Studying Wayfinding in Healthcare Facilities Using Two Different MCDA Approaches

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Biomedical Engineering

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Declaration

I declare that this document is an original work of my own authorship and that it fulfils all the requirements of the Code of Conduct and Good Practises of the University of Lisbon.

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Preface

The work presented in this thesis was performed at the Centre for Industrial Management/Traffic & Infrastructure of Katholieke Universiteit Leuven (Leuven, Belgium), during the period February-July 2019, under the supervision of Prof. Dr. Liliane Pintelon, and within the frame of the Erasmus programme. The thesis was co-supervised at Instituto Superior Técnico by Prof. Dr. Ana Vieira.

Abstract

Wayfinding in complex public buildings is an interesting and well-researched area, which discusses elements as static signage (e.g. arrow), use of apps (e.g. indoor GPS - Global Positioning System, for smartphones) and architectural elements of the buildings. This research focuses on a specific area, namely designing an inclusive hospital wayfinding system for patients (and their visitors). Challenges here are not only the complexity of the built environment and the stress patients usually have when visiting a hospital but also the large variety of patients. Some patients have functional disabilities (e.g. visual impairment), have limited mobility and are in wheelchairs, have autism or suffer from dementia. Each of these patient groups have other requirements and needs. Although this is generally recognized, not much work has been done so far to integrate all these different requirements – criteria for optimizing wayfinding systems – in a single model. The present research work provides a comprehensive explanation of the set of aspects collected in the available literature that are linked to the wayfinding performance in complex buildings and specially in healthcare facilities. Moreover, it brought together a set of experts that helped in the structuring process of this factors into a value tree of evaluation criteria and provided their contribute to complement what was previously retrieved from the literature. In order to evaluate the role that these factors play in the wayfinding performance of individuals inserted in one of the user groups here explored, two MCDA – Multi-Criteria Decision Analysis – approaches were selected. The use of MCDA in the current problem allowed to break down its complexity towards an intuitive and transparent process to access the priorities and values of the different users. The approaches used were adapted to the problem under study and an assessment session was conducted with elderly individuals from a retirement home facility. The obtained results contributed to a thorough understanding to which extent the inherent aspects of healthcare facilities affect users while trying to reach their destination in clinics and hospitals. Furthermore, they will hopefully be encouraging enough to expand the dimension of the sample used to assess the criteria weights and engage designers, facility planners and other researchers in the wayfinding domain to work together in developing effective wayfinding systems for such complex environments that account for the diversity of users.

Keywords: Wayfinding, Healthcare Facilities, User Groups, MCDA

Resumo

Wayfinding em edifícios públicos complexos é uma área interessante e onde muito trabalho de pesquisa tem sido desenvolvido. Discute elementos como a sinalização estática (como por exemplo, o uso de setas), o uso de aplicações (por exemplo, GPS – Sistema de Posicionamento Global – em espaços interiores para smartphones) e elementos arquitetónicos dos edifícios. Este trabalho centra-se numa área específica, nomeadamente em projetar um sistema de wayfinding hospitalar que seja inclusivo para pacientes (e para os seus visitantes). Os desafios aqui não são apenas a complexidade dos espaços e o stress dos pacientes quando visitam um hospital, mas também a grande variedade de pacientes. Alguns pacientes têm deficiências funcionais (por exemplo, deficiência visual), mobilidade limitada ou estão em cadeiras de rodas, autismo ou sofrem de demência. Cada um desses grupos de pacientes tem outros requisitos e necessidades. Embora isso seja geralmente reconhecido, o trabalho desenvolvido até agora não tem sido suficiente para integrar todos esses diferentes requisitos – critérios para otimizar o sistema de wayfinding – num só modelo. O presente trabalho fornece uma revisão abrangente do conjunto de aspetos encontrados na literatura que afetam o desempenho das atividades de wayfinding em edifícios complexos e, especialmente, em espaços de saúde. Além disso, reuniu um conjunto de especialistas que ajudaram no processo de estruturação desses fatores numa árvore de valor dos critérios de avaliação e forneceu a sua contribuição para complementar o que foi anteriormente recolhido da literatura. Para avaliar o papel que esses fatores exercem no desempenho de indivíduos inseridos num dos grupos de utilizadores aqui explorados, duas abordagens de MCDA - Análise de Decisão Multicritério - foram selecionadas. A utilização de MCDA no problema actual permitiu quebrar a sua complexidade em relação a um processo intuitivo e transparente para aceder às prioridades e valores dos diferentes utilizadores. As abordagens utilizadas foram adaptadas ao problema em estudo e foi realizada uma sessão de avaliação com idosos de uma instituição de repouso. Os resultados obtidos contribuíram para uma compreensão completa em que medida os aspectos inerentes dos espaços de saúde afetam os utilizadores ao tentar chegar ao seu destino. Além disso, espera-se que sejam encorajadores o suficiente para expendir a dimensão da amostra usada para avaliar os pesos de critérios e envolver designers, gestores de instalações e outros investigadores no domínio de wayfinding para trabalhar em conjunto no desenvolvimento de sistemas eficazes para tais ambientes complexos e que sejam inclusivos para a diversidade de utilizadores.

Palavras-chave: Wayfinding, Espaços de Saúde, Grupos de Utilizadores, MCDA

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List of Acronyms

AHP	Analytic Hierarchy Process
CR	Consistency Ratio
COP	Conditions of Order Preservation
DMs	Decision Makers
ICD	Inter-Connection Density
FPV	Fundamental Point of View
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique
MCDA	Multi-Criteria Decision Analysis
MCDM	Multiple Criteria Decision Making
NHS	National Health Service
LOS	Level of Service
LP	Linear Programming
PE	Passini Era
PoPE	Post-Passini Era
PrePE	Pre-Passini Era
VMM	Value Measurement Model
WG	Working Group
WHO	World Health Organization
WHS	World Health Survey

Chapter 1

Introduction

1.1 Motivation

Have you ever found yourself in the situation of entering a large and unfamiliar building without any clue of where to go? How would you manage to find your way around? Would you prefer to ask people who work there to provide you some orientation, follow signage or would you try to find a map of the place to help you reach the desired destination? Just by addressing these questions we have a little insight on how wayfinding affects our daily lives without even realizing that this important and complex process plays a major role in the way we move ourselves successfully in space from a point X to a point Y.

Back in 1960, the wayfinding concept was firstly introduced, by means of the architect Kevin Lynch on his book *Image of the City*. Five elements were pointed as essential for people to self-navigate themselves effectively in an unfamiliar environment: landmarks, districts (distinct areas within the overall place), nodes, pathways and edges (Lynch, 1960; McMurray, 2019). Approximately ten years after there was a huge revolution in urban signage and the Society of Environmental Graphic Design was founded with designers beginning to study the best way to orient and guide people through spaces (McMurray, 2019). Fifty-nine years after the launch of the concept in the world of research, the basis of wayfinding is still there and despite the large evolution observed on this field, it keeps been addressed the same way.

Wayfinding is present everywhere and anywhere, from shopping malls to airport terminals, from road signs to train and subway stations, from hospitals and healthcare facilities to universities and it has to be always present in the mind of those who are responsible for the design and planning of these public buildings and designated spaces.

The relentless pace of economic growth and the complex spaces that ended up being turned into commonplaces like shopping malls or airport terminals all over the globe urged the need for accurate navigational systems. Besides that, well-oriented people tend to be happier, are willing to spend more money and plan return visits to the same building, all reasons why businesses managers should never overlook the need for a good wayfinding system (McMurray, 2019). Furthermore, an effective and well-designed wayfinding system improves the efficiency, accessibility and safety of the users, and also helps decreasing frustration, stress, anxiety, late arrivals and time spent providing or looking for directions, which by its turn increases the chances of frequent subsequent visits with easily navigation, less frustration and greater satisfaction (Baskaya et al. 2004; Huelat, 2007; Morag et al., 2016).

The complexity of wayfinding goes far beyond getting lost and rather involves a broad set of decisions that an individual must make while moving through an environment to which he/she is not familiar with in order to reach a final destination. Developing a cognitive map, which is a mental representation of the attributes present in environment that surround us and trying to understand the cues that the architectural features provide (e.g. the presence of landmarks, symmetrical elements, signage) are some of the common tasks a user experiences in an unfamiliar building.

In a healthcare environment these tasks can become even more stressful and difficult to achieve as patients are coming in at every second already under stress, confused, nervous or upset, and despite the availability of information, their condition interferes in the retrieving process (Jeffrey, 2011). Plus, a large percentage of the hospital site users are elderly people (Jeffrey, 2011), which is illustrated by the most recent statistics of the British National Health Service (NHS) Information Centre. According to them, almost half (46%) of the patients at hospitals within the London Strategic Health Authority in the period between 2017-18 were aged over 60 years, with almost a fourth (24%) of these patients aged over 75 years (NHS Information Centre, 2018). These numbers have noticeably increased (by 9% and 5%, respectively) since the same statistics were accessed in 2009-10 (NHS Information Centre, 2010), with the highest number of episodes being registered within the 70-74 year group (NHS Information Centre, 2018). Although it would be interesting to cross these statistics with data from other European countries (e.g. Portugal, Belgium or the Netherlands), such information is not disclosure to public access in the same format, so a comparison is not possible.

Since the likelihood of having disabilities increases with the age, the previous group of patients as a frequent user of healthcare facilities, has to be taken into account when designing wayfinding systems in order to make them as inclusive as possible (Jeffrey, 2011).

Because wayfinding relies on the success of the combination between users' characteristics (e.g. sex, age or reported disabilities) and architectural features of the building itself, the work done by Farr et al. (2012) is a milestone in the wayfinding literature as it comprehensively brings together human and environmental related factors that have been used for years in the wayfinding modelling process.

The visibility index (VI) is a remarkable indicator developed by Braaksma et al. (1980) as a quantitative measure for the ease of wayfinding in a built environment. It appeared as an attempt to link the amount of sight lines available in the space with the ease of orientation for an individual (Braaksma et al., 1980, Farr et al. 2012) and in its original formulation was defined as the ratio between the number of sight lines that are available within the area of the building and the number of sight lines that effectively should exist (Tam, 2011). In order to do so, the building's available area has to be modulated and seen as a network with nodes representing the places where the facilities are located and arcs representing the sight lines that exist between the nodes (Tam, 2011).

Space Syntax is commonly defined in the literature as a combination of techniques and principles to analyse and describe the relationships between different spaces of a building or urban areas by looking at their spatial configuration (Jacoby, 2006). Besides the VI, another popular Space Syntax method used on wayfinding research is the Inter-connection density (ICD), developed by O'Neil (1991a) as an objective and quantitative measure that intends to measure the complexity of a floor plan. ICD can be expressed as the average number of directional choices at each decision point within the network (Slone et al., 2015) and O'Neil (1991b) demonstrated that the higher the ICD of a certain environment, the more difficult it becomes for subjects to find their way around.

The development of the present work is motivated by the creation of inclusive wayfinding systems in healthcare facilities and particularly in hospitals, often characterized as challenging environments due to their structure complexity and the large variety of patients they receive daily.

Independently of the context, and as previously stated, the effectiveness of wayfinding relies on the interplay between users' characteristics and the environmental features of the building itself. Retrieving these factors (both human and environmental) is thus essential to understand how different user groups value different characteristics of a certain building.

The introduction of the VI and the ICD was a huge breakthrough in determining the complexity of wayfinding in a built environment. The VI is commonly associated to previous wayfinding models (Braaksma et al., 1980; Farr et al., 2014), designed specifically for airports, but the existence of such models for healthcare facilities is still unknown. In the literature, a lower value of the VI and a higher value of the ICD can only be associated to a more complex environment to perform wayfinding tasks, but the relative importance of this contribution in the wayfinding performance is still unknown. Moreover, and as argued by Farr et al. (2014), the VI can only be used as a measure of visibility, not providing insights into other characteristics that influence the effectiveness of wayfinding in airports and other complex environments.

Other characteristics that affect the way people guide themselves in buildings and particularly in hospitals, like the degree of architectural differentiation or the amount of visible light, should also be part of the equation, which arises the need to build a model that would account for all the environmental factors involved and the estimation of their importance (i.e. their weights). In addition, it is expected a difference in the in this importance between different groups of patients as a user with mobility impairment has a lowered field of vision, so visibility might assume a higher role comparing to other factors, whereas for a user with cognitive impairment, the literature suggests that noticeable landmarks and the number of decisions to make along the way are important characteristics for these group of patients (International Health Facility Guidelines, 2016).

Studying and combining human and environmental factors is a complex and difficult task and only Farr et al. (2014) stand out in the literature for this accomplishment, by developing a Bayesian Network to model wayfinding as a complex system in a generic airport building.

This master thesis intends to follow a different approach to link the two branches of factors. The link will be established by directing the focus to the environmental factors of healthcare facilities that affect user’s wayfinding performance and by trying to establish a relationship between these factors and what the different type of users one can encounter in these places (unimpaired, mobility impaired, cognitive impaired, etc.) value the most.

Designers and facility planners hypothesize and implement multiple strategies to aid wayfinding, but all these strategies are linked with capital cost expenditure. Therefore, research on design prioritization, and concretely on the relative importance of the environmental factors that influence the different hospital user groups, is also fundamental to develop and implement effective wayfinding systems, which according to Pati et al. (2015) is currently missing in the existing literature. By knowing the architectural characteristics that play a major role in the wayfinding process combined with a cost/benefit analysis on design alternatives that address each of them, it’s possible to determine which changes in the design would be more beneficial in reducing the wayfinding complexity for the different categories of users in a short/long term.

1.2 Objectives and Methodology

The present work aims to develop and apply a methodology to determine the relative importance of the environmental factors that influence the different user groups of healthcare facilities. According to Pati et al. (2015), this is currently missing in the literature and is fundamental to develop and implement effective wayfinding systems. In order to meet this overall objective, the following research plan was adopted (from objectives to methods):

1. Ascertaining the environmental factors affecting the complexity of wayfinding tasks in healthcare facilities and the different groups of users that need to be considered when appraising this topic, by conducting an analysis of the available literature for this problematic together with the consultation of an expert panel on the topic;
2. Structuring a MCDA model by combining the environmental factors retrieved from the literature with the knowledge provided by the expert panel;
3. Obtaining the relative importance of the different environmental factors selected to be part of the model with different individuals belonging to one of the user groups predefined in earlier stages of the research, by exploring two MCDA methods. The idea behind the use of these two methods is superficially exploring which would be the most appropriate one to pursue with a conclusive study on the topic, by comparing their outcome and understanding which is the most intuitive according to the selected sample of users.

1.3 Thesis Outline

This master thesis is organized in six chapters – Chapters 1 to 6. Chapter 2 provides basic background concepts to the reader considered fundamental to understand the problem under study and a literature review on the wayfinding topic, both in built environments but also applied to healthcare facilities. It explores the key wayfinding human and environmental factors present in the literature that affect wayfinding complexity and provides a comprehensive framework of how MCDA problems are traditionally approached. Chapter 3 provides an overview of the proposed methodology developed to appraise the problem, detailing and explaining the reasoning behind each step performed. Chapter 4 aims to document how the methodology proposed was used to meet the goals of the present research by detailing all the steps followed in structuring a MCDA model and obtaining the relative importance of the different environmental factors selected to be part of it. Chapter 5 contains the results obtained from the methodology applied, which are further discussed in Chapter 6, where an interpretation of the main findings was conducted. This last chapter also presents the major strengths of the conducted research work together with its major limitations and provide recommendations and possible modifications to the future research to be developed in the topic.

Chapter 2

Background Concepts and Literature Review

The main goal of this chapter is to provide the reader with key concepts on the wayfinding research topic and how it has been addressed in the hospital framework so far (sections 2.1 and 2.2). Since the ease of wayfinding in an unfamiliar environment relies on the interplay between user's characteristics and the environmental cues that the user may extract from the surroundings, a literature review on the factors that contribute to the complexity of the problem is also presented in section 2.3. Because hospital wayfinding systems need to be as inclusive as possible and account for users with varying abilities, section 2.4 of this chapter is dedicated to outline the different user groups that need to be taken into consideration when planning the structure and design of healthcare facilities. Finally, and as explained in the previous chapter, the present master thesis intends to model and study wayfinding in a hospital or healthcare facility using MCDA techniques. Hence, section 2.5 will provide a general insight on this topic, reviewing the essential concepts to implement an adequate methodology.

2.1 Wayfinding Timeline

The existing literature on this topic tends to be subdivided into three different but slightly overlapping eras: the Pre-Passini Era (PrePE), the Passini Era (PE) and the Post-Passini Era (PoPE), with Romedi Passini providing the major breakthroughs on the wayfinding research domain (Hao and Ching Chiuan, 2009; Rooke, 2012). Figure 2.1 intends to depict the three eras by providing a synthesis of the main findings, key pioneers and theories involved. In the PrePE, the architect Kevin Lynch on his book Image of the City (Lynch, 1960), incepted the word wayfinding as he referred to elements like maps, directional signs and street numbers as means of "way-finding". The first definition of the word describes it as a "consistent use and organization of definite sensory cues from the external environment" (Lynch, 1960), which led to its association with spatial orientation and the development of cognitive maps in the PE. The former is defined as the natural ability to formulate an adequate cognitive map of a setting in relation to the surrounding environment (Passini, 1977, 1984) and the latter as a mental representation or overall mental image of the space and layout of a setting (Arthur and Passini, 1992). To better understand the underlying tasks of wayfinding in the real world, Downs and Stea (1973) suggested that it could be broken down into a four-step process represented in Figure 2.2. Their work was still developed in the PrePE, strongly characterized by the theory that individuals when experiencing a certain environment can build mental representations of it and use the available information to guide themselves (Rooke, 2012). The PE is pronounced by all the work developed by Passini (1977, 1984, 1996), an architect and environmental psychologist who argues that wayfinding can also be seen as a spatial problem-solving activity, comprising interrelated processes like decision-making (and the development of a plan of action), decision execution (transforming the plan into appropriate behaviour at the right time and place) and information processing (environmental perception and cognition, which are responsible for the information basis of the two decision-related processes) (Arthur and Passini, 1992).

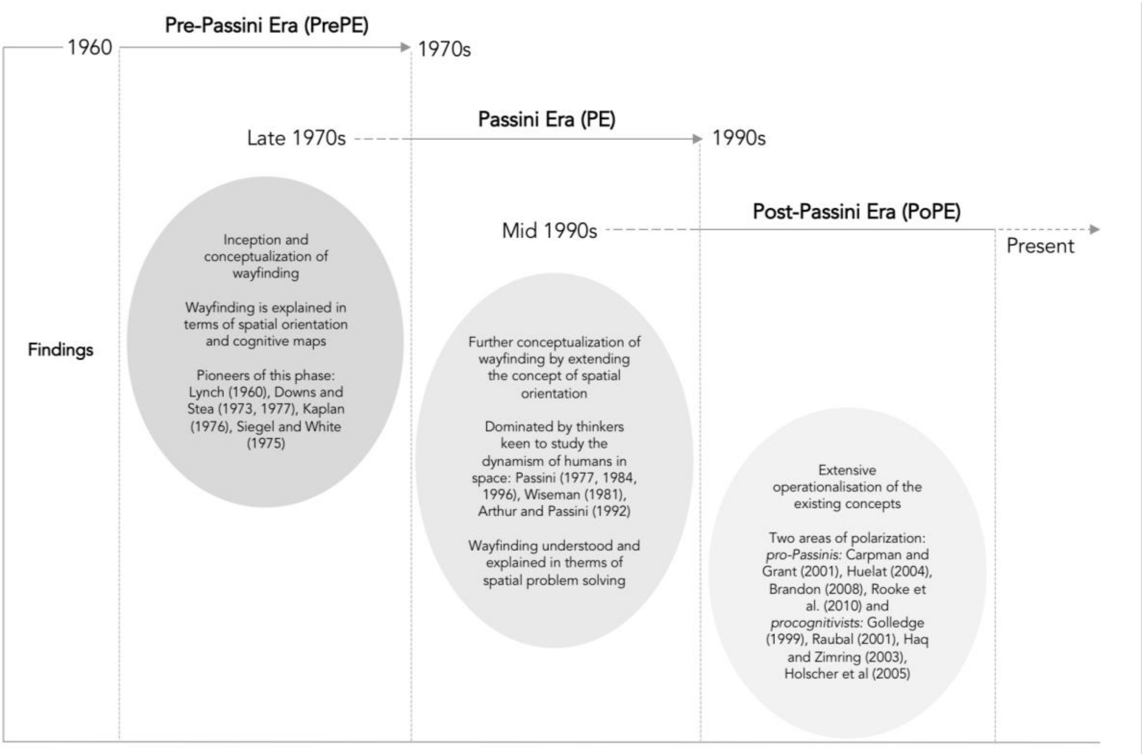


Figure 2.1: The eras of development in wayfinding (Adapted from: Rooke, 2012).

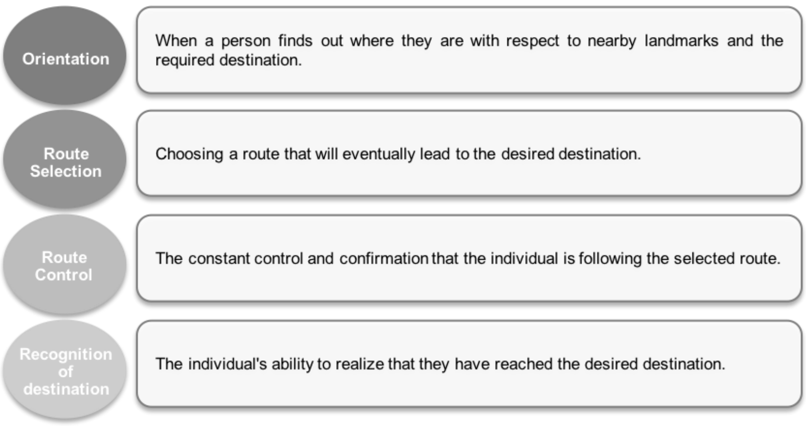


Figure 2.2: Steps involved in the wayfinding process (source: Downs and Stea, 1973).

Making the transition to the current days, wayfinding is defined as the process of people being able to locate themselves in the physical environment and use its cues to find their way to a desired destination (Farr et al., 2012). Although it is a simple concept, wayfinding is indeed a complex problem to deal with in public buildings such as healthcare and transportation facilities, shopping malls and educational campuses (Farr et al., 2012). The present wayfinding research mostly tends to operationalize the existing theoretical concepts developed in the previous eras: spatial orientation, cognitive mapping and spatial problem solving to design solutions, presented in the form of principles and guidelines.

2.2 Wayfinding in Hospitals

The hospital's framework poses several additional challenges to the already complex problem of wayfinding, namely the complexity of the building itself, the large variety of patients, and the fact that when visiting these environments patients may already be under stress, which combined with their navigation to multiple locations increases wayfinding difficulty (Morag et al., 2016). Furthermore, when considering patients within a hospital, one has to remember that there are those with functional disabilities (e.g. visual impairment), limited mobility or that are in wheelchairs or the ones who suffer from dementia or autism and need special attention (Morag et al., 2016). Hence, wayfinding systems in hospitals should be inclusive in the sense that every single patient "with the widest range of abilities within the widest range of situations without the need for special adaptation or design" should be able to find his/her way (BSI, 2008). This means that when considering the hospital architecture, designers should consider the wide range of users with varying abilities instead of trying to adopt a preconceived design to include them.

The 'Principles of Universal Design', outlined in Figure 2.3, and proposed by Connell at al. (1997) appeared as a need to build spaces able to accommodate people with varying abilities, i.e. as inclusive as possible, but can also be used as an evaluation tool to access the inclusivity of existing designs. Illustrative guidelines on how these principles could be addressed have been elaborated and can also be found in Figure 2.3. Although the importance of well-designed wayfinding systems in healthcare facilities like hospitals and clinics is always present, it is often underappreciated, overlooked and rarely included in the healthcare environment planning and design process (Devlin, 2014; Johanes and Yatmo, 2018). While getting lost is evidence of either a poorly designed environment or wayfinding system (rather than inadequacy on the part of the wayfinder), the presence of quality design can promote user's healing. When patients get a comprehensive understanding of the physical environment and are able to use its cues to find the desired destination this provides them with a sense of control and empowerment, which are key factors in reducing stress, anxiety and fear (Arthur and Passini, 1992; Baskaya et al., 2004; Huelat, 2007; Andersson, 2011; Passini et al., 2000; Carpman and Grant, 2001). Reported stress derived problems linked to wayfinding complexity are headaches, elevated blood pressure, increased physical exertion and fatigue (Baskaya et al. 2004; Huelat, 2007) with the likelihood of people avoiding or leaving such environments increasing with experienced wayfinding difficulties (Cubukcu and Nasar, 2005). At the Hospital level the consequences of a wayfinding system that lacks in design quality are related with: lost of time by the staff members, as they have to interrupt their activities to provide directions; delayed and missing appointments when patients don't reach the departments where they are scheduled to attend on time or because they already left the hospital due to dissatisfaction and frustration or even potential lawsuits as a result of users wandering into spaces that are not part of the hospital's public sphere (Carpman and Grant, 2001; Water et al., 2018; Morag et al., 2016).

In 2013, 6.9 million outpatient hospital appointments were report missing each year in the UK (where an average cost of one of these appointments was £108), with doctors attributing a significant blame to navigation problems within the facilities (Pinchin, 2015). Missed appointments are frequently related

1 Equitable Use

The design is useful and marketable to people with diverse abilities.

Guidelines:

- Provide the same means of use for all users: identical whenever possible; equivalent when not.
- Avoid segregating or stigmatizing any users.
- Provisions for privacy, security, and safety should be equally available to all users.
- Make the design appealing to all users.

2 Flexibility in Design

The design accommodates a wide range of individual preferences and abilities.

Guidelines:

- Provide choice in methods of use.
- Accommodate right- or left-handed access and use.
- Facilitate the user's accuracy and precision.
- Provide adaptability to the user's pace.

3 Simple and Intuitive Use

The use of the design is easy to understand, regardless of the user's experience knowledge, language skills or current concentration level.

Guidelines:

- Eliminate unnecessary complexity.
- Be consistent with user expectations and intuition.
- Accommodate a wide range of literacy and language skills.
- Arrange information consistent with its importance.
- Provide effective prompting and feedback during and after task completion.

4 Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines:

- Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.
- Provide adequate contrast between essential information and its surroundings.
- Maximize "legibility" of essential information.
- Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).
- Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

5 Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

Guidelines:

- Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
- Provide warnings of hazards and errors.
- Provide fail safe features.
- Discourage unconscious action in tasks that require vigilance.

6 Low Physical Effort

The design can be used efficiently and comfortably with a minimum of fatigue.

Guidelines:

- Allow user to maintain a neutral body position.
- Use reasonable operating forces.
- Minimize repetitive actions.
- Minimize sustained physical effort.

7 Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation and use regardless of users body size, posture or mobility.

Guidelines:

- Provide a clear line of sight to important elements for any seated or standing user.
- Make reach to all components comfortable for any seated or standing user.
- Accommodate variations in hand and grip size.
- Provide adequate space for the use of assistive devices or personal assistance

Figure 2.3: Principles of universal design proposed by Connell et al. (1997) with illustrative guidelines developed by Rhoads (2013).

with inefficiencies in the delivery of healthcare, giving rise to major monetary losses for health systems and delays in providing adequate healthcare to the nonattending patient (diagnosis and treatment) (Urganci, 2013). The most recent report on outpatient activity in English NHS hospitals was published in November of 2017 and shows us that the number of outpatients' appointments is increasing together with the number of attended ones as both have nearly doubled within the time window depicted in Figure 2.4 (Health and Social Care Information Centre (2018)). In 2016/17 the average cost of one of these appointments was £120 and according to Figure 2.5, 6.7% of the patients did not attend to them (which corresponds to approximately 8 million appointments missed), resulting in a loss of almost £1 billion to the English NHS (Slawson, 2017; NHS Digital 2018a). Although it would be interesting to cross these statistics with data from other European countries (e.g. Portugal, Belgium or the Netherlands), such information is not disclosure to public access in the same format, so a comparison here is not possible.

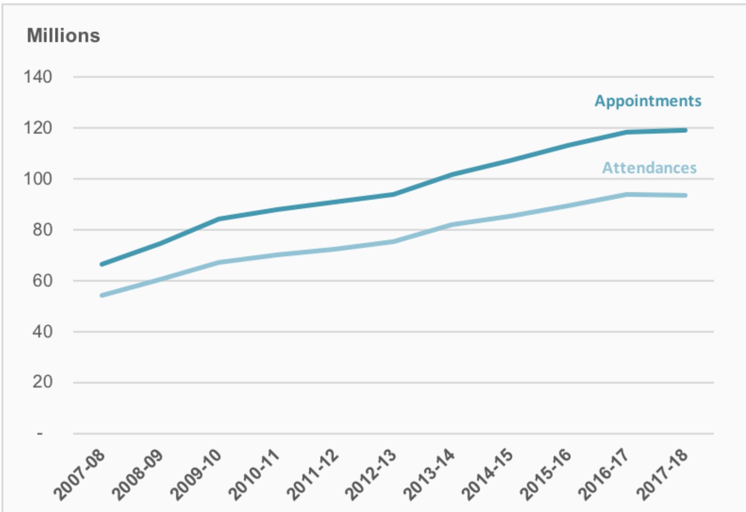
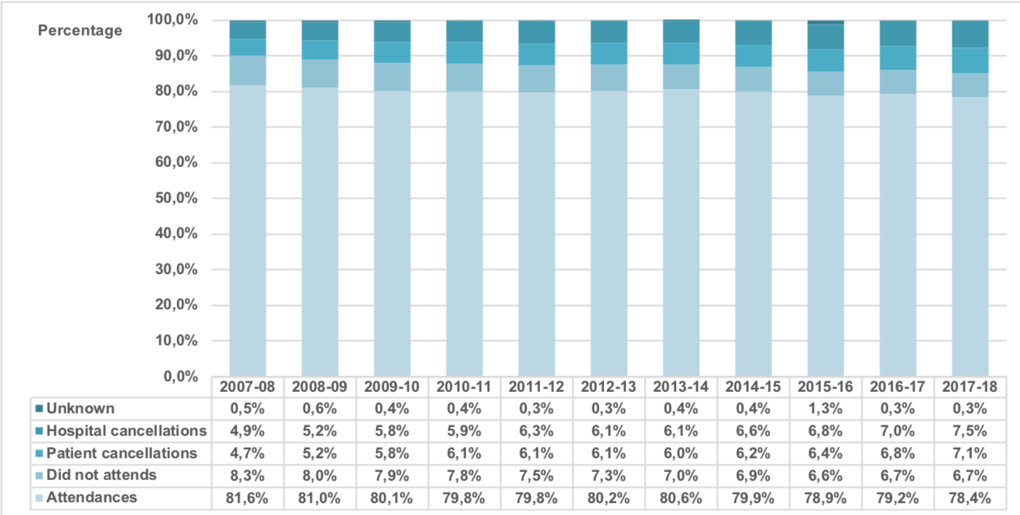


Figure 2.4: Summary of outpatient appointments and attendances from 2007-08 to 2017-18 (Adapted from NHS Digital; 2018a).

When additional orientation aids are present in the environment (e.g. directional signs) the stress levels of the users tend to decrease as determined by Berkowitz et al. (1979). Still. if the amount of signage present is too dense, this might also be an indication of a poor wayfinding system present in the facility, which hampers users to find their way easily with the signage being used as a remedy to improve the confoundedness of the building (Koncelik, 1976). The effectiveness of wayfinding, independently of the context, is always an interplay between users' characteristics (e.g. sex, age, reported disabilities such as vision impairment or dementia) and architectural features of the building itself, with visibility and accessibility playing a major role in the people's ease in guiding themselves. As a combination of both type of factors, a user is able to make decisions based on information depicted from the environment and move from his/her current position towards the desired destination (Casakin et al., 2000; Farr et al., 2012).



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Unknown	0,5%	0,6%	0,4%	0,4%	0,3%	0,3%	0,4%	0,4%	1,3%	0,3%	0,3%
Hospital cancellations	4,9%	5,2%	5,8%	5,9%	6,3%	6,1%	6,1%	6,6%	6,8%	7,0%	7,5%
Patient cancellations	4,7%	5,2%	5,8%	6,1%	6,1%	6,1%	6,0%	6,2%	6,4%	6,8%	7,1%
Did not attends	8,3%	8,0%	7,9%	7,8%	7,5%	7,3%	7,0%	6,9%	6,6%	6,7%	6,7%
Attendances	81,6%	81,0%	80,1%	79,8%	79,8%	80,2%	80,6%	79,9%	78,9%	79,2%	78,4%

Figure 2.5: Percentages of outpatient appointments by attendance type from 2007-08 to 2017-18 (Adapted from NHS Digital, 2018a).

2.3 Factors Involved in Wayfinding

A literature review to assess such wayfinding factors was conducted using PubMed, IEEE Xplore and ScienceDirect databases and included journals written in English that were published up to May 2019. The inclusion criteria were based on keywords as: “wayfinding”, “wayfinding in hospitals”, "wayfinding factors", "wayfinding human factors" and "wayfinding architectural/design factors". The results of the literature review are essentially categorized into two non-overlapping branches: the human factors branch (here presented in subsection 2.3.1) and the environmental branch with the factors that surround the wayfinder (presented in subsection 2.3.2). This categorization is consistent with the literature and supports the theory that wayfinding is in fact an interplay between both types of factors.

2.3.1 Human Factors

Given that the present research is focused on the wayfinding complexity as a result of the architectural characteristics of the facilities, the human factors will be only briefly addressed. In Table 2.1, a summary with the most relevant factors collected from the literature is presented. Figure 2.6 was developed based on the work of Farr et al. (2012) and provides an overview of how some of the human factors listed in Table 2.1 interrelate with each other. As can be depicted, spatial orientation is the ability of forming a cognitive map as described before, which in its turn is the result of the cognitive mapping process, but the spatial ability of an individual influences his/her capability of successfully obtaining spatial orientation.

Table 2.1: Summary of human wayfinding factors.

