been highly praised by the users, positioning the city on a global stage of excellence when it comes to enhancing the urban experience (SEGD, 2014). The vibrant, multilingual family of signs has quickly become the primary source of information for pedestrian guidance in and around the city. Despite their high contrast with the urban environment, the signage's elements catch the eye of travelers, encouraging flows of active mobility without drastically interfering with the landscape.

The positioning of the posts creates recognizable paths, visually linked throughout the urban fabric. The “walking man” cut into the panels fits into the environment dynamically and elegantly. This pictogram follows the approach of the Gestalt School, as a sign that is “outside the sign” and not in it, awakening instantaneous connections with the represented entities. The presence of consistent physical elements focused on pedestrian signage throughout the urban environment brought several solutions to the city of

Brisbane, as the information provided by the wayfinding system helps navigators form cognitive boundaries and points of contact.

The positioning of the panels follows the logic of the space, leaving clues in strategic places, guaranteeing the fluidity and coherence of the set. In addition, the aesthetics of graphic communication provoke the desired visual impact on the observer, encouraging pedestrian traffic in areas of high concentration of flows in the city, even at night, with poles equipped with lighting. The new wayfinding system has brought many benefits to Brisbane, adding value to public and private spaces. Besides, its installation technique allows changes over time without the need for major interventions.

3.4. LONDON – UNITED KINGDOM (2018)

3.4.1. PROJECT CONTEXT

The Legible London project's main goal was to make the United Kingdom capital one of the most walk-friendly cities in the world by 2015. A study commissioned by Central London Boroughs in 2005 and conducted by Applied Information Group revealed that the city's existing signage systems were ineffective and confusing. It also concluded that 44,5% of people walking guided themselves by the Tube maps (TfL & AIG, 2007).

Later, the partnership between Transport for London (TfL), Applied Information Groupe (AIG), and other entities culminated in urban design and planning strategies to provide information focused on pedestrians. The new PWS intended to benefit the public transport system, collective health, economy, tourism, and environment.

London is a historic and charming city composed of unique neighborhoods, places of interest, and landmarks. However, its organic evolution over time resulted in unplanned and labyrinthine streets, forming an urban fabric with undefined boundaries, full of obstacles, complicated access to the periphery, and dense road traffic.

These factors produce a complex and challenging environment for people to navigate on foot, which increases their fear of getting lost. In addition, studies have identified the presence of a significant volume of poorly positioned maps and signals. They had inconsistent information and varied designs, with no connection between them. The lack of a standard and maintenance of the existing structure also added to the problem.

Issues such as the existing pressure on transport infrastructure, over twenty-seven million visitors per year (many discovering the city for the first time), and estimated population growth in London were seen as opportunities for its sustainable development, focusing on three themes: “strong and diversified economic growth; social inclusion; and fundamental improvements in environmental management and resource use” (TfL & AIG, 2007). Another motivation for the change came from the arrival of the Olympic Games in 2012 and the urgency of implementing a system that would facilitate the movement of people from different parts of the world, making them feel safe, comfortable, and welcome.

3.4.2. DESIGN PROCESS AND MAIN FEATURES OF THE PROGRAM

The idea was to improve the experience of residents and tourists in the city through the simple act of walking. For this, it was necessary to create a practical and economic scheme that would meet the needs of pedestrians, in addition to making improvements to the built environment (lighting, street condition, moderation of car traffic, etc.), making it orderly, reliable, safe, attractive, and affordable. The development of the Legible London program had as its central theme the cognitive science regarding mental mapping (Figure 16), that is, how walkers build mental images from their experience in urban space as they travel around the city.

The agencies involved in the project led several feasibility studies focused on wayfinding behavior before defining a final version of the PWS. Based on these assessments, they concluded that “travel time is a more important factor than distance when it comes to deciding to walk” (TfL & AIG, 2007). Based on these assessments, they concluded that “travel time is a more important factor than distance when it comes to deciding to walk” (TfL & AIG, 2007).

A range of stakeholders also conducted a community workshop to discuss issues relating to the scheme. In addition to exploring branding, technology, planning, design, and management strategies, combining skills, knowledge, and resources towards a common goal, the event awakened great enthusiasm for the new project among the public. After the prototype development and refinement, AIG created a visual diary focused on people's differences (their goals, schedules, travels, etc.). Its drawings, designs, and concepts served as the foundation for Legible London's evolution in the years to come.



Figure 16 Mental mapping investigation process
Source: TfL & AIG, 2007.

One of the scheme's general principles is to divide the city into smaller spaces to facilitate management and make the whole less intimidating. In the case of London, to process the large quantity of information present in the urban environment, areas, towns, and neighborhoods were delimited. The logic and hierarchy of the subdivisions led to the definition of official street signs and the appropriate places to disseminate the necessary content. The environmental clues are provided progressively, that is, in the right amount throughout the journey.

Concerning typography, to obtain maximum legibility in the maps and signs, designers decided on the font sans-serif for its clear and recognizable character. The high contrast of blue, white, yellow, and black colors allows the fast distinction of new elements in the environment. Furthermore, the maps with 3D representations of landmarks, location of essential services, and places to rest were installed at 900 and 1800mm from the ground, guaranteeing access for people with reduced mobility.

Forty-six elements of the existing system in the study area were removed and replaced by nineteen new map-based signals such as monoliths, miniliths, and fingerposts (Transport for London [TfL], 2007a). Each panel contains addressing, directional information, a planner map with 15-minute destinations, a finder map with 5-minute destinations, and a street finder (SEGD, 2009). Additionally, they display the universal walking symbol at the top of each sign, in a yellow beacon above head height, which can be

seen from a distance. Offering heads-up maps makes it easy to fill in the gaps in front of the user, helping them to build their mind maps.

Applied Information Group and Lacock Gullam designed the signage's elements to fit into the urban landscape in a balanced way but with enough presence to be noticed and used. Also, to ensure the system's durability, Woodhouse fabricated the signs with materials such as vitreous enamel panels and shot peened stainless steel. Regarding sustainability, some panels were installed with solar panels to power the digital maps and illuminate the signs at night.

Some program's components were placed close to shops and streetlights to lower energy costs. The pieces of the panels are adjustable, including the north indicator on the base of them. Likewise, the modular approach of the scheme allows it to adapt to the historically sensitive architecture of the place, and future changes once can be easily maintained and updated. These aspects demonstrate the incredible attention to detail that has been paid to this project.

The language used on the surface corresponds to what is underground. Signs at bus shelters and subway stations, pocket-sized printed maps, integrated mobile devices, arrival markers, and other information tools make the system easier to understand (Figures 17 and 18). The new signage was planned to increase users' environmental knowledge, helping them plan their journey and find their way independently. "The result of the definition of these formats is a coherent array of maps, signs, indexes, lists, and diagrams that supports the way people learn" (TfL & AIG, 2007).



Figure 17 Legible London Product Range
Source: Transport for London (TfL). 2007b.



Figure 18 Legible London Product Range – Totems showing different transportation modes
Source: Transport for London (TfL). 2007b.

3.4.3. WAYFINDING SYSTEM PERFORMANCE ASSESSMENT

The installation of the prototype of the wayfinding system was carried out on Oxford Street during the Christmas period of 2007, at strategic points of busy and high-traffic sections, to help buyers and tourists to locate essential services, commerce, accommodation, and local attractions. Despite the tight deadline, the intense and detailed work of agents from the public and private sectors, and the wise investment made in infrastructure culminated in a PWS that turned out to be a legacy for decades to come, making a difference in the daily life of Londoners. Thereby, London stood out as one of the pioneer cities of what would become a worldwide phenomenon of change in urban transport.

The innovative program, conceived to respond to how people think and act when navigating the urban environment, sought to deliver information succinctly. Understanding the intuitive way in which individuals perceive the space and relate to it was an essential factor in defining the set of signs. Maps accessible at different scales convey content about the immediate surroundings and their context, connecting the particular to the general, through the hierarchy of names and places. Landmarks are represented in 3D on the maps to fix checkpoints in the minds of travelers (Figure 19). The “walker” pictogram, which symbolizes a symbolic pedestrian, appears at the top of the posts announcing its function.

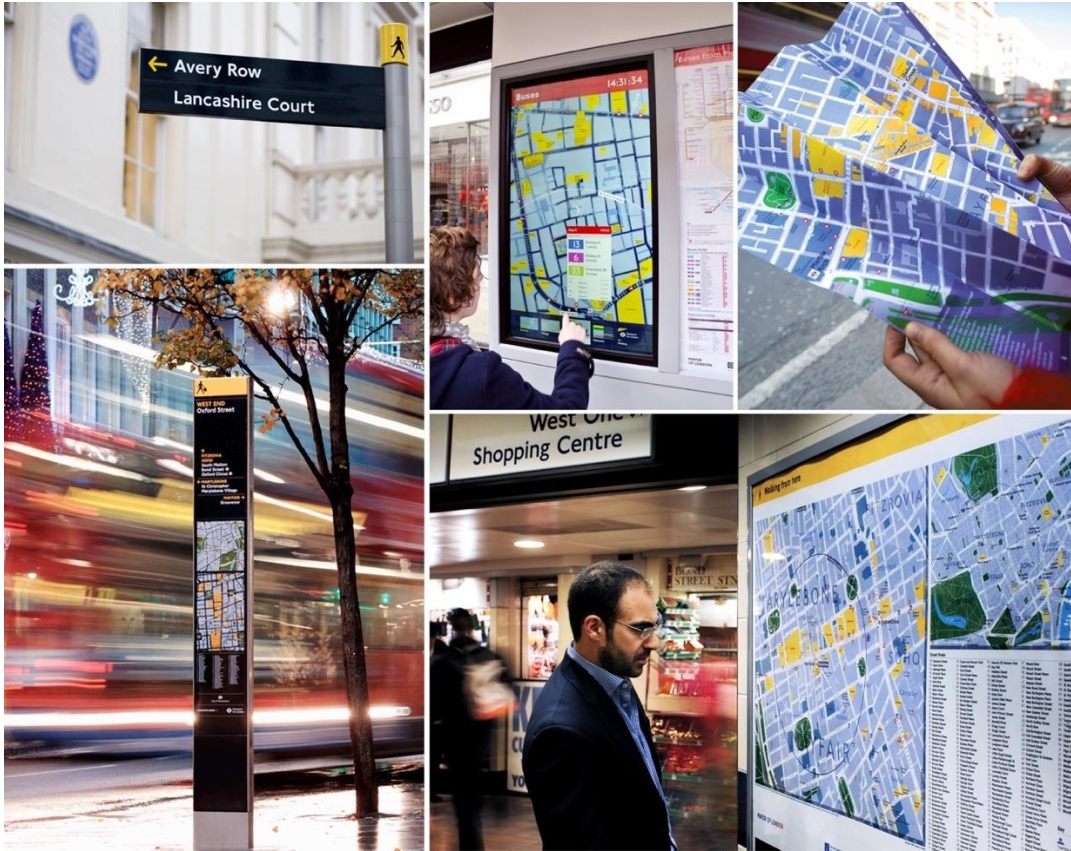


Figure 19 Legible London - Signage System

Source: SEGD, 2009.

The pilot testing on Oxford Street served to assess public reaction to the scheme and its performance under pressure. The prototype supported urban designers and planners to perceive aspects of the program that needed modifications and establish principles of what would become the Legible London, a comprehensive signage project committed to fluidly guiding pedestrian movement even in complex environments.

This program has a proven scientific basis in mental mapping processes and is a result of a joint effort between governmental authorities and private agencies. The mental models provided by the community during the workshop were a crucial component of this successful guidance system. A follow-up study (SEGD, 2009) involving 2,600 people presented the following data:

- 85% found Legible London easy to use.
- 90% felt that the system should be implemented in London.
- One-thirds said that the new signage would encourage them to walk.
- Pedestrian journeys became quicker by 16%.

3.5. SEATTLE – UNITED STATES (2019)

3.5.1. PROJECT CONTEXT

Over the years, Seattle has become a major global business center focused mainly on technology and study (due to the University of Washington and companies such as Amazon and Google), creating economic and social flows that increased housing and travel demands. The city's growing population, composed of people from different cultures, a high number of elderly, and individuals with reduced mobility have led to the need to invest in urban infrastructure, connecting transport services in a simple, reliable, and accessible way to all users.

The “Area Plan for Seattle-King County” report (Seattle Department of Transportation [SDOT], 2019a). found aspects such as the high proportion of people with disabilities in the city (23% of adults over 18 years old), the lower frequency of visits to civic facilities by low-income groups, and the number of residents speaking a different language at home (19% of adults over 65 years). Furthermore, the tourism component had a great influence on the choice of PWS. Seattle welcomes around 40 million visitors per year (17.3% are international), who spend approximately \$7.4 billion in the city.

Aiming to increase walking trips in the city by 35% until 2035, local authorities prepared a Pedestrian Master Plan in 2017 (SDOT, 2019a) whose strategies included the implementation of a wayfinding system to encourage journeys on foot as the preferential mode of transportation. In addition, this urban plan goals included reduction of car use and decreasing the emission of greenhouse gases, thus contributing to a more active and healthier lifestyle for the population in general.

The topography is a striking feature of Seattle, and its physical characteristics contribute to its legibility. The city has an urban fabric with a well-defined grid, areas delimited by the presence of bodies of water, hilly topography, and remarkable monuments. However, the terrain contains steep slopes, elevators, and stairs, making it a challenge for people to walk around the city.

Information about obstacles that may arise during a journey and the indication of alternative routes influence travelers' decisions. Another problem detected was the existence of several wayfinding systems with different qualities in terms of design, execution, and management, which did not work in an integrated way due to graphic material with inconsistent content and poorly maintained signage. The factors mentioned above have a significant impact on traffic. Therefore, to meet the community needs and relieve pressure on the road system, municipal authorities decided to invest in changing commuting

patterns in and around the city. In this context, an equitable wayfinding system could help meet diverse demands and support local amenities, promoting environmental cohesion in the public realm for both tourists and inhabitants.

According to SDOT (2019a), “including wayfinding design will include people-centered information that allows people to plan and execute their journey irrespective of their physical or cognitive ability, gender, age, language, location, ethnicity, wealth or access to online or digital tools”.

3.5.2. DESIGN PROCESS AND MAIN FEATURES OF THE PROGRAM

The Wayfinding Scoping Study carried out at the end of 2017 (SDOT, 2019a) defined that the new program should be recognizable throughout the city and adapted to the particularities of different neighborhoods, allowing the user to feel “comfortably lost”. In this regard, a modular and coordinated design approach and the reduction of street furniture would avoid visual clutter and increase pedestrian flow.