Human Factor	References
Spatial Orientation (Defined as the ability to form a cognitive map)	Tolman, (1948), Downs and Stea (1973), Arthur and Passini (1992), Jesus (1994), Borgianni and Setola (2016)
Brain Organization (Neuroanatomical differences in the brain regions involved in spatial orientation)	Iaria et al., (2003), Iaria et al., (2008)
Degree of familiarity with the environment **Age** **Occupation** **Individual psychology**	Weisman (1981), Bryant (1982), Peponis et al., (1990), O' Neill, (1991a)
Gender (Generally male subjects tend to perform better in spatial activities in wayfinding, while women show greater spatial anxiety than men, which negatively influences the navigational ability and spatial performance, but they have better object memory and object-location and tend to adapt more easily to changing route instructions)	Weisman (1981), Peponis et al., (1990), O' Neill, (1991a), Chai and Jacobs (2009), Slone et al., (2015)
Language and culture (E.g. cross-cultural understanding of symbols)	Whorf, (1941), Carroll, (1956), Grice, P. (1989), Foster and Afzalnia, (2005), Frank, (2009), Anacta and Schwering, (2010)
Biological (A better performance in spatial tasks can be attributed to testosterone or the exposure to this hormone or to a more pronounced right hemisphere in male subjects, whereas in women, the different phases of the menstrual cycle cause a fluctuation in the performance of such tasks)	McGlone, (1980), Chiarello et al., (1989), Halpern and Tan (2001), Jonasson, (2005), Lawton, (2010), Gabriel et al., (2011)
Route selection choices and strategies used (E.g. least angle, initial angle, least number of turns, fine-to-course)	Seneviratne and Morrall, (1985), Bailenson et al., (2000), Dalton (2003), Wiener and Mallot, (2003), Hochmair and Karlsson, (2005)
Cognitive factors (Environmental cognition and cognitive mapping)	Ueberschaer, (1971), Downs and Stea (1973), Kitchin, (1994), Borgianni and Setola, (2016)

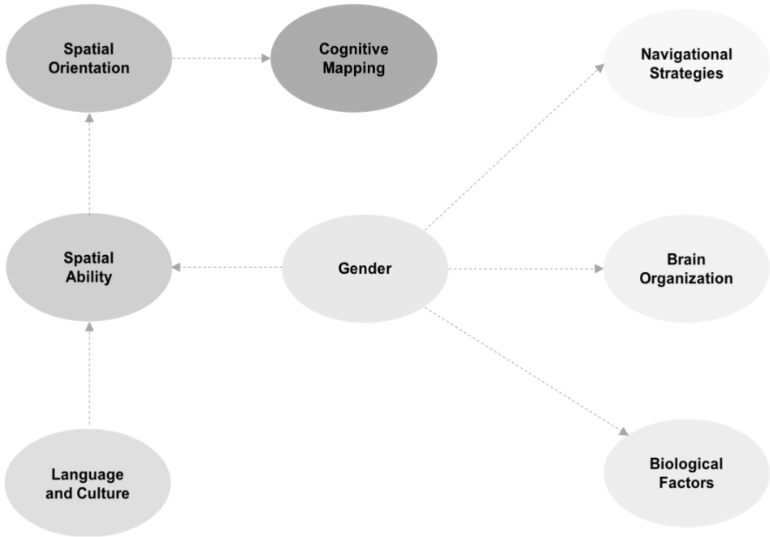


Figure 2.6: Interdependency between some of the human factors listed in Table 2.2 (source: Adapted from Farr et al., 2012).

2.3.2 Environmental Factors

The present subsection will focus on presenting all the key findings on how and to which extent, the different environmental factors found in the literature affect users' wayfinding performance. Concerning the environmental factors, the existing literature points out the morphological complexity of the facility's layout, also referred to plan configuration, as the most important architectural characteristic on wayfinding performance, followed by visual access, spatial differentiation and signage (Weisman, 1981; Montello and Sas, 2006). However, others argue that the traditional use of signage has failed to succeed in dealing with the wayfinding problem in hospitals, and it is being used as a remedy to overcome the poorly designed buildings (Koncelik, 1976; Rooke et al., 2009).

Wayfinding is also considered a multi-sensory exercise, as users make use of four of their senses (sight, sound, touch and smell), while performing a wayfinding task (Jeffrey, 1999). Therefore, another important contribution to the effectiveness of wayfinding systems is the extent to which healthcare facilities account for how the different users use their senses while walking around and trying to find their way (Jeffrey, 1999).

2.3.2.1 Route Complexity

The expansion and modernization of hospitals due do the increasing demand for healthcare, specialized care and diagnostic techniques, tends to increase the complexity of the routes that patients must follow to reach their destinations (Zijlstra et al., 2016). The complexity of these routes is intrinsically related with the morphological complexity of the facility's layout.

In order to define the degree of complexity of a flow, Borgianni and Setola (2016) aggregate four characteristics: the configurational accessibility of the environment, the distance between the steps of the path, the depth between arrival and destination and the sequence of procedures that the user must follow to reach his/her destination. It is desirable that a patient's flow would be able to follow a linear trend from the moment he/she enters the hospital until the moment the final destination/service is reached (environment A in Figure 2.7). Users find themselves passing places where they have already been for a different service and this creates disorientation and discontinuity (Borgianni and Setola, 2016). A low level of wayfinding complexity is represented by the situation where a patient moves from the main entrance of the hospital to the location of the service, shifting from more integrated spaces that can be easily accessed to less integrated ones, more isolated without passing through a place several times (Borgianni and Setola, 2016).

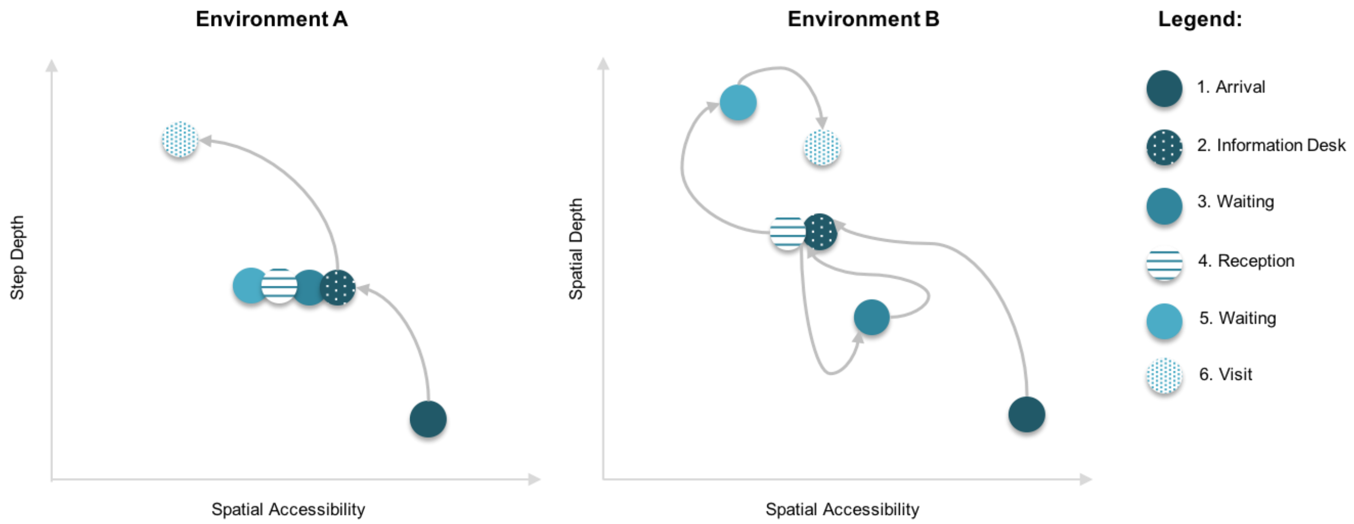


Figure 2.7: Diagrams representing the complexity of users' flow in two distinct environments (Adapted from Borgianni and Setola, 2016). **Notes:** In environment A, the flow presents a low degree of complexity whereas environment B presents a high degree of complexity. The x-axes show the evolution in the integration parameter at each spaced crossed, whereas the y-axes depict the depth of each space from the first step of the flow, the moment the user arrives at the facility. The arrows indicate the consequential order in which procedural steps must be performed.

The unit shape of the building depicts the main path of walking through it. It can for instance be an axial line, in which case the user has to pass the central point frequently when traveling between areas (e.g. I, H, T shapes), a circular one (O shape) or a combination of multiple basic shapes (Montello and Pick, 1993; Hozak, 2016). Thus, one can easily see that this aspect also influences the way people walk around the facility by confining the routes that can be followed. Zijlstra et al. (2016), enumerate other factors such as building interchanges and floor changes as attributes to increase the complexity of patients' route. For instance these floor changes contemplate the situations where the user needs to access floors that are not directly connected with the ground floor (e.g. the user needs to reach a certain location within a floor of the building but needs to go to an intermediate floor first and from there find the connection to the destination floor).

Finally, the literature also commonly refers to the ICD, introduced by O'Neil (1991a) as an objective measure of spatial complexity (Cubukcu, 2003; Slone et al., 2015). The ICD can be expressed as the average number of directional choices at each decision point, and can be calculated using equation 1

(Dada, 1997; Slone et al., 2015). Therefore, an ICD of 2 can be interpreted as a maximum of two directions to choose from at every decision point (Dada, 1997).

$$ICD = \frac{Total\ number\ of\ directional\ links}{Number\ of\ decision\ points} \quad (1)$$

A decision point is a node within the network, usually arising from the intersection of two or more corridors, where the user must choose the route to follow or where there is a need to acquire more information to help in finding the correct direction (Dada, 1997). O'Neil (1991b) developed experiments that verified the negative correlation that exists between the ease of wayfinding and the increase in the ICD. The availability of more options at every decision point (i.e., environments with higher values of ICD), increases the number of spatial relationships to be remembered, makes the user take more time to reach the destination, to take more wrong turns along the path and to backtrack his/her route more often (Slone et al., 2015).

The Level of Service (LOS) is traditionally defined in the literature as a qualitative measure to describe the quality of service of a travelling facility from the traveller's standpoint (Transportation Research Board, 2000). In its turn, the quality of service can be affected by aspects such as the travel time, the freedom to circulate, traffic interruptions, comfort and convenience (Transportation Research Board, 2000). In his research work, Dada (1997) also correlate the LOS within a certain airport terminal with the easy of orientation and ultimately with the ICD and the VI. Table 2.2 contains the five levels of service defined by Dada (1997) and the most suitable ICD intervals for each of them. From the information present on this table, one can also denote the relationship that can be established between the complexity of the building and the amount of signage needed to aid wayfinding. The more complex the building becomes, the more the wayfinders rely on signage to find their way around.

2.3.2.2 Visibility

Visual access or visibility is defined as the opportunity of people moving through a sequence of spaces to see into adjacent spaces (Trzpuc, 2010). It can be quantified by the extent to which the different parts of an environment can be seen from multiple viewpoints (Cubukcu, 2003). The literature often uses the VI as a quantitative measure for the ease of wayfinding in a built environment (Dada, 1997; Tam, 2011; Farr et al, 2012). This index was initially developed in 1980 by Braaksma et al. (1980), using the principle that individuals orient themselves towards a certain destination by finding sight lines that connect their current place in the environment with the place they want to move towards to (Farr et al. 2012). Sight lines are defined as visual connections between two points and are present in the network whenever one location can be visually accessed from another (Braaksma et al., 1980; Dada, 1997). Therefore, the VI attempts to link the amount of sight lines available in the space with the ease of orientation for an individual and can be defined as the ratio between the number of sight lines that are available within the area of the building and the number of sight lines that effectively should exist (Tam, 2011). In order to do so, the building's available area has to be modulated and seen as a network

Table 2.2: Levels of service proposed by Dada (1997) and their correlation with the ICD within airport terminals.

Levels of Service	Definition	ICD
LOS A	Building is not complex. There are few decision points and few choices to be made et these decision points. Most parts of the building are visually perceptible from all activity centers. There is little possibility of disorientation and wayfinding is very easy. There is little likelihood of asking for directions and there is little need for directional signs.	ICD < 1.7 (well above average)
LOS B	Building is not complex but there are more choices to be made at decision points. A good number of activity centers are visually perceptible from all points within the building. There is a low possibility of getting lost, but there is some propensity for asking for directions. Some directional signs are needed.	1.7 < ICD < 2.1 (above average)
LOS C	Building is moderately complex There are more choices to be made at decision points. Visibility is somewhat impaired. The possibility of wayfinding problems exists, and some disorientation is expected. Wayfinders are likely to ask for directions, and a fair number of directional signs are needed.	2.1 < ICD < 2.5 (average)
LOS D	Building is complex. There are more choices at decision points and confusion is likely. Visibility is limited and there is a high potential for wayfinding and problems. Wayfinders are more likely to ask for directions. Extensive directional signs are needed.	2.5 < ICD < 2.9 (above average)
LOS E	Building is very complex. There are many choices to be made at decision points. Only few places are visible from each activity center. Wayfinders rely almost entirely on directional signs and asking for directions. There is a high potential for getting lost and disoriented. Extensive signing is needed.	ICD > 2.9 (well below average)

with nodes, often referred to as activity centres, representing the places where the facilities are located and arcs representing the sight lines that exist between the nodes (Tam, 2011). Equation 2 describes how the VI can be calculated, where VI is the numerical value for the VI of the environment, L_s the number of available sight lines and N is the number of nodes in the network, with higher index values supporting the ease of wayfinding in a certain environment.

$$VI = \frac{L_s}{N\,(N-1)} \qquad (2)$$

Dada (1997) tested the relationship between the VI and the ICD using data from different airport terminals. The VI used was the pre-occupancy VI (the VI before the building becomes occupied) which accordingly to Braaksma et al. (1980), is strongly correlated with the post-occupancy VI (the VI while the building is being used). For the terminals included in the analysis (12 environments from 5 different airports), the results obtained demonstrated that there is a strong (inverse) relationship between the pre-occupancy VI and the ICD, with seventy six percent of the variation in the VI being explained by the ICD (Dada, 1997). ICD values greater than 3.0 were associated with very low VI values, and the opposite was also verified, with the environments presenting a very low ICD (lower than 2.0) having the highest VI (Dada, 1997). Furthermore, the proposed regression equation based on the available data (Equation 3) implies that when the ICD lies between 3.0 and 4.0, the VI will be close to 0 (Dada, 1997). Therefore, walking around the building and trying to execute wayfinding tasks may be very difficult for the users due to the lack of visibility.

$$VI = 1 - 0.3ICD \tag{3}$$

2.3.2.3 Differentiation

The degree of architectural differentiation in a building intends to quantify to which extent different areas of the building appear to be unique or confusing due to symmetry and repetition of similar elements. Differentiation of the architectural elements present in the various spaces of a facility can be introduced by varying their size, shape, colour or architecture style (Montello and Sas, 2006). According to Baskaya et al. (2004), the more distinct a place tends to be, the more easily it will serve as a cue to guide human experience and decision-making behaviour. Therefore, the monotony of architectural elements and the lack of reference points or landmarks tend to increase the complexity of wayfinding in hospital leaving each space less distinct and memorable from others. Nevertheless, facilities should present a balanced degree of differentiation within spaces, as the presence of extreme differentiation can lead to users' disorientation and frustration (Montello and Sas, 2006).

To evaluate the degree of differentiation of a certain environment there are two main characteristics that should be considered: 1) the degree of similarity within each floor and 2) its interchange between floors of the same building. In its turn, architectural differentiation within each floor can be evaluated by means of horizontal differentiation, vertical differentiation or a combination of both (Sun, 2010).

The existing literature states that vertical differentiations are the more memorable cues selected along a path, particularly in learning and recalling turning points along it, whereas horizontal differentiations enable the user to encode spatial relations between objects and paths, enhancing the development of a cognitive map of the area (Sorrows and Hirtle, 1999). Vertical differentiation is intrinsically related with the presence of landmarks, defined as objects or elements used to indicate a position or area along a route or at a destination (Sun, 2010). A landmark can be either considered local or global depending on how visible they are for the user (Cubukcu, 2003). The former tends to be visible within a restricted area and is normally present in the environment in the form of simple objects (e.g. a memorable bench, fountain or a flower pot), whereas the latter has a higher visual range, which means the user can see it from far away and from multiple locations (e.g. a monument) (Cubukcu, 2003). Finally, the last aspect to retain about landmarks is their uniqueness in the environment, as the more unique and non-repetitive these elements tend to be across the facility, the more value is added to the wayfinding experience (Cubukcu, 2003). Regarding their location in the facility, they should be placed strategically in the environment and along the patients' route as they tend to be more effective when associated with decision or transition points (nodes), acting as mental anchor points in the cognitive map developed by the user by helping him/her in the re-orientation process in case of getting lost (Cubukcu, 2003; International Health Facility Guidelines, 2006).

Path hierarchy was firstly associated to the legibility of a physical environment by Lynch in 1960 (Cubukcu, 2003). However, Cubukcu (2003) was the first to test empirically the extent to which changes in the pavement, often referred as horizontal differentiation, enhance users' wayfinding performance as vertical differentiation does. Horizontal differentiation can be introduced by varying road pavement and road width, creating path hierarchy (Cubukcu, 2003). Finally, vertical and horizontal differentiation can be achieved by varying the corridor width, also to create path hierarchy, with the most efficient corridors being wider between the start and the destination point (Sun, 2010). When considering the architectural variations that occur between floors of the same building, it is desirable to minimize them as much as possible as if two interconnected floors differ significantly from each other, the user has to repeatedly create a new cognitive map on every level and look for a new and unknown route (Montello and Pick, 1993). Following this line of thought, the wayfinding complexity is significantly decreased if space like reception desks at main departments, bathrooms, waiting areas and other common areas that are present in every floor are respectively placed of top of another, i.e. if the different floors of the facility are structural symmetric.

2.3.2.4 Trade-off Between Horizontality and Verticality

As the horizontal plane is neutral to the axis of gravity, it provides a stable walking and sitting surface and the storage of objects (Hölscher et al., 2013). Reflecting this property, the functions of a building are mostly organized horizontally, reflecting this property (Hölscher et al., 2013). However, it is frequent to find stack floors on top of one another, so the representational structure is known as "bicoded" with the space in the plane of locomotion being computed separately and represented differently from space in the orthogonal plane. Whereas the former is continuous and aligned with the floors, regardless of its division into corridors and partitions, the latter is discontinuous and discretized as we can encounter floors are on top of one another, with local connections being made through escalators, stairs or elevators (Jeffery et al., 2013; Hölscher et al., 2013). Furthermore, unlike the horizontal dimension, the vertical one is visually limited to the current or directly adjacent floor and it's perceived indirectly or derived by inference processes (Hölscher et al., 2013). Linking the trade-off between horizontally and verticality with wayfinding tasks, some studies demonstrated that humans often experience some difficulties in correctly aligning vertical spaces in pointing tasks and in integrating survey knowledge (related with the orientation and distance between locations in the environment) of different floors (Montello and Pick, 1993). Moreover, wayfinders may also experience other type of difficulties concerning the connection the mental horizontal floorplans at intersection points like staircases which can be increased by the changes in direction while climbing (Hölscher et al., 2006).

2.3.2.5 Circulation Flows

At the hospital level one can encounter several types of overlapping flows: patients who come for consultations or day clinic, patients who are in a ward, visitors, medical doctors, nurses, logistic staff, technicians, etc. According to Borgianni et al. (2016), the two main circulation flows are the public and the healthcare ones. It is desirable to have a separation between them that reflects the two different integration cores, each comprised of the spaces most accessible to the users of the two categories. It is important to understand how the hospital works in terms of co-presence and to which extent the two integration cores overlap. In other words, if the hospital was designed with the aim of separating public flows from healthcare flows or if these flows are mixed and patients often have to pass through corridors that intend to serve healthcare professionals to reach their destination (Borgianni et al., 2016). For some patients the experience of co-presence either can cause disorientation, confusion and delays in the time of travelling inside the unit and passing through corridors which contain rooms for the exclusive use of healthcare professionals can result in people trying to enter restricted areas where they don't belong. Thus, smoothing the flow of patients in the corridors of a Hospital, besides reducing the overflow also allows them to find their way easily and reliably by reducing the stress, anxiety and the time wasted and improves the user satisfaction. High flow intensities, i.e. crowded places, tend to affect user's movement pattern by diverting locomotion and forcing the user to adapt his/her wayfinding strategy (Yi et al., 2015; Li et al., 2019).

2.3.2.6 Environmental Sensations

As previously stated, wayfinding is considered a multi-sensory exercise, as users make use of their senses, while performing a wayfinding task (Jeffrey, 1999). Thus, the environmental sensation they experience while walking around the facility and the cues they are able to extract from their surroundings by making use of their senses affect the overall wayfinding performance. Among all the four senses, smell is typically the one which is not often directly linked with the wayfinding performance of users, as the smells from the environment tend to be not specific enough to help them finding their way around (Jeffrey, 1999). Nonetheless, smells can affect the emotional state of the user either by worsening his/her wayfinding experience (e.g. bad smells from toilets, medicines or artificial smells) or by aiding in spatial orientation (Kopvol, 2010). Detecting characteristic smells, like the smell coming from a cafeteria, helps the user in remembering and identifying spaces. Regarding the tactile sensations that users can experience while circulating around the facility, changes in internal floor and external pathway texture are used to delineate the different spaces (Jeffrey, 1999). The different kind of wall and floor coverings that are present in the facility are important to all users, but specially to users with visual impairments who rely on tactile wayfinding cues to guide themselves in the environment (Kopvol, 2010). In its turn, sight is the sense on which the users most rely on for wayfinding tasks due to its versatility (Jeffrey, 1999). Users use this sense to visualize the surrounding environments and their features both at a distance and nearby, which is not possible to accomplish to the same extent when users hear sounds for instance, often requiring them to be close to the source. An important aspect of the environment that enables people to see what surrounds them is the lighting of the spaces.

The type of light available, either artificial or natural, the existence of dark or less illuminated spaces in the building and the availability of windows to help users orientate themselves in the building are factors that should be taken into account when evaluating the degree of lighting present in healthcare facilities (Huelat, 2007; Kopvol, 2010). Another sensational input which can be easily overlooked is the one that provides sound cues. It is particularly important for users who deal with some kind of vision impairment, as they substitute this loss of sense by giving more importance to other unimpaired senses like sound perceiving. Needless to say, sound cues are also - to a lesser extent - important for the other users, except the ones with hearing impairments (who possess a limited auditory capacity) as people tend to use sound cues or noises, even sometimes not fully consciously, to help finding their way around (Jeffrey, 1999). Healthcare facilities are generally busy and noisy places, with the noise arising either from a good or a bad source (Jeffrey, 1999; Kopvol, 2010). An example of bad noise that users can experience is the sound of large traffic flows that pass by while he/she is in the waiting room, whereas an example of a good noise is a sound arising from an activity that is taking place around the user (e.g. piano music), making him/her feel less alone in the environment (Kopvol, 2010). The amount of background noise present in the environment may also interfere with the user's auditory perception and disrupt his/her capability to depict sounds that are being emitted from a close source. Finally, the existence of audible cues like spoken announcements inside the lifts, mentioning the current floor number and other information (e.g. the main services that exist in that floor) also support user's wayfinding performance (Jeffrey, 1999).

2.3.3 Influence in Wayfinding

Farr et al. (2014), interested not only in listing the human and environmental factors, but also in the influence that they might have on the wayfinding performance (i.e. to which extent they contribute to the effectiveness of the underlying tasks), developed a Bayesian Network approach to model this problem (applied to airport terminals). A simplified version of this Bayesian Network is presented in Figure 2.8.

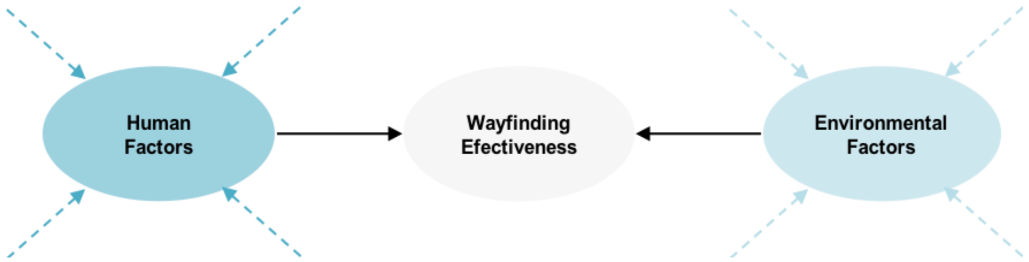


Figure 2.8: Simplified wayfinding Bayesian Network (Adapted from Farr et al., 2014). **Note:** the variable of interest is the node in the center, whereas the human and the environmental factors are internal variables of the network. For simplicity reasons the variables related to the previous ones mentioned are not represented here.

Despite the limitation constrains of their study and to the fact that is related with a generic airport building (and not a particular case study), the authors came to the conclusion that human factors have a greater influence in wayfinding effectiveness when comparing to environmental ones (Farr et al., 2014). Just to have an overview in terms of concrete measures, it is expected that to reach a wayfinding effectiveness of 100%, the human inherent factors would have to be good 94.17% of the times compared to only 79.17% of the times for the environmental ones. Furthermore, by assigning the probability of each state within one node to 100% (in this case the states were defined as “Good” and “Bad” for both nodes) it is possible to extract more information regarding the sensitivity of the network and how it affects wayfinding effectiveness. Table 2.3 outlines this sensitivity and provides a concrete overview on how each of the internal nodes of the network might affect its output.

Table 2.3: Sensitivity analysis of the wayfinding bayesian network presented in Figure 2.6 (source: Farr et al., 2014).

Human Factors	Environmental Factors	Wayfinding Effectiveness (%)
Good (100%)	Good (100%)	96.80
Bad (100%)	Bad (100%)	4.40
Good (100%)	Bad (100%)	89.60
Bad (100%)	Good (100%)	74.00
94.17%	79.17%	100
Good (100%)	-	95.14
Bad (100%)	-	21.02
-	Good (100%)	82.51
-	Bad (100%)	72.40

2.4 User Groups

Healthcare facilities should establish a wayfinding system capable of being used by users with different characteristics and levels of impairment (an “all-inclusive wayfinding system”), from children to elderly and from unimpaired users to users with different type of impairments (Jeffrey, 1999). Therefore, facilities should be able to provide an equal and convenient experience in terms of wayfinding effectiveness including different user groups without the need for adaptation or specialized design (International Health Facility Guidelines, 2016). According to the World Report on Disability published by the WHO and the World Bank in 2011, the global disability prevalence among adults was estimated to be 15.6%. The data was gathered through the World Health Survey (WHS), implemented in 70 countries, including approximately 300 000 individuals (Mitra and Sambamoorthi, 2013). It took place between 2002 and 2004, being the first source of comparative descriptive data on disability across the world (Mitra and Sambamoorthi, 2013). In this survey, the individuals were asked on a scale from 1 to 5 to evaluate their disabilities as follows: 1 – no difficulty, 2 – mild difficulty, 3 – moderate difficulty, 4 – severe difficulty and 5 – extreme difficulty/unable to do (WHO, 2002; Mitra and Sambamoorthi, 2013).
Users with different type of impairments are thus expected to walk through healthcare facilities in their daily functioning. The range of possible impairments includes perception, cognition, mobility or even illiteracy, with the degree to which these impairments affect the user fluctuating between temporary to permanent (International Health Facility Guidelines, 2016).

2.4.1 Unimpaired User Group

The International Health Facility Guidelines (2016) define an unimpaired user as someone whose physical, cognitive and psychologic capacities would allow the individual to perform a certain task within a certain environment. The user perception abilities like vision and hearing should not be limited at any level. The same is applicable to the mobility and cognitive ones (e.g. memory, reading and comprehension, no reported neurological disorders, etc.) together with spatial ability and environment cognition, i.e. the user should be able to navigate and orient him/herself independently in the space. Whether or not a user belongs to this group is relative and dependent on the design of the facility as poorly designed spaces may limit the extent to which the individual is able to make full use of inherent capacities and at some point, a perfectly normal individual without a diagnosed/formal disability can be considered impaired to a certain degree. A practical example is an individual pushing a baby stroller in an environment that doesn't provide reasonable accessibility to the upper floors (e.g. an elevator) who can be considered physical impaired (International Health Facility Guidelines, 2016).

2.4.2 Perception (Sensory) Impaired User Group

The two main type of sensory impairments that affect the user's wayfinding performance are the vision and hearing ones. According to the World Health Organization (WHO) global statistics from 2010, 285 million people are estimated to be visually impaired worldwide and within this group 39 million are blind (with 82% being over 50 years old) and 246 million have sight impairments (poor eyesight, partial vision, or abnormalities of vision such as colour deficiency and reduced field of vision) (Transportation Research Board, 1996; World Health Organization, 2010). For the ones with mild vision impairments, the International Health Facility Guidelines (2016) advises for the presence of strong colour contrast between surfaces, reduced glare, definition of main circulatory routes with tactile and visual cues and large and legible signage on site to help these users finding their way. Regarding the blind users, the way they perceive the environments and extract cues essentially relies on tactile and auditory input, so the background noise should be set to the lowest level possible and warning noises should be as clear and informative as possible, and – in rare circumstances – in the use of olfactory or heat perception (Transportation Research Board, 1996; International Health Facility Guidelines, 2016). The previous senses try to compensate for the missing or diminished sight capacity, but are considered in general less informative, reliable and efficient (Transportation Research Board, 1996). Also, accordingly to the WHO most recent statistics of the present year (2019), it is estimated that about 466 million people around the world have disabling hearing loss from whom 34 million are children. By 2050 it's expected that 900 million people will have this impairment (WHO, 2019a). Disabling hearing loss goes from moderate or severe (hearing impaired users) to profound (deaf users). In general, this type of user presents difficulties in understanding a conversation without visual support from any kind, so they mostly rely on lip-reading, sign language and written messages to obtain information and communicate (Transportation Research Board, 1996; International Health Facility Guidelines, 2016). Visual legibility of the built environment, the extent to which the environment can be 'read' using vision as main sense, is pointed as the most significant wayfinding characteristic for users with disabling hearing loss.

2.4.3 Cognitive Impaired User Group

The extent to which a cognitive impairment affects the user fluctuates between situational to developmental (Transportation Research Board, 1996; International Health Facility Guidelines, 2016). Situational impairments are temporary states of distress, anger, apprehension or confusion caused by a particular issue or by the environment itself (Transportation Research Board, 1996; International Health Facility Guidelines, 2016). When a user finds him/herself overloaded by the available information on the site can change his/her behavioural pattern and become temporarily cognitive impaired. In its turn, in the category of developmentally impaired users, one can find learning disabled, mentally retarded and mentally disturbed individuals, but also elderly people with reduced cognitive abilities or users who suffer from dyslexia, dyscalculia or dysgraphia (Transportation Research Board, 1996; International Health Facility Guidelines, 2016). The WHO statistics on the present group of users only include the ones who suffer from dementia, estimated to be around 50 million worldwide, with on average 10 million new cases every year, numbers that only represent a small portion of the total amount of cognitive impaired individuals (WHO, 2019b). For this user group and in order to ease the wayfinding experience, the International Health Facility Guidelines (2016), advises for the presence of striking landmarks across the facility, clearly defined paths to destinations with additional reinforcement of the route and destination along the way (e.g. by using signage), but also for the reduction of the number of decisions that the users should make along the path (influenced by the ICD and by the number of changes in direction).

2.4.4 Mobility Impaired User Group

Mobility impairments can be either temporary or permanent. Persons who belong to this category can be either wheelchair or walking aid users (who report strength, endurance, dexterity, balance, or coordination difficulties), but also individuals pushing a baby stroller or suffering from heart failure or other condition that reduces their mobility (Transportation Research Board, 1996). Heart failure and other related conditions tend to induce fatigue, frailty and interfere with users' balance, thus limiting their movement inside the facility (International Health Facility Guidelines, 2016). The International Health Facility Guidelines (2016) advise for an adequate placement of signage along the path as mobility impaired users tend to have a lowered field of vision (wheelchair users due to their seated position and users who rely on mobility aids tend to direct their vision towards the ground), but also for the existence of wide corridors to provide users a reasonable area to move themselves. Inaccessible routes for wheelchair users should also be effectively signalized to make sure users find alternatives before reaching an obstacle (International Health Facility Guidelines, 2016). In theory, mobility impaired users do not need special routes to navigate through as they should be able to use the same ones as unimpaired users (International Health Facility Guidelines, 2016). Although, if healthcare facilities design specific routes for this type of users, they should be similar or even easier in terms of difficulty to navigate without more changes in direction or with a higher ICD average (International Health Facility Guidelines, 2016).

2.4.5 Language and Illiteracy Impaired User Group

This type of impairment affects around 15% of the adult population worldwide and relies on the incapacity demonstrated by users in having adequate reading and writing skills to perform their daily living tasks (International Health Facility Guidelines, 2016; Vágvölgyi et al., 2016). Explanations for such impairment vary from congenital learning disabilities (e.g. dyslexia) to family or home influences or even for not completing school (International Health Facility Guidelines, 2016). Foreign users who are not able to read, write or communicate either in the local language of the country where they are based or visiting or in an international language (e.g. English) may also be considered functionally illiterate to a certain degree, especially if they cannot

understand the written signage present in healthcare facilities. However, to overcome this issue, design and facility planners tend to place in the environment not only written signage but also symbols and pictographs based on recognizable elements as a complement to it (International Health Facility Guidelines, 2016).

2.5 MCDA Overview

The MCDA field stands for Multi-Criteria Decision Analysis, but sometimes is also termed as Multiple Criteria Decision Aid or Multiple Criteria Decision Making) (Belton and Stewart, 2002). Over the past years this approach has been used in a variety of fields, in operations research – where it has its origins – in transportation or urban planning and in the healthcare sector where it has been used in different decision contexts (Hongoh et al., 2011). The most well-known definition for MCDA in the literature was presented by Belton and Stewart (2002, p.2) as "an umbrella term to describe a collection of formal approaches, which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter". This powerful umbrella includes a group of methods that intend to assist in decision evaluation and problem structuring, by helping individuals supporting their deliberation in the decision-making framework (Belton and Stewart, 2002). In their book *Multiple Criteria Decision Analysis: An Integrated Approach*, Belton and Stewart (2002) also present a detailed description of what are the three critical stages of MCDA: problem identification and structuring, model building and use and ultimately the development of action plans where for instance, a concrete choice may be implemented based on the outcome of the previous steps (Figure 2.9).

The final stage of any MCDA strategy comprises the implementation of the results previously obtained by translating them into specific action plans. Further analysis regarding the sensitivity or the robustness of the results is normally conducted, but by synthetizing and interpreting the information previously obtained, the Decision Makers (DMs) may even create new alternatives that were not part of the primary analysis. The use of the model not be further discussed since is outside of the scope of the present master thesis. As evidenced in the figure, MCDA comprises several activities spread along different stages of the process, whose sequence is not unidirectional, but instead flexible and iterative. This allows the entities involved in the decision-making process to return to previous stages and perform adjustments whenever it is necessary and is aligned with the constructivist perspective often used in MCDA (Vieira et al., 2019). In MCDA three different parties are commonly identified by assuming important roles in the process: decision-makers, stakeholders and decision analysts or facilitators (Belton and Stewart, 2002).

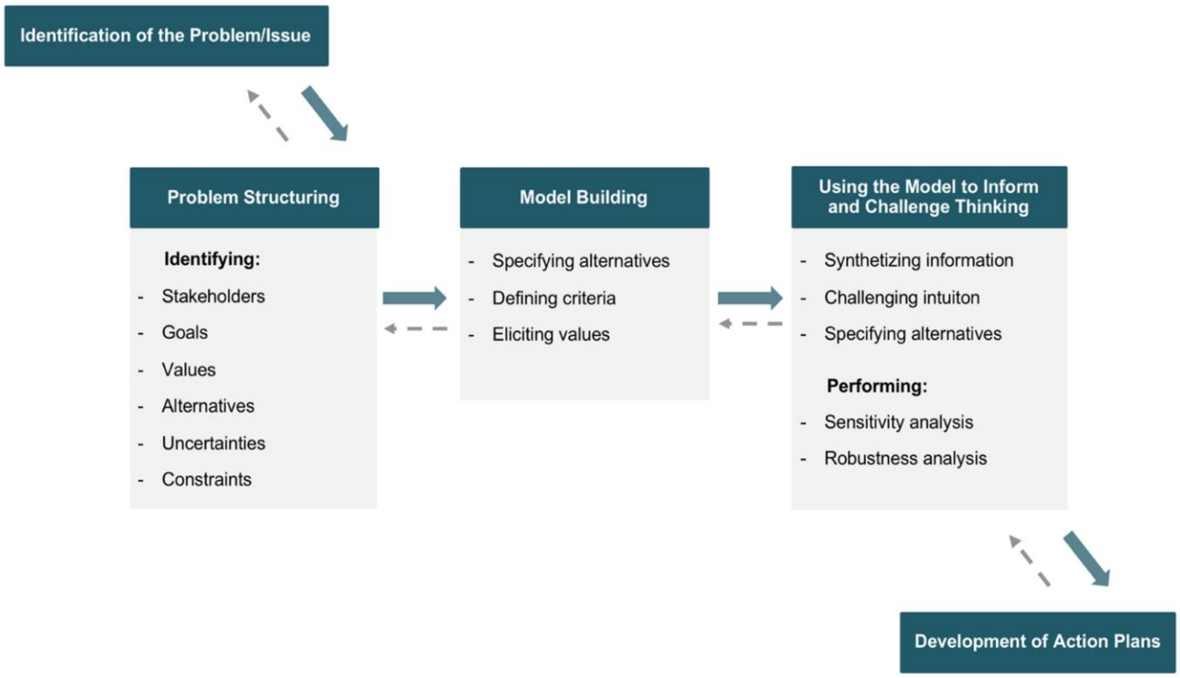


Figure 2.9: The MCDA process (Adapted from Belton and Stewart, 2002).

A DM is an individual, group, organization or other decision-making entity responsible for the decision in a particular decision-making context, whereas a stakeholder is an individual, group or organization that is affected or may be affected by the outcome of a decision (Freeman, 1984). In its turn, the role of facilitator is essentially the moderation of social processes encompassed by the MCDA approach, by providing insight and ensuring that good MCDA practices are being followed, but always assuming an impartial position regarding the matter being discussed. MCDA is also described in the literature as a sociotechnical approach comprising two dimensions: social and technical (Dodgson et al., 2009; Bana e Costa et al., 2014). The social dimension generally encompasses activities that include the ways to involve and engage the actors within the different entities, whereas the technical dimension is related with the MCDA approach used and implemented to solve a particular problem (Dodgson et al., 2009). These two aspects tend to be designed simultaneously in order to ensure that they are working together to aid and achieve the goals of MCDA (Dodgson et al., 2009).

2.5.1 Problem Identification and Structuring

Problem identification and structuring precedes the model building stage and together with the next steps is considered critical in a decision-making framework. It is characterized as being divergent in terms of thinking or an opening-up stage where all the entities responsible for the decision, the DMs, develop a common understanding of the problem, by discussing ideas and possible solutions for it (Belton and Stewart, 2002; Martunnen et al., 2019). Essential questions like 'What is the main goal or what are the main goals intended to achieve?', 'Who are the stakeholders responsible for the decision-making process?', 'What are the key issues and constrains that must be considered?' must be answered clearly before moving to the second stage. Alternatives are commonly defined as the options, strategies or action plans that should be evaluated towards their consideration of potential solutions for the problem. Generally, they are evaluated against a group of criteria, also denoted as values, objectives, goals or fundamental points of view of the model that arise from the problem structuring stage (Belton and Stewart, 2002). After the generation and exploration of multiple ideas and ways of thinking, a converging phase succeeds, still situated within the problem structuring and continuing until the end of the analysis. Its kick-off is pronounced by using structuring techniques – such as hierarchies – to organize the information collected in the preliminary stage (Martunnen et al., 2019).

2.5.1.1 Identifying and Generating Objectives

It is not always trivial for the DMs which objectives should be considered in a particular decision context. According to Belton and Stewart (2002), this step is still part of the problem structuring stage, but for Bana e Costa et al. (2008) such exercise is included within the construction of the model.
Three main approaches are identified in the literature for capturing evidence and generating objectives (Keeney and Raiffa, 1976; Thokala and Duenas, 2012): 1) performing a literature review, 2) holding meetings with experts in the field and 3) conducting surveys. By performing a literature review, it is possible to identify objectives that have been previously used for similar decision contexts, if the problem has been previously appraised by others (Keeney and Raiffa, 1976). Under other conditions, for instance if there is no solid evidence in the literature for generating objectives, consulting an expert panel may also help in the identification of objectives in a certain problematic. Back in 1976, Keeney and Raiffa had already identified the use of the "panel of experts" (a group of people with expertise in an area of interest) by the government and the private industry, especially in the technological and scientific fields. By including different entities in this stage of the analysis, a diversity of points of view can be captured, which latter one expects to result in finding a set of values that the various parties will recognize as adequate to appraise the problem being handled (Keeney, 2006). Finally, the third method previously identified for generating objectives, the use of surveys, can also be useful for instance, in situations where objectives must be selected for public decision making (Keeney and Raiffa, 1976). By conducting this type of research, DMs can include individuals who would be affected by a certain decision and benefit from their expertise, point of view or personal experience in the matter, by asking which objectives should be taken into account for such a study (Keeney and Raiffa, 1976).

2.5.2 Model Building

At some point, during the MCDA process, the main focus must shift from structuring the problem to build the model, by developing a framework able to weight the criteria and evaluate the different options (Belton and Stewart, 2002). The literature characterizes it as a transition that goes from having a solid and broad description of the problem, either represented by a cognitive map or a simple aggregation of ideas, to a preliminary representation of a model intended to be used for MCDA purposes (Belton and Stewart, 2002). The model building stage contemplates the development of models that depict the DMs' preferences in a structured and clear way and are considered a primary attribute of any MCDA approach. Here, the alternatives to consider in the problem must be specified, the final criteria used to access the value of the each of the alternatives must be determined. This step is often characterized as a very dynamic process and may involve multiple iterations and an extensive discussion between the facilitator and the DMs, either by looking for new options or criteria to include in the model, for discarding objectives that were previously considered or by restructuring previous ones (Belton and Stewart, 2002). It is important to highlight that this is the step that introduces variability among the different MCDA approaches allowing to distinguish them regarding the nature of the model, the required input and how the model is effectively used to obtain the desired output (Belton and Stewart, 2002). All the approaches must have in common the need to select the different options to be part of the decision, the criteria or objectives to evaluate the performance of the different options and measures to access the different levels of impact in each criterion (Belton and Stewart, 2002). According to Belton and Stewart (2002), the variability among the different methods is thus introduced by the level of detail used to define, summarize and elicit the information needed to aid decision-making.

Directives for this stage are provided by Bana e Costa et al. (2008) who separate the model building phase in three main steps: structuring, evaluation (accessing preferences) and validating the requisiteness of the model, which may overlap with the step "using the model to inform and challenge thinking" defined by Belton and Stewart (2002) in Figure 2.9. These guidelines can be complemented with the ones suggested by Angelis and Kanavos (2017), who define three main steps for the structuring step in the model building task: 1) structuring a value tree that identifies and represents the objectives or key concerns of the DMs, 2) defining attributes (or descriptor of performance according to Bana e Costa et al., 2008) at the bottom level of the value tree to measure the extent to which these objectives are achieved and 3) selecting decision alternatives.

2.5.2.1 Structuring

- ***Building a Value Tree***

The group of criteria to include in a complex decision-making problem is commonly described by a value tree, a simple visual and structured representation that tries to capture the key issues that the DMs value the most for solving the problem and reaching the desired outcome (Belton and Stewart, 2002). Thus, this schematic representation must include the different objectives and criteria under consideration (Angelis and Kanavos, 2017). This approach reflects how we humans conceptualize and structure a complex problem by allowing the DMs to construct a hierarchy (a set of integrated levels) and breaking down the problem into several factors, which by their turn are broken down into a new level of factors and so on and so forth up to a certain level. In a typical MCDA problem these levels are organized in a descending hierarchy where the overall goal of the decision problem is represented on the top, followed by the criteria and sub-criteria considered in the problem to achieve such goal and finally the different alternatives the DM can choose from to attain the goal in the lowest level of the hierarchy (Sen and

Yang, 1998; National Institute for Health and Care Excellence, 2013; Marsh et al., 2016). This strategy is commonly used in methods that have as underlying principle the use of value functions (further explained in the text), which aim to build a hierarchy of criteria (Belton and Stewart, 2002).

Two types of strategies used to structure the objectives are commonly identified in the literature: top-down and bottom-up approaches (Marsh et al., 2016). Top-down strategies make use of the "value-focused thinking" concept, by identifying fundamental objectives that the DMs want to achieve in a specific context and that can be decomposed into sub-objectives (Keeney, 2006; Marsh et al., 2016; Angelis and Kanavos, 2017). Therefore, the options are defined as ways to achieve those objectives. In its turn, bottom-up approaches make use of the "alternative-focused thinking" concept, by using characteristics or attributes that differentiate the different alternatives/options available that are then grouped into higher hierarchical objective/concern levels (Marsh et al., 2016; Angelis and Kanavos, 2017). These two different methodologies can give rise to different value trees, so an appropriate choice, based on the scope of the problem, must be made beforehand by the DMs (Marsh et al., 2016). On one hand, and according to Marsh et al. (2016), top-down strategies are more adequate to build models that can be used more than once, as they tend to generate a group of criteria difficult to relate with a particular option. On the other hand, bottom-up strategies are more appropriate to be used in "one-off" decision situations, as they tend to generate a group of criteria less versatile, that is particularly relevant for a specific context/problem (Marsh et al., 2016).

Although the two different strategies previously described do not seem plausible to combine and integrate in the methodology to appraise a certain MCDA problem, it is often common to use what Angelis and Kanavos (2017) denominate as a "value-alternative hybrid thinking approach". This strategy encompasses a top-down approach to build the core structure of a value tree and ultimately define the attributes based on the selection of alternatives or options suitable to the decision context as a result of applying a bottom-up approach (Angelis and Kanavos, 2017). Martunnen et al. (2019) also define the most common operations that DMs and analysts use, even intuitively, to build a hierarchy of objectives by structuring and positioning individual objectives, which are detailed in Figure 2.10.

- ***Use of Performance Descriptors***

A descriptor of performance is described in the literature as a plausible ordered set of impact levels, that either quantitatively or qualitatively, intends to measure the extent to which a certain criterion is fulfilled by the different options in the model (Bana e Costa et al., 2002; Carnero, 2017). Descriptors of performance are generally defined based on the intrinsic characteristics of criteria that make them operational (Bana e Costa et al., 2002). Also, in particular contexts, pictorial descriptors can also be used, where criteria are operationalized using visual representations to depict the different levels of performance. These attributes can be classified as direct (natural) or indirect (also referred as proxy), depending if the different levels directly measure the consequences of a criterion or instead represent causes rather than consequences (Carnero, 2017). Nevertheless, the performance level in some criteria cannot be measured using direct or proxy descriptors, due to their subjectivity or integration or interrelation of different concepts (Carnero, 2017). In these situations, constructed descriptors are used.

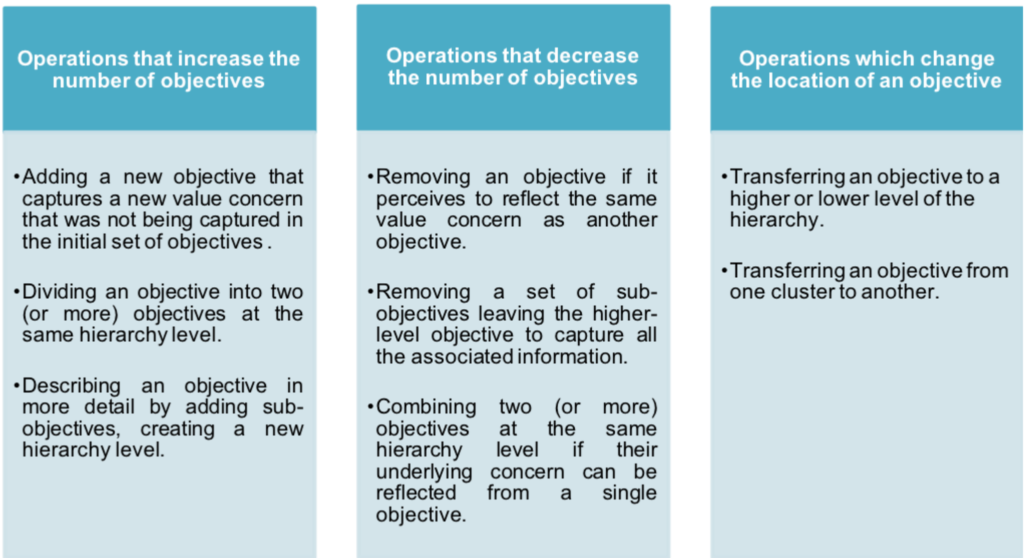


Figure 2.10: Operations used to build a hierarchy (Adapted from Martunnen et al., 2019).

Their most common representation is using verbal descriptions of expected consequences to characterize the different levels of performance (Carnero, 2017). As suggested in the literature, the definition of two reference levels of performance regarding every descriptor – one good and one neutral – significantly contributes to turn criteria more intelligible (Bana e Costa et al., 2008). According to Bana e Costa et al. (2008) the former represents an unequivocal attractive level of performance, whereas the latter represents a level of performance that is not attractive but also not unattractive.

- ***Value Tree Properties***

The complexity of the value tree depends on the level of detail that DMs incorporate in the problem, i.e. the number of criteria chosen to cover all the key issues intended to be addressed. The value tree size is really unstable among decision-making problems, and there is no specific answer for how many criteria DMs should use in the problem, although Belton and Stewart (2002) recommend the use of the simplest tree as possible, ensuring that it captures the problematic to a reasonable extent. Nevertheless, the level of complexity of the primary representation of this tree tends to be high, comparing to the level of detail or operationality desired, requiring further refinement of the criteria present in it (Belton and Stewart, 2002). The number of criteria present in the model also influences the length of the questionnaire used to access the DMs preferences. The more extensive it tends to be, the more likely is the appearance of inconsistencies in DMs responses - while using pairwise comparison methods - related with fatigue (Marsh et al., 2016).
The MCDA approach that the DMs choose to appraise the problem may differ on others in “the extent to which, and the way in which, the key objectives are elaborated in the model” as stated by Belton and Stewart (2002, p.55) and is intrinsically related with the “school” it comes from. However, certain considerations are a common practice, regardless of the methodology used, when identifying, describing and structuring criteria and attributes of the value tree (Belton and Stewart, 2002; Dodgson et al., 2009;

Marsh et al., 2016; Angelis and Kanavos, 2017). Among these considerations, criteria and attributes must meet the following requirements (Belton and Stewart, 2002; Dodgson et al., 2009; Marsh et al., 2016; Angelis and Kanavos, 2017):

1. **Value relevant (for the criteria):** every criterion selected to be part of the model must be relevant, i.e. add value to the model in the DMs' perspective.
2. **Non-redundant (for the criteria):** each point of view that the model tries to capture must be only represented and measured by one criterion, which means that one criterion must not indicate the consequences of other criteria present in the model.
3. **Complete and concise (for the criteria):** every criterion selected to be part of the model must have all the fundamental characteristics to perform the comparison of the available options, although the level of detail should be set to the minimum as possible, by only including criteria that capture key aspects of the problem.
4. **Unambiguous (for the attributes):** attributes must be clear regarding the impact intended to achieve with the options.
5. **Comprehensive (for the attributes):** attributes should cover all the possible consequences DM's intend to appraise in a criterion.
6. **Direct (for the attributes):** attributes should describe in the most direct and objective way as possible the consequences of going along with a certain option.
7. **Operational (for both criteria and attributes):** every criterion selected to be part of the model must be defined in such a way that allows to measure the performance of alternatives against each criterion, turning the model practical and intuitive to use.
8. **Preference-independent (for both criteria and attributes):** mutual independence of preferences must be verified by ensuring that the performance in one criterion is not influenced to any extent by the performance of other criteria present in the model. A common example where dependence occurs is when DMs cannot judge the performance of one criterion without knowing the score given to another criterion.
9. **Understandable (for both criteria and attributes):** the consequences of every criterion and attribute selected to be part of the model should be understood by the DMs.

2.5.2.2 Evaluation

After structuring all the necessary information to be part of the model, an elicitation step of values must be conducted. Here, the criteria weights and the scores that represent the value of the different alternatives present in the model are determined based on the relative importance of each criterion.

Concerning MCDA modelling techniques, they are essentially categorized into three types: value measurement models, goal, aspiration or reference models or outranking models (Belton and Stewart, 2002). The most appropriate model to use in a certain context relies on the type and the objective of the analysis that the decision-maker wants to conduct and on the nature of his preferences (Thokala et al., 2016). Giving the nature of the intended outcome in the present work, a Value Measurement Model (VMM) is considered to be the most appropriate direction to pursue for use of the model. Therefore, other techniques will not be further detailed. According to Marsh et al. (2014), this type of models is considered the most widely used approach within the healthcare domain when comparing to the other categories previously mentioned. The preference of this approach over the others regards the possibility of a trade-off between the different outcomes (Marsh et al., 2014). Decision Makers should use a VMM whenever they consider that the group of criteria present in the model is compensatory, i.e. a lower score of an alternative in one criterion can be compensated by a greater score in another criterion (Thokala et al., 2016). Baltussen et al. (2006) also argues that VMM are more adequate to elicit DMs' preferences than non-compensatory techniques. The underlying principle of these approaches is essentially the construction and comparison of numerical scores (also known as global or overall values) that help the DMs in determining to which extent an alternative is preferred over another and in the identification of the most preferred option (Belton and Stewart, 2002; Thokala et al., 2016). The overall score of the different alternatives is usually determined by means of additive models, also known as "weighted-sum" models or "additive multiattribute value models", considered the simplest category of a VMM (Thokala et al., 2016). This score is determined by the value function of each alternative, described by equation 4, where the numerical performance score of an alternative $v_j(a)$ in the criterion j is multiplied by the relative weight of that criterion (w_j). All these weighted products are then summed in order to obtain the final score of that alternative (Belton and Stewart, 2002).

$$V(a) = \sum_{j=1}^{n} w_j v_j(a) \; with \text{ with } \sum w_j = 1 \, , w_j > 0 \qquad (4)$$

The presence of a value function in a VMM allows the establishment of an order of preferences between the different alternatives, as explained before, and ensures that properties such as completeness and transitivity are verified within the model (Belton and Stewart, 2002). Completeness regards the relative importance of two alternatives, i.e. if the DM is comparing them then one of those options is at least equally preferred to the other one (same overall score) or more preferred (higher overall score). The transitivity property can be applied whenever the DM is simultaneously comparing at least three alternatives (e.g. A_1, A_2 and A_3). If V (A_1) > V (A_2) and V (A_2) > V (A_3), then it can be immediately concluded that V (A_1) > V (A_3).

- ***Weight Elicitation***

The existing literature on MCDA recognizes two different approaches to determine weights in a value tree: hierarchical weighting and non-hierarchical weighting as represented in Figure 2.11 (Martunnen et al., 2017). Hierarchical weighting can either be performed using a bottom-up or a top-down approach (Martunnen et al., 2017). In the former, the local weights of the lower-level objectives are firstly obtained for each branch, followed by the determination of the weights regarding the highest-level objectives, whereas in the latter the inverse procedure is followed. In both approaches, global weights of the lowest levels can be obtained by multiplying the respective local weight by the weight of the parent top-level objective, as illustrated on the left value tree on Figure 2.11. Martunnen et al. (2017) recommend following a bottom-up rather a top-down approach to elicit weights as participants better understand alternatives' impact ranges. Concerning a non-hierarchical approach, the lower-level objectives get their weights assigned in the first place. In the presence of an additive model, the higher-level objectives can also get their weights assigned by summing the weights of the corresponding lower-level objectives who belong to the same branch as illustrated on the right value tree on Figure 2.11. (Martunnen et al., 2017).

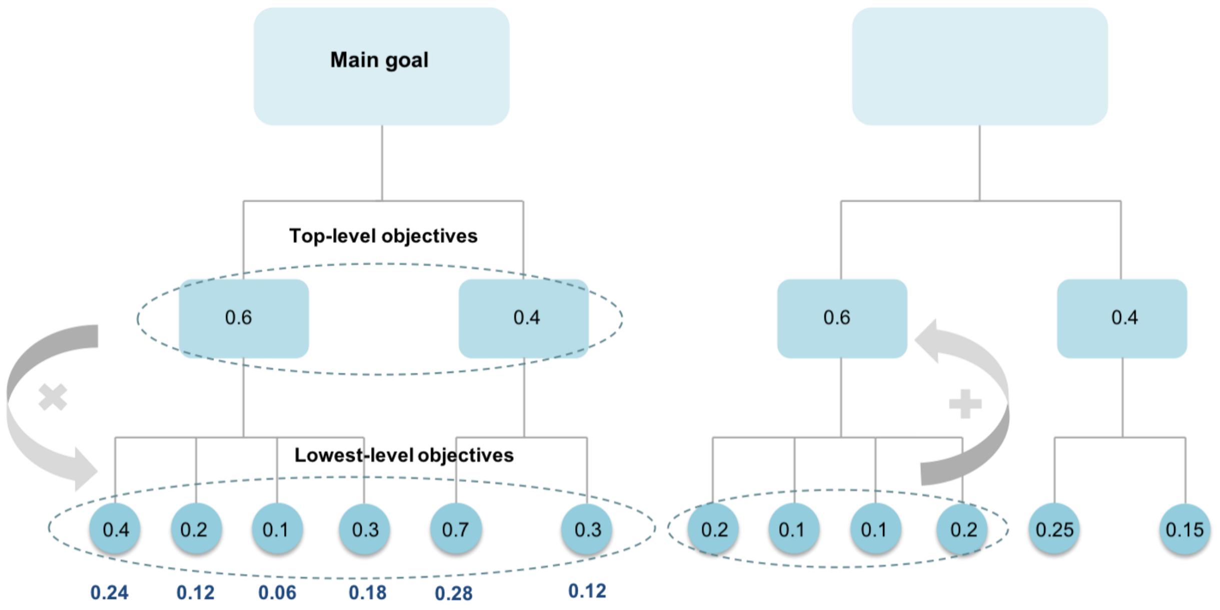


Figure 2.11: Bottom-up hierarchical weighting (on the left) and non-hierarchical weighting approaches to obtain criteria weights (Adapted from Martunnen et al., 2017).

Chapter 3

Methodological Approach

This chapter provides the details of the methodology developed to meet the objectives initially proposed in the first chapter of this master thesis. Firstly, a general overview of the proposed methodology is presented in section 3.1. Afterwards, each step followed to conduct this research is further detailed in subsequent sections.

3.1 Methodological Overview

The literature identifies the need to model wayfinding as a complex system, a system composed of different elements that may present interdependencies between them. The two main elements of this complex system are the human and environmental factors that influence users' wayfinding performance in healthcare facilities. This master thesis intends to explore the environmental factors of healthcare facilities that affect user's wayfinding performance and try to establish a link between these factors and that what the different type of users one can encounter in these places (unimpaired, mobility impaired, cognitive impaired, etc.) value the most. Reviewing the goals of the present research, one can highlight the structuring of a model containing the environmental factors that affect users' wayfinding performance and its further use to assess users' preferences and determine the relative importance of the different elements present in the model. The steps described are typical activities used in the MCDA framework. Hence, and adopting a similar approach to the one described in the section 2.5 of the previous chapter, three main stages are identified as being part of the methodology designed and presented in Figure A.1 (Appendix A): 1) Problem Formulation, 2) Problem Structuring and 3) Model Building, with this last stage being divided between the structuring of the model and its further evaluation. Figure A.1 also resembles Figure 2.9 presented in the previous chapter, although as previously mentioned, the current research work will only reach the Model Building stage (due to the problem's scope), so the last two boxes of Figure 2.9 are not included in the proposed methodology.

In the problem formulation step, detailed in section 3.2, the main goals are the identification and the development of a clear description of the problem under study, the definition of the problem's scope by detailing the entities that will take part in the process and what will be effectively entailed and the definition of an adequate methodology to appraise it.

The problem structuring step, presented in section 3.3, intends to identify the type of output required and how this output will be generated and finally, generating and identifying the objectives required to build the desired model. The identification and the generation of objectives to this problem had two distinct sources: the literature review conducted and its further complement with the consultation of experts in the same domain. Therefore, the literature review previously conducted was used as an input to this stage, as it highlighted the main environmental factors influencing the effectiveness of wayfinding in built environments and, particularly in healthcare facilities, but also detailed the different type of user groups that must be considered when designing and planning this type of spaces.

The model building stage (section 3.3) also comprises a structuring step (subsection 3.3.1) where the selection and the structuring of the criteria to incorporate in the model is performed with the ultimate definition of a value tree, ending up with the operationalization of criteria by defining suitable descriptors of performance for each of them with the respective levels of impact. The last step within the model building, the model evaluation (subsection 3.3.2), intends to test the built model within a group of interest by eliciting preferences and ultimately obtaining criteria weights. Although the model structuring succeeds the problem structuring phase, the sequence followed to perform these two steps was not unidirectional, but instead flexible and iterative, as represented in Figure A.1. This allowed the entities involved to return to previous stages and perform adjustments whenever necessary. On the other hand, the evaluation of the model was only performed after the completeness of the model structuring, so the transition from structuring the model to use the model to assess users' preferences was not iterative or flexible as previously described for the first two MCDA steps of the methodology. This separation is intended to be adequate as the entities involved in the model building activities differ from the ones with which the model will be tested, reason why this step could only be performed after the completeness of the model construction.

Two specific MCDA methodologies, the Analytic Hierarchy Process (AHP) and the Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) were selected to obtain the relative importance of the criteria present in the model. By using two different methods to assess users' preferences, the main goal is to superficially explore which would be the most appropriate one to pursue with a conclusive study on this topic. To do so, one intends to compare their outcome and to understand which is considered to be the most intuitive from the standpoint of the group chosen for the assessment step.

As mentioned in the section 2.5 of the previous chapter, MCDA is described as a sociotechnical approach comprising two different dimensions: social and technical (Dodgson et al., 2009; Bana e Costa et al., 2014). The methodology developed and here presented, by adopting some of the traditional MCDA steps to deal with the problem under study is no exception to this, being also characterized by the presence of a strong socio-technical component throughout its different stages.

The social component comprises an interactive process between a group of four experts in wayfinding and in architectural characteristics of built environments and the facilitator – from the formulation of the problem until its structuring – and between the facilitator and the group of individuals chosen to test the model – in the evaluation of the model. The role of facilitator was assumed by the author of the present master thesis aiming to moderate the social processes both with the experts consulted and with the sample used to test the model. The interaction between the different parts was conducted in early stages (problem formulation and structuring and model structuring) through several individual and group meetings. The reason behind it was exploring individual concerns and points of view by stimulating strategic reflection and sharing different perspectives and knowledge, which would lead to a common understanding of the problematic. In the later stage (model evaluation) this dimension was acknowledged through individual interviews with the participants to obtain personal value judgments that would be used later on for modelling purposes. This modelling step is part of the technical component and is conducted to obtain the criteria weights.

3.2 Identification of the Problem/Issue

This stage started with the identification and the development of a clear and precise description of the problem being addressed. The key step to understand the problem's nature and its desired output was the elaboration of its graphical representation, depicted in Table 3.1. It presents a group of factors affecting the wayfinding performance of individuals in healthcare facilities, represented as F_i ($i = 1, 2, ..., n$), which is intended to be weighted for the different type of user groups that visit these places UG_j ($j = 1, 2, ..., m$). After the problem representation, three different dimensions to follow in the present research were defined: 1) the identification of the group of factors F_i ($i = 1, 2, ..., n$), 2) the identification the groups of users UG_j ($j = 1, 2, ..., m$) and 3) how the weights w_{ij} ($i = 1, 2, ..., n; j = 1, 2, ..., m$) would be obtained. Hence, the final intended outcome of this research was also defined by then: a vector of weights regarding the criteria considered for each type of users. Since the problem's nature resembles a typical MCDA framework, where conflict multicriteria are present, this was the approach chosen to appraise it. Therefore, the group of factors F_i ($i = 1, 2, ..., n$) can actually be seen as a set of criteria C_i ($i = 1, 2, ..., n$), which weights are unknown in a particular context.

Table 3.1: Problem Representation.

	Wayfinding Factors			
User Groups	F_1	F_2	...	F_n
UG_1	w_{11}	w_{12}	...	w_{1n}
UG_2	w_{21}	w_{22}	...	w_{2n}
...	...	...	...	...
UG_m	w_{m1}	w_{m2}	...	w_{mn}

A Working Group (WG) of four experts in the wayfinding domain and in the architectural features of built environments was brought together to collaborate in this stage and in the model building one. This collaboration allowed to explore individual perspectives, but also share different points of view and knowledge that would enrich the quality of the work developed. This group of experts had previously conducted research work in wayfinding, namely in Hospitals, which was a determinant factor in developing a common understanding of the current problematic. Since studying and analysing the factors that influence wayfinding in healthcare facilities is a very dense topic, an initial approach prior to their identification was necessary in order to define a scope for the problem. Hence, the requirements that these factors should meet in order to be considered for further analysis were defined. Nonetheless, the WG also expressed that their interest was to build a broad and exhaustive value tree, but conciseness was also important, as complexity increases with the number of criteria that are part of it. Also, considering the aim of the present work, the development of a generic but versatile hierarchy of criteria suitable to be subsequently reused and adapted for other decision-making contexts is crucial. In this line of thought the WG also agreed on this stage that a generic hierarchy would be constructed, without focusing in a particular environment, but instead, healthcare facilities in general. The reason for this hierarchy to be generic is the lack of knowledge regarding the relative importance of the factors that should be part of it. Thus, by retrieving such information, one can determine which factors should be included in further models concerning one particular facility.

3.3 Problem Structuring

As indicated in subsection 2.5.1.1, this stage may overlap to a certain extent with the structuring step of the model building (represented in Figure A.1), namely in the activity of identifying and generating objectives. The first dimension mentioned in the previous section, the identification of the group of factors F_i (i = 1, 2, ..., n), will have two major contributions: the literature review previously conducted – focusing on environmental features only given the problem's scope – and the contribution of the WG selected to be part of this research. In the previous chapter (subsection 2.5.1.1) different methodologies were described as illustrative approaches of collecting evidence to build a value tree, which may provide to the DMs a solid foundation to generate the appropriate objectives for a specific decision context. Nevertheless, in certain circumstances, the DMs choose a hybrid approach to appraise the problem, by combining at least two of these methodologies (Keeney and Raiffa, 1976). The present master thesis is an example of research work that follows this principle, as it combines a literature review to access the group of environmental factors that affect user's wayfinding performance in the healthcare facilities' framework and the consultation of a group of experts in the domain of wayfinding. The role of the expert panel in this context is essentially to help structuring the evidence retrieved from the literature and to enrich the quality of this evidence using their expertise and experience in the field. Moreover, this WG – prior to this research – elaborated an extensive list of aspects that influence the wayfinding of users in healthcare environments based on their own literature retrieval. This previous research on the topic was thus considered a solid foundation to the current one, bringing together a list of aspects that would be further used to consolidate and complete the literature review presented in subsection 2.3.2.

3.4 Model Building

The process of constructing the model begins after obtaining a clear and complete description of the problem, defining the type of decision output desired and organizing an aggregation of ideas or aspects intended to be explored. The construction of the multicriteria model incorporated the structuring of the model and its further evaluation though the elicitation of preferences that result in the obtention of criteria weights. The structuring stage comprised the definition of a value tree of criteria that are ultimately operationalized by using descriptors of performance. Regarding the evaluation stage, the methods to be used in the elicitation process and measurement of value were defined. Both steps, structuring and evaluation, involved an interactive and learning process in which the facilitator assisted the experts and the users that participated in the model evaluation as described earlier.

3.4.1 Structuring

Figure 3.1 schematically represents the different iterative steps followed to complete the structure of the model. During the three stages of the model structuring process, the information gathered from the literature study and from the consultation of the expert panel was used to inform criteria selection and structuring and to define appropriate impact levels for the different evaluation criteria, ultimately resulting in the development of a value tree. As previously emphasized in subsection 2.5.2.1, it is desirable to obtain a visual representation of the objectives during the MCDA structuring process. It can be achieved by building a value tree and decomposing the global goal into concern areas and lower level objectives and ultimately turning them operational by assigning descriptors of performance to each of them. Building a value tree starts with identifying the main areas of concern or clusters of criteria that represent the different dimensions of the strategic objectives that the model intends to appraise. 4 that in a value tree, the evaluation criteria are organized in a hierarchal structure where the main criteria are represented in the top levels or layers and the secondary criteria (sub-criteria), which result from the decomposition process of the criteria, are represented in the bottom level. It is extremely important that both evaluation criteria and sub-criteria respect the properties enumerated in subsection 2.5.2.1 (Value Tree Properties), in order to be part of the value tree. Concluded the second step – described in Figure 3.1 – the value tree was presented and discussed with the WG, who proposed adjustments (that were further incorporated) and validated the final value tree of criteria. After building the value tree and identifying all the criteria intended to be evaluated, they must be operationalized using descriptors of performance, previously detailed in subsection 2.5.2.1 (Use of Performance Descriptors) (Bana e Costa et al., 2008). This also involves the definition of local scales composed of at least two impact levels for each of them that intend to appraise their level of fulfilment. The process of assigning performance descriptors to each criterion was conducted by the facilitator together with the WG, also supported by evidence found in literature, but always ensuring that the properties listed in subsection 2.5.2.1 regarding these attributes were respected. Whenever it was possible, a direct descriptor was assigned to each criterion, but in most of the cases, given the nature of the criteria present in the model, a constructed descriptor was found to be the most appropriate alternative due to the lack of direct or indirect descriptors to measure the level of fulfilment in a criterion. The process of assigning performance descriptors to the criteria (step three in may also reveal certain redundancies within the list of criteria or bring to the discussion criteria that have not been considered before. Hence, after this step is complete, the first two steps present in Figure 3.1 must be reviewed, which confers an iterative nature to the model structuring stage.

3.4.2 Evaluation

The goal of this stage was the obtention of the criteria weights previously represented in Table 3.1. For this specific problem, the weights represented in Table 3.1 were actually obtained after an aggregation of the different models obtained for users belonging to the same user group, being a result of a further analysis conducted subsequently to the application of the methodology proposed. The aggregation of the different models per type of user was considered fundamental as each subject assessed only generates one vector of weights and the preferences of multiple users belonging to the same category will be elicited.