For that, it was fundamental to establish a creative partnership between the public and private sectors and the community members. The idea was to develop and implement an equitable system with a universal design that would deliver information of the places and times needed to reach them, inspiring tourists and residents to explore the city safely.

Seattle's new wayfinding system was based on people's behavior as they navigate the urban environment, what questions they ask along the way and the factors that influence route planning and choice. Thus, it was essential to investigate aspects related to spatial cognition regarding how individuals think and build mental maps (Figure 20).



Figure 20 Mental mapping investigation process
Source: Seattle Department of Transportation (SDOT), 2019b.

In this context, it was required to understand how people move and understand the city, making them aware of the opportunities and benefits the wayfinding system can offer, getting people to walk. Several community meetings were held with different social groups, apart from interviews, questionnaires, government meetings, and evaluation of prototypes. This stage of preliminary studies had the collaboration of 200 people (Figure 21).

“The Stakeholder Advisory Committee was comprised of decision-makers within their respective organizations representing the municipality, transit agencies, tourism, design, historic preservation, community organizations, business chambers, etc.” (SDOT, 2019b).



Figure 21 Community participation for co-design Seamless Seattle project
Source: Seattle Department of Transportation (SDOT), 2019b.

The primary focus of this strategy are people, including residents and visitors). Thereby, basic principles were adopted to ensure a consistent approach throughout the system: seamless (1), stepping-stones (2), system naming (3), system codes (4), progressive disclosure (5), predictable (6), don't make me think (7), inclusive (8), help me to learn (9) and, tone of voice (10). Thus, information would be connected and available when and where needed, avoiding physical and visual clutter.

Furthermore, the program would be a reflection of real journeys that people make, helping them to navigate without friction in every change of mode, regardless of their abilities, in a simple and predictable way, through a unique set of elements and rules (colors, numbers, icons, names, etc.) easy to interpret and memorize. The community feedback was essential to refine the program, which was tested in two pilot areas (Jackson Hub and Westlake Hub) in 2019 and later used citywide (Figure 22).



Figure 22 Seamless Seattle - Pilot testing.
Source: Seattle Department of Transportation (SDOT), 2019b.

The Seamless Seattle project main concepts include: modal integration (1) aiming to connect physical walking information and digital tools; local distinctiveness (2) with the creation of a unique and consistent wayfinding layout that allows personalization for local content; design for all (3) with the development of an inclusive design that guarantees information and accessibility for all, prioritizing safe walking routes and people with greater needs; and systemization (4) through the implementation of a standard system with a high degree of commonality throughout the city, whose management must ensure its integrity.

According to SDOT (2020), the program contemplates the key design features:

- “Heads up mapping on street signs to help the user to quickly orient themselves in reference to their immediate surroundings.
- Pilot integration with King County Metro and Sound Transit to provide a more seamless customer experience.
- Integration of illustrations, slope information, accessible entrances to transit, and publicly accessible through building Hillclimb assists to meet the needs of the widest range of users.
- Use of proper contrast for legibility, optimization for color blindness, large type sizes, careful balance of content, and simplification of complex topography for accessibility.
- Integration of braille and tactile panels providing orientation information on all signs.
- Integration of non-English languages in specific areas.

- Recognizable product design, tested through rapid prototyping, predictably deployed across different areas to maximize system legibility so users know where to go for information.
- Careful design adaptations to respond to historic landmarked areas without reducing overall system legibility”.

3.5.3. WAYFINDING SYSTEM PERFORMANCE ASSESSMENT

The new wayfinding system implemented by the SDOT aims to turn Seattle into the most walkable city in the US for its residents and visitors due to the legibility and accessibility of the program (Smart Cities World,2021). The quality of planning and design of the program is undeniable and is visible in each detail of it. Also, the community involvement thought the whole process reinforced the inclusive and democratic character of the project (SDOT, 2019b).

The strong partnerships citywide over the years to create the Seamless Seattle scheme became a reality in the first trimester of 2021 through the installation of signs on the busiest intersections of the town. It's still too soon to assess the performance of this wayfinding strategy that was delayed by the Covid-19 pandemic. Up to this moment, there are no concrete studies about the system's impact on the social, environmental, and economic dimensions. Nevertheless, the future holds greater expectations to make Seattle a more sustainable, livable, and diverse city.

3.6. SYNTHESIS

Each project presented in this chapter has a different scale. Some municipalities implemented the scheme throughout the city, while others did it only in the central and busiest areas of the urban environment. This fact modifies aspects related to the value invested in the program, the entities involved in the design process, and the users' response to the signage's installation. In addition, the research revealed that not all examples had a substantial amount of information accessible for consultation, which posed a challenge in the analysis of the reference cases presented in Table 4 (review of studies).

Table 4 Reference cases - review of studies

Source: author of this work.

CITY	LISBON	DUBLIN	BRISBANE	LONDON	SEATTLE
PROJECT YEAR	1998	2011	2016	2018	2019
NAME	Nations Park Signage	The Dublin Wayfinding Scheme	Brisbane Multilingual Pedestrian Signage	Legible London	Seamless Seattle
AREA OF IMPLEMENTATION	50.000,00 m ²	Central District	2.582.704,51 m ² in central Brisbane	Oxford Street, Bond Street, Westminster/Camden, South Bank, Richmond and Twickenham and West End	Citywide wayfinding system
BUDGET	N/A	€4,106,000	\$80,000 AUD	N/A	Over \$1,000,001
REASON	Provide a clear identity and simple understanding for Expo'98, facilitating the orientation of foreign visitors to the area	To make Dublin a world-class friendly city for pedestrians; avoid street clutter and conflict between walkers and other transportation modes; reduce car use and increase walking journeys to work; the city's infrastructural deficit	The need to serve its growing multi-cultural population and help immigrants, tourists, and students navigate the city	The city's population growth; the pressure on transport infrastructure due to a large number of visitors and residents; the ineffective and confusing existing signage.	The city's growing population; the need to serve people from different cultures; the high number of elderly and individuals with a cognitive or physical deficiency; increasing economic and social flows due to the presence of tech-based industries and the University of Washington; housing and travel demands
NUMBER OF SIGNS	60 signs	Total of 104 signs sited across the city, including 20 double-sided map panels	33 fingerpost signs	Removal of 46 existing objects and implementation of 19 new signs in 2007 and more 23 in 2008	N/A
LANGUAGE	Portuguese and English	English and Irish	English, Traditional Chinese, Japanese, Korean, and Arabic	English	English. The use of a second language in areas where it has strong ties to a community or a majority of residents speaks a language other than English
SYSTEM FEATURES	Directional plates in blue and red colors; design of pictograms exclusively for the program	This cutting edge system includes signage structures with LED illuminated maps to ensure that information is legible 24/7, advertising billboards, a hand-held map and digital on-line maps	Pictograms (universally recognized symbols), arrows, and walking distances; walking map with key destinations	Panels of different scales ("Monolith", "Midilith", and "Minilith"), heads-up maps, location of steps, pavement widths, and pedestrian crossings, time to walk, "walk this way" marker, 3D representations of landmarks, planner map, finder map, identification of transport integration (bus, tube, cycling docking, taxi), A-Z street finder and hierarchy of name and places	Area sign (planner and finder maps), linear area sign, bus/street-car shelter, bus flag area map, in-station, overview sign, nudge sign, interpretive sign, public art, site-specific overview sign, route marker, sidewalk medallion, time to travel, 3D representations, place ID marker, tactile pole panel with braille content, en-route to a destination and the address information, printed maps, leaflets, and ambassadors

MATERIAL DESCRIPTION	N/A	Shot peened stainless steel frames, with powder-coated fingers. The maps are housed in toughened, low iron glass panels and digitally printed and reverse applied so they can easily be updated	Stainless steel (1 cm) in the poles and other corrosion-resistant materials due to the coastal environment's heavy salt-air concentration	Vitreous enamel panels and shot peened stainless steel have been used to make sure the signs are durable and easy to clean. Coated materials have been avoided because of gradual deterioration and the need for annual recoating	N/A
INSTITUTIONS	Commissioner: City Councils and the State Design: Pierluigi Cerri, Shigeo Fukuda, Henrique Cayatte Fabrication: Larus	Commissioner: JC Decaux Ireland Partners: Dublin City Council, Department of Transport, Tourism & Sport, Dublin Tourism, national cultural institutions, and other civic interests Design: Fwdesign Fabrication: Wood and Wood Signs	Comissioner: Brisbane City Council Design: Dotdash Fabricator: Harlequin Signs and Plastics	Comissioner: Westminster City Council, New West End Company, Transport for London, Crown Estate, Greater London Authority Planning and Design: Applied Information Group (AIG) and Lacock Gullam Fabrication: Woodhouse Installation: Westone	Comissioner: Seattle Department of Transportation (SDOT), King County Metro Sound Transit, Washington State Department of Transportation Design and planning: Applied Wayfinding with Alta Planning + Design Community engagement: 3 Square Blocks
INVOLVEMENT	N/A	Involvement of a group consisting of key stakeholders led by the City Council. Public engagement through semi-structured interviews and mental mapping studies with different organizations.	Pilot testing on site	Stakeholder engagement through a meeting with members of the community, mental mapping studies, public hearings, and prototype testing	Rigorous and far-reaching engagement process with focus groups. Stakeholder involvement through community meetings, briefings, interviews, workshops, public hearings, mental mapping studies, and prototype testing

4

GUIDELINES FOR DESIGNING PEDESTRIAN WAYFINDING SYSTEMS

Traveling around the city is an activity of everyday life for most people. Hence, any intervention in the urban realm that influences pedestrian movement should meet their needs. The design and planning of a wayfinding system must be people-centered irrespective of their abilities, encompassing a practical set of signs that simplify the spatial relationships between the various uses and functions that exist in the built environment.

An effective Pedestrian Wayfinding System has the potential to engage people in every sense, encouraging them to walk. Its main goal is to help navigators plan their journeys and orient themselves in the city in an easy way, regardless of its purpose. Legibility is personal but is also a matter of time and familiarity.

Therefore, in addition to the product design, the program must contemplate elements such as a water fountain, floor texture, a bakery, or a coffee shop, once they can be significant sensory markers in the user's mind. Stimulating cognitive skills will reinforce the generation of mental maps, giving the user the comfort to move around the city and the confidence to get lost. According to this research, the core principles that guide the development of pedestrian wayfinding systems are the following:

1. Consistency: the system must have a universal design. It is imperative to ensure harmony between the signage elements and the surrounding environment to avoid visual clutter and obstruction for pedestrians. Clarity of content at every touchpoint is also essential to creating a simple and intuitive PWS.

2. Continuity: the system must work as a network of progressive disclosure (just enough information where is needed). Thus, the placement of the signs should be predictable for the user to confirm their location during a trip or re-plan their journeys.
3. Connectivity: the system must connect key points of the city through pedestrian routes and provide information about linkages with other transportation mode. In addition, when incorporating technology, the mapping and codes used for digital strategies should be the same as the signage on site.
4. Accessibility: the system must be inclusive and accommodate all potential walkers, regardless of their physical or cognitive capacity, gender, age, education, income, ethnicity, etc.
5. Local Distinctiveness: the system must stand out against road signs and other elements in the urban environment to be recognizable. Also, the design should be flexible and respective to distinctive areas of the city without compromising the legibility of the system.

4.1. ANALYSIS OF THE SELECTED AREA

The first step to developing a wayfinding strategy is to define the *signage area*. This geographical delimitation will help identify the urban elements and their configuration in the space. It is essential to learn how the physical components of the place affect movement to provide the appropriate tools for pedestrians to navigate through a wide range of environments regardless of their complexity. The shape and size of the signage area influence the number, location, and type of signs. Table 5 exemplifies the aspects of the city's structure to consider when analyzing the dynamics of the site.

Table 5 Aspects of the urban form that affect walker's movement

Source: author of this work.

Urban Form	
Aspects	Examples
Urban development	City's growth vectors over time and historic characteristics
Topography and geography	Gradient, steps, stairs, and barrier shapes
Density of the built environment	Size and direction of the grid
Street typology	Street hierarchy and walking routes
Points of interest	Landmarks, focal points, decision points, and historic locations
Movement	Understanding of different flows (pedestrians, vehicles, etc.)
Transit identity	Transportation modes available in the area

Note: the entities responsible for the program should photograph and maintain a record of all the information gathered during the site audit, so this can be referred to at a later point.

4.2. COMMUNITY AND STAKEHOLDER ENGAGEMENT FOR CO-DESIGNING A PWS

Urban designers and planners must work alongside stakeholders, including residents, government authorities, transport operators, and business sections. This partnership represents a crucial bonding between the involved agents to get maximum benefits from the new wayfinding system. In this regard, public involvement through community meetings is essential to engage people during the planning process and keep them informed from the beginning to the end of the project. These events should encourage mental map drawing, landmark recognition testes, verbal interviews, and questionnaires to identify neighborhood limits, decision points, and landmarks, besides establishing appropriate naming and defining which contents are most relevant to show on maps.

In addition to public meetings, studies conducted in loco can provide data regarding the number of visitors to certain places or attractions, the density of movement during the day, etc. The goal is to design according to how people think. Using as reference a study made by Transport for London in 2005 (Valuing Walking: Evaluating Improvements to the Public Realm), urban designers and planners identified two types of pedestrians: striders and strollers (Figure 23).

For example, some navigators (striders) are methodical and seek the fastest and most efficient route. They are not concerned with its quality. These journeys can be for learning (how to get from point A to point B) or for the frequent user to determine the best path to fit into their daily routine. Differently, other travelers (strollers) are looking for a memorable experience. They have time to spend and want to drift and discover new places.

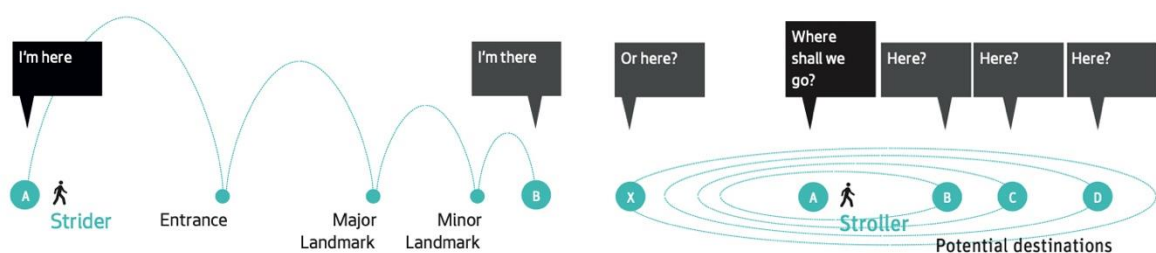


Figure 23 Types of pedestrian mindsets: striders and strollers

Source: SDOT, 2019a.