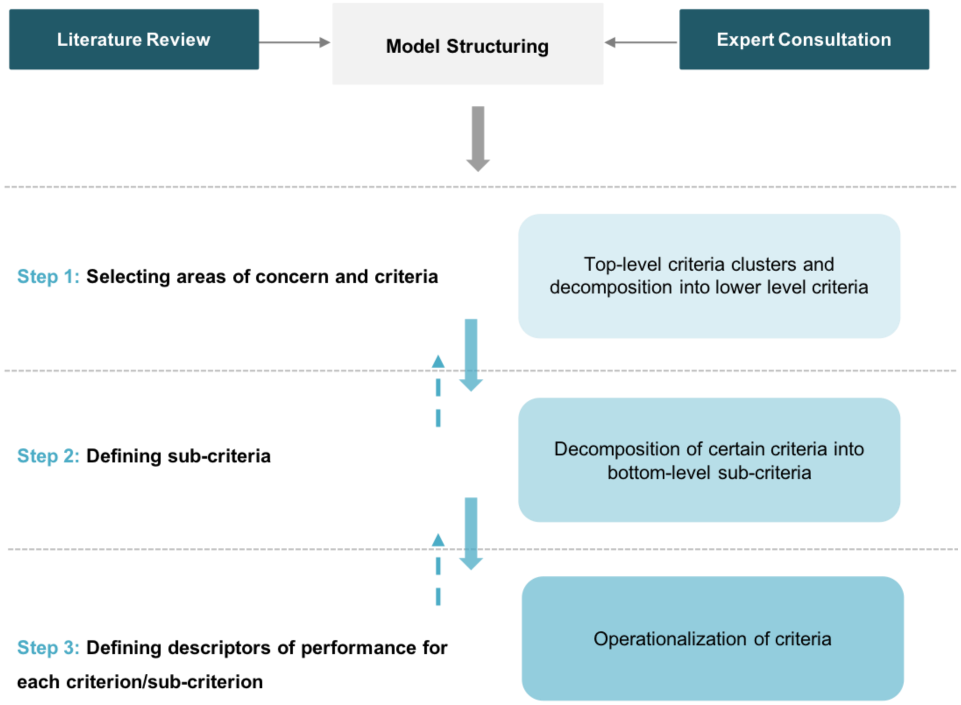


Figure 3.1: Schematic representation of three steps to structure and operationalize the value tree. **Note:** full arrows represent sequential processes whereas the dashed ones represent iterative process.

The first important step followed to evaluate the model was the selection of the most appropriate methods to do so. Giving the nature of the intended outcome, a VMM was considered to be the most appropriate direction to pursue for the application part. Such type of model assigns partial scores to each element present in the framework, i.e. the evaluation criteria, and allows the user to compare the different alternatives by means of global scores (Garson, 2006). As previously mentioned, two specific MCDA Value Measurement methodologies, the AHP (Analytic Hierarchy Process) and the MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) were selected to obtain the relative importance of the criteria present in the model. Experts have identified a growth trend in the application of the MCDA within the healthcare framework and these two different methodological approaches are widely used in prioritization and decision-making problems when dealing with multicriteria (Frazão et al., 2018). They will be further explained in the subsections 3.4.2.1 and 3.4.2.2, respectively. Both are VMM and follow an identical decision-making framework. A hierarchic structure is built to structure the problem and afterwards pairwise comparisons are performed using absolute judgments by filling in a pairwise comparison matrix. The consistency of the judgments provided by the user also takes place and is a critical step within the evaluation of the model. These judgments are the basis to derive criteria weights which are further aggregated into an additive value function to calculate the overall score of alternatives. However, both techniques substantially differ in their questioning protocol. MACBETH makes use of qualitative or semantic judgments to express the difference in attractiveness between pairs of options whereas AHP uses qualitative judgments to express the same difference but regarding its importance for the user. The difference in terms of questioning is the following: for each pair of criteria (x,y), such that x is preferred to y from the standpoint of the user, in AHP the evaluator is asked to judge how many times x is preferred to y – a ratio judgment – whereas in MACBETH the user is asked what is the difference in preference between x and y. Hence, the AHP approach is characterized by obtaining ratio scales derived from quantitative (numerical) pairwise comparisons of hierarchical levels, whereas in MACBETH interval scales are derived by qualitative (nonnumerical) pairwise comparison judgments (Bana e Costa et al. 2008). One of the major differences between both methods is also how the priority vector that provides the estimation of the criteria weights is obtained. AHP uses an EM (eigenvector method) whereas MACBETH makes use of LP (linear programming) to transform the DMs' preferences into a numerical value scale (Bana e Costa and Vansnick, 2008; Bana e Costa and Vansnick, 2012).

As reviewed in subsection 2.5.2.2, there are two different approaches to elicit weights, hierarchical and non-hierarchical weighting. AHP uses the latter approach to obtain criteria weights whereas MACBETH uses both approaches, so the user can choose between them. As it is intended to use both methods simultaneously in this research work, hierarchical weighting was the elicitation method to pursue for the obtention of criteria weights.

3.4.2.1 AHP

AHP was originally developed by Prof. Thomas L. Saaty (1977) as tool to ease and assist complex decision-making problems and deal with situations characterized by multiple criteria and alternatives. It is widely used in MCDA for being flexible, simple and intuitive for the user and for allowing incorporating both qualitative and quantitative, tangible or intangible factors. One of the software applications that implements the AHP approach is the SuperDecisions and will be the one used in the present work. Figure 3.2 depicts how problems are structured using this approach and shows the hierarchy present on the model. Each model requires at least three layers, the goal, the criteria and the alternatives, although these last two levels could also be broken down into sub-criteria and sub-alternatives, respectively. After structuring the problem, by breaking it down as suggested by Figure 3.2, pairwise comparisons within the same layer of the hierarchy are performed. A pairwise comparison can be defined as a comparison of two criteria established to determine their relative importance from the standpoint of the user (Saaty, 2008). Pairwise comparison matrices are used to keep record of user's preferences and to determine how the different criteria contribute to the fulfilment of the goal. These matrices allow to establish a prioritization between objectives and to derive comparative judgments into ratio scale measurements (Saaty, 2008). The first matrix is created to compare elements within the highest level of the hierarchy and further matrices are constructed for the remaining levels, but always to compare criteria belonging to the same parental node. An example of such matrix is presented below in Table 3.2. These are real matrices where the number of rows must equal the number of columns since we are using pairwise comparisons with every element a_{ij} (i = 1, 2, ..., n; j = 1, 2, ..., n), represents the relative importance between criteria i and j. Plus, the following properties must be satisfied for all (i = 1, 2, ..., n, j = 1, 2, ..., n): a_{ii} and $a_{ji}*a_{ij}$ must be equal to 1. The number of judgements to be performed in order to fill in the matrix is $\frac{n\,(n-1)}{2}$, with n being the number of different criteria present in the matrix.

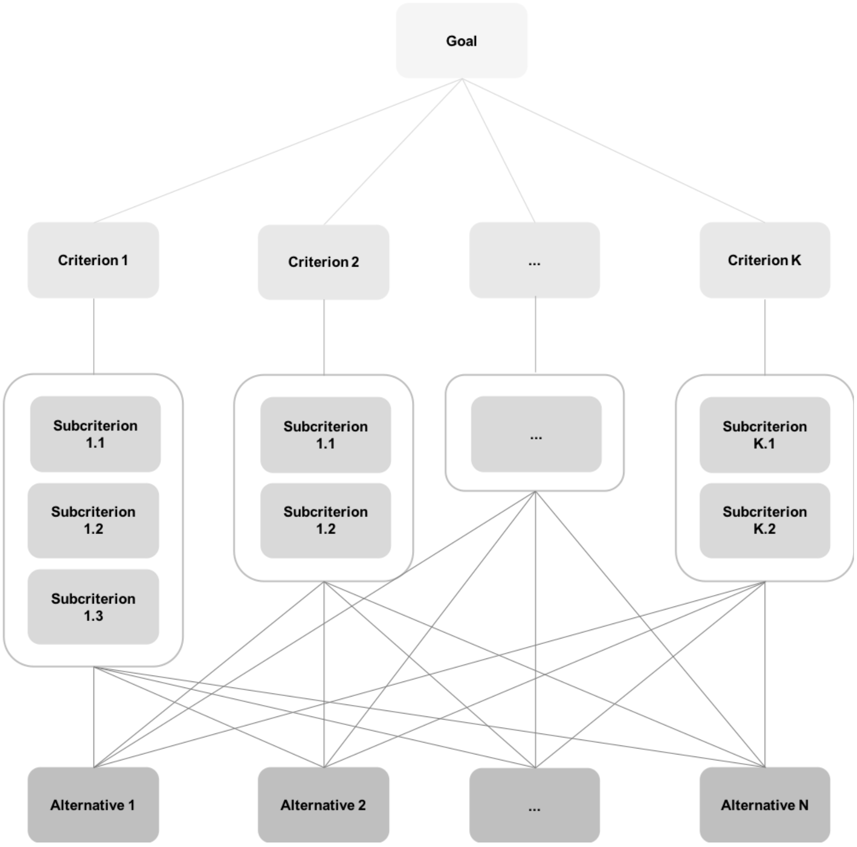


Figure 3.2: The AHP structure for solving decision making problems.

Table 3.2: Pairwise comparison matrix.

Criteria	C_1	C_2	…	C_n
C_1	1	a_{12}	…	a_{1n}
C_2	$1/a_{21}$	1	…	a_{2n}
…	…	…	…	…
C_n	$1/a_{n1}$	$1/a_{n2}$	…	1

Saaty (1987, 2008) defined a nine-point scale to quantify the relative importance between criteria, presented in Table 3.3. Figure 3.3 illustrates with an example how pairwise comparisons are performed in the SuperDecisions software for two generic criteria.

After building the pairwise comparison matrices, it is possible to derive the vector of weights regarding each matrix. This vector of priorities can be obtained through the eigenvector of the matrix (Saaty, 2001). The first step is to normalize the pairwise comparison matrices by dividing each entry by the sum of the correspondent column, which is followed by the determination of the mean of each row regarding the normalized matrix. In the presence of more than one level or layer in the hierarchy, this method only results in the obtention of the local weights. Therefore, global priorities must be obtained as explained in subsection 2.5.2.2.

Table 3.3: Nine-point scale proposed by Saaty (1977, 2008).

A_{ij}'s value	Subjacent Interpretation
1	Criterion i and j are **equally important**
3	Criterion i is **moderately more important** than j
5	Criterion i is **strongly more important** than j
7	Criterion i is **very strongly more important** than j
9	Criterion i is **extremely more important** than j
2,4,6,8	Intermediate values
Reciprocal Values	If criterion i has one of the above importance levels assigned to it regarding its comparison with criteria j, then j has the reciprocal value when compared with i

Given the nature of the AHP approach, a statistical measure must be used in order to check the consistency of the pairwise comparisons performed as inconsistencies may appear during the process, especially in decision contexts where the number of criteria to be compared is high (Asadabadi, Chang and Saberi, 2019). The consistency concern arises from the incapacity of humans in keeping consistent pairwise judgments when the number of elements intended to be compared increase (Asadabadi, Chang and Saberi, 2019).

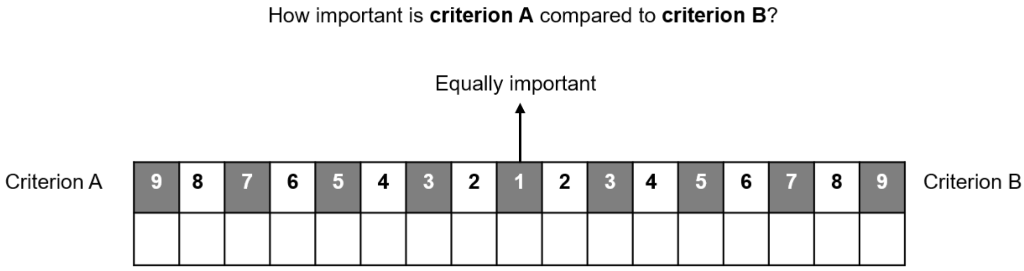


Figure 3.3: Illustrative example of how pairwise comparisons are performed in AHP. **Note:** The user is asked to indicate the criteria that is more important to him/her and how much more important it is in comparison to the other one. Table 3.3 should also be considered when performing the comparisons to make sure the user understands the subjacent interpretation of each number.

The statistical measure widely used when implementing AHP in MCDA problems is the Consistency Ratio (CR), which is used as an indicator to whether or not revise the judgements obtained (Saaty, 1977). According to Saaty (2001), the CR can be obtained by the following computation in equation 5:

$$CR = \frac{CI}{RI} \quad (5)$$

Saaty (1977) have firstly developed the Consistency Index (CI) as defined in equation 6, with λ_{max} representing the highest entry of the eigenvector of the consistency matrix – i.e. the highest eigenvalue – and n the number of criteria compared in that matrix (or its size). RI represents a random index, available in the literature (Saaty, 2001) and determined based on the average CI of random matrices. The pairwise matrices are considered consistent whenever the CR is below 0.1 or 10%, otherwise the judgments must be revised until this condition is satisfied. After obtaining a consistent matrix, the weights for the different criteria must be calculated and validated with the DMs. In this stage, adjustments can be done, but always ensuring that the condition CR < 0.1 is verified.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

Figure 3.4 intends to provide a summary of the main steps described for the AHP methodology in the present subsection. Despite the large number of advantages that turn AHP into a MCDA method with many applications in real-world decision-making problems, there are several critical analyses in the literature that expose its deficiencies (Bana e Costa and Vansnick, 2008; Asadabadi, Chang and Saberi, 2019; Karthikeyan, Venkatesan and Chandrasekar, 2016).

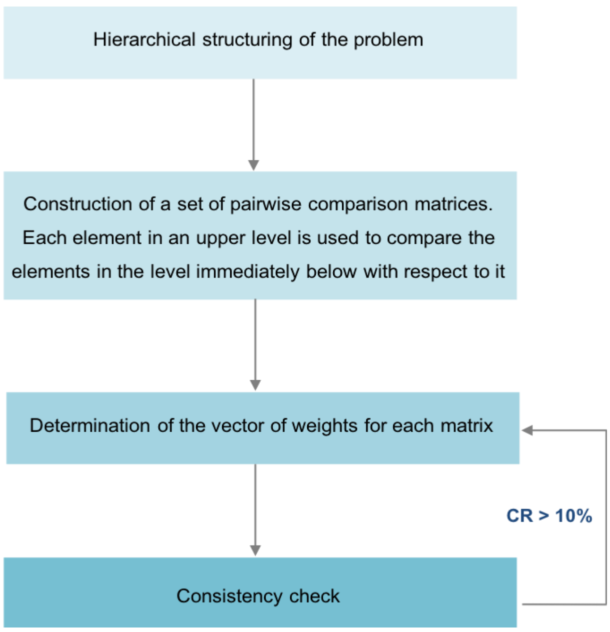


Figure 3.4: AHP fluxogram (Adapted from Saaty, 2008).

Bana e Costa and Vansnick (2008) focus their critical evaluation in the method used to derive priorities in AHP (the eigenvalue method). The authors defined two postulates – the conditions of order preservation (COP) presented in Table 3.4 – and demonstrated with examples that consistent pairwise comparison matrices (CR < 0.1) may not satisfy these postulates (Kułakowski, 2015). Is also important to mention that although these COP were formulated under the critical evaluation of an eigenvalue method, they should be satisfied in every priority deriving approach (Kułakowski, 2015). As previously mentioned, when the number of comparisons to be performed increase, it is difficult to ensure the consistency of the matrices, which requires the improvement of the CR, making sure it falls behind 0.1. Typically, in this approach the consistency of the judgments is only verified once the process is concluded, differing from other methods such as MACBETH – detailed in subsection 3.4.2.2 – where the user is warned every time an inconsistent judgment is inserted in the matrix. By doing so, inconsistencies are corrected on the ongoing evaluation of the model instead of afterwards.

Table 3.4: COP proposed by Bana e Costa and Vansnick (2008) (Adapted from Kułakowski, 2015).

COP	Definition
Order Preservation	For a pair of criteria $(c_i, c_j) \in C_k$ (k = 1, 2, ..., n) where c_i dominates c_j i.e., $a_{12} > 1$, the following condition must be verified: $w(c_i) > w(c_j)$.
Intensity Preservation	If c_1 dominates c_2, more than c_3 dominates c_4 (for $c_i, ..., c_4 \in C_k$), i.e. if in addition to $a_{12} > 1$, $a_{34} > 1$ and $a_{12} > a_{34}$, the following condition must be verified: $\frac{w\ (c_1)}{w\ (c_2)} > \frac{w\ (c_3)}{w\ (c_4)}$

There are two options to achieve a higher level of consistency in AHP, either by modifying the priority vector or the pairwise comparison matrices (Kułakowski, 2015). According to Bana e Costa and Vansnick (2008), the first option is best approach to follow as the weighting vector can suffer slightly modifications to ensure that the COP are satisfied without modifying the pairwise comparison matrices. The second option would imply the modification of the initial judgments, which would require special attention from the facilitator to ensure that a fair comparison is made between the elements instead of just manipulating of the pairwise comparisons' values in order to get rid of the inconsistency (Asadabadi, Chang and Saberi, 2019). Such manipulation often implies that evaluators of the model pay less attention to their preferences, which ultimately may lead to a dramatic change of the criteria weights (Asadabadi, Chang and Saberi, 2019). Karthikeyan, Venkatesan and Chandrasekar (2016) on their work highlight another weakness of the AHP approach – the unrealism of rank conservation when adding or removing criteria (or alternatives) to the model. The reason behind leads to another critic, the lack in defining reference levels for both criteria and alternatives under comparison. Revising such critics present in the literature was determinant to understand the drawbacks of this approach and adopt methodological adjustments to the way it is typically used in the MCDA framework. The detailed description of how AHP was implemented in the current research work to translate users' preferences into criteria weights will be provided in the next chapter.

3.4.2.2 MACBETH

The MACBETH approach is characterized by deriving a cardinal preference scale from semantic judgments used to express the difference in attractiveness between pairs of options (Bana e Costa, De

Corte and Vansnick, 2012). It was chosen together with AHP (detailed in the previous subsection) as it consists of a simple approach to solve decision-making problems, reflecting a lower complexity process than the one required by conventional methods and allows to eliminate inconsistencies during the elicitation process. Pairwise comparisons are performed using qualitative judgements, thus not requiring the attribution of numerical values and not being susceptible to the influence of the user's numeracy (Fasolo e Bana e Costa, 2014).

The MACBETH approach is implemented using the software M-MACBETH. It requires the use of descriptors of performance to define the different impact levels for each criterion. According to the content presented in subsection 2.5.2.1., two reference levels are assigned, an inferior and a superior one. The inferior level typically represents a neutral level of performance (not attractive but also not unattractive) whereas the superior level aims to capture a good performance level (unquestionably attractive) (Bana e Costa et al., 2008). These levels are used to anchor the value function model, defined in equation 4 (subsection 2.5.2.2). Revising the key concepts presented in subsection 2.5.2.2. and applying them to the MACBETH particular case, the overall benefit of an option j – $\boldsymbol{v_j}$ – is obtained by using an additive model, composed by a set of evaluation criteria $\boldsymbol{E_i}$, i = 1, 2,..., n and their respective performance descriptors $\boldsymbol{X_i}$, i = 1, 2,..., n. The performance of an option j in a criterion i – $\boldsymbol{x_{ij}}$ – can be measured by one of the performance levels of criterion i. Hence, the global score for a certain option j ($\boldsymbol{v_j}$) is given by (7):

$$\boldsymbol{v_j\left(x_{1j}, \dots, x_{nj}\right) = \sum_{i=1}^{n} v_i(x_i) w_i} \text{ with } \boldsymbol{\sum w_i = 1,\ w_i > 0} \text{ and } \begin{cases} \boldsymbol{v_i(x_i^+) = 100} \\ \boldsymbol{v_i(x_i^-) = 0} \end{cases} \quad (7)$$

where $\boldsymbol{v_i}$, i = 1, …, n are single attribute value functions – not explored here and MACBETH is only used with the purpose of deriving the criteria weights – $\boldsymbol{w_i}$, i = 1, …, n – and $\boldsymbol{x_i^+}$ and $\boldsymbol{x_i^-}$ are respectively the good and the neutral performance levels assigned to each descriptor.

The weight elicitation step in the MACBETH approach can either be obtained by hierarchical (using a beta version of the software) or non-hierarchical weighting. This step will determine the relative importance of each criteria in the evaluation of the model. Regardless of the weight elicitation technique chosen, the users who will evaluate the model will start by ranking the swings concerning the different criteria in terms of global attractiveness, considering for that purpose the swing that exists between the neutral and the good level of performance in each criterion (Bana e Costa et al., 2008). Therefore, the users will be confronted with all the different swings and will be first asked to select the most preferred swing, i.e. the criterion where going from the lower to the upper level is most desirable, as illustrated in Figure 3.5 (Beyer et al., 2014).

The step that follows the ranking of the swings is the construction of the judgement's matrix, a result of performing pairwise comparisons between pairs of criteria by evaluating the attractiveness of their swings. This difference in attractiveness is expressed by seven semantic categories ($\boldsymbol{C_k, k = 1, \dots, 7}$): (1) no difference, (2) very weak, (3) weak, (4) moderate, (5) strong, (6) very strong, (7) extreme (Bana e Costa et al., 2008). To perform these comparisons the user is asked the following: "What is the difference in attractiveness between the swing from the neutral to the good level in criterion A and the swing from the neutral to the good level in criterion B?" (Bana e Costa et al., 2008). Before starting the questioning protocol, the facilitator must rank the different criteria in the matrix according to the

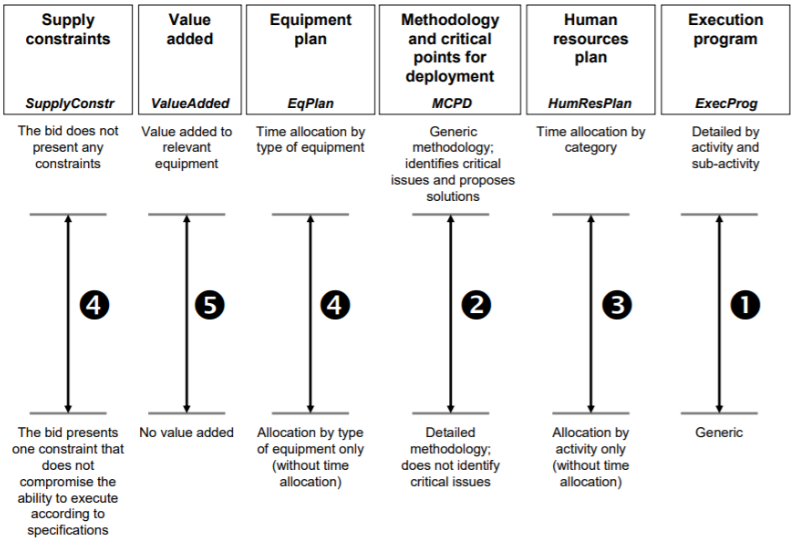


Figure 3.5: Example of ranked swings between neutral and good levels of performance (Bana e Costa et al., 2008). **Note:** In this example the supply constraints and equipment plan were considered to be equally attractive, thus the same rank was assigned, resulting in these criteria to have equal weights in the model.

attractiveness of their swings, from the left to the right, according to the result of the swing ranking process. Once the criteria are correctly ordered, each pair is compared using the questioning protocol and the semantic scale mentioned above. Therefore, the user starts by comparing the first most attractive criteria with the second most attractive, shifting to the comparison with the third one, and so one and so forth, until all the judgments are filled in the matrix as depicted in Figure 3.6. If once the matrix is filled, the criteria swings are correctly ranked according to the user's preferences, only the superior diagonal of the matrix needs to be filled in, as the M-MACBETH software can complete the remaining entries by transitivity. By completing a similar matrix to the one provided in Figure 3.6 with consistent judgments the criteria weights can be calculated using LP. The judgments present in the matrix are considered consistent if the following properties are satisfied:

1. If two swings in two different criteria (x,y) have the same level of attractiveness, the same weight should be assigned to them. Moreover, if x and y are individually compared to a criterion z, the difference in attractiveness between x and z should be the same as x and y.
2. A more attractive criterion has a higher weight assigned than the criteria that are less attractive.
3. If the difference in attractiveness between two criteria x and y is higher than the difference in attractiveness between w and z, the difference between the weights of the first pair is higher than difference between the weights of the second one.

The consistency of the judgments provided by the user is checked during the completion of the pairwise comparison matrix by the software M-MACBETH. Once an inconsistency is detected, the software alerts the facilitator and the judgements must be revised. The software is user friendly regarding this matter as suggestions are provided on how to solve this issue, by identifying which judgments should be modified. Once the process is completed and all the entries in the matrix are filled in (the ones in the superior diagonal), the software proposes a weight for each criterion as illustrated in Figure 3.7, with the sum of all the criteria weights being 1. The user must then validate the criteria weights obtained and, like in AHP, adjustments can be performed, but without violating the consistency of the judgments (Bana e Costa et al., 2008).

	[ExecProg]	[MCPD]	[HumResPlan]	[EqPlan]	[SupplyConstr]	[ValueAdded]	Neutral all over
[ExecProg]	I	weak	weak	strong	strong	v. strong	vstrg-extr
[MCPD]		I	weak	P	P	P	v. strong
[HumResPlan]			I	moderate	P	P	v. strong
[EqPlan]				I	I	P	strong
[SupplyConstr]				I	I	moderate	strong
[ValueAdded]						I	moderate
Neutral all over							I

Figure 3.6: Weighting judgment matrix for the evaluation criteria of the case study conducted by Bana e Costa et al. (2008). **Note:** The P and I entries in the matrix respectively represent a positive difference of attractiveness and an indifference (as the same weight was assigned to the two criteria in question).

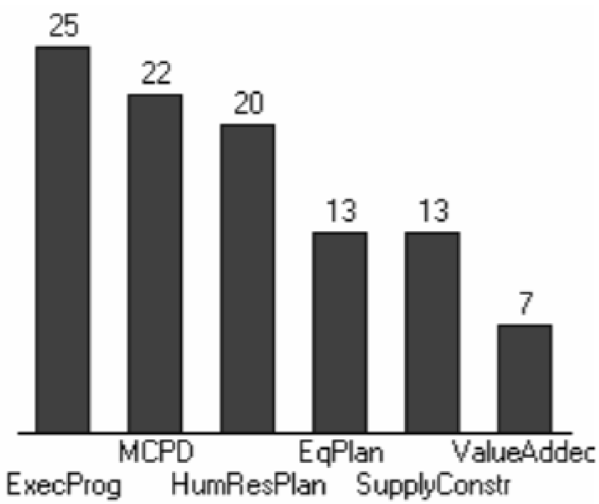


Figure 3.7: Criteria weights of the case study conducted by Bana e Costa et al. (2008).

Chapter 4

Application of the Methodology

The present chapter aims to document how the methodology previously proposed was used to meet the goals of the present research by detailing all the steps followed in structuring a MCDA model and obtaining the relative importance of the different environmental factors selected to be part of it. In addition, by applying the methodology designed it is possible to detect its major weaknesses and propose improvements for its further use in similar research work.

4.1 Problem Formulation

In section 3.1 it was detailed how the problem was appraised and it was highlighted the importance of its graphical representation in order to identify the most appropriate methodology to appraise it.
Since studying and analysing the factors that influence wayfinding in hospitals is a very dense topic, an initial approach was necessary to question the WG regarding the existence of possible exclusion criteria that would not be included in the final model. It is desirable to build a broad and exhaustive model, but conciseness is also important, as its complexity increases with the number of criteria that are part of it. Therefore, the problem's scope regarding the wayfinding factors or criteria C_i (i = 1, 2, ..., n) that should be considered to construct the model was defined:

I. Only the architectural features of the building that influence wayfinding will be considered as criteria to integrate the model, whereas the individual's characteristics (human factors presented in the literature review – subsection 2.3.2) will be considered to categorize different groups of users for whom the model will be tested later on.

II. Characteristics that regard the possibility of expansion or modernization of a certain building and the extent to what it would affect the impact of functioning of the existing hospital will not be considered, as the model intends to evaluate the ease of wayfinding in a stationary facility.

III. The extent to which the signage present in the environment reduces the complexity of wayfinding tasks will not be considered, leaving this factor out of the model. Although there are multiple characteristics to have to be taken into account when designing and placing signage in an environment (e.g. type, size, colour, place of mounting, frequency of placing, etc.), the WG agrees with the perspective of the authors who believe it has been used as a remedy to overcome problems arising from a poorly designed building.

IV. Even though for the hospital users the wayfinding tasks start from the moment they park the car outside the facility or walk from the bus stop nearby until the entrance, as depicted in Figure 4.1, a starting pointing for analysing wayfinding complexity needs to be defined. Ideally the distinctiveness of the main entrance and perhaps external architectural characteristics of the building would be picked as criteria for the model, but regardless its unquestionable importance, the WG agreed that the model will only consider the moment from which the user is already at the main entrance/reception desk of the facility, which is highlighted in Figure 4.1 as well.

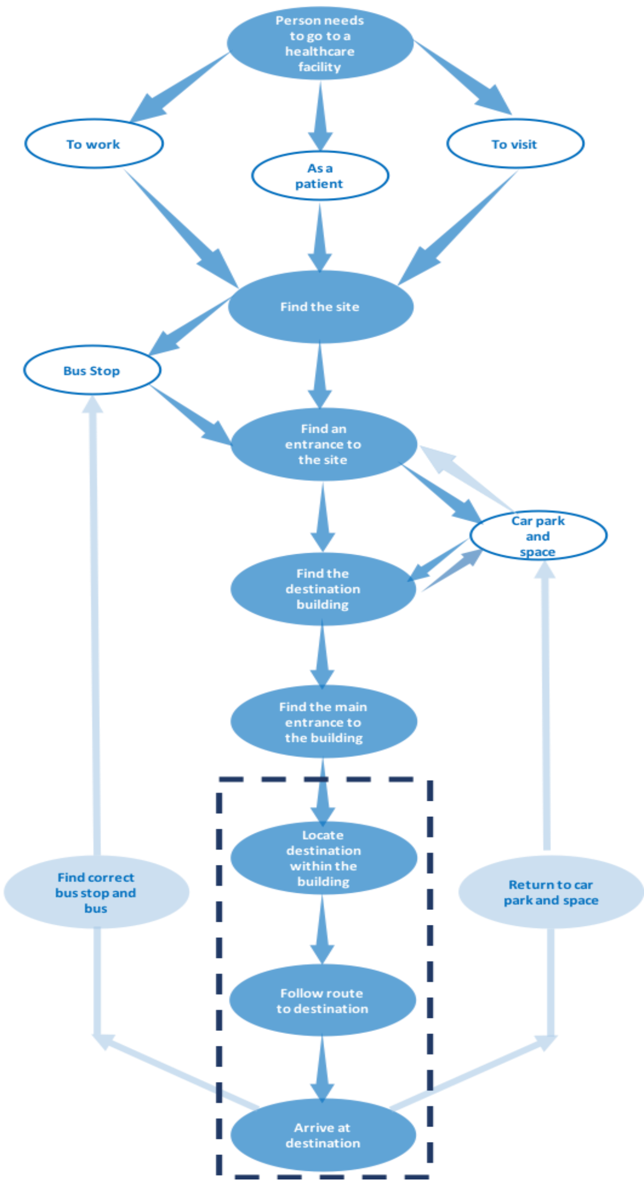


Figure 4.1: Common wayfinding related tasks when visiting a healthcare facility with the dashed rectangle comprising the activities that part of the problem's scope (source: Jeffrey, 1999). **Note:** The degree of layout complexity that characterizes a healthcare facility affects to a minimal extent the individuals who work there, as the more familiar with the building they become, the easier it will be to find their way around (even in an extreme complex building). Therefore, major relevance in this research is given to patients and visitors, the two groups of users for whom the degree of familiarity with these buildings tends to be low.

The identification of the groups of users UG_j (j = 1, 2, ..., m) was based on the literature review conducted on this topic (section 2.4), supported by the *Wayfinding Guidelines* (International Health Facility Guidelines, 2016) for healthcare facilities. Five main distinct groups of users where identified in this section – unimpaired, perception (sensory) impaired, mobility impaired, cognitive impaired and language and illiteracy impaired). The users who reveal a language or an illiteracy impairment are typically distinguished between users without reported impairments by their limitation in reading and extracting cues from the signage present in the environment. As this factor was not contemplated within the problem's scope, the WG determined that there was no reason to consider the mentioned group of users for further analysis. Hence, UG_1, UG_2, UG_3, UG_4 were defined as referring to unimpaired, perception (sensory) impaired, mobility impaired and cognitive impaired groups of users, respectively.

4.2 Problem Structuring

As previously mentioned in chapter 3, the problem structuring stage of MCDA also involves the generation of objectives. These objectives constitute the primary piece of information that later in the course of the model structuring step will give rise to evaluation criteria. Such process was mostly supported by the previous research conducted by the expert panel and the literature review presented in subsection 2.3.2. Presenting and organizing this literature in a comprehensive way is also part of the problem structuring step, as the evidence collected was summarized in different categories (subsections 2.3.1.1 – 2.3.1.6).

4.3 Model Building

As previously mentioned on the last chapter, the model building stage comprises the structuring and evaluation activities, respectively detailed in subsections 4.3.1 and 4.3.2.

4.3.1 Structuring

The structuring stage of the model building started with the combination of evidence coming from the literature review regarding environmental factors affecting wayfinding performance and the list of aspects provided by the WG. It was followed by the definition of areas of concern that would represent the different strategic objectives intended to be appraised by the MCDA model. These areas of concern comprise different evaluation criteria which weights need to be determined in the weighting elicitation step. On their prior list of aspects, the experts had identified four different areas of concern (architectural shape and scale and spatial relationships and quality) which are defined in Table 4.1. These different areas of concern represent the fundamental points of view (FPV) of the expert panel and allow to identify the evaluation criteria to use in the model (Beinat, E. and Bana e Costa, C., 2005). Therefore, in a preliminary stage all the four areas were considered. After defining them, the list of aspects provided by the WG was analysed as indicated Figure 4.2. In a preliminary analysis, the aspects that were not part of the problem's scope were not considered for further steps. Afterwards, a second analysis was conducted to determine if some aspects could be aggregated following the conciseness property of a value tree but also to remove aspects that were not trying to capture a FPV. In this step, six aspects were aggregated with others and three were removed as did not meet the requirements to be used for a detailed analysis. As figure 4.2 indicated, the initial list of aspects provided by the WG (n=24) was shortlisted to n=10.

Table 4.1: Areas of concern identified by the group of experts.

Area of Concern	Definition
Architectural Shape	It refers to how the building is built.
Architectural Scale	It refers to the building's dimensions.
Spatial Relationships	It refers to how the building is used or to how the different spaces are connected.
Spatial Quality	It refers to how the individuals experience the building while performing their wayfinding tasks.

An example of an aspect that was not considered after the preliminary analysis was the 'consistency', defined by the WG as "how the masterplan of the hospital can be expanded/modernized and what will be the impact on the functioning of the existing hospital". This aspect was excluded as the scope of the problem limits the wayfinding task to a stationary building. The 'number of rooms of the building' was another aspect not considered at this step as it strongly varies across healthcare facilities. It is related with the geographic location, the number of healthcare professionals and the affluency of visitors. Thus, it is expected that facilities located within urban areas serving many inhabitants in a certain region have a larger number of rooms that the ones located within rural areas for example.

The 'unit shape of the building' (which refers to its geometric shape, e.g. I, H, T, O shape) was an aspect considered as particularly important for the WG. Although it was not included after the further analysis for not capturing a FPV, by incorporating aspects such as visibility, topological organization of the building, average number of intersections per corridor, etc. In addition, some hospitals have simple unit shapes, such as a H shape or an O shape, but others have very complex shapes (difficult to describe) or are composed of several buildings, not presenting a unique shape. Being a characteristic with a high degree of variability and intrinsic of the building (and this research work is not focused in a particular healthcare facility, but instead intends to be as broad as possible) it cannot be included in the model. Moreover, as one can understand due to the nature of this aspect it is also not possible to assign a descriptor of performance to it. Other aspects were aggregated with ones that were capturing the same FPV. For instance, the WG included aspects on their list such as 'images/zones' – defined as areas characterized by a particular feature or function thus creating an identity for special groups of patients – or 'furniture' – to help the familiarity and legibility of the spaces. Both aspects are related with the 'degree of differentiation present in the building' and can be considered as landmarks (a variety of different objects that help providing legibility to the site), also identified as an aspect by the WG. Other example of an aspect that was aggregated is the 'number of elevators/staircases' present in the facility. The WG defined the 'quality' aspect as being related with the proximity of bathrooms, staircases or elevators and emergency exits along the way. The first aspect was integrated with the second one mentioned as quality also intends to determine whether or not such facilities are proximal to the user or if he/she has to move a lot in order to reach them. If so, it might be an indicator that such elements are not that abundant within each floor of the facility. Therefore, the two aspects were aggregated into a single one named as ‘availability and proximity of facilities’.

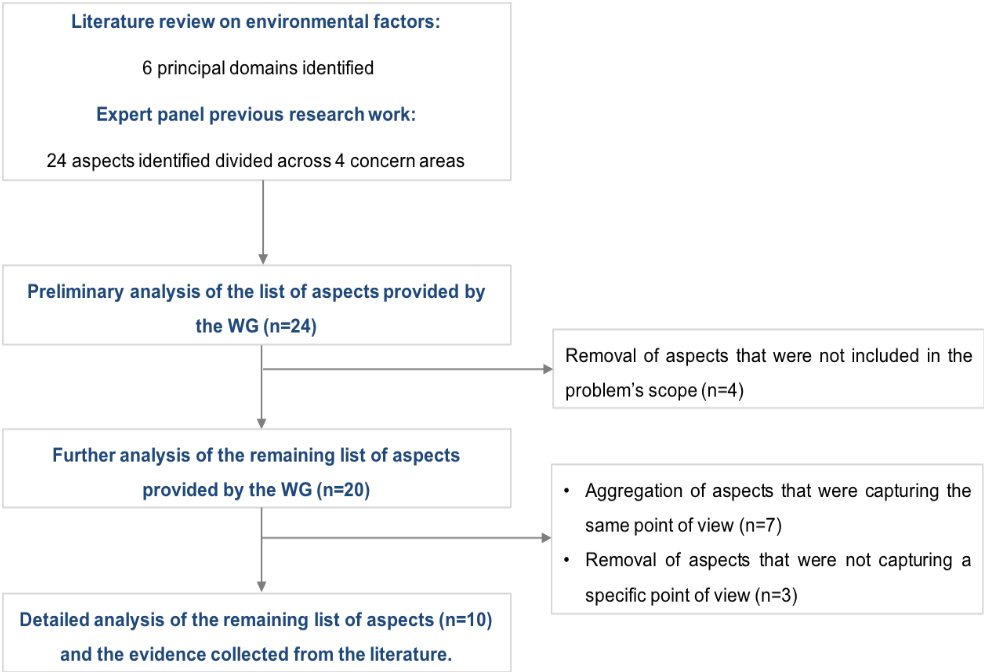


Figure 4.2: Flowchart of the analysis conducted on the list of aspects provided by the WG.

The operations listed in Figure 2.9 (subsection 2.5.2.1) were used to build the hierarchical structure of the value tree, combining the two different sources of information (after shortlisting the aspects provided by the WG) and aiming to respect what was previously defined as being the problem’s scope. The criteria collected from the literature review presented in subsection 2.3.2 were thus inserted into one of the initial areas of concern. Any criterion from the list that the experts provided, which value concern was not being addressed by any other criterion already present in the hierarchy and that was within the problem’s scope, was added to the value tree. However, if at some time in the process it was perceived that one criterion would reflect the same value concern as another one, one them would be removed to avoid duplicates. A criterion was also divided into two (or more) sub-criteria in the same hierarchical level if more than one FPV was trying to be captured. Furthermore, two (or more) criteria would be aggregated if their underlying point of view could be captured by one single criterion following the conciseness property of a value tree. A final list of ten criteria with their respective sub-criteria (when applicable) was elaborated in collaboration with the WG (Table 4.2) and an effort was made to describe each of them as clearly as possible, also indicating how they could be measured. The four initial areas of concern were narrowed to two in the end of the model structuring as no longer four different FPV were being “purely” captured. The WG decided that more relevance should be given to the ‘Architectural Shape’ and ‘Spatial Quality’ of the building, which consequently resulted in the criteria belonging to the other areas of concern being integrated into one of former two. The concern area ‘Architectural Shape’ comprises FPV which importance was highlighted in section 2.3.2, such as the ‘route complexity’, the ‘degree of differentiation present in the spaces’ and the ‘integration of the different flows’. Other aspects were inserted in this concern area due to the expertise and knowledge of the WG in this domain, namely the ‘boundaries’ evaluation criterion, which intends to quantify the ratio between soft and hard spaces (a detailed definition of such terms is also provided in Table 4.2). By its turn, the concern area ‘Spatial Quality’ comprises fundamental points of view that will help measuring the extent to which the way individuals experience their presence in the environment while performing wayfinding tasks. Part of the evaluation criteria present in this area also regard concerns briefly explored in the literature review (‘environmental sensation’ and ‘crowdedness’) but others were added based on the research work conducted by the WG. The list of criteria was validated by all the parts involved in the process and was further used to construct descriptors of performance for each criterion. Although, before moving to an evaluation of this model, it was necessary to shortlist one more time the set of evaluation criteria in order to minimize the cognitive burden of the stakeholders involved in the evaluation of the model. This time with a more in-depth analysis, by considering what would might not be such as relevant for the wayfinding performance, using the evidence available in the literature and the expertise of the WG. The result of this analysis is presented in Figure 4.3 in the form of a value tree of evaluation criteria, denoting the hierarchical structure that exists between them.

The ‘visibility’ criterion was not considered for further analysis, since as reviewing section 2.3.2.2, there is evidence in the literature that supports that it might be related to the criterion ‘intersections’. Ideally, the visibility within a certain area of the building would be measured by the VI, although it is difficult to predict what is a good value of the VI for the wayfinding performance as there is no evidence in the literature that supports so. Moreover, it has only been used as a measure to determine the degree of visibility within spaces of airport terminals and one cannot generalize its applicability to healthcare facilities. Therefore, in the context of this research, the VI could not be assigned as a descriptor of performance to the visibility criterion as the measure of its performance would not be realistic. Dada (1997) demonstrated in his research work within airport terminals that a higher ICD generally implies a lower visibility for the users, although the researcher also recognizes that not all the variation in the VI can be explained by the ICD, which is also concordant with the position assumed by Slone et al. (2014). In order to avoid the preference dependence of both criteria (intersections and visibility) only the intersections criterion was kept in the list as it is more accessible to measure through the ICD and does not bring variability across different environments. Given the extension of the list of criteria present in Table 4.2, four other criteria/sub-criteria were also not included in the evaluation of the model stage in order to diminish the cognitive burden of the assessors, namely the ‘topology’ of the building, the ‘horizontal architectural differentiation’ and the ‘smell’ and ‘climate’ (these last two in regard the ‘environmental sensations’ experienced by the users). The first was excluded based on the lack of healthcare facilities that do not present a balance between horizontality and verticality. Regarding ‘horizontal architectural differentiation’, Cubukcu (2003) recognizes that this parameter is somewhat important to wayfinding performance, but also that ‘vertical architectural differentiation’ – particularly expressed through the presence of landmarks in the environment – is strongly more important, setting the relevance of the horizontal aspect to a lower level. Finally, for the two sub-criteria part of the ‘environmental sensation’ criterion, their exclusion was based on the insufficiency of evidence found in the literature regarding their contribution to the wayfinding performance of users, when comparing to the other sub-criteria under the same parental node.

Table 4.2: List of criteria elaborated during the model structuring stage.

<table>
<tr><th>Concern Area</th><th>Criteria</th><th colspan="2">Sub-Criteria</th><th>Definitions</th></tr>
<tr><td rowspan="8">Architectural Shape

(how it is built)</td><td rowspan="5">Route Complexity</td><td colspan="2">Distance</td><td>This criterion intends to represent a distance estimation from the onset of wayfinding tasks until the final destination is reached and it and can be measured through the distance estimation in meters.</td></tr>
<tr><td colspan="2">Verticality</td><td>This criterion intends to quantify the number of floor changes that occur during the patient’s route within the same building (Zijlstra, 2016).</td></tr>
<tr><td colspan="2">Building Interchanges</td><td>This criterion intends to quantify the number of building changes that occur during the patient’s route (Zijlstra, 2016).</td></tr>
<tr><td colspan="2">Changes in Direction</td><td>This criterion intends to quantify the number of turns taken along the path (Turner, 2004).</td></tr>
<tr><td colspan="2">Intersections</td><td>This criterion intends to quantify the average number of directions to choose from at any decision point and can be measured using the ICD as a direct measure (O’Neill, 1991).</td></tr>
<tr><td rowspan="3">Differentiation
(The extent to which different areas of the building appear unique or might be confused due to symmetry and repetition of similar elements)</td><td rowspan="2">Architectural</td><td>Horizontal</td><td>This criterion intends to measure the degree of horizontal differentiation present in different floors of the facility. Horizontal differentiation is intrinsically related with path surfacing (e.g. changes in the pavement and in the width) (Sun, 2010; International Health Facility Guidelines, 2016; Cubukcu, 2003).</td></tr>
<tr><td>Vertical</td><td>This criterion intends to measure the degree of vertical differentiation present in the different floors of the facility. Vertical differentiation is intrinsically related with the presence of landmarks (Sun, 2010; Cubukcu, 2003).</td></tr>
<tr><td colspan="2">Structural Symmetry Between Floors</td><td>This criterion intends to measure the degree of similarity and symmetry, with a major focus on the structure, between different floors of the same building (Adapted from Montello and Pick, 1993).</td></tr>
</table>

Concern Area	Criteria	Sub-Criteria	Definitions
Architectural Shape (how it is built)	**Visibility**		The extent to which people moving through a sequence of spaces have the opportunity to see into adjacent spaces (Trzpuc, 2010). The more connected the adjacent spaces are, the more visible the surrounding environment will be for the user, i.e. if one space is isolated from the others the degree of visibility will be lower, whereas if there is a great connectivity between the different spaces of the facility, the degree of visibility significantly increases. This criterion can be measured through the isovist concept (the amount of space that can be seen from any vantage point), when considering a hypothetical 100% percentage for a full 360º visibility (Batty, 2001; Haq, 2012).
	Boundaries		The extent to which the building addresses the separation between different spaces regarding the presence of hard boundaries like walls versus soft boundaries like changes in wall colour or floor surface. (International Health Facility Guidelines, 2016). According to Trzpuc (2010) the boundaries of the building also allow to access the degree of openness of the different spaces. Notice that soft boundaries are also related with the presence of soft spaces or rooms, a flexibility attribute. A space or room is considered soft if it can be easily moved from one place to another (e.g. visitors may encounter rooms that were moved out of place from on visit to another) whereas a hard space is fixed in the building and it can't be moved (Rostenberg, 1995; Levin, 2014).
	Integration of Flows		The extent to which the building provides private corridors for the various types of healthcare flows (e.g. if the hospital was designed with the aim of separating public flows from healthcare flows or if these flows are mixed and patients often have to pass through corridors that intend to serve healthcare professionals to reach their destination) (Borigianni and Steola, 2016).
	Topology		The extent to which the building structure swifts between horizontality and verticality (e.g. if it's built across a large horizontal area and presents a small number of floors or if it's built with a lot of floors stacked on top of another) (Hölscher et al., 2013).

Concern Area	Criteria	Sub-Criteria	Definitions
Spatial Quality (how it is experienced)	**Crowdedness**		This criterion intends to evaluate the degree of crowdedness present in the facility and it can be measured through the density of people observed in the circulation spaces (Borigianni and Steola, 2016). It is positively influenced by the degree of centralization present in the facility's layout and the affluence of users.
	Environmental Sensation	**Lighting**	This criterion intends to appraise the building's amount and type of light available (e.g artificial light versus sunlight) (Kopvol, 2010; Huelat, 2007).
		Smell	This criterion intends to appraise the building's fragrances users may experience while traveling around the facility (e.g. smell of foods, toilets, medicins) (Kopvol, 2010).
		Sounds	This criterion intends to appraise the building's different type of sounds users may experience while traveling around the facility (e.g. unpleasant sounds arising from traffic flows or from the crowdedness versus pleasant sounds like background music) (Kopvol, 2010; International Health Facility Guidelines, 2016).
		Tactile	This criterion intends to appraise the different tactile sensations (e.g. different kind of wall and floor coverings) users may experience while traveling around the facility (Kopvol, 2010; International Health Facility Guidelines, 2016).
		Climate	This criterion intends to appraise the building's climate regarding its ventilation, degree of humidity and differences in temperature users may experience while traveling around the facility (Pütsep, 1981).
	Safety		The extent to which the building perceived to be safe by the users. There are several factors that contribute to the user's safety namely the floor slip resistance (a smoother surface provides less slip resistance and a rougher surface provides greater slip resistance), the presence or absence of objects in the path (visual noise), the corridor dimensions in terms of width and height and all the safety aspects related with elevators and staircases (Galper, 1987).
	Availability and Proximity of Facilities		The extent to which the building provides a reasonable access in terms of proximity to toilets, emergency exits, staircases and elevators. It can be measured through the number of each of these elements that are present per floor and the distance that the users need to travel in order to reach them (Adapted from Hozak, 2016).

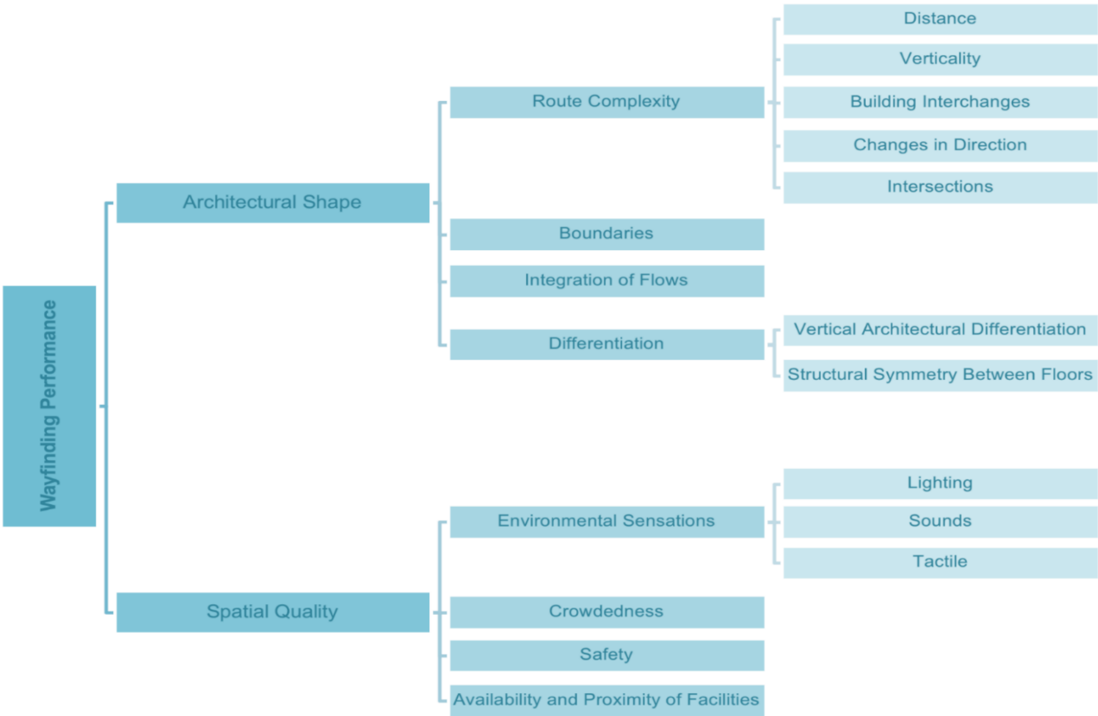


Figure 4.3: Value tree of evaluation criteria.

In order to avoid the preference dependence of both criteria (intersections and visibility) only the intersections criterion was kept in the list as it is more accessible to measure through the ICD and does not bring variability across different environments. Given the extension of the list of criteria present in Table 4.2, four other criteria/sub-criteria were also not included in the evaluation of the model stage in order to diminish the cognitive burden of the assessors, namely the 'topology' of the building, the 'horizontal architectural differentiation' and the 'smell' and 'climate' (these last two in regard the 'environmental sensations' experienced by the users). The first was excluded based on the lack of healthcare facilities that do not present a balance between horizontality and verticality. Regarding 'horizontal architectural differentiation', Cubukcu (2003) recognizes that this parameter is somewhat important to wayfinding performance, but also that 'vertical architectural differentiation' – particularly expressed through the presence of landmarks in the environment – is strongly more important, setting the relevance of the horizontal aspect to a lower level. Finally, for the two sub-criteria part of the 'environmental sensation' criterion, their exclusion was based on the insufficiency of evidence found in the literature regarding their contribution to the wayfinding performance of users, when comparing to the other sub-criteria under the same parental node. After the definition of the evaluation criteria and their hierarchical structuring in a value tree, each criterion was operationalized by constructing descriptors of performance. Such construction was based on the available literature and then presented to the WG for further adjustments and approval. Two reference levels were defined for each evaluation criterion (one neutral and one good), following the guidelines presented in subsection 2.5.2.1. The result of this activity can be found in Tables 4.3 – 4.17. The definition of the different reference levels was carefully performed to ensure a clear and unambiguous interpretation of their meaning. For some criteria more than two levels were defined in order to understand what would be a neutral and a good level of performance. It is important to note that although the operationalization of the evaluation criteria is not part of the AHP approach (only the MACBETH one), it ensures that they are compared using references levels. By doing so, all the participants are placed at the same level, as they do not evaluate the model and its different criteria from an unspecified level of performance. Furthermore, without references the participants' judgements might be influenced by their knowledge and experience, which could introduce bias during the assessment.

Table 4.3: Constructed performance scale for the *distance* subcriterion.

Performance Levels	
For the wayfinding task the user distance estimation lies between…	
…]0, 500] m	L1
…]500, 1000] m	**L2 = Good**
…]1000, 1500] m	**L3 = Neutral**
…> 1500 m	L4

Table 4.4: Constructed performance scale for the *verticality* subcriterion.

Performance Levels	
Within a wayfinding task the user needs to change floors of the same hospital/facility…	
…0 times	L1
…1 time	**L2 = Good**
…2 times	**L3 = Neutral**
…> 2 times	L4

Note: The good level of performance – L2 – represents the hypothetical situation where the floor where the main entrance is located has a direct connection (e.g. an elevator) to the floor where the user's destination is located. Therefore, if the user's main destination is in a different floor than the floor where he/she entered the building, he/she would only have to change between floors one time. L1 represents the situation where no changes between floors are required, i.e. the user's main destination is located within the same floor where he/she entered the building. L3 and L4 represent situations where no direct connection is provided between the main entrance's floor and the floor where the user's destination is located, requesting one (or more) floor changes along the route. Two floor changes are expected in situations where the user needs to travel between the floor where the main entrance is located to an intermediate floor, and from there find the connection to the destination floor.

Table 4.5: Constructed performance scale for the *changes in direction* subcriterion.

Performance Levels	
Within a wayfinding task the user needs to change his/her direction along the path…	
...Up to 3 times	**L1 = Good**
…4-6 times	**L2 = Neutral**
…More than 6 times	L3

Table 4.6: Constructed performance scale for the building *interchanges* subcriterion.

Performance Levels	
Within a wayfinding task the user needs to change between buildings of the same hospital/facility…	
…0 times	**L1 = Good**
…1 time	**L2 = Neutral**
…>1 time	L3

Note: The good level of performance – L1 – represents the hypothetical situation where the user's main destination is located within the same building from where he/she entered. L2 and L3 represent situations where building interchanges are required along the user's route, even though a direct connection exists between the different buildings.

Table 4.7: Constructed performance scale for the *intersections* subcriterion.

Performance Levels	
The building presents an ICD that lies between…	
…]0, 1.7]	L1
…]1.7,2.1]	**L2 = Good**
…]2.1,2.5]	**L3 = Neutral**
…]2.5,2.9]	L4
…>2.9	L5

Note: The definition of the performance level was based on the information retrieved from the research work of Dada (1997), which is summarized in Table 2.2.

Table 4.8: Constructed performance scale for the *vertical architectural differentiation* subcriterion.

Performance Levels	
The building presents…	
…a good amount of memorable and unique landmarks with a high visual range (visible from multiple locations) along the route and within the main decision points	**L1 = Good**
…a good amount of memorable and unique landmarks visible within certain restricted areas and within the main decision points	**L2 = Neutral**
or	
… a small amount of memorable and unique landmarks with a high visual range along the route and within the main decision points	

Table 4.9: Constructed performance scale for the *boundaries* criterion.

Performance Levels	
The building is composed of…	
…a greater amount of soft spaces versus hard spaces	**L1 = Good**
… a similar amount of hard and soft spaces	**L2 = Neutral**

Table 4.10: Constructed performance scale for the *structural symmetry* subcriterion.

Performance Levels	
The building presents…	
…a good level of structural symmetry between its different floors with facilities such as toilets, elevators and stairs placed within the same location on each floor	L1 = Good
…a low level of structural symmetry between its different floors, but common identifiable characteristics regarding the structure of the different floors	L2 = Neutral

Table 4.11: Constructed performance scale for the *integration of flows* criterion.

Performance Levels	
In general, the hospital was designed with the aim of separating public flows from healthcare flows	L1 = Good
Public flows are not well separated from healthcare flows and patients often have to go through corridors that intend to serve healthcare professionals to reach their destination	L2 = Neutral

Table 4.12: Constructed performance scale for the *availability and proximity of facilities* criterion.

Performance Levels	
In each floor the elements are placed near to the main decision points and can be easily reached	L1 = Good
In each floor the elements are not so close to the main decision points, but can still be reached without a lot of effort	L2 = Neutral

Table 4.13: Constructed performance scale for the *lighting* subcriterion.

Performance Levels	
Within a wayfinding task the user experiences…	
…an appropriate amount of lighting available without the presence of dark spaces, with the type of lighting being a balanced combination of natural sunlight with artificial light	L1 = Good
…either an appropriate amount of lighting available with the presence of few dark spaces or an unbalanced combination of natural sunlight with artificial light	L2 = Neutral

Table 4.14: Constructed performance scale for the *sounds* subcriterion.

Performance Levels	
Within a wayfinding task the user experiences…	
…a withstandable amount of background noise that does not interfere with his/her auditory perception	L1 = Good
…a moderate to high amount of background noise that starts to interfere with his/her auditory perception and may disrupt his/her capability of depicting sounds from the surrounding environment	L2 = Neutral

Table 4.15: Constructed performance scale for the *tactile* subcriterion.

Performance Levels	
Within a wayfinding task the user experiences…	
…a good diversity of tactile sensations throughout the facility that arise from the different kinds of floor and wall coverings present in the environment	**L1 = Good**
…a poor diversity of tactile sensations throughout the facility	**L2 = Neutral**

Table 4.16: Constructed performance scale for the *crowdedness* criterion.

Performance Levels	
Within a wayfinding task the user experiences that…	
...the main circulation spaces in the facility present a low degree of crowdedness	**L1 = Good**
...the main circulation spaces in the facility present a moderate degree of crowdedness	**L2 = Neutral**

Table 4.17: Constructed performance scale for the *safety* criterion.

Performance Levels	
Within a wayfinding task the user experiences…	
…a good level of safety provided by the environment	**L1 = Good**
…a moderate level of safety provided by the environment	**L2 = Neutral**

4.3.2 Evaluation

The conclusion of the model structuring was followed by activities focused on assessing the relative importance of the different environmental factors (selected in the previous stage) affecting the wayfinding performance of healthcare facilities' users.

Given,

1) the nature of the current problem, where scarce research work has been conducted so far – especially in close contact with the different user groups that one can encounter in healthcare facilities; and

2) the methodology defined to appraise it, where two different methods were selected to obtain the criteria weights,

a pilot study was the research technique considered to be the most appropriated direction to follow. The goal of conducting a pilot study is essentially evaluating the feasibility of a full-scale research project. Moreover, it is also desirable to "test the methods and procedures to be used on a larger scale" and determine which amendments would be necessary in order to extend the dimension of the study (Thabane et al., 2010, p.1). Furthermore, since two different methods were selected to obtain the criteria weights, one also intends to determine which would be the most appropriate one to use with a larger sample, based on the feedback provided by the users who were selected in this stage.

4.3.2.1 *Preparation of the Practical Assessment*

During the last two weeks of July 2019, the researcher tried to establish contact with retirement and nursing homes located within the Flanders region of Belgium, the country where the research was conducted. A positive feedback was received from a facility located within the target region, whose manager was contacted for further details and explanation of the entire project and showed interest in collaborating in this research work by allowing several visits and personal interviews with the patients interested in participating. This facility is a dedicated housing facility for elderly or people with impairments (e.g. mobility, cognitive), but it also works as an adult day care centre, with most of the patients aging over 70 years old. Its permanent residents have their own suite and access to a large variety of recreational activities organized by the two occupational therapists that are part of the staff.
Prior to the practical assessment, an information sheet and an informed consent were prepared to distribute among the participants. Two versions of these documents were elaborated, one in English and one in Dutch, as although the patients were fluently in spoken English (according to indications from the facility's manager), Dutch was their mother tongue. It is important that they would develop a full understanding of how the information gathered will be further used and processed but also, of what is expected from their participation. Moreover, the informed consent form (Appendix C) emphasizes the voluntary character of such participation. This implies that participants can drop out of the process even after having agreed to participate or refuse to answer certain questions during the course of action. The information sheet (Appendix B) provides a brief description of the full research project to the participants but also the objectives and methodology developed to conduct the case study. Figure 4.4 illustrates the three different steps of this methodology intended to be performed by each participant. Details on how each step was organized and conducted will be further discussed in the next subsection. Prior to the practical assessment (in particular to the weight elicitation), the value tree presented in Figure 4.3 was introduced in the software programs used to support this step (SuperDecisions for AHP and M-MACBETH for MACBETH) (Figures F.1 and G.1 of Appendices F and G, respectively).

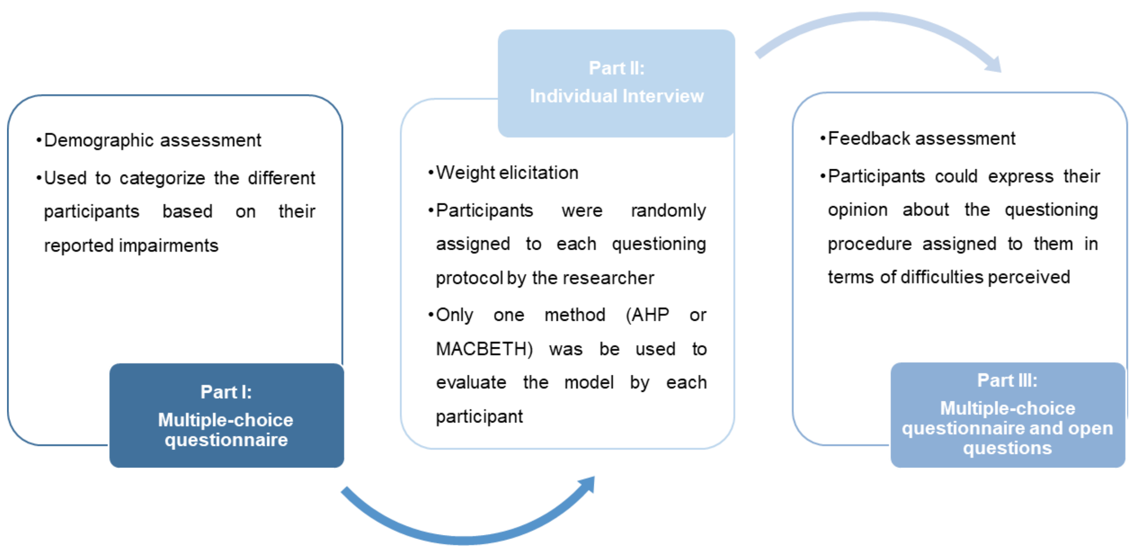


Figure 4.4: Methodology developed for the pilot study.

The manager of the facility together with one of the occupational therapists were previously familiarized with the target participants for this pilot study. It was predetermined that only participants with a full cognitive capacity could take part of this study and that their families and/or their legal guardians had to agree on their participation by also signing the informed consent. In addition, these two members of the staff were informed about the need for a balanced sample of users regarding not only the gender but also the type of disabilities reported.

4.3.2.2 Practical Assessment

Five visits took place to the retirement home during the month of August 2019 in order to conduct the study. A preselection of participants was performed by the facility's staff who provided the researcher a preliminary list of 16 patients who demonstrated interest in collaborating in the study. Furthermore, and given the constrains previously imposed (of not including participants without a full cognitive capacity), one occupational therapist agreed on evaluating the model on behalf of a user with a cognitive impairment. Since these professionals are used to deal with such patients in their daily work, they have a good perception on how the factors present the model contribute to a decline in their reasoning and ability to find their way around healthcare environments. Other two members of the staff (another occupational therapist and one general assistants) also agreed on participating in the study as representatives of users without reported disabilities. Therefore, a total amount of 19 participants was scheduled to participate in the assessment. Finally, it was also predetermined that each participant would have to perform all the three parts of this assessment in the same day, following the sequence illustrated on Figure 4.4.

- ***Part I – Demographic Assessment***

A demographic assessment took place in the form of a multiple-choice questionnaire, in order to categorize the patients by age, gender and type of impairment (Appendix D). It was composed of eight questions and the ones used to assess users' impairments where adapted from the WHS (WHO, 2002). As mentioned earlier, this survey was conducted worldwide by the WHO aiming to obtain a global picture on the prevalence of disabilities among the population. These subgroup of questions (3-7) aimed to evaluate on a scale from none to extreme, the extent to which each impairment affects their ability to perform daily routine tasks, considering the 30 days that preceded the practical assessment (excluding the 6th and the 7th question, where no specific period of time was mentioned). This time window is adequate for participants to recall about their increased effort, pain or any type of discomfort experienced by carrying out an activity (WHO, 2002). Moreover, it is also seen as a good indicator for the model evaluation activity as users with a temporary impairment might not have a broad perception of which are the most limiting factors for wayfinding activities in healthcare environments. In order to correlate both variables (the extent to which each impairment affects their ability to perform daily routine tasks and how often they tend to have contact with healthcare facilities) an extra closed-ended question was introduced in the questionnaire. Users who are often confronted with wayfinding difficulties in such built environments tend to have a good overview of which factors contribute to a greater extent to the deterioration of their ability to find their way around, which is a great asset for the model evaluation exercise.

- ***Part II – Weight Elicitation***

The second part of the practical assessment was exclusively dedicated to deriving the criteria weights based on the users' judgements. It was conducted in the form of personal interviews (in English) between each participant and the researcher. An occupational therapist was also present to provide translation assistance whenever necessary. The researcher randomly assigned each participant to one of the two questioning protocols, having in mind the need for a balanced sample of participants per method and type of impairment. The interaction with each participant started by providing some context and detailing the objectives of the research work. A list of the criteria included in the model (Table 4.2) together with all the performance descriptors that operationalize each of them (Tables 4.3 – 4.17) was also provided. The participants were asked to carefully read these supporting materials and to try to get familiar with the terminology used. An effort was made by the researcher to answer as clear as possible to all the questions about the content present in the supporting material provided. Once the participants had developed a common understanding of the factors present in the model and were ready to move forward, the weighting protocol was implemented.
The technical steps required at this stage to perform the elicitation of weights in each software were performed by the facilitator. Appendices F and G provide support to the reader by detailing how each approach was implemented in M-MACBETH and in SuperDecisions. Prior to the completion of each pairwise comparison matrix, the ranking of the swings for each criterion took place in both questioning protocols, following the example of Figure 3.6 and the guidelines of subsection 3.4.2.2. Although the swing ranking step is not contemplated in the AHP approach, it was adopted as an attempt to provide valid references for the criteria under comparison and to reduce the inconsistency of the future judgements – given the number of criteria present in the model. A total amount of 15 cards (the number of evaluation criteria) containing each swing being evaluated was distributed to the participants during the interview. An example of such card is presented in Figure 4.5. In total, 42 pairwise comparisons were requested to each participant. Giving the extension of this part of the assessment, participants were allowed to take breaks whenever necessary. The pairwise comparison matrices were filled in the following order for both approaches: 1) Route Complexity node, 2) Environmental Sensation node, 3) Differentiation node and 4) Wayfinding Complexity global node. To ease the reasoning behind each pairwise comparison, similar cards to the one presented in Figure 4.6 were distributed to them. The researcher suggested the consideration of two distinct situations in each criterion: situation A and B. Situation A would represent a neutral level of performance, whereas situation B a good level of performance. The participants would then evaluate the transition from one situation to another in both criteria under comparison (from left to right in Figure 4.6).

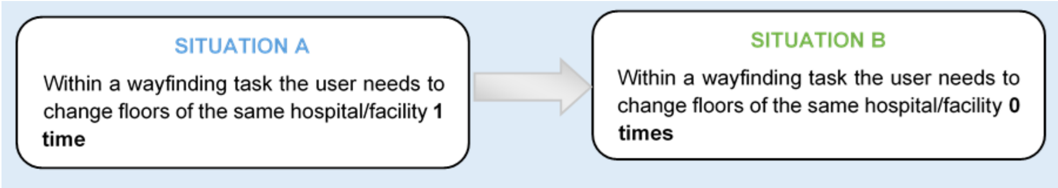


Figure 4.5: Example of one of the 15 cards distributed to the participants for the swing ranking procedure.