4.3. PILOT TESTING

Pilot projects aim to assess the useability of the system and justify its implementation as a solution for the city. Prototype tests in the busiest and most complex transit centers of the urban fabric ensure a more comprehensive evaluation of the program's elements. The feedback from this feasibility study concerning the number of trips, efficiency, difficulty levels, reliability, and speed allows changes in aspects of the PWS or its refinement before installing the final product in the public domain.

4.4. DEVELOPING WAYFINDING PRODUCTS FOR WALKERS

4.4.1. SIGNAGE FAMILY

The signage family has to be consistent, with reliable information at every point of contact to solidify local knowledge and develop environmental familiarity. For that, the scheme's components need to have the same design language based on a unique and concentrated mapping system. The formats must contemplate different scales of use with a coherent content hierarchy.

Figure 24 shows the types of signs of the core family (maxi-totem, mini-totem and fingerposts) and additional elements (transport totem, route marker & description, and sidewalk medallion). The scheme presents some estimated measurements of what would be ideal for the pedestrian viewing angle, as well as locating important information on the signs in an accessible way for people with reduced mobility.

The heights were determined based on the following references: Neufert, 2000; Teles, 2006; TfL & AIG, 2007; The State of Queensland (Department of Transport and Main Roads), 2020; tender specifications of the PISI of the city of Oporto, 2022. The specifications of the signage family elements and the description of their function (identification, directional, information, and regulatory signs) are as follow:

1. Fingerposts: directional signage to places nearby, providing route confirmation in local areas.
2. Maxi-totem: fast reading overview sign that provides a wider context of the city as well as transit connections to help people orient themselves, locate places and plan longer journeys.
3. Mini-totem: this sign includes two scales of map and generally contains the same information as the maxi-totem. The planner-map shows districts in a broader context and strategic destinations within a range of 15-minute walk circle. The finder-map allows users

to explore their immediate surrounds and locate points of interest within a 5-minute walk circle (or 400 meters trips).

4. Transport totems: a combination of an area map of the district and content for the transport network (transit connections to support multi-modal journeys).
5. Route marker & Description: these signs are able to adapt according to their specific location. They can be wall-mounted signage with mapping of the vicinity, transit connections (Hubs and Bus Schedule Panels), and directions to accessible routes through a building for example (Hillclimb) or interpretative signs with educational, cultural and historic information.
6. Sidewalk medallion: provide users with information about an alternative accessible path if they need to replan a journey or continue along that route.

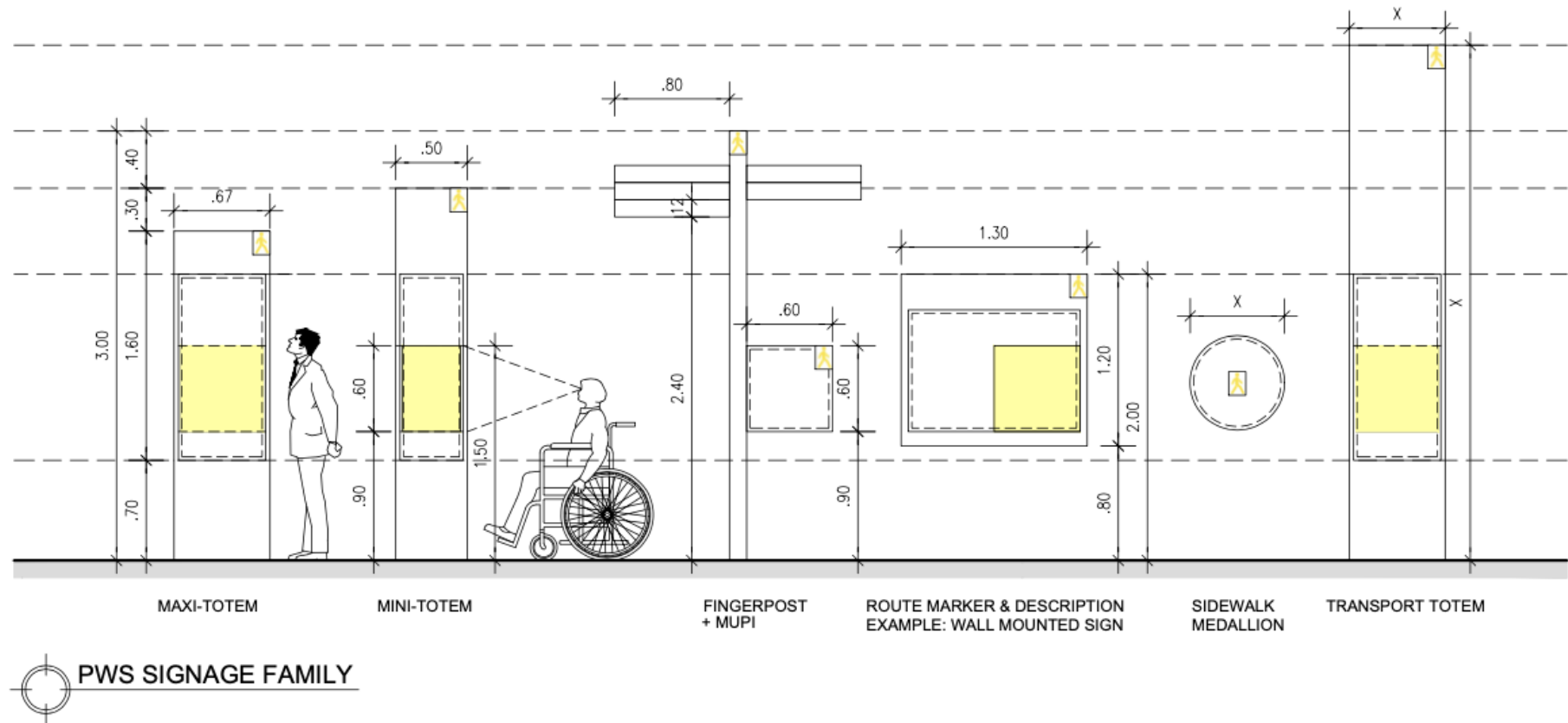


Figure 24 Family of signs for pedestrian wayfinding systems
Source: author of this work.

4.4.2. SIGNAGE LAYOUT

The system's layout must be minimalist and functional, with common characteristics to promote familiarity through repetition and simplification of environmental complexities. Thus, to create a friendly and practical design that combines aesthetics and usability, it is important to pay attention to details, such as colors, font, and symbols.

For that, Table 6 provides general rules (TfL & AIG, 2007; TfL, 2007a; City of Toronto, 2016; SDOT, 2019a; Driven X Design, 2020); The State of Queensland (Department of Transport and Main Roads), 2020) for the visual appearance of the scheme regarding graphic design, text, and illustration contents to ensure proper standardization. The careful balance of information in each sign is essential to reinforce legibility. However, despite the defined pattern, the project needs to be flexible to reflect the city's identity and respect local distinctiveness.

Table 6 General rules to develop the signage's visual identity

Source: author of this work.

General rules		
Graphic design	Colors	Use of enough visual contrast
	Typography	Use of appropriate font style, size and height
	Pictograms	Use of recognizable internationally symbols
	Identifier	Use of a bright strip on the top of the sign with "the walker" pictogram, visible from distance
Text content	Name of suburbs, neighborhoods, places and streets (addressing), A-Z street finder, distance (m), walk times to key destinations (min), native and second language where needed, arrival points, heritage content, "you are here" and "walk this way" markers	
Illustration content	Heads-up maps with simplified 3D landmark representations; emphasis on steep gradients, steps, narrow or high pavements, pedestrian crossings, building Hillclimb and civic and local amenities; traffic network diagram with the identification of the entrance of metro stations and bus stops; directional arrows; historic mapping	

Note: the entities responsible for the program must select the content of the signs carefully once the inclusion of too many symbols can clutter the map, reducing legibility.

4.4.3. SIGNAGE PLACEMENT

The number and location of the signage elements in the public realm must follow a logical arrangement to reduce clutters and improve awareness. It is necessary to provide just enough information to answer the user's questions where needed during their journey. That said, the progressive disclosure in the key locations can prevent distractions caused by potentially confusing content. The installation of the signs

must ensure visibility from key origins and destinations at right angles to the direction of travel to accommodate pedestrians, allowing them free movement and sufficient space for people with disabilities to perceive them.

In most cases, people's first point of contact to look for guidance information in the city are decision points such as transit nodes or transit stations. The location of the signage also depends on the density of flows of the environment within the urban context. These spaces have to be studied carefully before deciding the position of the signs. Every city must have policies compatible with its diverse dynamics. However, it is possible to apply some general placement strategies (TfL & AIG, 2007; TfL, 2007a; City of Toronto, 2016; SDOT, 2019a; Driven X Design, 2020); The State of Queensland (Department of Transport and Main Roads), 2020) to achieve a coherent approach:

1. Fingerposts: located at low density of destinations such as intersections of pedestrian routes and minor decision points.
2. Maxi-totem: located at places of high density of destinations, routes or journey choices such as stations, transit nodes, and large parking lots.
3. Mini-totem: located at key intersections or major decision points in busy environments (retail clusters and main streets, for example) where there is limited space for a maxi-totem.
4. Transport totems: located at entrances and exits of transport stations.
5. Route marker & description: used in locations where a panel or a pole may affect the usable width of the walking route (building façade, bus shelters, dwell spaces, etc.); and points of interest such as monuments, parks, open spaces, as well as commercial, cultural, historical, and sporting venues.
6. Sidewalk medallion: placed at the sidewalk of complex environments.

4.4.4. SIGNAGE ACCESSIBILITY

The wayfinding system must ensure accessibility regardless of environmental conditions and the navigator's individual abilities in terms of physical, cognitive, financial, and social capacity. Creating an equative public domain is fundamental to removing possible physical and mental barriers in the built environment and developing an inclusive product design with adequate materials and dimensions. The following recommendations (Neufert, 2000; Teles, 2006; TfL & AIG, 2007; SDOT, 2019a; The State of Queensland [Department of Transport and Main Roads], 2020) have the intent to improve universal access in the city:

- Import content must be located between 900 and 1500mm above the ground.
- Fingerpost information should not be higher than 3000 mm.
- Use of tactile signage with raised letters and symbols, including braille.
- Use of ground surface signs with different textures.
- Provide information about modal integration within the city and its surroundings.
- Prioritize safe and guarded routes.
- Display of alternative routes to avoid a steep slope or a set of stairs.
- Provide free maps available throughout the city.

It is important to emphasize that the level of accessibility of a given area is directly related to its climatic and topographical characteristics. Figure 25 shows the impact of the terrain on the movement of an adult without special needs, demonstrating that depending on the presence of obstacles such as stairs and slopes along the journey, the time taken to cover different distances may be the same. The relationship between distance and time in the PWS design can also vary depending on the availability of alternative routes through urban elevators, for example.

According to the Global Street Design Guide (Rockefeller Philanthropy Advisors Inc /Global Designing Cities Initiative, 2016), walking speeds range from 0.3 m/s to 1.75 m/s. Therefore, to accommodate people with reduced mobility, a walking speed of 1.4 m/s is recommended when determining the configuration of 5 and 15minute walking maps, allowing the inclusion of destinations inside a radius of 420m and 1260m, respectively. It is necessary to assess the locations displayed on maps to guarantee that they have a safe infrastructure for pedestrians and are within acceptable walking distances. Walking times are essential for fingerposts and may also be provided as a list in maxi-totems and transport/local area totems (if space allows).



Figure 25 Distance versus time - the impact of terrain slope on people's movement
Source: SDOT, 2019a.

4.4.5. INCORPORATION OF TECHNOLOGY AND DIGITAL STRATEGY

A digital wayfinding platform should have the same mapping and visual design as the system's physical components to ensure a consistent and accurate image of the city. Therefore, to incorporate technological solutions in the program, the spatial information must have a common language digitally distributed in all online services, including tools such as websites, social media, and smartphone applications. The digital strategy also has to contemplate on-street information with living maps in digital kiosks, Wi-Fi hotspots, and Bluetooth beacons in the signs.

Technology is an industry in constant change, and its products become obsolete quickly. Its application in the Pedestrian Wayfinding Systems represents an innovative approach with a wide range of opportunities. However, it requires high investment and commitment from the agents who operate its maintenance to ensure that the database that supports digital maps is continually updated and the urban furniture is working correctly. In addition, not all people have access to digital devices and an internet connection. Therefore, the use of technology should be seen as a complementary tool since it doesn't replace signage.

4.5. PWS MANAGEMENT

Regarding the post-installation of the pedestrian wayfinding system, it's imperative to consider all the costs from the beginning of the project to ensure its maintenance and updating for future years. The management of the PWS can be a responsibility of public authority (local government, for example),

private organizations, or a partnership between these two sectors. Moreover, the prior development of strategies for temporary signage placement is essential to allow interventions of public information such as during construction works, temporary route closures/diversions, or for special events.

The number of elements and types of signals to be implemented represent a significant percentage of the program's budget. Furthermore, a clear understanding of manufacturing expenses depends on the choice of materials since their quality can secure the system's longevity. They must be robust, sustainable, and compatible with the climate and environmental conditions of the city. Also, the wayfinding signs and maps should be installed close to ambient lighting whenever possible to reduce energy costs.

4.6. SYNTHESIS

The criteria and principles of this guide are a combination of characteristics of pedestrian wayfinding systems that are repeated and stand out in the reference cases presented in chapter three. According to the literature review of this dissertation, navigating spaces requires the understanding of the environment and cognitive skills.

In this sense, this chapter proposes guidelines for the design of PWS, as a well-designed scheme can facilitate essential activities of everyday life, such as going to work, school, leisure, commuting, or shopping. Besides, the signage and information program for pedestrians/walkers can become a vital tool for visitors in a different city, helping them explore the city, find amenities and enjoy local resources such as tourist attractions and cultural events.

5

EXPLORING THE FUTURE SIGNAGE SYSTEM OF OPORTO

5.1. METHODOLOGY

This chapter intends to analyze the case of the city of Oporto, by applying two different approaches. The first approach consists of analyzing the PISI programmed for the Oporto in light of the guidelines presented previously; and the second approach to apply an interactive exercise with people, as part of the co-design process of a wayfinding system.

So, given the criteria and principles established in the guide for the design of pedestrian wayfinding systems (chapter four), section 5.2 presents strategic recommendations to be incorporated into the PISI to help define aspects of the project and contribute to the requirements of the tender specifications.

The second approach is more interpretive and consists of a mental mapping workshop. Although the event was an initial experiment to encourage the involvement of the population and stakeholders in the co-design of the new signage, it does not represent a consistent conclusion to be applied in the case of Oporto. The event's volunteers were people who live and know the Oporto municipality. In addition, they are sensitive to the study of the city.

It is necessary to build trust with the community and approach tourists so that diverse groups of people with different interests participate in various activities related to this research. During the one hour of the workshop, the exercises of landmark recognition and sketch map drawing were prioritized in the context of this investigation, as they were the tasks that could most reflect characteristics of spatial cognition in such a short time.

5.2. THE INTEGRATED SIGNAGE AND INFORMATION PROJECT

The PISI (Projeto Integrado de Sinalização e Informação) is a strategy to improve the urban realm of Oporto, reinforcing its visual identity and legibility, balancing the traffic dynamics between cars and pedestrians, and encouraging walking as the preferred mode of transport. The new project seeks to improve the image of the city as a destination, increasing the number of visitors and residents opting for active mobility. This initiative also aims to boost the local economy, enhance public domain infrastructure and reinforce the sense of community.

The project's main objective is to integrate road and pedestrian signage into a single system, prioritizing information for travelers on foot in central areas of Oporto with a high density of flows. Thus, it intends to enhance the quality of the built environment, optimizing the occupation of public space by connecting places of interest, transport, and services through more pedestrian-friendly paths.

In addition to making the city more accessible, the project aims to enrich the user's experience in the urban context by promoting touristic destinations, notable points, and thematic itineraries. The Municipal Master Plan of the City of Oporto is an essential document regarding regulations for the intervention strategies.

To avoid redundancies, enhance the use of the system, and ensure its coherence, Oporto local authorities established criteria for the standardization of equipment and signage content, interchanges with the transport network, and the hierarchy of information. To define the amount of urban furniture and its distribution in the city, a team composed of urban designers and planners assessed the axes of great pedestrian density and then presented a proposal for efficient and friendly routes for walkers (Figure 26). Studies conducted by the municipality also made it possible to identify the area with existing pedestrian predominance and other centralities with potential for project implementation.



Figure 26 Pedestrian signage network

Source: PISI (Projeto Integrado de Sinalização e Informação) – Oporto municipality.

The signage hierarchy, illustrated in Figure 27, establishes distances for transport infrastructures (metro stations and bus hubs), emergency facilities, landmarks, and urban amenities within circles of 500, 300, and 150m radius. Based on the Guide to Traffic Management Part 13: Road Environment Safety (Austroads, 2007), the estimation of the time spent in minutes to complete these journeys considers the minimum speed of 0.75 m/s, medium of 1.2 m/s, and maximum = 2.4 m/s.



Figure 27 Pedestrian signage hierarchy

Source: PISI (Projeto Integrado de Sinalização e Informação) – Oporto municipality.

The goal is to create a comprehensive plan that includes signs, maps, and technology in a complementary way. For this, the pedestrian wayfinding system should contain the same references, codes, and language throughout the route. Regardless of the location where information is made available, the traveler must be able to perceive the environmental cues as a set. It is imperative to identify and assess existing structures, remove elements from the street, and make the new scheme direct and minimalist.

Once the system functionality is confirmed, the navigator will feel confident using it again. The idea is to improve the quality of signage and make the cityscape more pedestrian-oriented, communicating messages that people can easily understand and learn from the urban space dynamics. Thus, the types, dimensions, and the number of signs proposed in the PISI (Figure 28) seek to ensure proximity to the user.

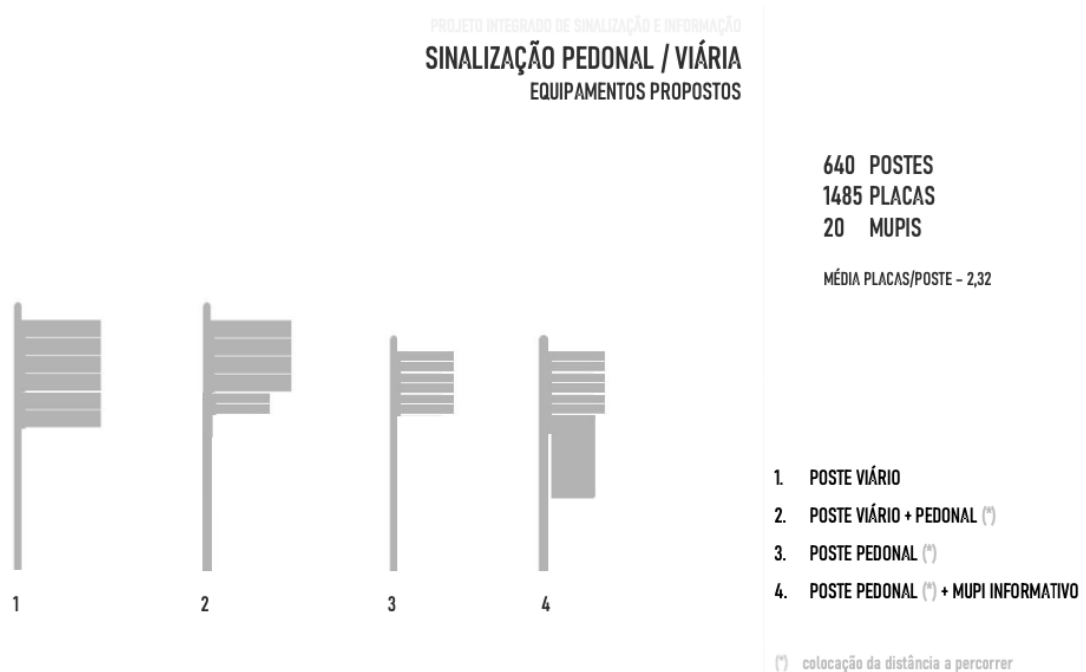


Figure 28 Signage base proposal for pedestrians and roads

Source: PISI (Projeto Integrado de Sinalização e Informação) – Oporto municipality.

5.2.1. STRATEGIC RECOMMENDATIONS

The PISI tender specifications include the clauses of the contract for the supply, installation, and maintenance of urban furniture intended for traffic direction signs under the terms of the Traffic Signaling Regulation (RST). It also contemplates directional and informative pedestrian signage in the Municipality of Oporto.

Incorporating new concepts and techniques during the PWS planning stage is an opportunity to explore ideas that can better people's well-being, both as individuals and as community members. Table 7 highlights excerpts from the tender specifications and offers practical recommendations to support technical decisions by the City Council and serve as basic rules for the participants of the public tender when developing their proposals for the new signage of Oporto.

Table 7 Tender specifications excerpts and recommendations

Source: author of this work.

<i>Tender specifications excerpts</i>	<i>Recommendations</i>
All signs directed to pedestrians must include inscriptions in two languages: Portuguese and English (p.35)	Incorporate additional language(s) onto wayfinding signage in touristic areas and specific zones if appropriate. This need may change over time depending on demographic characteristics or the increase in tourism (review the content annually)
All directional pedestrian fingerposts must indicate the distance to the destination (p.35)	All fingerposts must have walk times to key destinations.
Type I informational signs should include information to support users in the pedestrian area (p.35)	The Type I sign must have the same function and description as a Maxi-totem (chapter 3 of this work). Also, it is essential to establish which information is more relevant for the City of Oporto to communicate its unique urban morphology appropriately
Type II informational signs may contain a map of the redirection of the pedestrian network (p.35)	The Type II sign must have the same function and description as a Mini-totem (chapter 3 of this work) and display a panner-map and a finder-map with respective walking circles
The contractor is responsible for providing a Visual Identity Manual with standards for the size of the characters, colors, symbols, pictograms, and directional arrows (p.36)	The pictograms should be preferably internationally recognizable symbols to ensure legibility
The contractor is responsible for ensuring the maintenance of installed equipment during the term of the contract, scheduled for 3 years (p. 8 and p.10)	Based on the reference cases presented in this study, the contractor is responsible for the maintenance of the system for at least 15 years, considering that it will have a lifetime of 25 years. The tender specifications must allow possible extensions in the contract

In addition to the recommendations mentioned above, the final version of the document should incorporate the following suggestions after validation by the tender organization committee:

- The project's budget must include costs related to the removal of existing signage, fabrication of structural elements, product design, community and stakeholder meetings, prototype testing, delivery, installation, and maintenance throughout the contract.
- The scheme should be prepared by a company with proven expertise in the wayfinding area and developed in conjunction with Oporto municipality.
- The contractor is responsible for preparing a detailed design scheme for a wayfinding system for the inner city and other adjoined/outlying areas outlined in the tender submission.
- The signage of the downtown tourist area that connects the cities of Oporto and Gaia must be developed jointly by the respective municipalities to ensure the legibility of the information, avoiding interruptions in the system.
- Provision of additional elements of the core signage family, such as wall-mounted sign and route marker & Description.
- Use of braille in and tactile ground surface indicators (TGSI).
- Community and stakeholder engagement for co-design the PWS.

5.2.2. DELIVERING THE PLAN

This topic proposes a specific development and implementation plan for the PWS of Oporto to support the criteria already defined by the PISI. For that, the five core principles outlined in chapter 4 (Consistency, Continuity, Connectivity, Accessibility, and Local Distinctness) should be applied when designing a pedestrian signage system that truly meets the needs of city users. To deliver a PWS without problems, every change of mode or environment (physical or virtual) must be intuitive and effortless for the user. Thus, guidance system providers must collaborate to ensure the predictability of all program elements. This structured approach aims to avoid interruptions in the system (Figure 29).

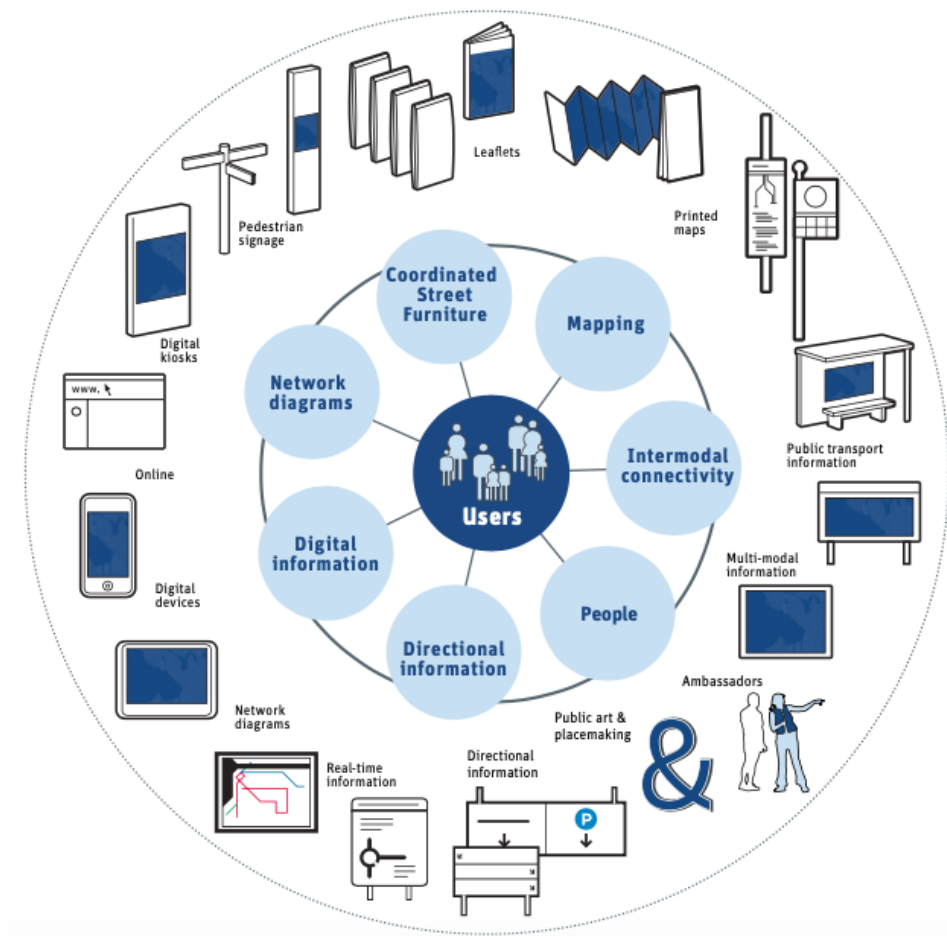


Figure 29 Pedestrian Wayfinding Systems: a user-oriented approach
Source: SDOT, 2019a.

It is essential to delineate routes that contemplate consolidated tourist sites. Nevertheless, the suggested pathways in the maps must also pass-through streets where the offer of commerce and services can be challenging to find, or there are underused spaces with the potential to promote social interactions. Besides, in case lack of funding to implement the PWS city-wide, government authorities, urban designers, and planners should identify and prioritize areas with the highest pedestrian flow and assess the level of existing infrastructure to support walking comfortably and safely.

After confirming the destinations of interest to walkers and the infrastructure conditions of the routes, it is necessary to create conditions for people to stay in the places along the paths, as transformations in the urban environment change the way people navigate and use the city spaces. The hierarchy of destinations of the PISI should be adequate to the scale and complexity of the areas covered by the project, allowing users to create their own hierarchy in their mind maps.

In certain zones of the city of Oporto, the Douro River is an important landmark. Like other natural elements of the landscape or the built environment, such as historical monuments or distinctive buildings, these landmarks can serve as a reference and a key destination, helping people in the wayfinding task. These focal points can also be streets or places people know because they are part of their daily journeys, such as transportation stations, parking lots, sports facilities, community centers, hospitals, and parks.

One of the goals of PWS is to support economic development. However, the reference points selected for the scheme should be defined through community and stakeholder engagement, considering the connectivity and legibility of the environment and not just based on commercial interests. Exploring the meaning of spaces from the perspective of inhabitants and visitors can help define the content of the signs. In this sense, end-users must confirm the names of streets and places, so architects and urbanists can include this information in the signage system.

Before starting the PWS project and preparing its installation, the public entities and private agencies involved need to agree on approval of designs, authorization for the manufacture of signs, and maintenance responsibilities. In addition, the installation plan must contain a schedule of activities with diagrams, photos, or maps with specifications regarding the placement of the signs and their contents.