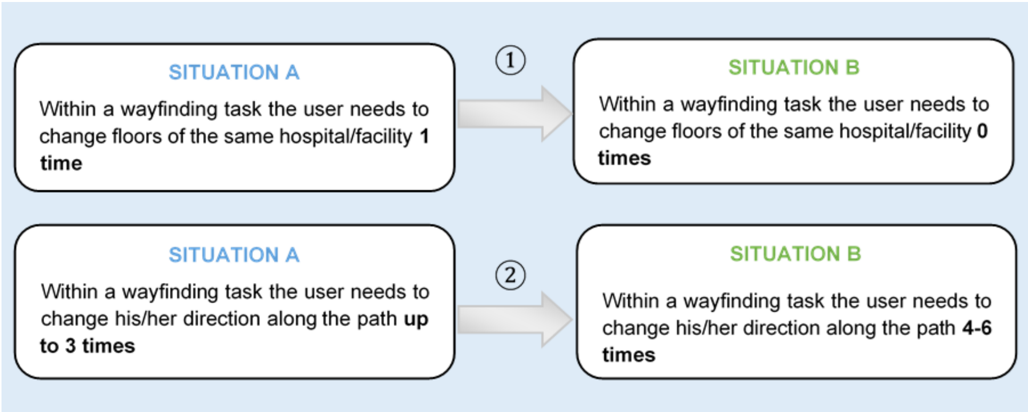


Figure 4.6: Example of pairwise comparison card given to the participants.

For each pairwise comparison in the MACBETH approach, the participants were asked "What is the difference in attractiveness between the transition from situation A to situation B in (1) and the transition from situation A to situation B in (2)?". Each of these questions was answered using one of the levels of the following scale: (1) no difference, (2) very weak, (3) weak, (4) moderate, (5) strong, (6) very strong, (7) extreme, which was also provided to each participant beforehand. During the completion of the pairwise comparison matrices, every time the software alerted for the introduction of an inconsistent judgement, the researcher asked the participants to revise it, by proposing the suggestions available on the screen. After the completion of each pairwise comparison matrix, the software generated the correspondent interval scale for the criteria being evaluated and the respective histograms with the weights as depicted in Figures G.11 – G.18. These figures were shown to the participants in order to obtain their validation for the criteria weights derived from their judgements. It was also given the opportunity to them to adjust the values if they intended so, without violating the consistency of the judgements. In contrast to the MACBETH approach, the participants to whom the AHP questioning protocol was assigned to were asked "How important is the transition from situation A to situation B in (1) in comparison to the transition from situation A to situation B in (2)?". In other words, each user was asked to indicate the transition – (1) or (2) – that he/she considered more important and by how much in comparison to the other transition. To quantify this importance, the nine-point scale of Table 3.3 was used, being provided to the participants during the practical explanation of this step of the assessment. For this questioning protocol, the consistency of the judgements was only performed after the determination of the vector of weights for each matrix as indicated on Figure 3.4. If the CR for each matrix was equal or higher than 0.10, the participants would be asked to revise their judgements. Suggestions on how to reduce the CR were given to the participants, by indicating examples of modifications proposed by the software. The modification of the initial judgments was performed with a close follow up from the researcher, ensuring that fair comparison was made between the elements avoiding the manipulation of the pairwise comparisons' values in order to get rid of the inconsistency. Although this was not described as the least preferred alternative to reduce the CR in subsection 3.4.2.1, it was identified as the easiest way to do so for the participants, as modifying the priority vector without knowing the cause of such inconsistency would have been a difficult to accomplish by them. Moreover, and aiming to ensure that the ranking of the swings completed in the previous step was respected, the researcher also alerted the participants for inconsistencies detected during the weight elicitation that would infringe this ranking. Similar to the procedure described for the MACBETH questioning protocol, the participants were also confronted with the histograms of weights derived from their judgements in order to validate them. Adjustments in the weighting vectors were performed upon request, always ensuring that the condition of the CR falling below 0.10 was being respected.

- ***Part III – Feedback Assessment***

The final part of the practical assessment consisted of a feedback questionnaire where the participants had the opportunity to express their opinion about the questioning procedure used to assess their preferences by answering simple multiple-choice questions about its difficulty and overall satisfaction. They were also submitted to a hypothetical questioning protocol different from the one used in the part II of their assessment, i.e., the one they were not assigned to. The idea behind was trying to perceive which would be the most intuitive questioning protocol to use with a larger sample if the results were robust enough to draw such conclusion. It was asked the difficulty perceived in performing pairwise comparisons using the new questioning protocol and if the participants would rather prefer the new questioning protocol over the one they were assigned to, or if they were indifferent to it. Thus, two versions (A and B) of this questionnaire were elaborated (see Appendix E), differing in the question regarding the exposure of the participants to the new questioning protocol. The feedback assessment questionnaire also had a section dedicated to the feedback of the researcher regarding each participation. Feedback on the main difficulties reported by the participants during the interview and while answering part I and III questionnaires, accompanied by the duration of the assessment and overall difficulty perceived in completing it, from the researcher's point of view was provided. A final question was also asked to the participants regarding possible suggestions that could enhance similar future research conducted in this topic.

Chapter 5

Results

The upcoming chapter presents the results obtained after the completion of the model evaluation (integrated in the model building stage of the methodology developed) which was performed by the different participants involved in the practical assessment. Therefore, it will follow the same organizational structure as subsection 4.2.2.2 of the previous chapter.

In the first section (5.1), the sample of users used to estimate the criteria weights will be characterized. Given that part I of the assessment aimed to collect demographic information of the participants (sex, age and type of impairments reported) and the frequency of visits to healthcare facilities, it was possible to structure the gathered information and obtain a global picture of their characteristics. Moreover, as the participants were randomly assigned to one of the two distinct questioning protocols used for the evaluation step, the subsamples used for each of them will also be characterized in this section, aiming to determine if the intended goal of a balanced sample of users (per type of impairment) was achieved.

Section 5.2 comprises the analysis of the criteria weights obtained using the AHP and MACBETH approaches where an aggregation of the individual judgements for each approach within the same user group (when applicable) took place. Hence, the main intended results of the present research were obtained. According to several authors there are two ways of performing such aggregation, and this procedure has been widely used in group decision making where multiple stakeholders or DMs evaluate the built model, aiming to obtain a consensus outcome (Ramanathan and Ganesh, 1994; Belton and Pictet,1997; Ishizaka et al., 2011; Hummel et al., 2014). The first method, using the geometric mean as statistical measure to calculate the average score on each pairwise comparison, was originally proposed by Saaty (1982) as in the AHP approach the uses a ratio scale (Hummel et al., 2014). In alternative, the weighted average mean can also be used. According to Ramanathan and Ganesh (1994), the weighted average mean is the most appropriate statistical measure to reflect the priorities of the group as a whole. In this approach, all the individuals assigned to participate in the assessment perform their individual pairwise comparisons and once this step is concluded, the individual outcomes are aggregated using the arithmetic mean (Hummel et al., 2014). After this aggregation, the weight obtained for each criterion could be interpreted as the relative importance of having a similar experience to situation (1) rather than situation (2) – following the reasoning depicted in Figure 4.6 – in that criterion during the completion of wayfinding tasks (from the standpoint of the user group).

The last section of the present chapter (5.3) is dedicated to the characterization of the results obtained for what regards the overall satisfaction and difficulty perceived by the participants in completing the second part of the practical assessment. Furthermore, it also includes the preferences manifested by them in what would be the most wanted questioning protocol for expressing value judgements. Finally, it will also combine the individual feedback collected by the researcher for each participant regarding the type of difficulties manifested, the duration of the weight elicitation exercise and the suggestions proposed to enhance the quality of future work.

5.1 Characterization of the Sample

A total amount of 19 participants was scheduled to participate in the practical assessment. 16 of them were patients of the retirement home whereas the other three were healthcare providers (two occupational therapists and one general assistant). As mentioned earlier, one of the providers evaluated the model in order on behalf of a user with a cognitive impairment. The multiple-choice questionnaire regarding part I of the assessment was answered according to this individual demographics, and part III questionnaire according to his overall feedback, thus not reflecting the difficulties that would be experienced by someone with this type of impairment. Two of the 16 patients scheduled to participate in the assessment stage withdrew before completing all steps. Therefore, their demographic information is not considered in this section. The withdraw of these participants was related with the cognitive burden of the weight elicitation exercise given the number of pairwise comparisons required. One of these participants was expected to perform the weight elicitation step using the AHP questioning protocol, whereas the other the MACBETH one. Both manifested discomfort during this part of the assessment and expressed interest in stopping the interview, decision which was naturally respected by the researcher.

Table 5.1 provides an overall sociodemographic characterization of the sample used to evaluate the built model based on the sociodemographic variables assessed on the part I multiple-choice questionnaire. This characterization is performed considering the overall sample but also the subsample of participants assigned to each of the questioning protocols used. A distinction between the type of participants is also made (as there is a column designated to the patients and other to the providers – occupational therapists and assistants).

Table 5.1: Characterization of the sample used to assess the model.

		Total Sample		AHP Sample		MACBETH Sample	
		Patients	Providers	Patients	Providers	Patients	Providers
N		14	3	6	2	8	1
Sociodemographic Variables		n (%)		n (%)		n (%)	
Gender	Female	8 (57.1)	1 (33.3)	4 (66.7)	1 (50.0)	4 (50.0)	-
	Male	6 (42.9)	2 (66.7)	2 (33.3)	1 (50.0)	4 (50.0)	1 (100.0)
Age	18-19	-	-	-	-	-	-
	20-29	-	3 (100.0)	-	2 (100.0)	-	1 (100.0)
	30-39	-	-	-	-	-	-
	40-49	-	-	-	-	-	-
	50-59	2 (14.3)	-	2 (33.3)	-	-	-
	60-69	3 (21.4)	-	1 (16.7)	-	2 (25.0)	-
	70+	9 (64.3)	-	3 (50.0)	-	6 (75.0)	-

Difficulty in moving around (in the last 30 days)	**None**	4 (28.6)	3 (100.0)	2 (33.3)	2 (100.0)	1 (12.5)	1 (100.0)
	Mild	3 (21.4)	-	-	-	3 (37.5)	-
	Moderate	5 (35.7)	-	2 (33.3)	-	4 (50.0)	-
	Severe	2 (14.3)	-	2 (33.3)	-	-	-
	Extreme	-	-	-	-	-	-
Difficulty in concentrating and remembering things (in the last 30 days)	**None**	4 (28.6)	3 (100.0)	2 (33.3)	2 (100.0)	2 (25.0)	1 (100.0)
	Mild	8 (57.1)	-	4 (66.7)	-	4 (50.0)	-
	Moderate	1 (7.1)	-	-	-	1 (12.5)	-
	Severe	-	-	-	-	-	-
	Extreme	1 (7.1)	-	-	-	1 (12.5)	-
Difficulty in learning a new task (in the last 30 days)	**None**	5 (35.7)	3 (100.0)	3 (50.0)	2 (100.0)	2 (25.0)	1 (100.0)
	Mild	7 (42.9)	-	3 (50.0)	-	4 (50.0)	-
	Moderate	1 (7.1)	-	-	-	1 (12.5)	-
	Severe	1 (7.1)	-	-	-	1 (12.5)	-
	Extreme	-	-	-	-	-	-
Vision Impairment	**None**	3 (21.4)	3 (100.0)	1 (16.7)	2 (100.0)	2 (25.0)	1 (100.0)
	Mild	6 (42.9)	-	2 (33.3)	-	4 (50.0)	-
	Moderate	3 (21.4)	-	2 (33.3)	-	1 (12.5)	-
	Severe	1 (7.1)	-	-	-	1 (12.5)	-
	Extreme	1 (7.1)	-	1 (16.7)	-	-	-
Hearing Impairment	**None**	5 (35.7)	3 (100.0)	3 (50.0)	2 (100.0)	2 (25.0)	1 (100.0)
	Mild	7 (50.0)	-	2 (33.3)	-	5 (62.5)	-
	Moderate	1 (7.1)	-	-	-	1 (12.5)	-
	Severe	1 (7.1)	-	1 (16.7)	-	-	-
	Extreme	-	-	-	-	-	-
Frequency of Healthcare Facility Visits	**Never or Very Rarely**	-	-	-	-	-	-
	Rarely	1 (7.1)	-	1 (16.7)	-	-	-
	Occasionally	5 (35.7)	2 (66.7)	2 (33.3)	2 (100.0)	3 (37.5)	-
	Frequently	5 (35.7)	1 (33.3)	2 (33.3)	-	3 (37.5)	1 (100.0)
	Very Frequently	3 (21.4)	-	1 (16.7)	-	2 (25.0)	-

The sample used to test the model can be considered well balanced concerning the number of participants assigned to each questioning protocol (47.1% for the AHP and 52.9% for the MACBETH), although slightly unbalanced if one considers only the patients subsample (42.9 and 57.1%, respectively).

The frequency of healthcare facility visits for the overall sample demonstrated to be above average as 35.3 and 17.6% of the participants reported to visit such places frequently and very frequently, respectively. Although this is only a qualitative indicator – as it was not specified by them how many visits (on average) are performed on a monthly or six-monthly basis for instance – it was considered extremely positive given the aim of the present research work.

In the participants' subsample, 64.3% of the individuals were aged 70 or higher, with the female gender being the most representative (57.1%). Regarding the three providers who participated in the study, all of them were aged between 20 and 29 years old and no impairments were reported for this group.

All the patients reported at least one type of impairment in the demographic questionnaire filled in, with some participants reporting more than one type of difficulties. Given the inherent characteristics of this subsample, especially the age of the group and the fact that all of them were inhabitants of a retirement home facility, this was somehow expected. However, it is important to highlight that the evaluation of their health status in what regards the degree of perception of the impairments was performed by the participants themselves. Therefore, it might not correspond to the full veracity of their condition or differ from a hypothetical standard evaluation performed by a medical doctor or other type of healthcare professional. In order to categorize the patients into one or more user groups UG_j (j = 1, 2, 3, 4) included in the problem scope, it was necessary to analyse their answers to the questionnaire. In a scale from none to extreme concerning the extent to which each impairment affects their ability to perform daily routine tasks, only participants who reported at least a moderate restriction were integrated in the respective user group UG_j (j = 1, 2, 3, 4). Mild difficulties were not considered as the health condition of these patients is extremely influenced by their age, leading to the natural deterioration of their ability to move around, remembering things or even learn new tasks. The inclusion criteria in UG_4 – cognitive impaired user group – were predefined as reporting at least a moderate difficulty in concentrating or remembering things and/or learning a new task in the last 30 days. A similar rule was applied to integrate participants under the UG_2 – perception (sensory) impaired user group, by considering individuals with at least a moderate limitation regarding their vision and/or hearing capability. The result of the integration of the participants (both providers and patients) into one of the user groups predefined in the problem's scope – per assigned questioning protocol – is presented in Table 5.2.

Table 5.2: Integration of the participants into one of the user groups predefined in the problem scope per assigned questioning protocol.

User Group	Questioning Protocol	
	AHP	MACBETH
UG_1 – Unimpaired User Group	1	1
UG_2 – Perception (Sensory) Impaired User Group	3**	2**
UG_3 – Mobility Impaired User Group	4****	4
UG_4 – Cognitive Impaired User Group	1*	2***

Notes: * – Provider who evaluated the model on behalf of a cognitive impaired user. ** – One of the patients reported both vision and hearing impairments. *** – Both patients reported difficulties in concentrating and remembering things and learning a new task. **** – One of the patients in this group is also categorized under UG_2.

5.2 Weight Elicitation Results

This section is organized in two subsections (5.2.1 and 5.2.2). The former comprises the results of the weight elicitation step for the participants to whom the AHP questioning protocol was assigned to, whereas the later follows the same structure but for the MACBETH approach instead. Additionally, subsection 5.2.1 will begin with an evaluation of the inconsistencies detected in the judgements for each of the criteria nodes under evaluation, following an analogous approach found in the literature for a similar problem. The results here presented will be discussed in the next chapter, by comparing the weights obtained for the factors under analysis with the findings presented in the literature review.

5.2.1 AHP

The result of a similar analysis to the one conducted by Danner et al. (2017) is presented in Figure 5.1. It was conducted in order to evaluate the overall inconsistency of the judgements performed by the participants who used the AHP approach in the weight elicitation step. Therefore, an average of the CR for the individual judgements performed by the patients' subsample regarding each node was calculated. Since the CR is only calculated when three or more pairwise comparisons are performed, the differentiation node was not considered for this analysis (as only one pairwise comparison was required). By analysing Figure 5.1 one can depict that the average value of the CR progressively increased with the number of pairwise comparisons required in each node (3, 10 and 28, respectively). Regarding the obtained CR values for the provider included in the AHP subsample (8.25, 8.20 and 11.16), they are considerably lower than the averaged ones presented in Figure 5.1, with only the last CR value requiring a review of the judgements. Although, a comparative analysis between the CR values obtained for the two subsamples would be desirable here, in order to determine if the inherent characteristics of the patients' subsample influenced the outcome, the size of the providers' subsample (n=1) does not allow so.

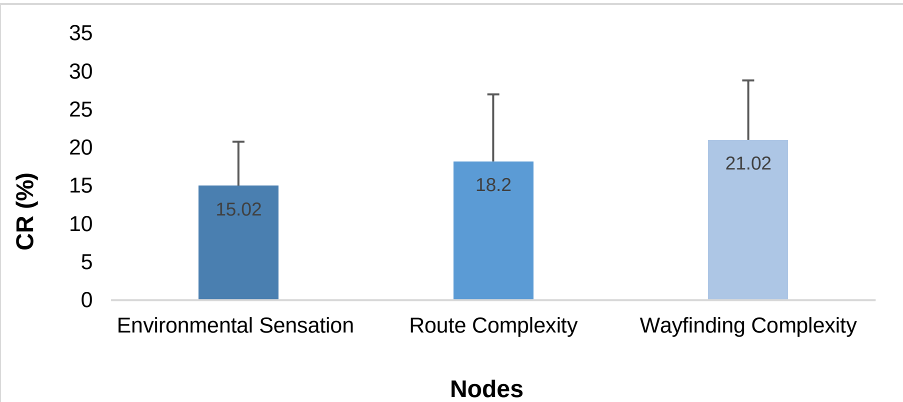
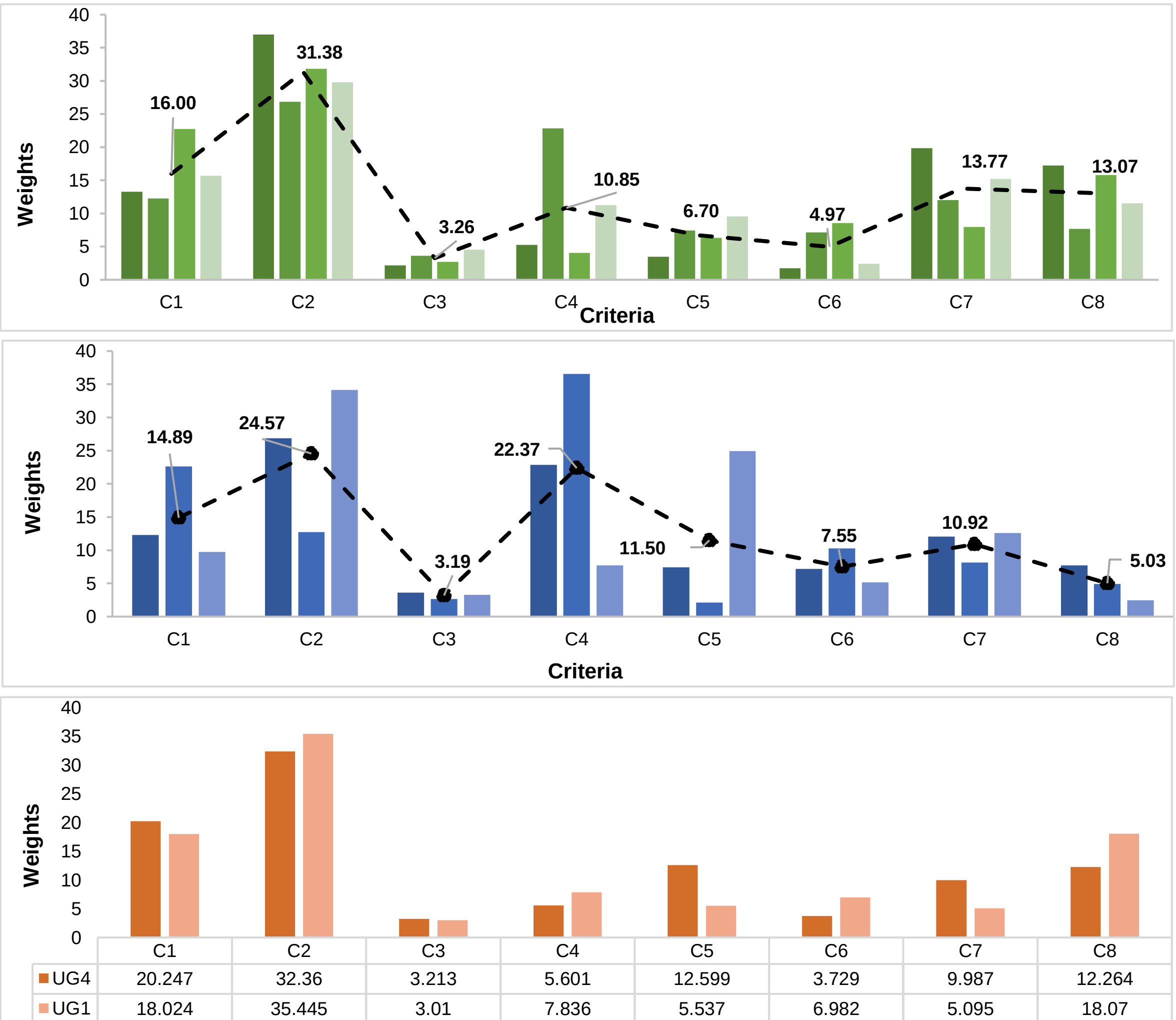


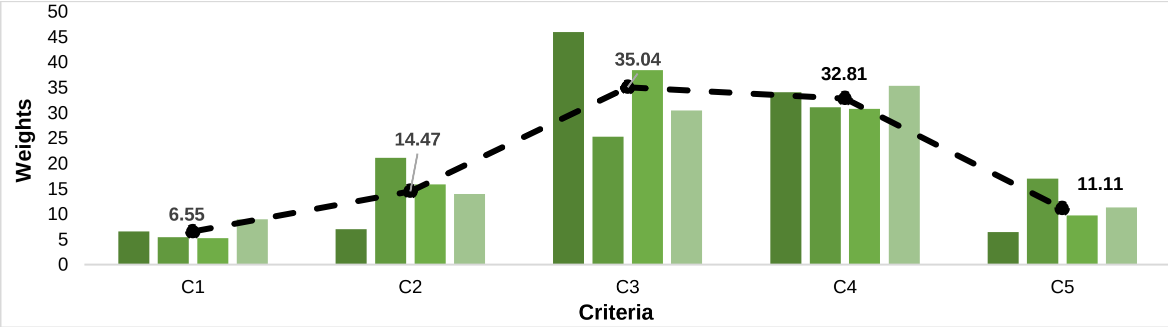
Figure 5.1: Averaged CR for the individual judgements performed by the patient's subsample (n=7) using the AHP approach for the different nodes.

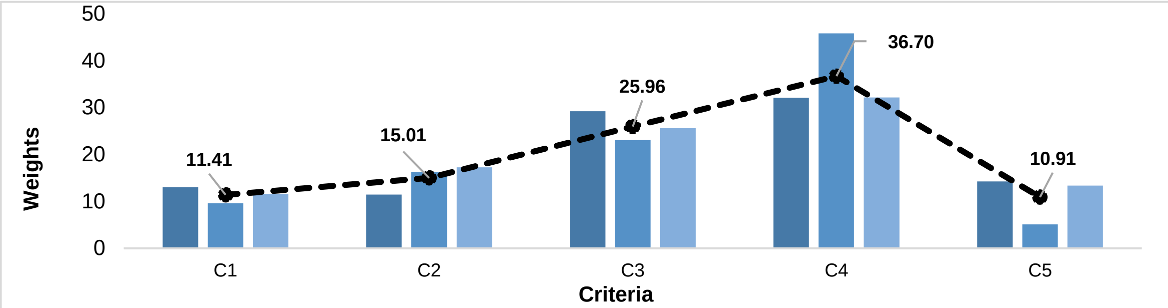
Figures 5.2 to 5.10 include the individual and overall (when applicable) criteria weights obtained for each user group and criteria node under evaluation following the respective categorization of the participants provided in Table 5.2. In Figures 5.5 to 5.10 the criteria weights are displayed in a local scale, so in order to obtain the global weights for those parameters, it would be necessary to multiply their weights by the weight of the parental node. Finally, Table 5.3 presents the obtained weights for the Spatial Quality and Architectural Shape nodes. These weights were calculated based on the sum of the weights of their respective children nodes (according to the properties of an additive value model). The results obtained and here presented need to be interpreted as reflecting the amendments made in the original AHP questioning protocol to implement in the current study. In the traditional approach, the higher the weight, the more important the respective criterion is for the user. Here the weight attributed to the different factors regards the importance that the users give to the transition from a neutral to a good performance level in each of them.

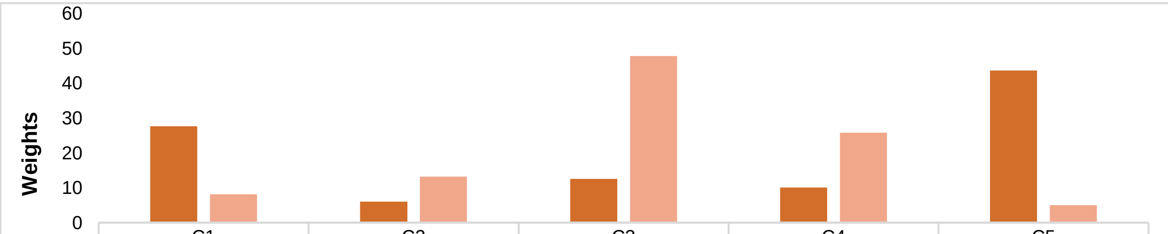


	C1	C2	C3	C4	C5	C6	C7	C8
UG4	20.247	32.36	3.213	5.601	12.599	3.729	9.987	12.264
UG1	18.024	35.445	3.01	7.836	5.537	6.982	5.095	18.07

Figures 5.2 – 5.4: Individual and aggregated (dashed lines) criteria weights criteria weights obtained for the wayfinding complexity (global node) for the users included in UG_3, UG_2 and the two participants included in UG_1 and UG_4, respectively Legend: C1 – Availability and Proximity of Facilities, C2 – Route Complexity, C3 – Environmental Sensation, C4 – Safety, C5 – Boundaries, C6 – Integration of Flows, C7 – Crowdedness, C8 – Differentiation.







	C1	C2	C3	C4	C5
UG4	27.63	6.039	12.59	10.059	43.682
UG1	8.112	13.173	47.857	25.857	5.001

Figures 5.5 – 5.7: Individual and aggregated (dashed line) criteria weights obtained for the route complexity for the users included in UG_3, UG_2 and the two participants included in UG_1 and UG_4. Each colour represents one participant of the group (the same as in Figures 5.3 and 5.4) and the aggregated weights are displayed for the respective data points. Legend: C1 – Intersections, C2 – Distance, C3 – Verticality, C4 –Building Interchanges, C5 – Changes in Direction.

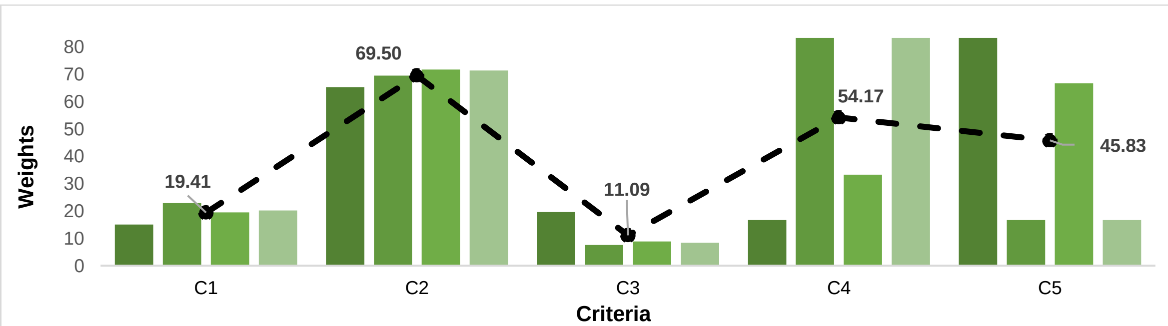
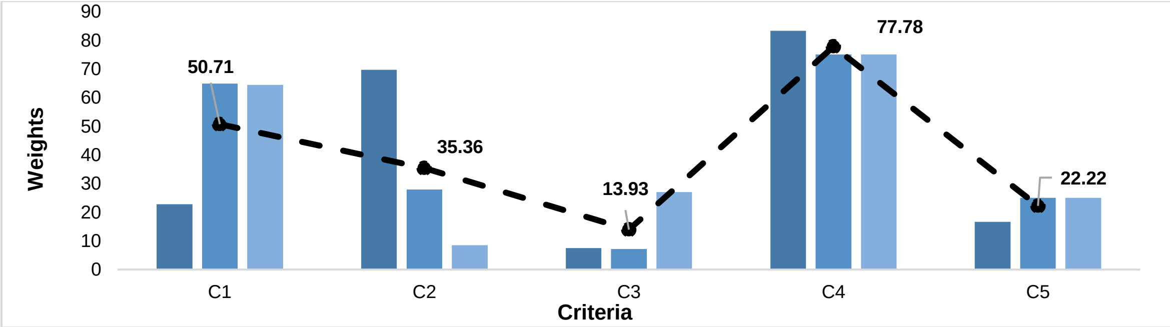
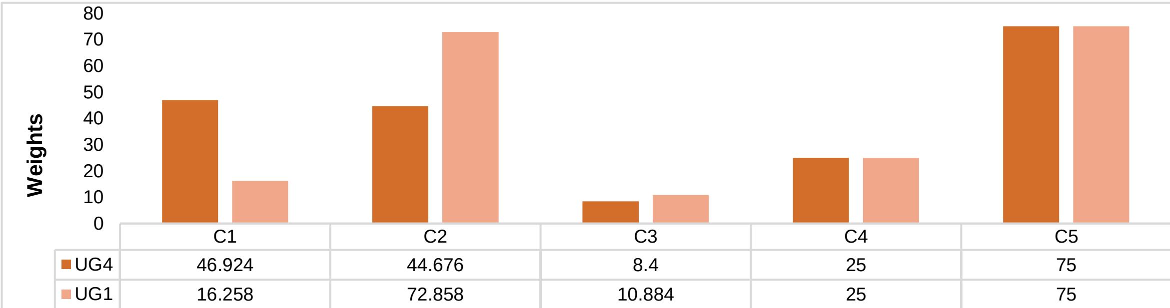


Figure 5.8: Individual and aggregated (dashed line) criteria weights obtained for the environmental sensation (C1-C3) and differentiation (C4 and C5) nodes for the users included in UG_3. Each colour represents one participant of the group (the same as in Figures 5.2 and 5.5) and the aggregated weights are displayed for the respective data points. Legend: C1 – Sounds, C2 – Lighting, C3 – Tactile, C4 –Structural Symmetry, C5 – Vertical Architectural Differentiation.





Figures 5.9 and 5.10: Individual and aggregated (dashed line) criteria weights obtained for the environmental sensation (C1-C3) and differentiation (C4 and C5) nodes for the users included in UG2 and the two participants included in UG1 and UG4. Each colour represents one participant of the group (the same as in the previous figures) and the aggregated weights are displayed for the respective data points. Legend: C1 – Sounds, C2 – Lighting, C3 – Tactile, C4 –Structural Symmetry, C5 – Vertical Architectural Differentiation.

Table 5.3: Weights obtained for the spatial quality and architectural shape nodes.

User Group	**Weights**	
	Spatial Quality	**Architectural Shape**
UG_1 – Unimpaired User Group	28.97	71.03
UG_2 – Perception (Sensory) Impaired User Group	51.35	48.65
UG_3 – Mobility Impaired User Group	43.88	56.12
UG_4 – Cognitive Impaired User Group	39.05	60.95

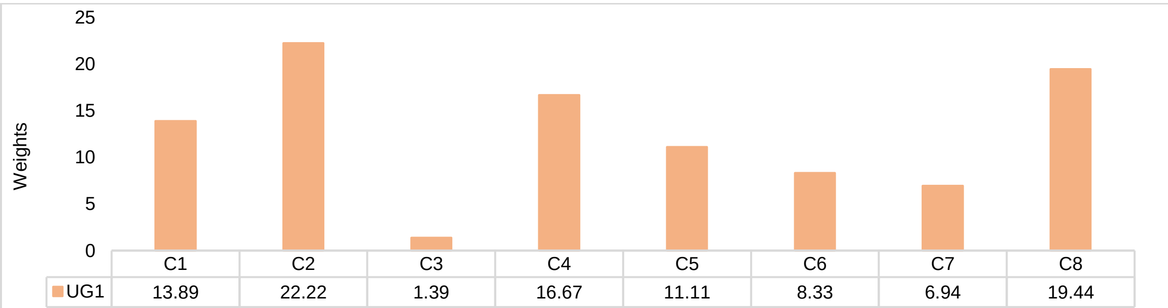
Note: The weights displayed for UG_2 and UG_3 are aggregated values.

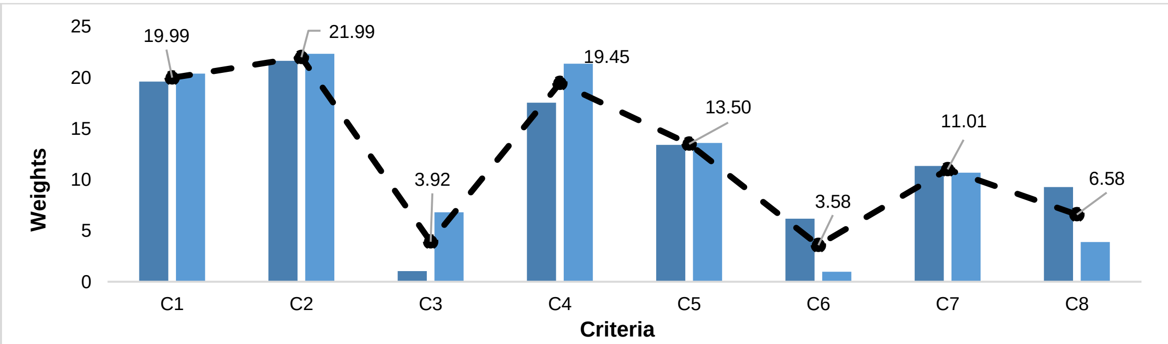
After analysing the aggregated criteria weights obtained for the UG_3, the route complexity seems to be the factor to which the participants would value the most in obtaining an improve from a neutral to a good level of performance (31.38%), followed by the availability and proximity of facilities (16.00), the crowdedness (13.77%) and the differentiation of the spaces (13.07%). In the route complexity node, this subsample considered expressed preference for the verticality and building interchanges aspects, where aggregated criteria weights of 35.04% and 32.81% were respectively obtained. In the environmental sensation node, all the participants gave more importance to the lighting aspect (which obtained an aggregated weight of 69.50%), whereas in the differentiation node, both factors appeared to show similar importance to the participants (54.17% and 45.83% for the structural symmetry of floors and vertical architectural differentiation). The UG_2 tended to attribute similar value to some of the factors mentioned above for the wayfinding complexity node, but also recognized as highly important aspects like the own safety of the users (with a weight of 22.37%). Major differences between these two user groups were detected in the environmental sensation and differentiation nodes. In the former, the aggregated weights showed that the UG_2 would preferer an improve from a neutral to a good level of performance in the sounds' criterion (which obtained a weight of 50.71%), followed by the lighting aspect (with a weight of 35.36%). In the latter node, the participants gave considerably more importance to the transition from situation A to B in the structural symmetry of the floors (77.78%) in comparison to the same transition in the vertical architectural differentiation present in the building. In the route complexity node, the building interchanges and the verticality were also the factors which obtained the higher weights (36.70 and 25.96%, respectively), similar to what was observed in UG_3. The participant who performed the weight elicitation exercise on the behalf of a cognitive impaired user assigned the complexity of the route as the factor that most influences the wayfinding complexity in a healthcare environment (32.36%), followed by the availability and proximity of facilities (20.24%), the boundaries (12.60%) and the differentiation (12.26%). In the route complexity node, in opposition to the results obtained for the other user groups, the changes in direction (with a weight of 43.68%) and the intersections (27.67%) seem to be the factors that assume more relevance when considering an individual with such disabilities, from the perspective of the occupational therapist. In the environmental sensation node, the sounds and lighting obtained similar weights of 46.92 and 44.68%, respectively, whereas in the differentiation node, the vertical architectural differentiation was the subcriterion with the highest weight (75.0%). Finally, for the unimpaired user included in the AHP questioning protocol, the route complexity was also assigned as the factor with the highest weight in the wayfinding complexity (35.45%), followed by the differentiation (18.07%) and the availability and proximity of facilities (18.02%). In the route complexity node, the ranking of the criteria was quite similar to the one obtained for the UG_2, with the exception of the first two factors, where verticality was assigned to the highest weight (47.86%), followed by the building interchanges (25.86%). The criteria weights obtained for the environmental sensation node were very similar to the aggregated weights of UG_3, whereas in the differentiation node were the same as the ones obtained for UG_1.