Each signage element must be selected and located to adapt to the characteristics of its surroundings (scale and angle, for example) and guarantee harmony with the other components of the environment. Also, they must be accessible and perceptible to all people, regardless of their physical or cognitive abilities. The flowchart in Figure 30 describes the strategy for the development and implementation of a Pedestrian Wayfinding System in the city of Oporto.



Figure 30 Indicative implementation plan
Source: author of this work.

The tender specifications of the Integrated Signage and Information Project indicate that the urban equipment to be supplied by the contractor must meet minimum technical and functional specifications, ensuring the following:

- (1) the adoption of environmentally sustainable solutions.
- (2) the durability of all equipment, with the use of high-quality materials and elements of easy maintenance (whether preventive or corrective).
- (3) the equitable use of the system so that the information provided is accessible and perceptible to all groups of users.
- (4) the versatility in use and installation.
- (5) everyone's safety and preventing accident risks.

However, despite the PISI covering principles and criteria that were applied in previous examples and contemplated in the guide of chapter four, in meetings held at the City Council to discuss the development of the project, the following doubts were raised by the members of the Division of Requalification of Public Space:

- How to design an efficient network and spend as little as possible?
- What information is more relevant to communicate in the new signage system? (time or distance to destinations, for example).
- How to create an integrated city database and keep SIA Porto and Mobi-age updated?
- How can we promote a collaborative design process between the community and stakeholders?
- How can we define accessible routes on maps considering obstacles such as street and sidewalk width, steep slopes, and a set of stairs?
- Which agencies should be involved in the design and planning process? (Sociedade de Transportes Colectivos do Porto - STCP and Metro do Porto, for example).

These and other issues need further investigation before finalizing the tender specifications. For this, it is necessary to understand which spatial and cognitive factors influence people's decision to walk through urban space. This knowledge is essential for redefining Oporto's signage and information plan, focusing on the comfort and safety of end-users.

In addition, it is imperative to perform an in-depth analysis of the project's impact on mobility in general, especially concerning the integration with other means of transport. Finally, it is necessary to dedicate

more time to refining the aspects already covered by the PISI and identify and address other demands that might arise.

5.3. WORKSHOP: THE MENTAL MAPS OF THE CITY

In terms of visual connectivity and spatial accessibility, the affective image of the city serves as a powerful tool to help travelers recognize and differentiate urban entities in their mental maps, improving their wayfinding performance. In this way, the analysis of the mobility history provided by the user regarding the navigation task can facilitate the identification of relevant elements and places to be included when designing a PWS.

To reinforce the practical component of this research and gather information for this analysis, a small experimental test (Workshop: the mental images of the city) took place on May 25, 2022, at the Faculty of Engineering of the University of Porto, allowing to test the potential interaction between the stakeholders and the public through a traditional open-style approach (Figure 31).

Fourteen people attended the one-hour meeting, including researchers from the Center for Territory, Transport, and Environment (CITTA), students of the MPPU (Master in Spatial Planning and Urban Project), and community members. Some representatives of the Division of public space requalification of the Oporto municipality were also present.



Figure 31 Workshop: The mental maps of the city
Source: author of this work.

After a brief presentation of the PISI and the schedule of workshop activities, participants received a base map in A3 format. Then they were asked to recognize six points of reference and draw their mental maps of the study area (Annex 1). The first task consisted of looking at the projected images, writing on paper the name they gave to the places, and marking their location on the map. The second task consisted of drawing preferred routes connecting the landmarks and other points of personal interest. All

participants tried to write down and illustrate as much environmental information as they could remember, such as streets, buildings, transport stations, parks, etc. (Annex 2).

5.3.1. THE STUDY AREA

Cities with historical developments are unique and have elevated sensory potential due to their multifaceted urban spaces, which are essential to the dynamic of community life (Wankhede & Wahurwagh, 2016). These distinctive places have a strong imagery signature due to their architectural style, specific cuisine, popular manifestations, everyday life, or the simple engagement in some creative activity.

In this regard, the urban configuration of Oporto is similar to reference cases such as London and Dublin, once they have a high prospect for tourism due to their strong local identity linked to rich historical, cultural, and natural resources. To explore these characteristics is an opportunity to create a multisensory experience in the built environment, shape the affective image of the city, reinforce people's mental maps, and encourage them to walk.

The study area comprises the territory identified as Baixa do Porto. The city cutout of Figure 32, defined by members of the city council's urban space requalification department, has approximately 2,02 km². It is a port zone predominantly focused on commerce and services, focused on tourism. Over the last decade, the city center has become a cosmopolitan center of immeasurable historical value and civic and cultural significance. The presence of public institutions and companies involved in financial and business activities makes the site even more lively and attractive to residents and visitors.

The Baixa do Porto delimitation is a consolidated part of the city. "Composed of blocks from the XVIII, XIX or early XX century, it includes isolated buildings and sets of buildings with heritage interest, very striking for the image of the city of Oporto." (Câmara Municipal do Porto (CMP), 2021). This area can benefit from pedestrian signage. As shown throughout this dissertation, the PDW has the potential to qualify the public space and improve the well-being of users.

In this panorama emerges the urgent need to structure a strategic plan for sustainable growth for the city with a popular participation component to meet the community demands and accommodate the contemporary urban dynamics related to the flow of tourists and demographic changes. To achieve these goals, the agents involved in the transformation of public spaces must work to provide universal access to places of interest and means of transport through the practice of walking.



Figure 32 The map of the study area
Source: author of this work (using Google Maps).

The paths people use to circulate in this area are not the most comfortable and safe. That is because of topographical aspects, obstacles in the streets, and the dominant presence of the car in space. Furthermore, the existing signage is confusing due to the lack of standardization of street furniture and the information communicated by the signs. Therefore, there is an urgent need to implement a pedestrian wayfinding system that conveys a clear message that people can identify and assimilate without effort.

5.3.2. RESEARCH TASKS

The community and stakeholder meeting for co-designing the new pedestrian signage system aims to ensure an inclusive and dynamic research approach and expand the comprehension of the city's legibility through landmark recognition and mental mapping exercises. Proactive participation in the construction of visual and textual narratives of the urban context can help us understand the cognitive process during the wayfinding task and how individuals generate mental images. The workshop's main objective was to gather the information that can be decisive for the PISI and expose different points of view about it.

Landmark recognition tests (Piaget and Inhelder, 1956) allow us to understand people's spatial knowledge. Sketch mapping tasks (Lynch, 1960) enable us to learn how individuals perceive and make

sense of their surroundings, revealing which environmental aspects influence wayfinding behavior the most. Thus, the research tasks were the following:

- (1) Show photographs of six pre-selected landmarks and ask the participants to recognize and locate them on a given paper map.
- (2) Ask the participants to draw mental maps connecting the landmarks and write as much information from their memory, such as streets, buildings, parks, transport stations, reference points, etc.

The predetermined destinations were as follows: Torre dos Clérigos, Estação de São Bento, Mercado Ferreira Borges, Praça da Ribeira, Hospital de Santo António e Praça da República. The images of the landmarks were obtained through Google Street View. The base map showed only the outline of the Douro River and the location of the Oporto City Hall and the D. Luís I Bridge (Figure 33).



Figure 33 Base map for the workshop
Source: author of this work.

The listening process can help decision-makers identify priorities and opportunities related to the project. In addition, the interaction between city planners and end-users is imperative to promote early awareness and support for the project. Finally, to obtain more insights regarding the PISI, questions

related to the content of the signs were presented to encourage people to share their knowledge and opinions through spontaneous conversations:

- (1) What aspects of urban space draw your attention while walking along a city street?
- (2) What information would encourage you to walk more often?

5.3.3. DISCUSSION OF RESULTS

This study analyzed the results through quantitative methods such as counting the number of repetitions of environmental information in the sketch maps and calculating the percentage of accuracy of the names given by the participants to the reference points presented in the photos (Lynch, 1960; Appleyard, 1973).

In addition, the researcher evaluated the spatial representations made by the volunteers according to qualitative criteria such as *map goodness* (in terms of distinction and arrangement of the five urban elements defined by Lynch) and the *relative object positioning* when compared to reality (Willis et al., 2009).

5.3.3.1. Landmark Recognition test

Regarding the accuracy of the location of reference points in the sketch maps, most participants made the spatial arrangement of objects coherently, despite the scale of the drawings being quite different compared to the delimitation of the study area (Figure 34). Although some maps are more detailed than others, this analysis considered the sketches of all 13 volunteers.

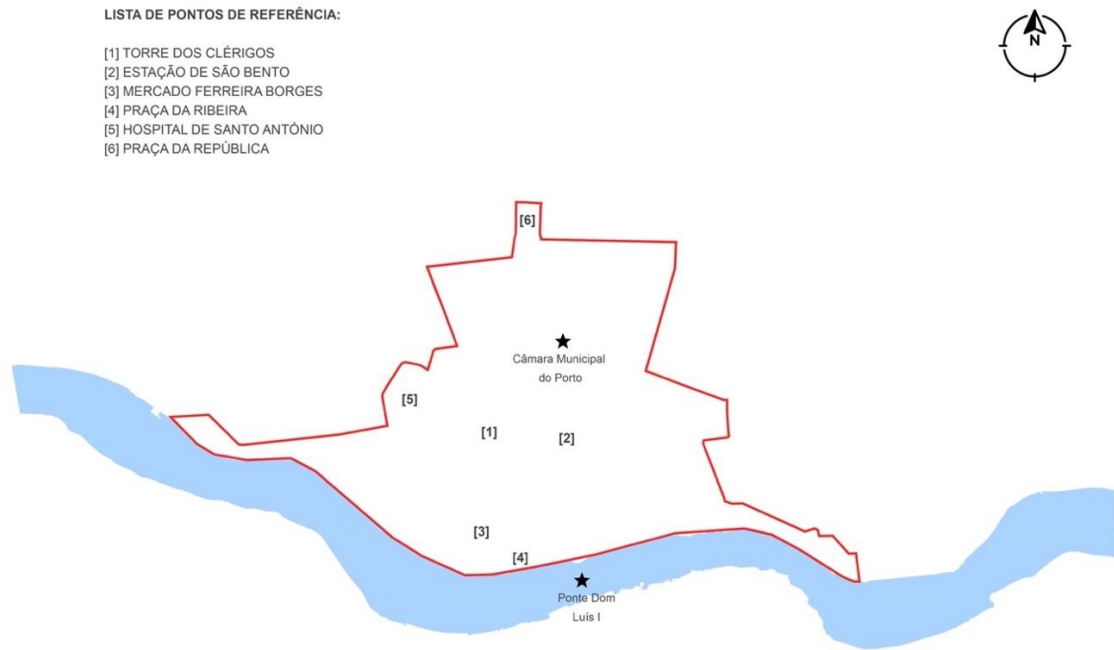


Figure 34 Base map of the workshop with the correct name of landmark and their placement within the study area
Source: author of this work.

The data revealed that not everyone gives the same name to landmarks (Annex 3). Nevertheless, most people knew them by association with other places nearby or their placement in the city, indicating that the presence of these reference points in the built environment may create strong mental images that help people situate and orient themselves when traveling the urban space. Of the total responses, only three did not correspond to the location. Also, two participants did not identify landmark 6 (Praça da República).

5.3.3.2. Sketch Mapping task

The analysis of the maps drawn by the participants made it possible to count landmarks, points of interest, streets, and transport stations aside from those previously identified in the recognition task (Annex 3). This type of exercise can serve as a tool to understand how people articulate urban spaces in the form of mental maps and use them to navigate around the built environment. Nonetheless, the amount of data gathered in the workshop was not enough to define any aspect of the new signage of Oporto. Hence, an efficient pedestrian wayfinding system must enlarge the number of respondents and diversify groups of people involved to better understand perceptions and behaviors and contribute to build a stronger image of the city.

Of the 13 sketch maps of the participants, 6 presented an amount of information considered relevant for this assessment, and 7 of them were too simple to be analyzed as cognitive maps from the perspective

of the five elements of Lynch's urban image (landmarks, paths, nodes, edges, and districts). In the scope of this study, the Douro River (previously established in the base map) is considered an essential edge for the navigation task in the city of Oporto.

Based on the maps, paths include any route illustrated by arrows or lines, referring to streets, tunnels, viaducts, and bridges. Landmarks are not only emblematic points of the city but any building that serves as a personal reference for orientation in the urban environment, such as supermarkets, coffee shops, hotels, bars, restaurants, etc.

The nodes are meeting points such as squares, parks, and transport stations. Although the boundaries of the districts were not very clear in the drawings, it is possible to see the repetition of zones with similar urban characteristics within the study area. For all participants, the landmarks were the most drawn urban elements in their mental maps, followed by paths (Figure 35).

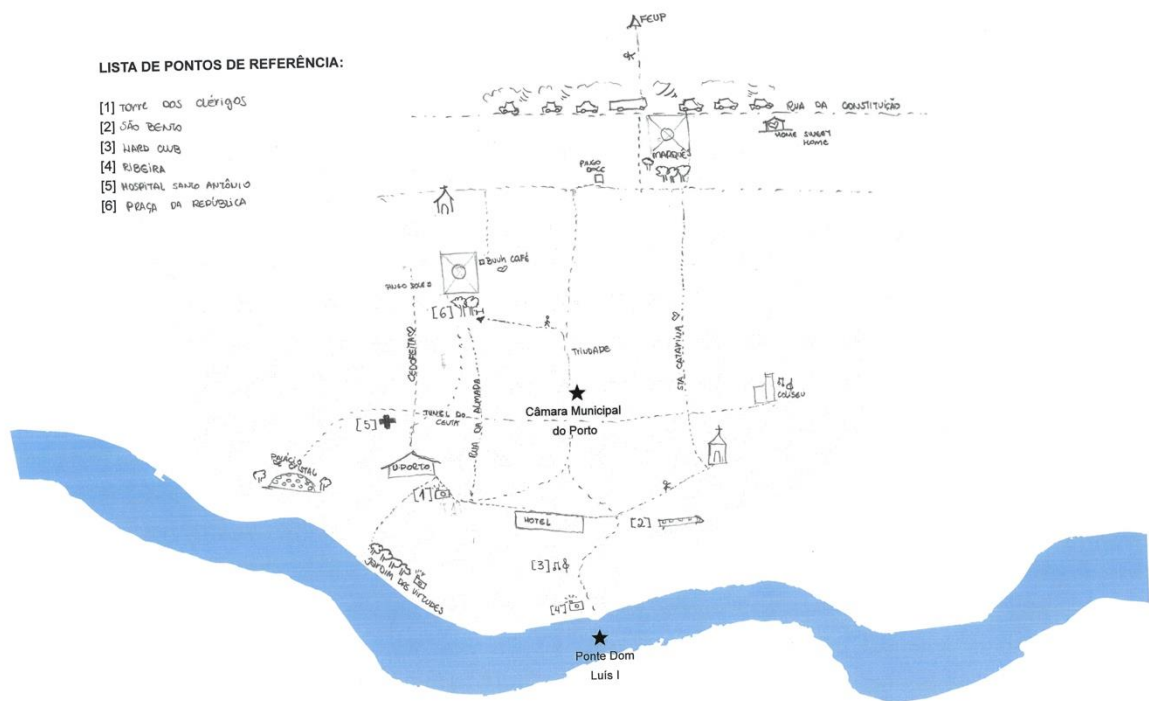


Figure 35 Sketch map of one of the participants of the workshop

Sketch maps were fundamental in studying the emotional bond between people and the city. Some participants drew specific symbols and traced routes based on places they have some affective connection, such as their homes, friends' houses, and recreational spaces. Through illustrations, the participants also identified areas of intensive car traffic and pollution.

Although sketch maps are vulnerable to subjectivity and limited to individual graphic skills (Blades, 1991) most of the results of this research lived up to expectations. Through this activity, people had the opportunity to create their own paths, enabling a better understanding of the influence of urban form on cognitive processes.

5.3.3.3. Answering Key Questions

When asked which aspects of urban space draw their attention while walking along a city street, participants generally mentioned:

- The presence or absence of vegetation/green spaces (natural elements such as trees and gardens).
- The width of the sidewalks.
- The cleanliness of the street.
- Bus stops, subway stations, bike lanes, and parking lots.
- The lack of street lighting during the night, trash bins, excess of visual information, sounds such as music and traffic noise, shadow of the trees, thermal sensation, space crowded with people or cars, and street artists.
- Landmarks such as churches and bridges.
- The state of conservation of buildings and empty spaces.
- Commerce and services (such as coffee shops, bakeries, public amenities, etc.).

When asked what information would encourage them to walk more, participants generally mentioned:

- Maps of the city with places to visit (such as historical monuments), location of pedestrian amenities nearby, the indication of accessible and safe routes, and suggestions for themed tours.
- Directions to transport stations and parking lots.
- Information about physical obstacles such as steep grades, set of stairs, and construction impacts.
- Distance or walk time to destinations.
- Reliable public transport schedules in real-time.
- Information about upcoming events.
- The connection between signage elements and coherence of content.

During the discussion, people also shared that they tend not to explore the city because of their routines and the fact that they feel unsafe walking the streets. In addition, they said that they sometimes make short journeys by car due to a lack of information about pedestrian routes and transport interchanges. Finally, participants expressed that signs with the distance to destinations would encourage them to walk but that the notion of time they would take to get from one place to another promotes a greater sense of mastery over space.

The workshop's results showed that the study area (Baixa do Porto) is a complex environment mainly due to its historical and topographical characteristics. Navigating such spaces is not easy for city residents, and it can be even more complicated for its visitors, especially if the spatial entities are not well defined for navigation and the visual cues are confusing (Stankiewicz and Kalia, 2007).

5.4. SYNTHESIS

This chapter is a summary of the activities developed during the internship to meet the demands of the City Council. It presents a deep analysis of the PISI and its tender specifications, allowing the comparison of the proposal for Oporto with the project guidelines for PWS defined in chapter four. This evaluation aimed to improve the signage and information project from a technical point of view through practical suggestions for urban design and planning.

In addition, it sought to exemplify, through the workshop experiment, how shared experiences and insights from the population have the potential to contribute positively to the process of planning interventions in the city. This participatory approach is also directly related to the experiences of listening to the other, the choice of interlocutors, and the different ways of reporting the meetings (Jacques, 2013). It is important to emphasize that chapter four established phases for designing and delivering pedestrian wayfinding systems. However, this study did not perform all of them due to the lack of time and resources. It is, however, essential that the entities responsible for the program follow each step of the process.

6

CONCLUSIONS AND RECOMMENDATIONS

6.1. MAIN CONCLUSIONS

As explored in the literature review, factors related to human spatial cognition, such as environmental familiarity, cultural and individual differences, sensory experience, urban complexity, and sociodemographic variables, influence people's ability to find their way and navigate through space. Likewise, responsive behaviors such as searching, planning, and following routes not only depend on urban elements and their arrangement in the city but on people's cognitive abilities to capture environmental information and create mental images full of meanings.

People first need to learn from the environment, process the information, and then choose the suitable path to follow according to their needs. Wayfinding behavior is related to spatial cognition, and the users are the ones to assess the quality of environmental elements and defines their hierarchy in mental maps. That said, wayfinding performance depends on physical aspects of space and strategies based on individual experiences.

A person's physical and cognitive abilities influence how they perceive and appropriate their surrounding environment. Thereby, pedestrian wayfinding systems must be empathetic and responsive to the needs of all people, bringing comfort, safety, and confidence for them to travel in the city on foot. It is not just about transformation in physical space but a cultural change. People become much more receptive to active mobility once they know its benefits. Besides that, the user needs to be aware of the navigation tools available and how they work.

Therefore, the perception and representation of spaces can be experienced by all the senses, not just the vision, enriching the personal experience and strengthening the connection between the real world and

generated mental maps. Pedestrian wayfinding systems should provide the necessary tools for the users to become familiar with the city by observing the surroundings. Navigation aids must be connected to different urban layers, including the general transport system, expanding the network and offering people a choice. The goal is to promote path searching and cognitive mapping to improve environment familiarity.

The urban space is constantly changing. Due to this fact, even people familiar with the environment eventually need to discover new places to reinforce the affective image of the city. The simple action of walking benefits people's physical and mental health, so it is imperative to encourage individuals to explore the city through active mobility. This modal change also reduces car traffic and greenhouse emissions, contributes to economic development, attracts investments for public and private sectors, and improves the quality of spaces. These aspects are essential to increase sociability and well-being, promoting urban vitality.

Thus, it is essential to study how the individual's affective image of the city influences the evaluation of the quality of the urban environment. In other words, public spaces are places that reflect the identity of cities, their levels of economic development, and environmental and social balance. With that said, it's necessary to perceive the real journeys people make and stimulate the connections between them and the places, beginning with small interventions and short-term actions to understand the navigators' response to the proposed project and gain their trust.

Given the aspects presented throughout this dissertation, one of its main conclusions refers to the importance of involving the public and stakeholders in co-designing interventions in the urban space, such as the implementation of pedestrian wayfinding systems. Participatory design and urban planning processes focused on end-users arouse people's interest and awareness, encouraging them to explore the city while reinforcing the affective value they attach to places.

Though the mental mapping workshop of Baixa do Porto is considered a test, it was a starting point for future events of similar nature due to its good receptiveness by the agents involved. This experiment demonstrates that methods of interacting with people through community meetings and public hearings, for example, can provide important insights about what the user value as a reference in the environment, helping decision-makers define aspects of the new signaling and information system.

Other contributions of this research are related to the development of the practical guide for the development of PWS based on the understanding of spatial cognition and analysis of reference cases,

whose criteria and principles served as a basis for the recommendations made for the case study of Oporto. In addition to helping to review and propose improvements to the PISI specifications, this work provided suggestions on how to think and design the system legibly and efficiently and raised questions about responsibilities for the project maintenance in the future concerning updating information and conservation of the signage's elements.

6.2. RESEARCH LIMITATIONS

The implementation of the wayfinding system does not represent a definitive solution for the city since its effectiveness depends on the support of several other urban infrastructures and sociocultural factors. Also, it is necessary to analyze the whole map of the Oporto municipality to determine a viable area with a proper scale and demand to design and plan a more detailed PWS and carry out prototype testing.

Furthermore, other research techniques could be applied within the scope of this investigation to obtain more concrete results, such as studies conducted in loco (GPS tracking, think-aloud records, filming, and photography, for example), questionnaires, and verbal interviews, etc. The workshop served as a test to illustrate one of the possibilities of observing and studying the interaction of people concerning the participatory processes between the public and stakeholders in the city's transformation.

These particular limitations leave gaps that need to be filled in the future, allowing the researchers to address conceptual and practical issues in understanding how urban form and its patterns affect route choice behavior. It's also imperative to promote end-user engagement in designing the PWS in different cities to help clarify aspects of navigation and human orientation in urbanized environments, increasing the possibility of the program achieving a good performance after its implementation.

6.3. FUTURE RECOMMENDATIONS

There is a constant desire in contemporary society to create places where people feel a part of them. In this sense, community involvement in urban planning is a decisive matter to be addressed, as it is an approach in which everyone learns. Architects and urban planners have the opportunity to know the patterns and particularities of the built environment and develop skills to design solutions that adapt to changes over time. Likewise, locals can learn about planning, designing, building, and managing spaces.

The new architecture and urbanism projects need to create spaces that suit how people's minds work: how they perceive, imagine, and feel the characteristics of their surroundings. Therefore, identifying the spatial elements and navigation tools that residents and visitors of a city use to orient themselves in the

urban space is essential to understanding how they structure imagery representations of places into mental maps. In this way, decision-makers must pay attention to people's perceptions and emotions about the urban realm, anticipating potential physical and sensory needs and reinforcing key environmental components such as landmarks and paths.

Collaborative action in this process through community and stakeholder engagement creates awareness of how to take care of the inhabited space, improving the quality of the urban domain. This possibility arises from individual and collective experiences in the context of the city and its modes of sharing, in particular, using imagery narratives in forms of mental images and cognitive maps. The observation exposes how people relate to their surroundings.

According to the knowledge revealed by this research, spatial cognition and wayfinding behavior involves a range of aspects and dimensions related to the user's perspective. Therefore, it is necessary to include this understanding in the PWS from the beginning of the project so the city's signage system can adapt and respond effectively to the demands of its inhabitants and visitors, balancing consistency and local diversity. Hence, it is necessary to acknowledge the complexity of the configuration of urban life once it is both dynamic and evolving and static due to its historical heritage. After all, the cities are created and recreated as time goes by.

In this context, the analysis of the subjective and material dimensions that influence people's actions in the city can help the development of navigation tools for pedestrians and improve their wayfinding performance. Urban designers and planners need to create legible places that make people feel welcome. Moving towards a user-oriented approach, the strategies for designing and implementing successful pedestrian wayfinding systems must allow for flexibility and intuitive interpretation. In this sense, it is necessary to include common knowledge in the signage associated with the meanings attributed to space by the users and invest in the infrastructure of streets and urban equipment.

The literature addressed in this dissertation, the activities developed during the internship at Oporto municipality, and the results of the workshop on mental maps reinforced the need for further investigation into how wayfinding systems communicate environmental information in the form of symbolic and textual content. Also, it's essential to continue studying the way people perceive and understand these cues in the navigation task. Finally, exploring spatial cognition and preferences of users in the PWS design can help improve the effectiveness of guidance tools and the overall program performance.

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ANNEX

A1. LANDMARK RECOGNITION TEST



(1) Torre dos Clérigos.



(2) Estação de São Bento.



(3) Mercado Ferreira Borges.



(4) Praça da Ribeira.

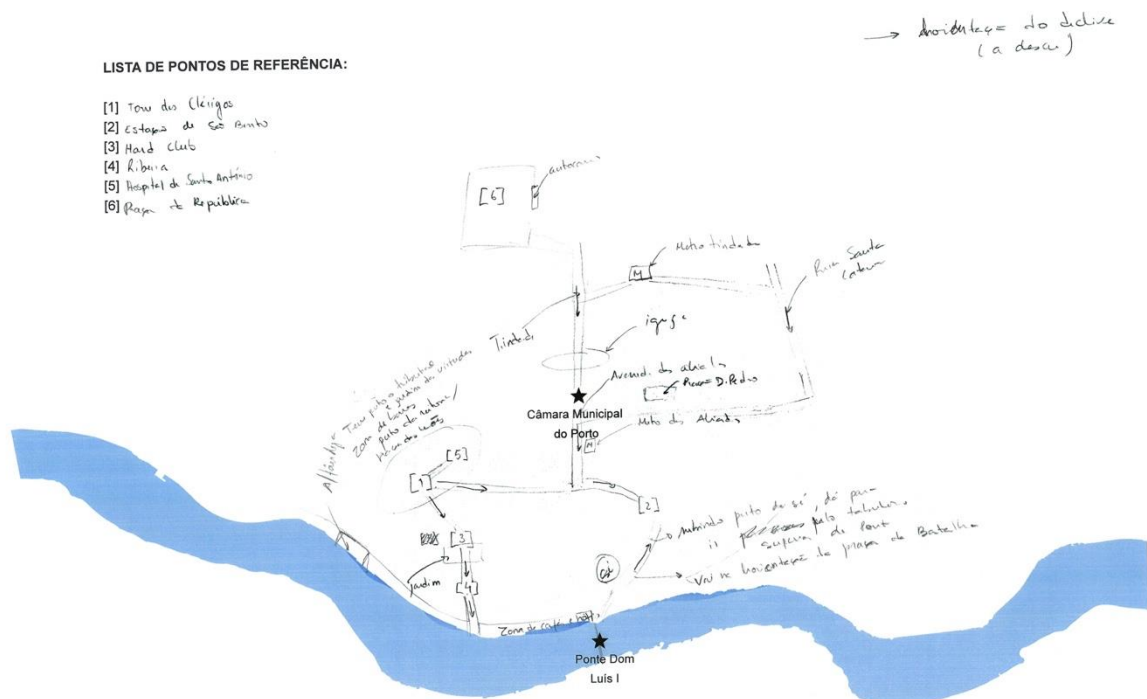
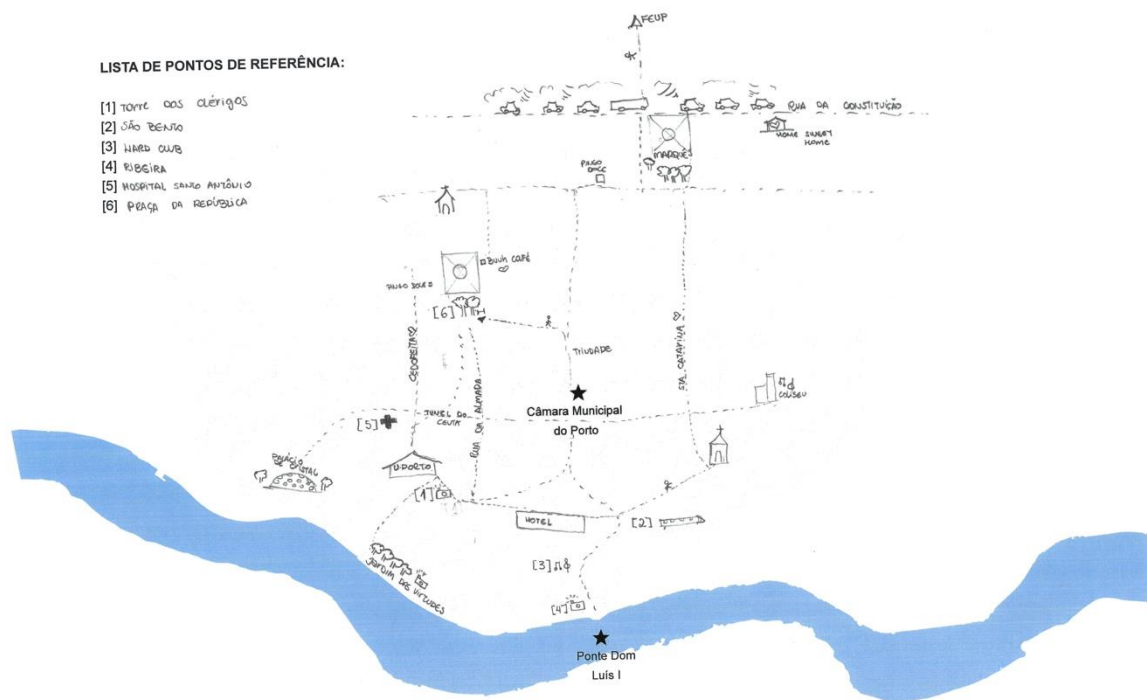