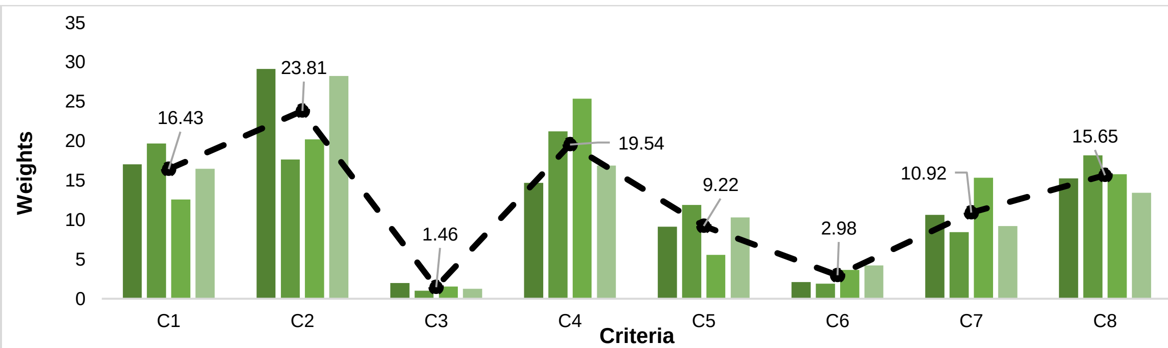
Overall, and after reviewing the summary of the obtained results, the route complexity was identified by all the user groups UG_j (j = 1, 2, 3, 4), as the factor that plays a major role in the wayfinding complexity (with obtained individual and aggregated weights within the range [24.57,35.45]) and the environmental sensation as the factor with the least importance (with obtained individual and aggregated weights within the range [3.01,3.26]). In the environmental sensation node, the tactile subcriterion was also identified as the least important factor for all the user groups UG_j (j = 1, 2, 3, 4) in comparison to sounds and lighting. Finally, by observing Table 5.3, one can denote that the architectural shape node was identified by three of the four user groups – UG_j (j = 1, 3, 4) as being the one with the highest importance in the wayfinding complexity (in comparison to the spatial quality). Only for the UG_2 the sum of the criteria weights for the spatial quality node was slightly higher than for the architectural shape, with respective weights of 51.35 and 48.65%. The most pronounced difference between the weights of the two nodes was observed in the unimpaired user group, where the sum of the criteria weights was 28.97% for the spatial quality node and 71.03% for the architectural shape node.

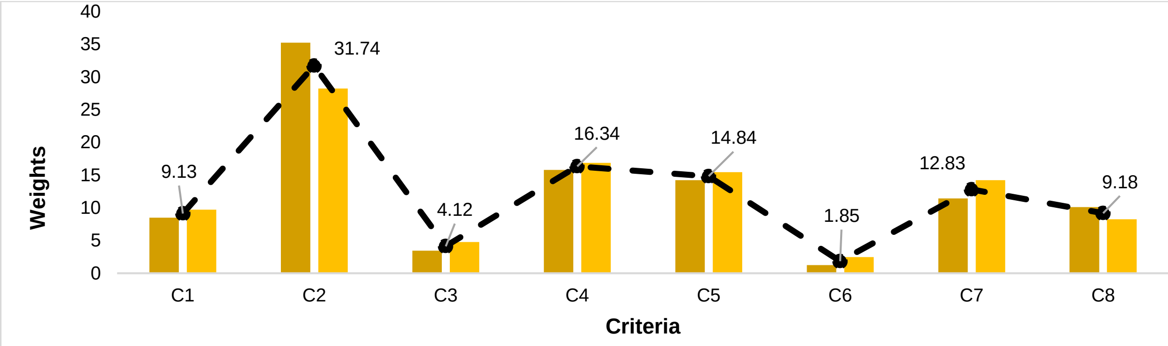
5.2.2 MACBETH

This subsection comprises the obtained criteria weights for the participants to whom the MACBETH questioning protocol was applied to. Figures 5.11 to 5.18 include the individual and overall (when applicable) criteria weights obtained for each user group and criteria node under evaluation following the respective categorization of the participants provided in Table 5.2. In Figures 5.15 to 5.18 the criteria weights are displayed in a local scale, so in order to obtain the global weights for those parameters, it would be necessary to multiply their weights by the weight of the parental node. Finally, Table 5.4 presents the obtained weights for the Spatial Quality and Architectural Shape nodes.

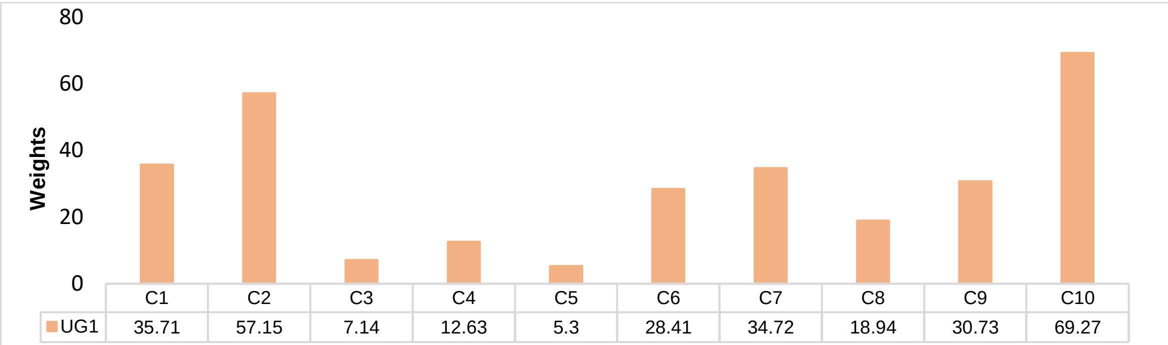


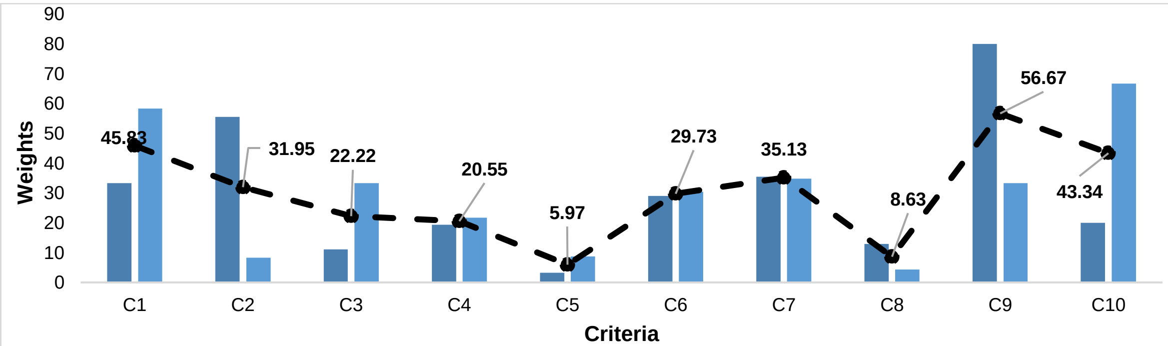


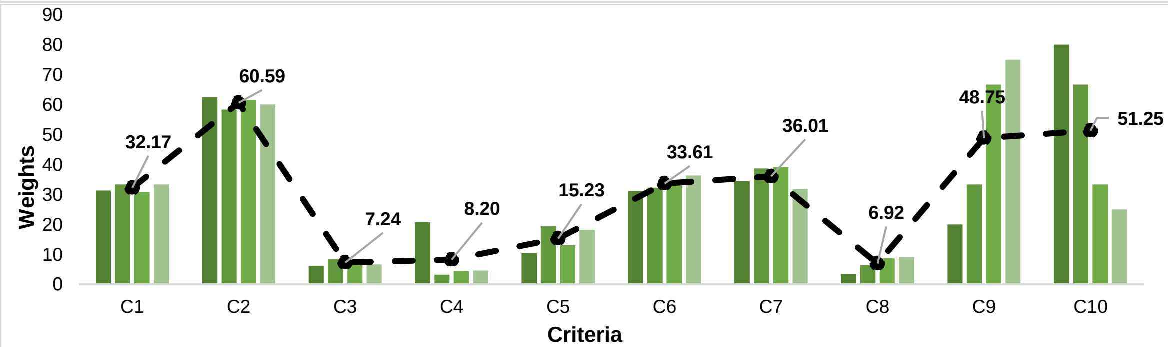


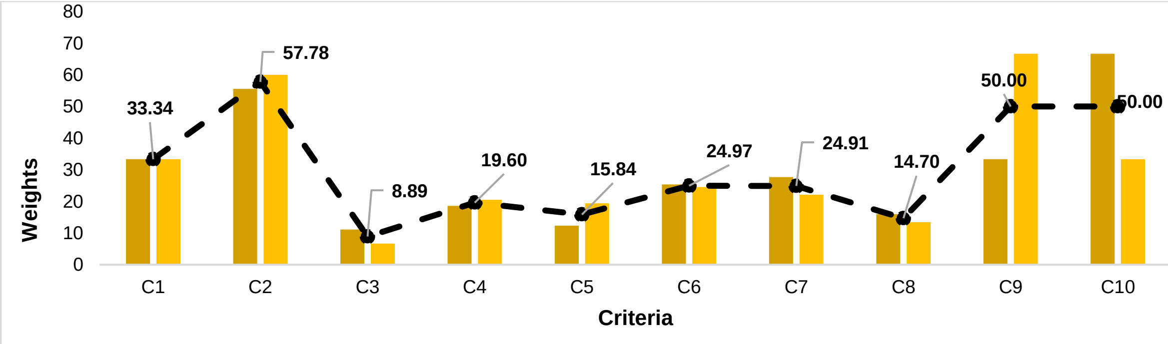


Figures 5.11 – 5.14: Individual and aggregated (dashed line) criteria weights obtained for the wayfinding complexity (global node) for the users included in UG_1, UG_2, UG_3 and UG_4, respectively. Each colour represents one participant of the group and the aggregated weights are displayed for the respective data points. Legend: C1 – Availability and Proximity of Facilities, C2 – Route Complexity, C3 – Environmental Sensation, C4 – Safety, C5 – Boundaries, C6 – Integration of Flows, C7 – Crowdedness, C8 – Differentiation.









Figures 5.15 – 5.18: Individual and aggregated (dashed lines) criteria weights obtained for the environmental sensation (C1-C3), route complexity (C4-C8) and differentiation (C9 and C10) nodes for the users included in UG_1, UG_2, UG_3 and UG_4, respectively. Each colour represents one participant of the group (the same as in Figures 5.12 – 5.14) and the aggregated weights are displayed for the respective data points. Legend: C1 – Sounds, C2 – Lighting, C3 – Tactile, C4 – Intersections, C5 – Distance, C6 – Verticality, C7 –Building Interchanges, C8 – Changes in Direction, C9 –Structural Symmetry, C10 – Vertical Architectural Differentiation.

Table 5.4: Weights obtained for the spatial quality and architectural shape nodes.

User Group	**Weights**	
	Spatial Quality	**Architectural Shape**
UG_1 – Unimpaired User Group	38.89	61.11
UG_2 – Perception (Sensory) Impaired User Group	54.36	45.64
UG_3 – Mobility Impaired User Group	48.35	51.65
UG_4 – Cognitive Impaired User Group	42.40	57.60

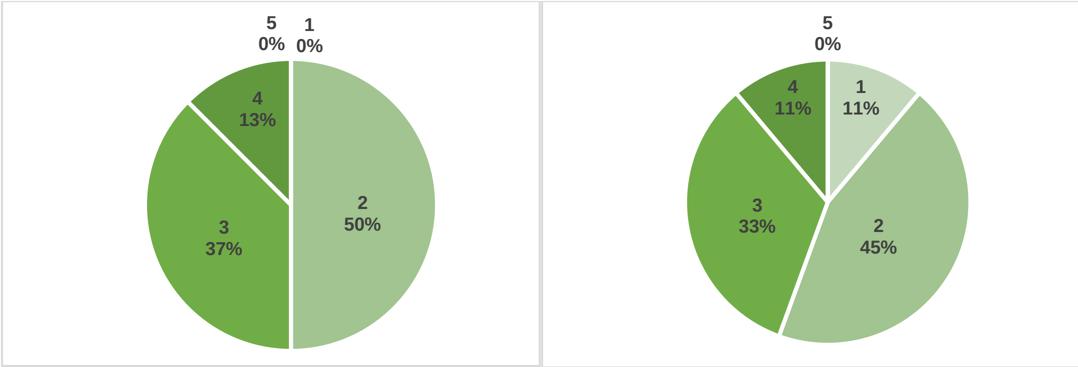
Note: The weights displayed for UG_2, UG_3 and UG_4 are aggregated values.

Reviewing the results obtained for the individual (UG_1) and aggregated criteria weights (UG_2, UG_3 and UG_4), the route complexity seems to be the factor where these users would prefer the most to have an improvement from a neutral to a good level of performance in the wayfinding complexity node. Similar weights for this criterion were obtained for UG_1-UG_3 (22.22, 21.99 and 23.81%, respectively), with the UG_4 assigning an aggregated weight of 31.74% to this factor. For the UG_1 and UG_3 other factors revealed to be highly attractive as well, like the differentiation (19.44 and 15.85%, respectively), safety (16.64 and 19.54%, respectively) and the availability and proximity of facilities (13.89 and 16.43%, respectively). The UG_2, besides the route complexity in the global node, also considered similar attractive the availability and proximity of facilities and the safety (19.99 and 19.45%, respectively), whereas the UG_4 ranked the safety and the boundaries as the second (16.34%) and third (14.84%) most attractive criteria in the global node. Two user groups (UG_1 and UG_3) ranked the environmental sensation criterion as the least attractive (1.39 and 1.46%, respectively), whereas the two others (UG_2 and UG_4) considered the integration of flows as the least attractive criterion (3.58 and 1.85%). In the environmental sensation node, the tactile was considered the least attractive criterion for the four user groups. The weights ranged from 7.14 to 8.89% for UG_1, UG_3 and UG_4, with a more expressive weight of 22.22% being obtained for UG_2. The lighting was considered the most attractive criterion in this node for UG_1, UG_3 and UG_4 with weights ranging from 57.15 to 60.59%, whereas UG_2 ranked it as the second most attractive, preceded by the sounds with a weight of 45.83%. In the route complexity node, similar weights were obtained to the verticality and the building interchanges in all the user groups, with these two factors being listed as the two most attractive ones. In the UG_4 it is important to highlight that the criteria weights are more uniformly distributed among the five factors under comparison in the route complexity node, as no criterion seems to be extremely less or more attractive than others as observed for other user groups. In the differentiation node, similar weights were obtained for both factors for UG_3 and UG_4. For the differentiation node UG_3 and UG_4 attributed similar weights to both factors, whereas noticeable differences were observed for UG_2 and specially for UG_1. The participant included in the latter user group considered that an improvement from a neutral to a good level of performance was considerably more attractive for the vertical architectural differentiation (with a weight of 69.27%).

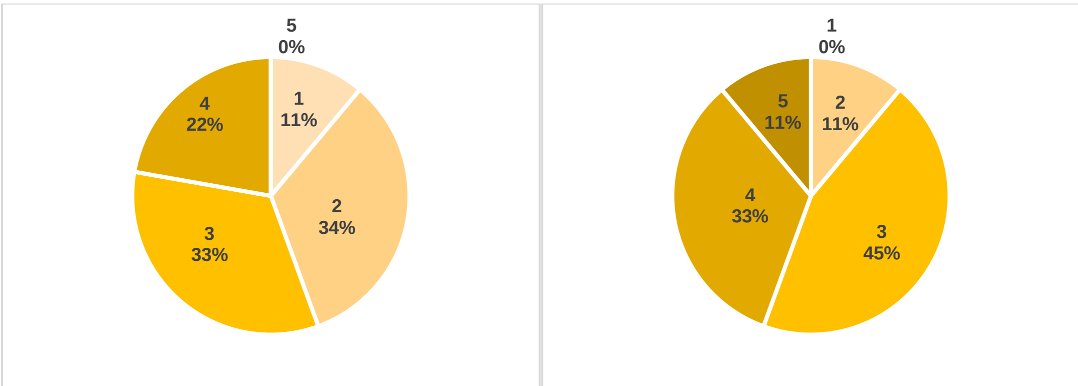
Finally, by observing Table 5.4, one can denote that the architectural shape node was also identified by three of the four user groups – UG_j (j = 1, 3, 4) as being the one with the highest importance in the wayfinding complexity (in comparison to the spatial quality), similar to what was previously presented in the previous subsection for the participants assigned to the AHP questioning protocol. Only for the UG_2 the sum of the criteria weights for the spatial quality node was slightly higher than for the architectural shape, with respective weights of 54.36 and 45.64%.

5.3 Feedback of the Assessment

The results obtained for what regards the overall satisfaction and difficulty perceived by the participants in completing the second part of the practical assessment are divided by questioning protocol (Figures 5.19 – 5.22). The averaged difficulties perceived in expressing preferences by the participants for both questioning protocols (AHP and MACBETH) were very similar, 2.63 and 2.67 (in a scale from 1-5), respectively. The researcher had quite a similar perception of their performance, as the averaged perceived difficulties obtained were respectively 2.89 and 2.88 (in a scale from 1-5). None of the participants revealed extreme limitations in completing the assessment, although the researcher noticed that the scale used to complete the pairwise comparison matrices in the MACBETH was more straightforward for the participants. In the AHP approach, they were asked to quantify the difference in importance between the transition from one situation to another regarding two different criteria. A scale from 1-9 was used, however the participants were asked to answer these questions having in mind the subjacent interpretation of the values (according to Tabe 3.3). Hence, having to look to a similar table to perform their judgements required an extra effort comparing to the MACBETH approach, where no subjacent interpretation of the qualitative judgments was needed. This difference is somehow reflected in the overall satisfaction of the participants after completing their assessment, where averaged satisfaction values of 2.5 (50.0%) and 3.4 (68.9%) were respectively obtained for the participants assigned to the AHP and MACBETH questioning protocols.



Figures 5.19 and 5.20: Difficulty perceived in expressing preferences by the participants to whom the AHP questioning protocol was assigned to, using a 1-5 scale – from 1=very easy to 5=very difficult (on the left) and overall satisfaction regarding the questioning protocol assigned using a 1-5 scale – from 1=very dissatisfied to 5=very satisfied (on the right).



Figures 5.21 and 5.22: Difficulty perceived in expressing preferences by the participants to whom the MACBETH questioning protocol was assigned to, using a 1-5 scale – from 1=very easy to 5=very difficult (on the left) and overall satisfaction regarding the questioning protocol assigned using a 1-5 scale – from 1=very dissatisfied to 5=very satisfied (on the right).

Regarding question 3b) of the feedback assessment questionnaire – where the participants were supposed to express the difficulty perceived in expressing their preferences using the new questioning protocol – the results were inconclusive. Some participants manifested preference over the new questioning protocol but considered it more difficult than the one assigned to them. Others manifested preference over the questioning protocol assigned to them but still considered it more difficult, so no conclusions can be taken from this question. Regarding the general preference for one of the methods (or the indifference in being assigned to one of them), the results are presented in Table 5.5. Most of the participants (70.6%) did not express interest in having been assigned to a different questioning protocol, with only 11.8% manifesting a preference over the new approach and 17.6% revealing indifference over the two methods.

The researcher monitored the time the participants took to complete the weight elicitation step, as contemplated in the fifth question of the feedback assessment questionnaire. 30 minutes was the initial time estimated to complete this task given the number of pairwise comparisons required and the characteristics of the sample. Ten participants (58.8%) were able to do so, while seven others (42.2%) exceeded the estimated time. The average time spent to complete the task was 35.2 min for the overall sample, and 33.3 and 37.4 min for the subsamples assigned to the MACBETH and AHP questioning protocols, respectively. The difference in time between the two questioning protocols can also be explained by the extra effort associated to the subjacent interpretation of each value in the scale used in the AHP approach.

Table 5.5: Preferences manifested by the participants in being assigned to one of the questioning protocols.

Questioning Protocol	Number of Users
AHP	6 (35.3%) *
MACBETH	8 (47.1%) **
Indifferent	3 (17.6%)

Notes: * – Five of them were initially assigned to this questioning protocol. ** – Seven of them were initially assigned to this questioning protocol.

Regarding the type of difficulties felt during the study, all the participants point out that the weight elicitation step was too extensive and required too many pairwise comparisons, more than they were expecting in the beginning of the assessment. Overall, most of the participants, especially the patients of the retirement home facility, felt tired by the end of the exercise. In addition, the researcher noted that for some of them, the cognitive overload associated to this assessment exceeded their cognitive capacity, and close to the end of the weight elicitation exercise, they were not fully focused as in the beginning. The large number of factors present in the model and the non-familiarity with the scale used were also aspects mentioned by some of them, while others manifested discomfort with the number of options to choose from in the scales used. This discomfort was more expressive in the AHP approach, were some participants questioned the researcher why the scale was built from 1-9 and not from 1-5, which would have reduced the cognitive burden associated to the number of options to choose from. During the time the participants had contact with the detailed description of all the factors present in the model (Table 4.2), the researcher also noticed that some concepts were not as clear or easy to assimilate as desirable (given the characteristics of the sample), as some participants asked for further clarification.

The final question of the feedback assessment intended to gather suggestions from the participants, that could enhance the quality of a future similar study conducted in the topic. Here the researcher highlights the criticism presented to the number of factors present in the model. This was considered a major drawback of the present study by some of the participants, by arguing that the study should have been focused on a smaller group of factors. One participant also suggested that if the number of factors present in the model would have been lower, a small group of people could have been brought together to perform the weight elicitation exercise, instead of conducting individual interviews with the different participants. Moreover, the individual said that the contact with others during such activity would stimulate the discussion about the topic and would be interesting to collect other points of view.

Chapter 6

Discussion

The present chapter aims to discuss the obtained results by interpreting the main findings, present the major strengths of the conducted research work together with its major limitations and provide recommendations and possible modifications to the future research to be developed in the topic.

6.1 Interpretation of the Main Findings

- ***Inconsistencies in the Judgements for the AHP Questioning Protocol***

For the AHP questioning protocol, the average value of the CR (Figure 5.1) progressively increased with the number of pairwise comparisons required in each node (3, 10 and 28, respectively). This is an expected result as the increase in the number of pairwise comparisons is associated to a higher cognitive burden. Hence, it may lead the users to pay less attention to the judgments previously performed in order to complete the process in the shortest time span, which consequently increments the likelihood of having a higher CR. In Danner et al. (2017) research work, an average inconsistency level of 16.4% was obtained for the global node, which was only composed of five criteria (requiring the completeness of ten pairwise comparisons). The averaged CR for the wayfinding complexity node (21.02%) is not very distant from the previous value, especially if one considers the number of pairwise comparisons required to obtain the weights for this node. In addition, the ranking of the swings for each criterion that preceded the pairwise comparisons performed for each weighting matrix might have contributed to lower the averaged CR values obtained, as the researcher ensured that the ranking previously determined was respected during this exercise. However, no further conclusions can be drawn on this matter as none of the groups who use the AHP approach to determine criteria weights (either patients or providers) perform such exercise without previously ranking the respective swings, which would be required to perform a comparative analysis.

- ***Obtained Criteria Weights***

Both questioning protocols generated quite similar results in what regards the criteria weights obtained within the same type of user group, with small differences in the ranking of the factors and the magnitude of the weights. These differences can be attributed, among other causes, to the knowledge of each participant regarding the factors under consideration, the differences associated to the scales used and to how the priorities are derived from the participants' judgements, as in MACBETH is through the use of LP and in AHP using the eigenvalue method. Therefore, none of the methods used, revealed to be inadequate to represent the manifested preferences of the users and the results can be simultaneously analysed at the same level.

Overall the participants assessed considered that the simpler the route, the easiest the wayfinding task becomes in a healthcare facility, but also that having available a set of facilities along their route (elevators and staircases, toilets and emergency exits) have almost similar importance as walking around in crowded places or in spaces where the differentiation pattern is not the highest. Moreover, the participants also demonstrated that feeling that the environment where they perform the wayfinding task provides them a good level of safety (rather than a moderate one) is quite important. Feeling threatened in such crowded environments by walking in a floor with a low slip resistance, encountering disturbing objects in the path or using facilities like elevators or staircases with a questionable level of safety would normally affect the users' ability to find their way around. The participants (especially UG_2-UG_4) also expressed a noticeable preference for a higher number of soft (open) spaces compared to hard spaces in healthcare facilities. Having to pass through a lot of doors along the route might be quite unpleasant for users in wheelchairs or with vision impairments, thus open spaces would ease their ability to freely move around, especially in crowded areas. In the wayfinding complexity node, the integration of flows and the environmental sensation were overall identified as the criteria with the least importance for the different user groups. It seems that these individuals would not mind circulating in corridors and spaces together with healthcare professionals or other type of users, as they believe that this does not affect to a major extent their ability to perform wayfinding tasks. Regarding the environmental sensation perceived while trying to find their way around, the users expressed in the assessment that an improvement from a neutral to a good level of performance would only decrease the wayfinding complexity to a minimal amount. Regarding the route parameters under evaluation, the participants expressed strong preference for not changing between the facility buildings along their route and to circulate in buildings with direct connections between all the floors. For users with cognitive impairments other factors seem to play a major role as well, namely the estimated distance to travel from the onset of the wayfinding tasks to the final destination, the average number of directions to choose from at a decision point and the number of turns taken along the path. In the environmental sensation node, the amount and type of light available in the environment and the sounds users may experience while traveling around the facility were the factors that obtained the highest local weights, with the tactile aspect only obtaining noticeable weights for the users included in UG_2. However, the three criteria weights obtained for this node are not globally significant, giving the low weight of the parental node. In the differentiation node, both factors assumed similar importance for the users, with the vertical architectural differentiation playing a major role for the unimpaired user group. Thus, having striking landmarks across the route and specially in the main circulation spaces was identified as a great differentiation asset that helps the users in locating themselves in the environment. Moreover, having structural symmetric floors considerably helps them in moving between floors and in locating facilities like toilets, elevators or emergency exits.

- ***Preferences Manifested for the Questioning Protocols Used***

Since the participants were only exposed to one of the methods during the weight elicitation step and the second approach was only presented in the feedback questionnaire without requiring any pairwise comparisons, one can denote that the contact that the participants had with the new approach was minimal. This might have influenced the results obtained, as they most likely could not perceive all the potential advantages or disadvantages associated to the new questioning protocol with just a simple question. Moreover, by the end of the exercise, the participants were already quite familiar with the questioning protocol assigned to them, which might also have interfered in their decision of not selecting a different method. The obtained results express this familiarity by a certain extent, as 70.6% of the participants selected the same method assigned to them as the most preferred one. Given the participants performance regarding the two different questioning protocols selected to obtain the criteria weights, one can say that both are adequate to pursue for a large-scale research on the topic. The AHP approach revealed to be slightly more time consuming than the MACBETH one, but the results were not significant enough to state that the latter should be chosen over the former if one would only intend to select one questioning protocol in the future.

6.2 Strengths and Limitations

The methodology designed and implemented in the present research work incorporates theoretical principles that are commonly used in the literature to tackle similar problems to the current one, although in different contexts. Nonetheless, it completely deviates from the techniques used so far to explore the interplay between human and environmental factors in the wayfinding research topic. In this line of thought, the present work can be seen as an exploratory study, commonly as a study whose aim is not to provide conclusive answers to current research issues, but rather exploring a new problematic that lacks on previous or meaningful research (Singh, 2007). Therefore, this type of research can be seen as an initial step to form solid foundations for a possible subsequent conclusive research. Often named as a pilot or feasibility study given its prematurity and novelty appraisal of a research topic, exploratory research focuses essentially on secondary means of research such as the review of available literature studies, consultation of experts in the field or data collection from focus groups or case studies (Singh, 2007). Focus groups are referred as small groups of people chosen to explore their insights, personal opinion or experience in a particular research subject, often through interviews or group discussions (Singh, 2007). Nonetheless, the data collected from these sources does not allow to draw general conclusions regarding bigger categories of users as the results may not be representative enough of the population under study (Singh, 2007).

The present research work provides a comprehensive explanation of the set of aspects collected in the available literature that are linked to the wayfinding performance in complex buildings and specially in healthcare facilities. Moreover, it brought together a set of experts that helped in the structuring process of this factors into a value tree of evaluation criteria and provided their contribute to complement what was previously retrieved from the literature. In order to evaluate the role that these factors play in the wayfinding performance of individuals inserted in one of the user groups here explored, two MCDA approaches were selected. The use of MCDA in the current problem allowed to break down its complexity towards an intuitive and transparent process to access the priorities and values of the different users. The approaches used were adapted to the problem under study and an assessment session was conducted with elderly individuals from a retirement home facility. The participation of these users was extremely valuable and the author's knowledge, no similar research has been conducted until now in the topic. The obtained results contributed to a thorough understanding to which extent the inherent aspects of healthcare facilities affect users while trying to reach their destination in clinics and hospitals. Furthermore, they will hopefully be encouraging enough to expand the dimension of the sample used to assess the criteria weights and engage designers, facility planners and other researchers in the wayfinding domain to work together in developing effective wayfinding systems for such complex environments and accounting for the diversity of users.

The fact that participants assigned to two different questioning protocols decided to withdraw before completing the practical assessment leads to the early conclusion that the cognitive load is common to both approaches. Moreover, considering the age of the participants, the high number of criteria under comparison and the difficulties felt in choosing a judgment from the scales composed of several options was identified as considerable burden for them.

The use of the arithmetic mean to obtain the aggregated criteria weights can be seen as advantageous measure to analyse the preferences of each user group as whole as it would be extremely difficult to look at the outcome obtained for each participant individually. The literature supports its use in complex decision-making contexts for heterogeneous groups, where a consensus is difficult to reach. However, some limitations are also associated to the use of this statistical measure. Its use might be inadequate in situations where the sample is not representative enough and where the individual criteria weights show a high variance. In addition, by using it one is foreseeing that all the participants have the same interpretation of the problem, criteria definitions and levels of performance, but especially of the scale used to perform the judgements. Another limitation can be identified by the differences in the health status of participants who were integrated in the same user group. Each pairwise comparison might be influenced by how and to which extent the impairment affects the wayfinding performance of the users. If participants tend to struggle with a particular issue – due to their health condition – when visiting such environments, the corresponding criterion may receive a higher weight. Although it can have an impact in the stability of the results, this is particularly difficult to overcome. Developing patient profiles, by assessing as much sociodemographic variables as possible, and creating homogenous groups with that information might be a good approach to strengthen future research.

For the UG_2 user group, it is important to mention that the distance between the weights and the ranking attributed to the evaluation criteria differed among the participants in some of the factors assessed. The fact that participants with vision and hearing impairments were included in the same user group explain the obtained results. Ideally, two subcategories of users should have been created (one for each impairment) and the results should have been analysed separately. Therefore, further research would be necessary, using a larger group of patients with both impairments to obtain accurate results of the UG_2 preferences (by category).

6.3 Recommendations and Future Work

In the feedback assessment, one participant suggested that, if the number of factors present in the model would have been lower, a small group of people could have been brought together to perform the weight elicitation exercise, instead of conducting individual interviews with the different participants.

Moreover, the individual stated that the contact with others during such activity would stimulate the discussion about the topic and would be interesting to collect other points of view. Given this suggestion, by the end of all the assessments, the researcher questioned the facility manager and the staff members who also participated in the study, regarding the possibility of bringing together smaller groups of participants to perform the pairwise comparisons (resembling the concept of a focus group). From this discussion, two different hypotheses for a similar study design (that could be combined) were elaborated and validated by the group. The first one would consist in bringing together all the participants for a common presentation to the topic, where the goal of the research and what would be expected from them would be briefly introduced. This session would be more dynamic for the participants in the sense that they could ask and hear the questions from the ones present. Furthermore, it would be open to all the inhabitants of the facility and afterwards all the users interested could participate. The second hypothesis regards the design of the weight elicitation step. In order to promote the contact between the users by sharing opinions, the group considered that after a demographic assessment to categorize the different participants, small groups could be created to represent a particular impairment. Each group would then perform the weight elicitation exercise as a whole. The entities agreed that, in order to make it happen, this activity would be focused on a smaller group of factors (compared to the amount assessed in this study), as debating about each pairwise comparison would require more time and extra effort from the participants.

The next step to pursue towards a quality, stability and conclusiveness improvement of the obtained results would start with a systematic review of the main limitations identified in this study. Furthermore, it would be necessary to adjust the proposed methodology to account for the recommendations presented in this section and major flaws detected in the analysis that preceded the practical assessment.