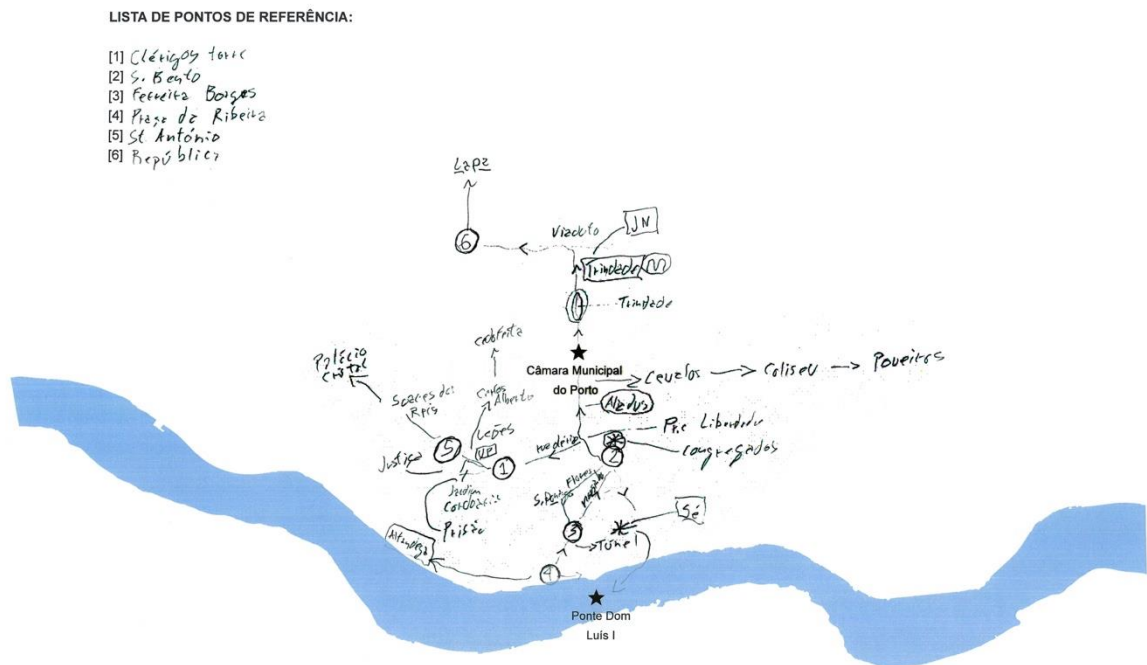
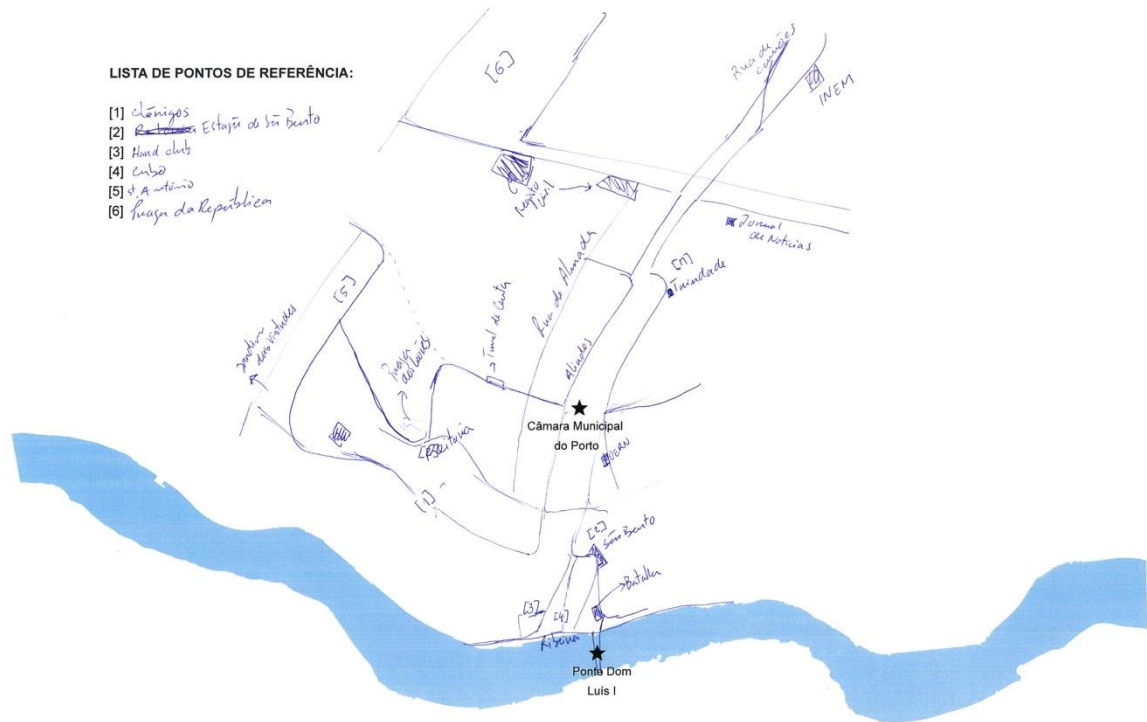
(5) Hospital de Santo António.

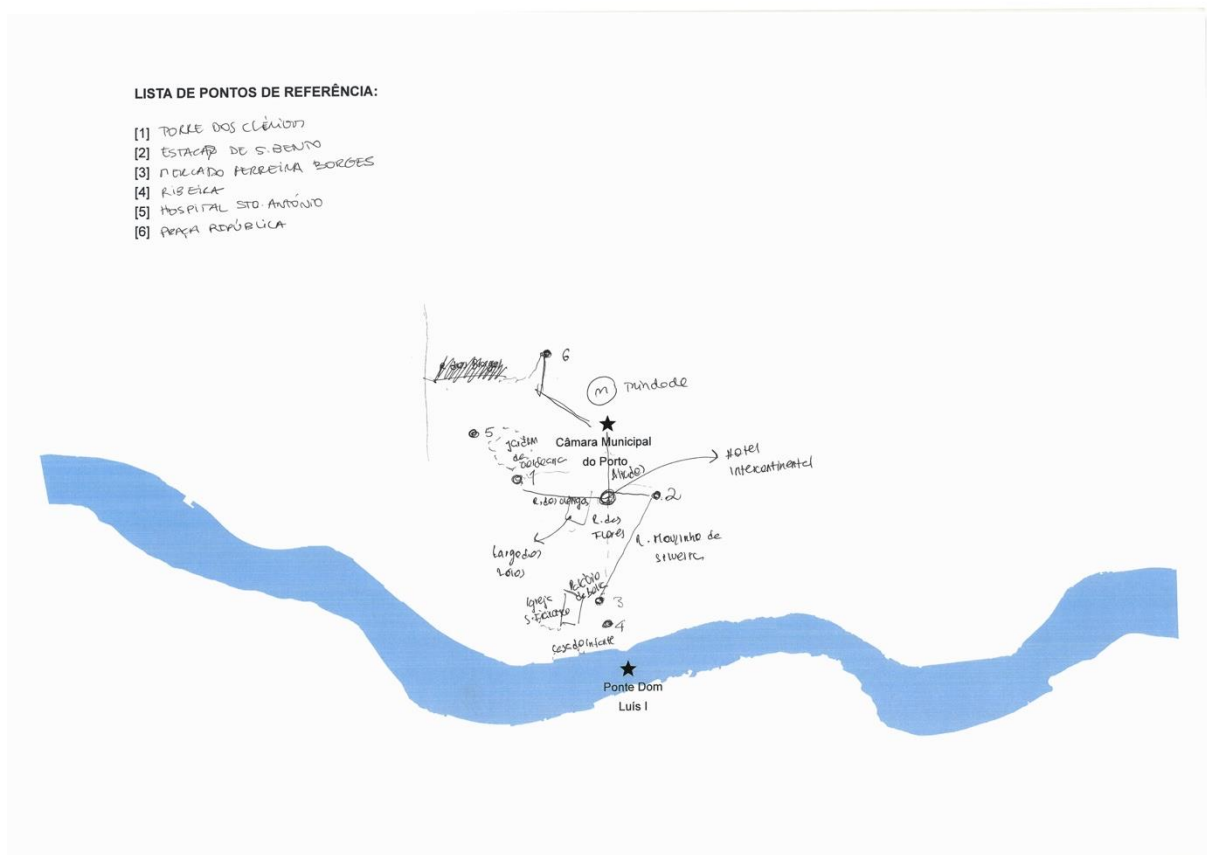
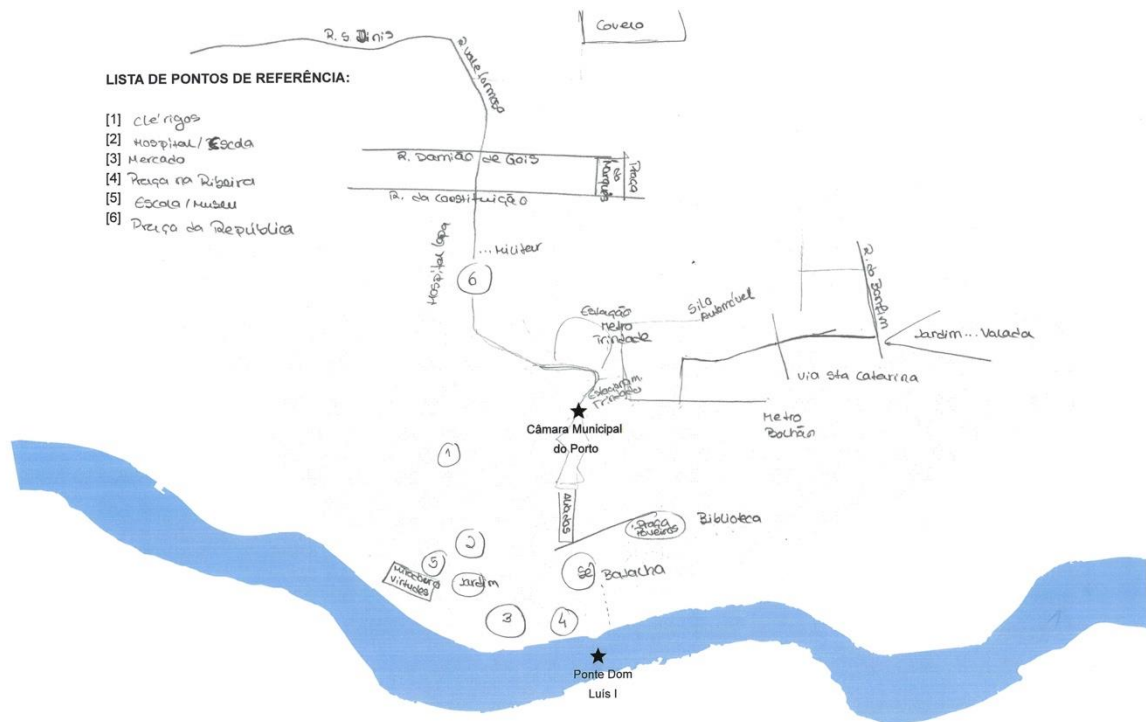


(6) Praça da República.

A2. SAMPLE OF SKETCH MAPS DRAWN FROM MEMORY

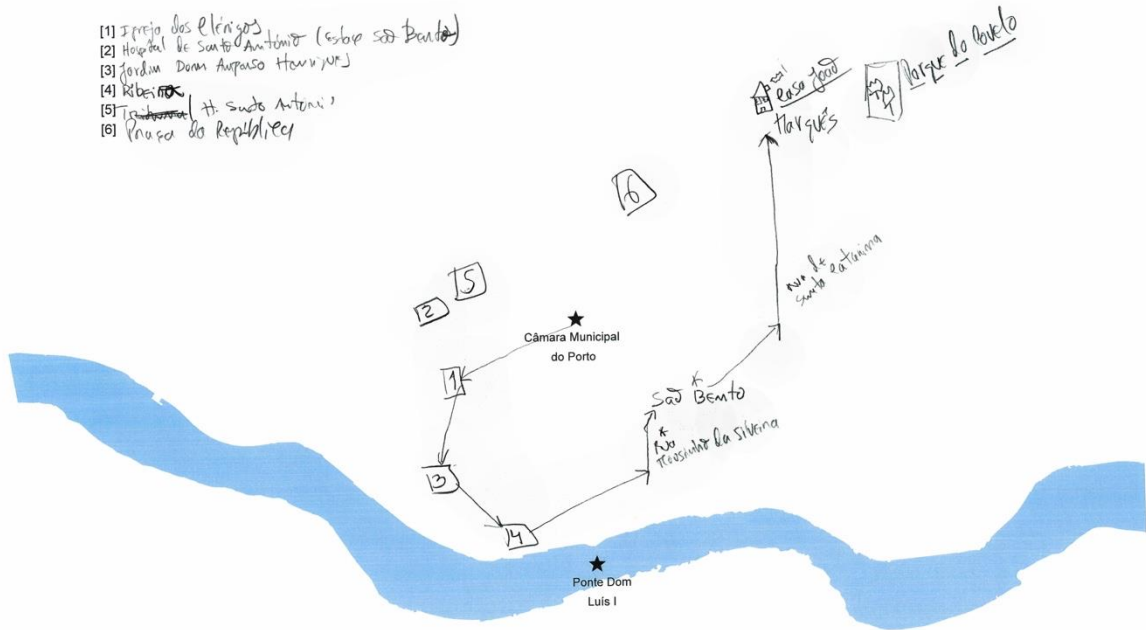






LISTA DE PONTOS DE REFERÊNCIA:

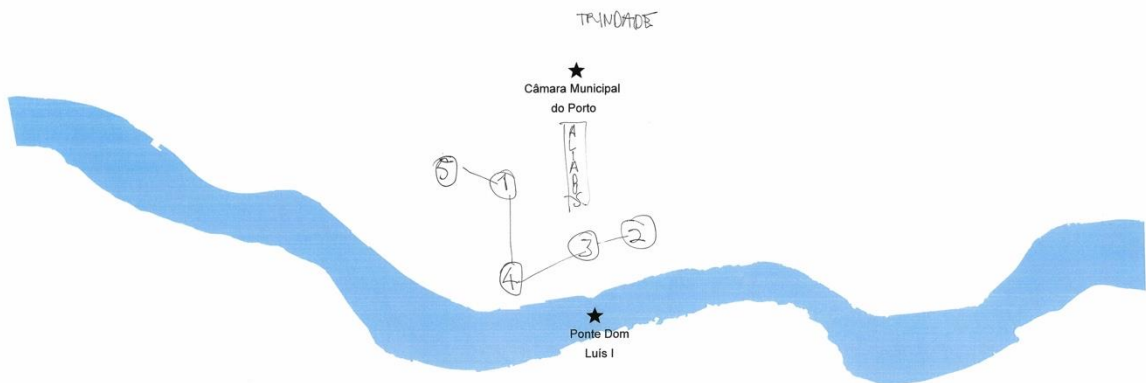
- [1] Igreja dos Clérigos
- [2] Hospital de Santo António (est. São Bento)
- [3] Jardim Dom Afonso Henriques
- [4] Ribeira
- [5] ~~Teatro~~ H. Santo António
- [6] Praça da República



LISTA DE PONTOS DE REFERÊNCIA:

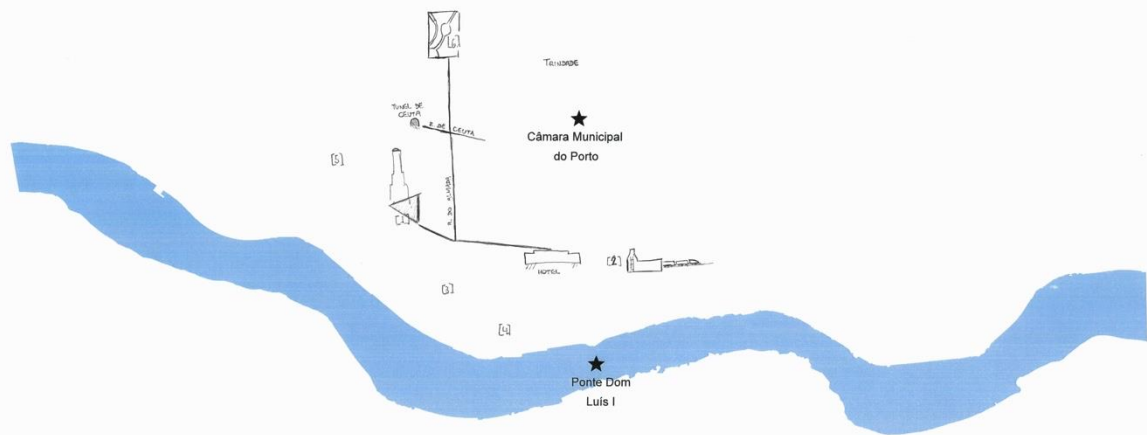
- [1] Torre dos Clérigos / Clérigos (Est. S. Bento)
- [2] Estação S. Bento
- [3] Mercado F. Borges
- [4] CUBO (Centro Histórico)
- [5] Hospital São António
- [6]

DA ESTAÇÃO DE S. BENTO DESCEM ATÉ AO RIO E SEGUIR PELA RIBEIRA ATÉ À ATACA DO CUBO (A FE)



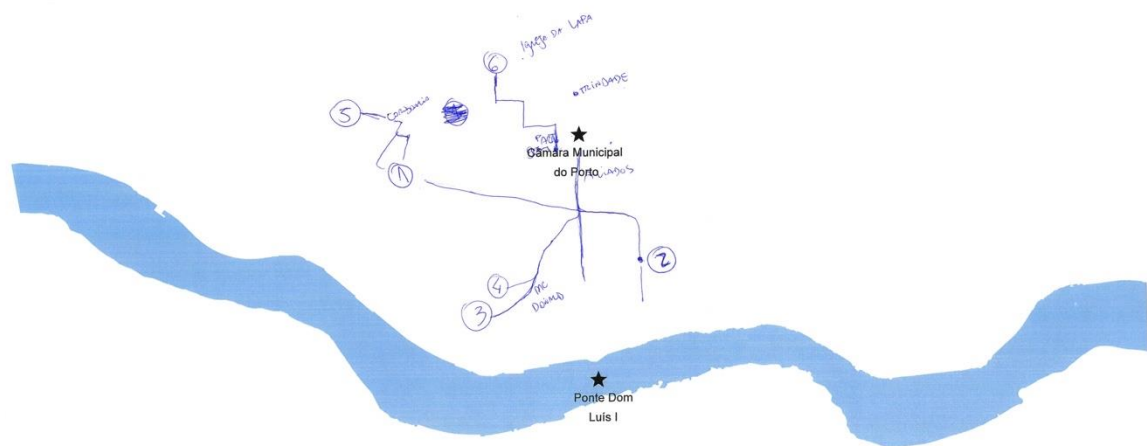
LISTA DE PONTOS DE REFERÊNCIA:

- [1] Torre dos Clérigos
- [2] Estação de S. Bento
- [3] Hotel da Praça da Balsa
- [4] Ribeira
- [5] Hospital / Fac. de Medicina
- [6] Praça da República



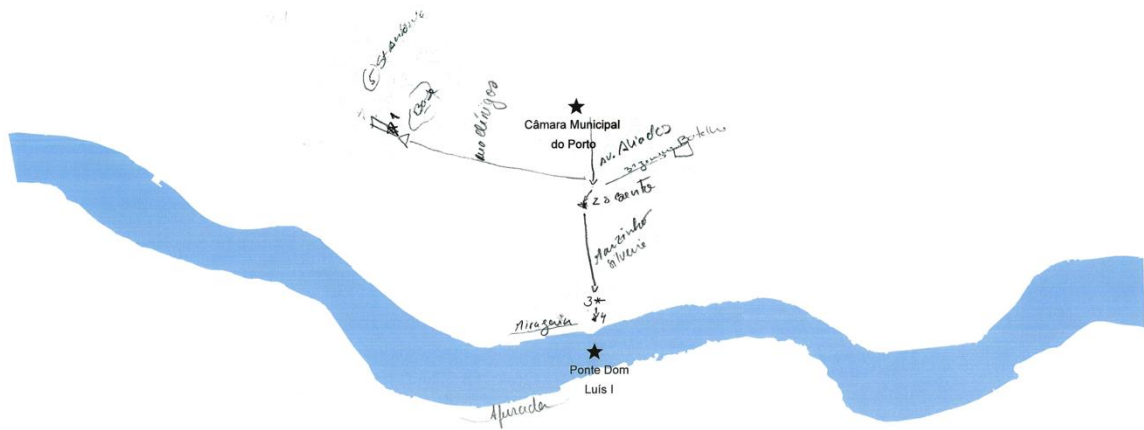
LISTA DE PONTOS DE REFERÊNCIA:

- [1] Clérigos
- [2] Estação São Bento
- [3] Hard Rock
- [4] Rua das Flores
- [5] ~~Praça da República~~ Hospital St. Antonio
- [6] Praça da República



LISTA DE PONTOS DE REFERÊNCIA:

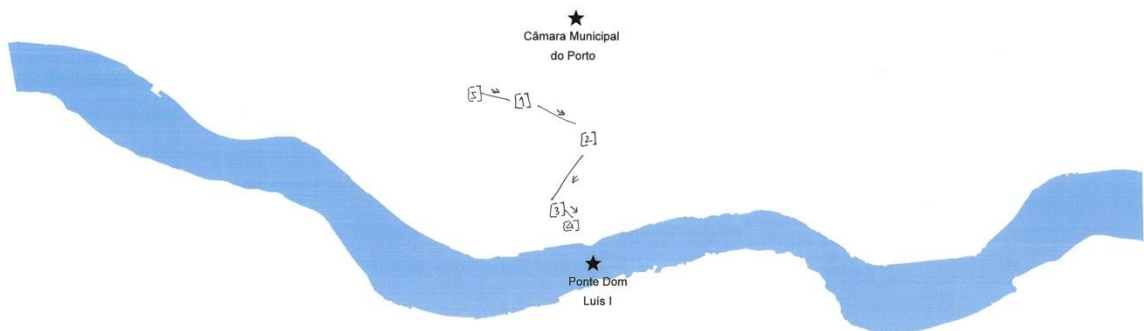
- [1] toro eúrigues
- [2] b bento
- [3] mercado pereira borges
- [4] eubo
- [5] sant antónio
- [6] Praça República



LISTA DE PONTOS DE REFERÊNCIA:

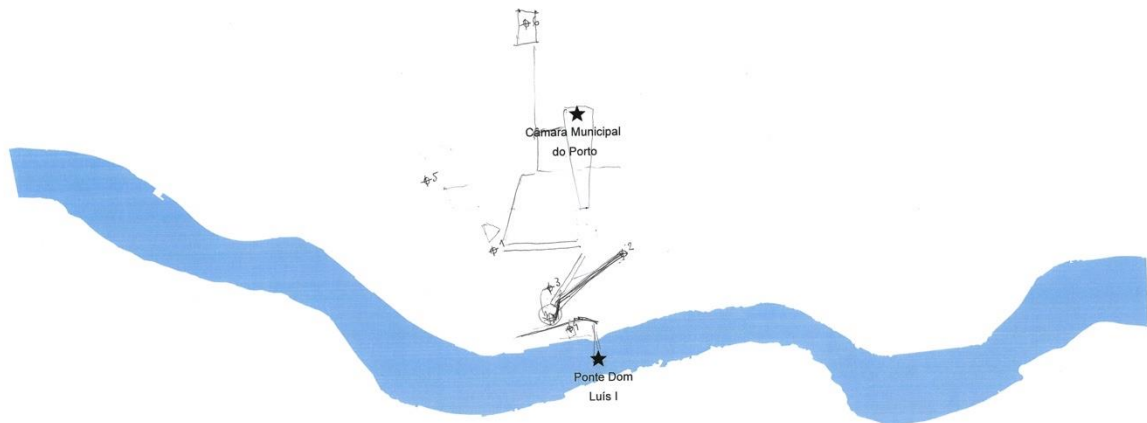
- [1] TOLZE CLÉRIOS - CLÉRIOS
- [2] ESTACÃO S. BENTO - BAIKA
- [3] MERCADO PEREIRA SOARES - BAIKA / RIBEIRA
- [4] PRAÇA DA RIBEIRA / COBO - RIBEIRA
- [5] HOSPITAL SÃO ANTÓNIO
- [6] ?

- ⑤ → ① farro pelos 'leões' + zona tra clérigos
- ① → ② 2. Clérigos + Alameda (Hotel)
- ② → ③ ou pela 2. da igreja ou pela Rua Maria
- ③ → ④ atravessa a rua e fazo a 2. da casa do Infante
- ④ → ⑤



LISTA DE PONTOS DE REFERÊNCIA:

- [1] CIGUELOS
- [2] ESTACÃO SÃO BENTO
- [3] MERCADO PEREIRA ROBERT
- [4] PRAÇA DA LIBERDADE
- [5] HOSPITAL SÃO ANTONIO
- [6] PRAÇA DA BOVATECA



A3. WORKSHOP RESULTS

- **Landmark 1:** 61,5% of the participants got the exact name of the place right or close – Torre dos Clérigos (8); Clérigos (4); Igreja dos Clérigos (1).
- **Landmark 2:** 69,2% of the participants got the exact name of the place right – Estação de São Bento (9); São Bento (3); hospital or School (1).
- **Landmark 3:** 46,1% of the participants got the exact name of the place right – Mercado Ferreira Borges (6); Hard Club (5); Jardim do Infante Dom Henrique (1), Mercado (1);
- **Landmark 4:** 23% of the participants got the exact name of the place right – Praça da Ribeira (3); Ribeira (6); Cubo (3); Rua das Flores (1).
- **Landmark 5:** 61,5% of the participants got the exact name of the place right – Hospital de Santo António (8); Santo Antônio (3); Faculdade de Medicina (1); school or museum (1).
- **Landmark 6:** 76,9% of the participants got the exact name of the place right – Praça da República (10); República (1); Not identified (2).

Table 8 Frequency of landmarks and points of interest remembered by participants

Source: author of this work.

<i>Landmarks and points of interest</i>	<i>Number of mentions on sketch maps</i>
Jardim das Virtudes	3
Sé do Porto	3
Alfândega	3
Hotel Aliados	3
Praça do Marquês de Pombal	3
Fonte dos Leões	3
Túnel do Ceuta	3
Palácio de Cristal	2
Praça dos Poveiros	2
Parque do Covelo	2
Coliseu	2
Reitoria da UPORTO	3
Faculdade de Engenharia	1
Praça Dom João I	1
Igreja da Lapa	1
Palácio da Bolsa	1
Casa do Infante	1

Praça da Liberdade	1
Praça de Carlos Alberto	1
Jardim da Cordoaria	1
Faculdade de Engenharia da UPORTO	1

Table 9 Frequency streets and transport stations remembered by participants

Source: author of this work.

	<i>Streets and transport stations</i>	<i>Number of mentions on sketch maps</i>
<i>Street</i>	Santa Catarina	4
	Cedofeita	4
	Almada	3
	Mouzinho Silveira	3
	Constituição	2
	Vale Formoso	1
	Camões	1
	Damião de Góis	1
	Bonfim	1
	São Dinis	1
<i>Transport stations</i>	Trindade	9
	Aliados	7
	Batalha	4
	Lapa	2
	Bolhão	1