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Appendices

Appendix A – Schematic Representation of the Proposed Methodology

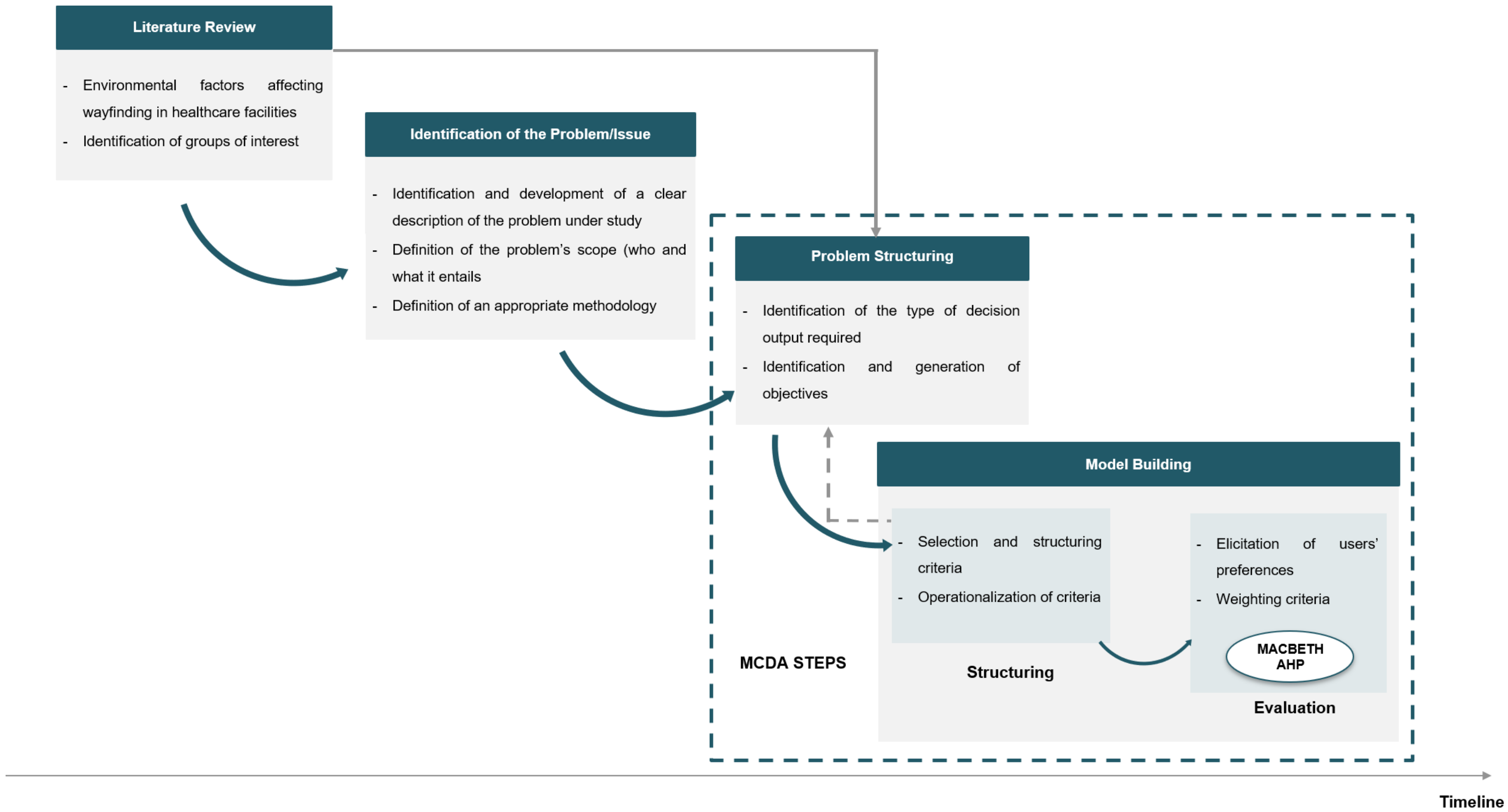

Figure A.1: Schematic representation of the proposed methodology. **Note:** full arrows represent sequential processes whereas the dashed one represents an iterative process.

Appendix B – Information Sheet (English and Dutch Version)

INFORMATION SHEET FOR PARTICIPANTS

My name is Sara Arez Simões and I am a Biomedical Engineer Student, currently doing my master thesis at KU Leuven (Belgium) in collaboration with Instituto Superior Técnico (Lisbon, Portugal). I'm currently conducting research in the domain of Inclusive Wayfinding Systems in Hospitals.

Context: Wayfinding ("finding your way") is related with the way people self-navigate themselves in an unfamiliar environment. Healthcare facilities should be able to provide an equal and convenient experience in terms of wayfinding effectiveness for the broadest group possible without the need for adaptation or specialized design, since users with different type of impairments are expected to visit these places in their daily functioning.

Objective of the study: Access the relative importance of different environmental factors (previously selected in earlier stages of the research) that affect the wayfinding performance of users with a similar profile to yours.

Methodology: Participants will be asked to take part in the research work by means of a demographic multiple-choice questionnaire, followed by an individual interview with the researcher responsible for the project. The total time of participation in the present study will be approximately 30 minutes.

I. The first multiple-choice questionnaire will be used to categorize the different participants based on their demographics (age range, sex and type of impairment) and by how often they visit healthcare facilities

II. The individual interview with the researcher responsible for the study has as main purpose the **collection of user's preferences** regarding the different factors present in the model.

   a. These preferences will be accessed using two pair-wise questioning procedures, where the participant is asked to compare two factors at once.

   b. The answers provided by the participant will be inserted in software tools during the course of the interview and will be used to generate the weights of the different factors being evaluated.

   c. Once the pair-wise questionnaire is finished, the software will generate a graph with the different percentages attributed to the different factors users were asked to compare. In this stage, users will be asked to validate the obtained scale or propose adjustments that better represent their preferences.

   d. In the end of the interview the participants will have the opportunity to express their opinion about the questioning procedure used to access their preferences by answering simple multiple-choice questions about its difficulty and overall satisfaction. Finally, the participants will be submitted to an hypothetical questioning procedure different from the one used to access their preferences (the one they were not assigned to) in order to perceive which would be the most intuitive questioning protocol to use for the present study.

Questions: If you have any questions about my research or about the questionnaire you may contact me by sending an email to saraarezsimoes@tecnico.ulisboa.pt.

INFORMATIEDOCUMENT VOOR DEELNEMERS

Mijn naam is Sara Arez Simões en ik ben een student biomedisch ingenieur. Momenteel doe ik mijn master thesis aan de KU Leuven (België) in samenwerking met Instituto Superior Técnico (Lissabon, Portugal). Ik voer onderzoek uit op het gebied van 'Inclusive Wayfinding-systemen' in ziekenhuizen.

Context: 'Wayfinding' ("de weg vinden") is gerelateerd aan de manier waarop mensen zichzelf navigeren in een onbekende omgeving. Zorginstellingen moeten in staat zijn om een gelijkwaardige en gemakkelijke ervaring te bieden op het gebied van routebepaling voor de breedst mogelijke groep zonder de noodzaak van aanpassing of gespecialiseerd ontwerp, aangezien gebruikers met verschillende soorten beperkingen verwacht worden deze plaatsen in hun dagelijks functioneren te kunnen bezoeken.

Doel van de studie: Het verwerven van het relatieve belang van verschillende omgevingsfactoren (voorheen geselecteerd in eerdere fasen van het onderzoek) die van invloed zijn op de routeprestaties van gebruikers met een soortgelijk profiel als dat van u.

Methodologie: Deelnemers zullen worden gevraagd om deel te nemen aan het onderzoek door middel van een demografische meerkeuzevragenlijst, gevolgd door een individueel interview met de onderzoeker die verantwoordelijk is voor het project. De totale tijd voor deelname aan het huidige onderzoek zal ongeveer 25 minuten bedragen.

I. De eerste meerkeuzevragenlijst zal worden gebruikt om de verschillende deelnemers te categoriseren op basis van hun demografie (leeftijdscategorie, geslacht en type beperking).

II. Het individuele interview met de onderzoeker die verantwoordelijk is voor het onderzoek heeft als hoofddoel het **verzamelen van gebruikersvoorkeuren** met betrekking tot de verschillende factoren die aanwezig zijn in het model.

   a. Deze voorkeuren zullen verworven worden met behulp van één uit twee paarsgewijze vraagprocedures, waar de deelnemer gevraagd wordt om twee factoren te vergelijken. De deelnemers worden willekeurig toegewezen aan elk vraagprotocol door de onderzoeker.

b. De antwoorden van de deelnemer worden in de loop van het interview ingevoerd in een software-tool waarna ze gebruikt worden om de gewichten van de verschillende factoren te genereren.

c. Zodra de paarsgewijze vragenlijst is voltooid, genereert de software een grafiek met de verschillende percentages die worden toegeschreven aan de verschillende factoren die de gebruikers werden gevraagd te vergelijken. In deze fase wordt aan de deelnemers gevraagd de verkregen schaal te valideren of aanpassingen voor te stellen die hun voorkeuren beter weergeven.

d. Aan het einde van het interview krijgen de deelnemers de gelegenheid om hun mening te uiten over de vraagprocedure, die werd gebruikt om hun voorkeuren te achterhalen, door eenvoudige meerkeuzevragen over de moeilijkheidsgraad en de algemene tevredenheid te beantwoorden.

Vragen: Als u vragen heeft over mijn onderzoek of over de vragenlijst, kunt u contact met mij opnemen door een e-mail te sturen naar saraarezsimoes@tecnico.ulisboa.pt.

Appendix C – Informed Consent (English and Dutch Version)

CONSENT FORM FOR PARTICIPANTS

- The information you provide will only be used to access the relative importance of the different factors that affect the wayfinding performance of users with a similar profile to yours.
- The information you provide is totally confidential and will not be disclosed to anyone. It will only be used for research purposes.
- Your participation is voluntary, and you can stop answering the questionnaire after having agreed to participate. You are free to refuse to answer any question that is asked in the questionnaire.
- Signing this consent indicates that you understand what will be expected of you and are willing to participate in this study.

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(Signature of the participant) (Date)

TOESTEMMING VOOR DEELNEMERS

- De informatie die u verstrekt wordt enkel gebruikt voor het bekomen van het relatieve belang van de verschillende factoren die de 'wayfinding-prestatie' beïnvloeden (en dit voor gebruikers met een vergelijkbaar profiel).
- De informatie die u verstrekt, is volledig vertrouwelijk en wordt aan niemand bekendgemaakt. Het zal alleen worden gebruikt voor onderzoeksdoeleinden.
- Uw deelname is vrijwillig en u kunt stoppen met het beantwoorden van de vragenlijst nadat u hebt ingestemd met deelname. U bent vrij om elke vraag te beantwoorden die in de vragenlijst wordt gesteld.
- Ondertekening van dit formulier geeft aan dat u begrijpt wat van u wordt verwacht en bereid bent om aan dit onderzoek deel te nemen.

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(Handtekening van de deelnemer) (Datum)

Appendix D

Part I: Multiple-Choice Questionnaire

1. Are you a male or a female?

A. Male
B. Female

2. What is your age-range?

A. 18-19
B. 20-29
C. 30-39
D. 40-49
E. 50-59
F. 60-69
G. 70+

3. Overall in the last 30 days, how much difficulty did you have with moving around?

A. None
B. Mild
C. Moderate
D. Severe
E. Extreme

4. Overall in the last 30 days, how much difficulty did you have with concentrating and remembering things?

A. None
B. Mild
C. Moderate
D. Severe
E. Extreme

5. Overall in the last 30 days, how much difficulty did you have with have in learning a new task (for example, learning how to get to a new place, learning a new game, learning a new recipe etc.)?

A. None
B. Mild
C. Moderate
D. Severe
E. Extreme

6. Overall how do classify your vision impairments (if you use glasses or contact lenses please answer the question considering your corrected vision)?

A. None
B. Mild
C. Moderate
D. Severe
E. Extreme

7. Overall how do classify your hearing impairments (if you use an auditory aid please answer the question considering your corrected audition)?

A. None
B. Mild
C. Moderate
D. Severe
E. Extreme

8. In general, how often did you visit healthcare facilities (namely hospitals or outpatient clinics), both as a visitor or a patient?

A. Never or Very Rarely
B. Rarely
C. Occasionally
D. Frequently
E. Very Frequently

Appendix E

Part III : Multiple-Choice Questionnaire – Version A

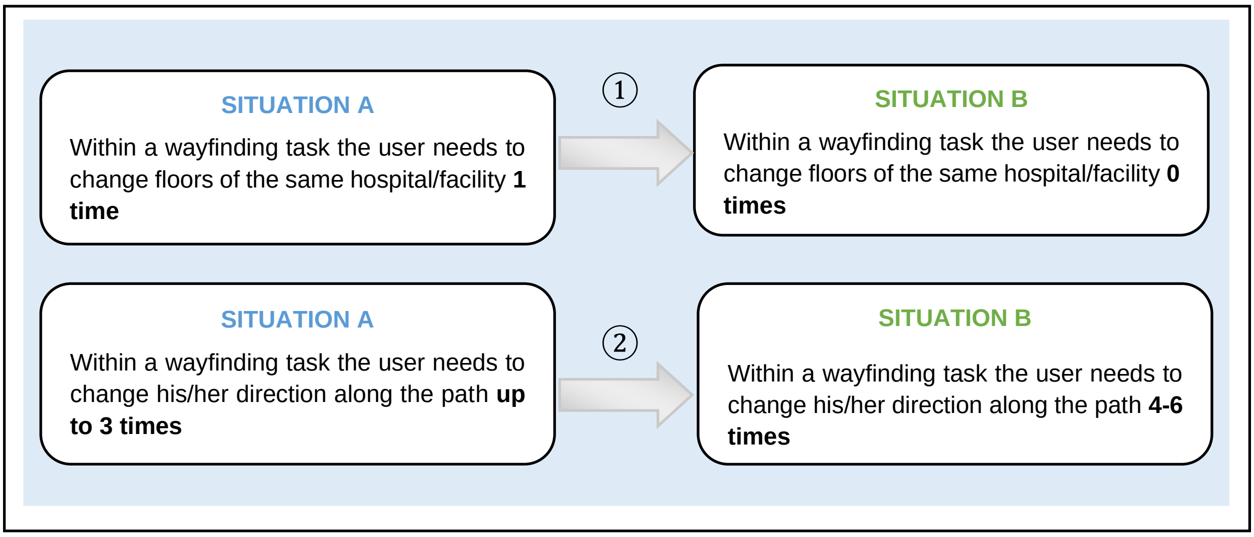
1. **Considering the questioning protocol assigned to you, what was the difficulty in expressing your preferences in a 1-5 scale (from 1=very easy to 5=very difficult)?**

A. 1
B. 2
C. 3
D. 4
E. 5

2. **Considering the questioning protocol assigned to you, how do you rate your satisfaction with this technique in a 1–5 scale (from 1=very dissatisfied to 5=very satisfied)?**

A. 1
B. 2
C. 3
D. 4
E. 5

3. **Consider the questioning protocol assigned to you (see example below) and assume that the transition from situation A to situation B in (1) is preferred over the transition from situation A to situation B in (2):**



In a scale from 1-9 how important is the transition from situation A to situation B in (1) in comparison to the transition from situation A to situation B in (2)?

1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9

1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate values

a) Now consider that instead of this questioning protocol you would be asked the following:

In a scale from no difference to extreme, what is the difference in attractiveness between the transition from situation A to situation B in (1) and the transition from situation A to situation B in (2)?

No Difference – Very Weak – Weak – Moderate – Strong – Very Strong – Extreme

b) Considering the new questioning protocol, which difficulty would you perceive in expressing your preferences in 1-5 scale (from 1=very easy to 5=very difficult)?

A. 1
B. 2
C. 3
D. 4
E. 5

c) Comparing the two questioning protocols, would you prefer the one presented in a)?

A. YES
B. NO
C. INDIFFERENT

YOUR PARTICIPATION ENDS HERE, THANK YOU FOR YOUR TIME AND COOPERATION!

4. **[To be answered by the researcher] Considering the questioning protocol assigned to the participant, what was the user’s difficulty in expressing their preferences in a 1–5 scale (from 1=very easy to 5=very difficult)?**

A. 1
B. 2
C. 3
D. 4
E. 5

5. **[To be answered by the researcher] How much time did it take for the participant to complete the Part II of the assessment?**

6. **[To be answered by the researcher] What were the main difficulties (e.g. length, type of questions asked, concepts that were not clear, etc.) in completing the assessment experienced by the participant?**

7. **[To be answered by the researcher] Which suggestions and comments did the participant report regarding the assessment?**

Part III : Multiple-Choice Questionnaire – Version B

1. **Considering the questioning protocol assigned to you, what was the difficulty in expressing your preferences in a 1-5 scale (from 1=very easy to 5=very difficult)?**

F. 1
G. 2
H. 3
I. 4
J. 5

2. **Considering the questioning protocol assigned to you, what was the difficulty in expressing your preferences in a 1-5 scale (from 1=very easy to 5=very difficult)?**

F. 1
G. 2
H. 3
I. 4
J. 5

3. **Consider the questioning protocol assigned to you (see example below) and assume that the transition from situation A to situation B in (1) is preferred over the transition from situation A to situation B in (2):**

(1)

SITUATION A

Within a wayfinding task the user needs to change floors of the same hospital/facility **1 time**

→

SITUATION B

Within a wayfinding task the user needs to change floors of the same hospital/facility **0 times**

(2)

SITUATION A

Within a wayfinding task the user needs to change his/her direction along the path **up to 3 times**

→

SITUATION B

Within a wayfinding task the user needs to change his/her direction along the path **4-6 times**

In a scale from no difference to extreme, what is the difference in attractiveness between the transition from situation A to situation B in (1) and the transition from situation A to situation B in (2)?

No Difference – Very Weak – Weak – Moderate – Strong – Very Strong – Extreme

a) Now consider that instead of this questioning protocol you would be asked the following:

In a scale from 1-9 how important is the transition from situation A to situation B in (1) in comparison to the transition from situation A to situation B in (2)?

1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9

1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate values

b) Considering the new questioning protocol, which difficulty would you perceive in expressing your preferences in 1-5 scale (from 1=very easy to 5=very difficult)?

A. 1
B. 2
C. 3
D. 4
E. 5

c) Comparing the two questioning protocols, would you prefer the one presented in a)?

A. YES
B. NO
C. INDIFFERENT

YOUR PARTICIPATION ENDS HERE, THANK YOU FOR YOUR TIME AND COOPERATION!

4. [To be answered by the researcher] Considering the questioning protocol assigned to the participant, what was the user's difficulty in expressing their preferences in a 1–5 scale (from 1=very easy to 5=very difficult)?

A. 1
B. 2

C. 3
D. 4
E. 5

5. [To be answered by the researcher] How much time did it take for the participant to complete the Part II of the assessment?

6. [To be answered by the researcher] What were the main difficulties (e.g. length, type of questions asked, concepts that were not clear, etc.) in completing the assessment experienced by the participant?

7. [To be answered by the researcher] Which suggestions and comments did the participant report regarding the assessment?

Appendix F – Software Implementation: AHP Approach

The SuperDecisions software was used to implement the AHP approach, where the 2.10 software version was used. The first step performed was the hierarchical structure of the criteria in the form of a value tree (similar to the one presented in Figure 4.3), which is illustrated in Figure F.1. Figure F.2 depicts how the pairwise comparisons are performed in the software for one of the nodes. After the completion of all the pairwise comparisons for each node, the criteria weights become available (on the Results column) and the inconsistency in the judgments needs to be revised in order to obtain a CR below 0.10. The process was repeated for each participant for the three nodes under evaluation.

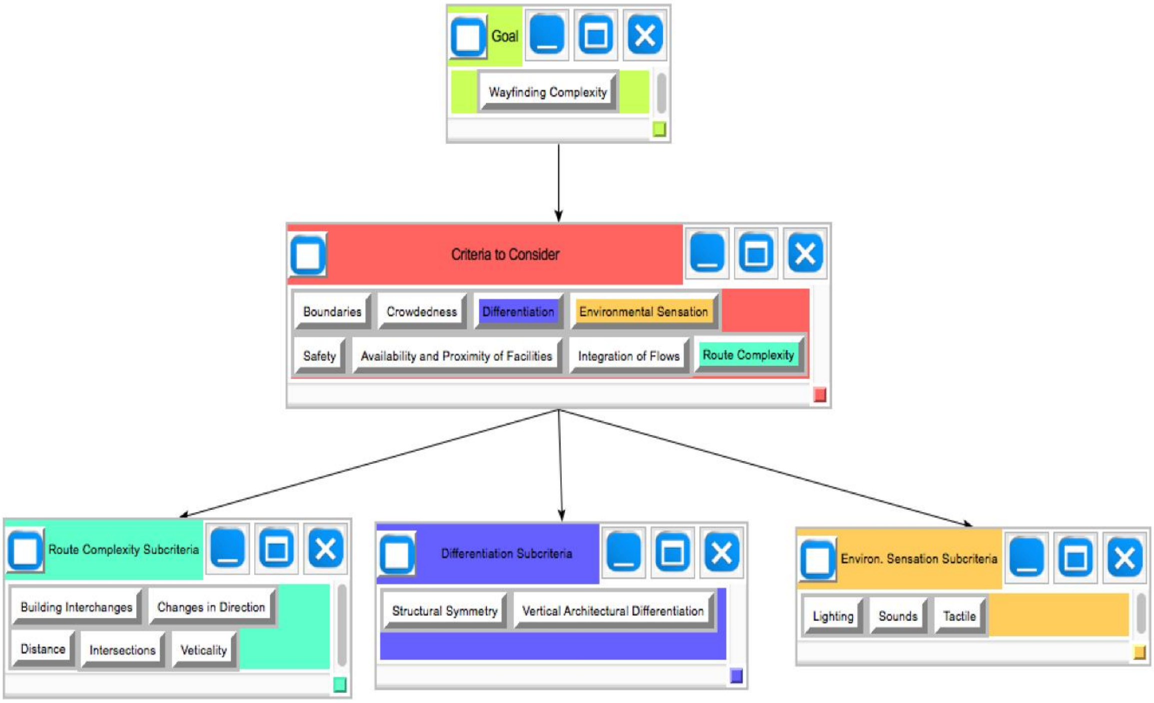


Figure F.1: Value tree of criteria created in the M-MACBETH software.

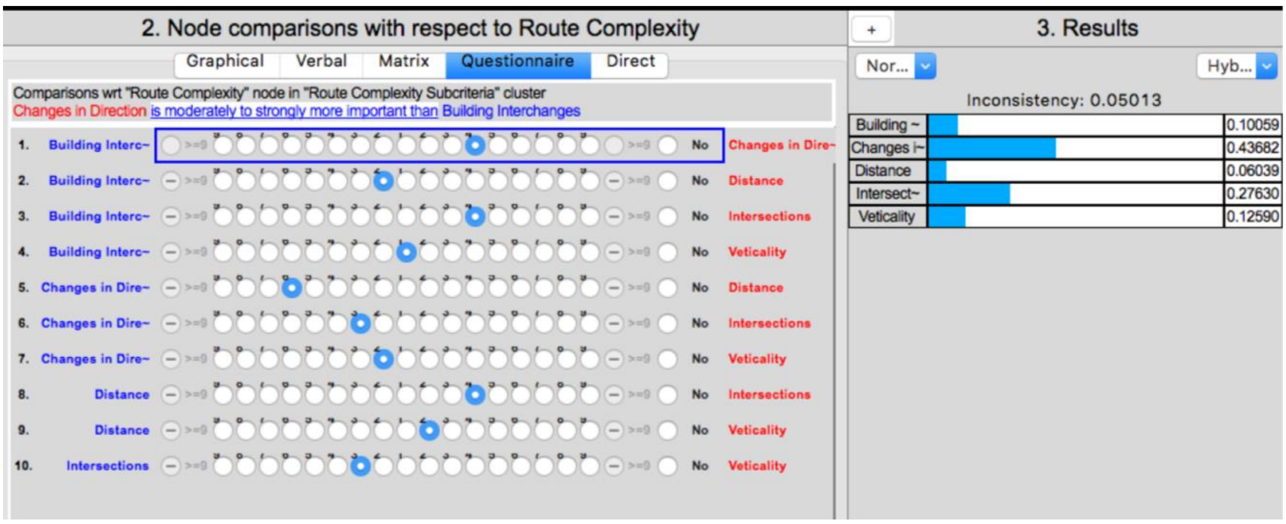


Figure F.2: Illustration of how the pairwise comparisons were performed in the SuperDecisions software.

Appendix G – Software Implementation: MACBETH APPROACH

This section will detail all the steps performed in the M-MACBETH software in order to obtain the criteria weights. In this implementation of the MACBETH approach a beta version of the software was used (version 3.3.0).

The first step performed was the hierarchical structure of the criteria in the form of a value tree (similar to the one presented in Figure 4.3), which is illustrated in Figure G.1. The two areas of concern of this decision-making problem (Architectural Shape and Spatial Quality) are represented by the two descendants of the global node (Wayfinding Complexity).

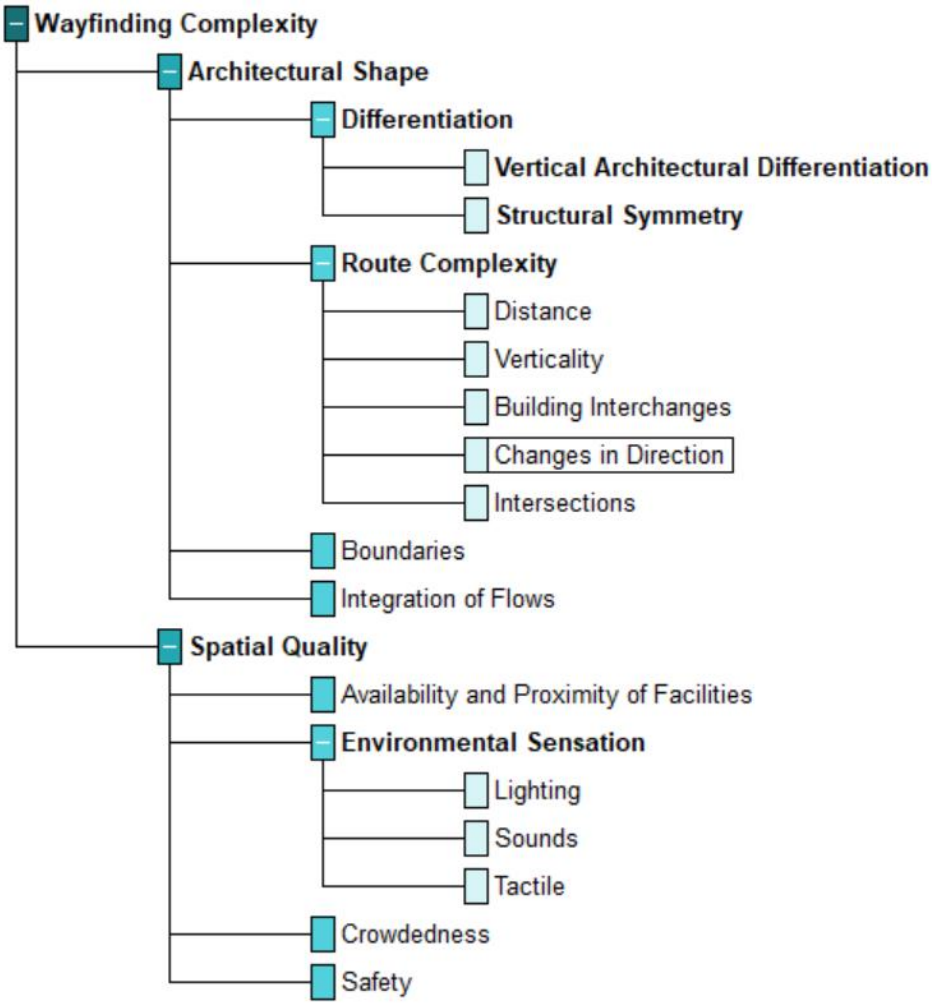


Figure G.1: Value tree of criteria created in the M-MACBETH software.

In the MACBETH approach, since hierarchical weighting was the method chosen to derive the criteria weights from the users' judgements, it was necessary to partitioning the criteria into subsets. It that sense, "non-criteria" nodes and the global node were activated (marked in blue in Figure G.2). It is important to note that the non-criteria nodes "Architectural Shape" and "Spatial Quality" were not activated as one does not intend to evaluate them against each other, but instead evaluate all their direct descendants globally.

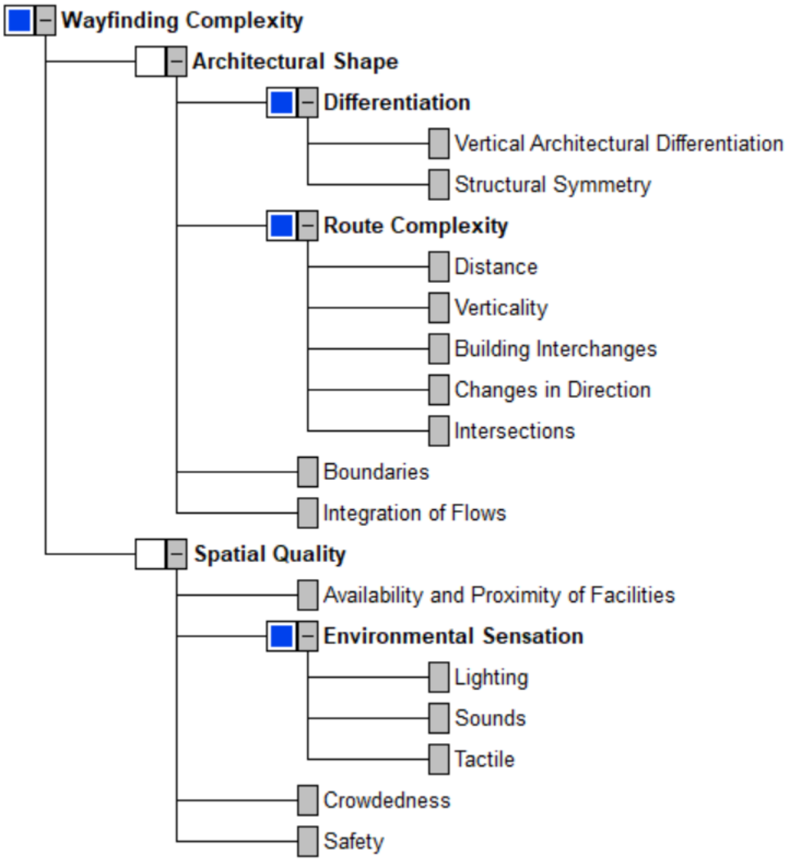
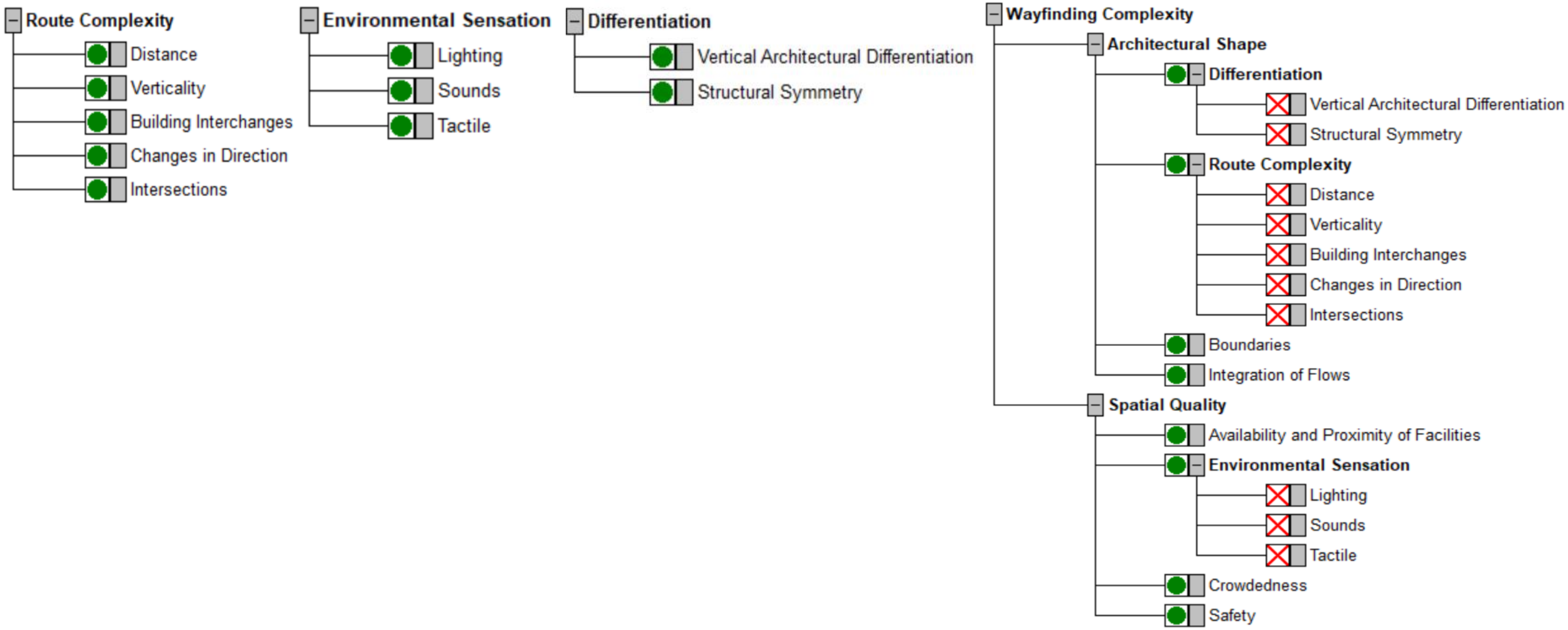


Figure G.2: Activated nodes for hierarchical weighting.

In this approach, the weighting of the criteria present in the model is done through global references. Based on the four activated nodes, four matrices will be generated, three to evaluate the descendant criteria of the route complexity, environmental sensation and differentiation nodes and one to evaluate the criteria of the wayfinding complexity global node. Figures G.3 to G.6 contain the global references to be evaluated in the nodes mentioned above. Figures G.7 to G.10 illustrate an example of how these matrices were filled in during the assessment for one of the participants to whom the MACBETH questioning protocol was assigned to. Figures G.11 to G.14 show the respective thermometer scales generated from the pairwise comparisons, which could be adjusted if the participants intended so. From these thermometer scales it was possible to obtain the histograms of local and global weights, represented on Figures G.15 – G.17 and G.18, respectively. The complete results of the weight elicitation process are represented on Figures G.19 and G.20.



Figures G.3 to G.6: Evaluation of global references that took place in the Route Complexity, Environmental Sensation, Differentiation and Wayfinding complexity (global) nodes, respectively.

Route Complexity

	[Building Interchange]	[Verticality]	[Changes in Direction]	[Intersections]	[Distance]	[all lower]
[Building Interchange]	no	weak	moderate	moderate	strong	positive
[Verticality]		no	moderate	moderate	mod-strg	positive
[Changes in Direction]			no	weak	moderate	positive
[Intersections]				no	moderate	positive
[Distance]					no	positive
[all lower]						no

Consistent judgements

Figure G.7: Example of a constructed pairwise comparison matrix for the Route Complexity node.

Environmental Sensation

	[Lighting]	[Sounds]	[Tactile]	[all lower]
[Lighting]	no	moderate	extreme	positive
[Sounds]		no	strong	positive
[Tactile]			no	positive
[all lower]				no

Consistent judgements

Differentiation

	[VAD]	[Symmetry]	[all lower]
[VAD]	no	moderate	positive
[Symmetry]		no	positive
[all lower]			no

Consistent judgements

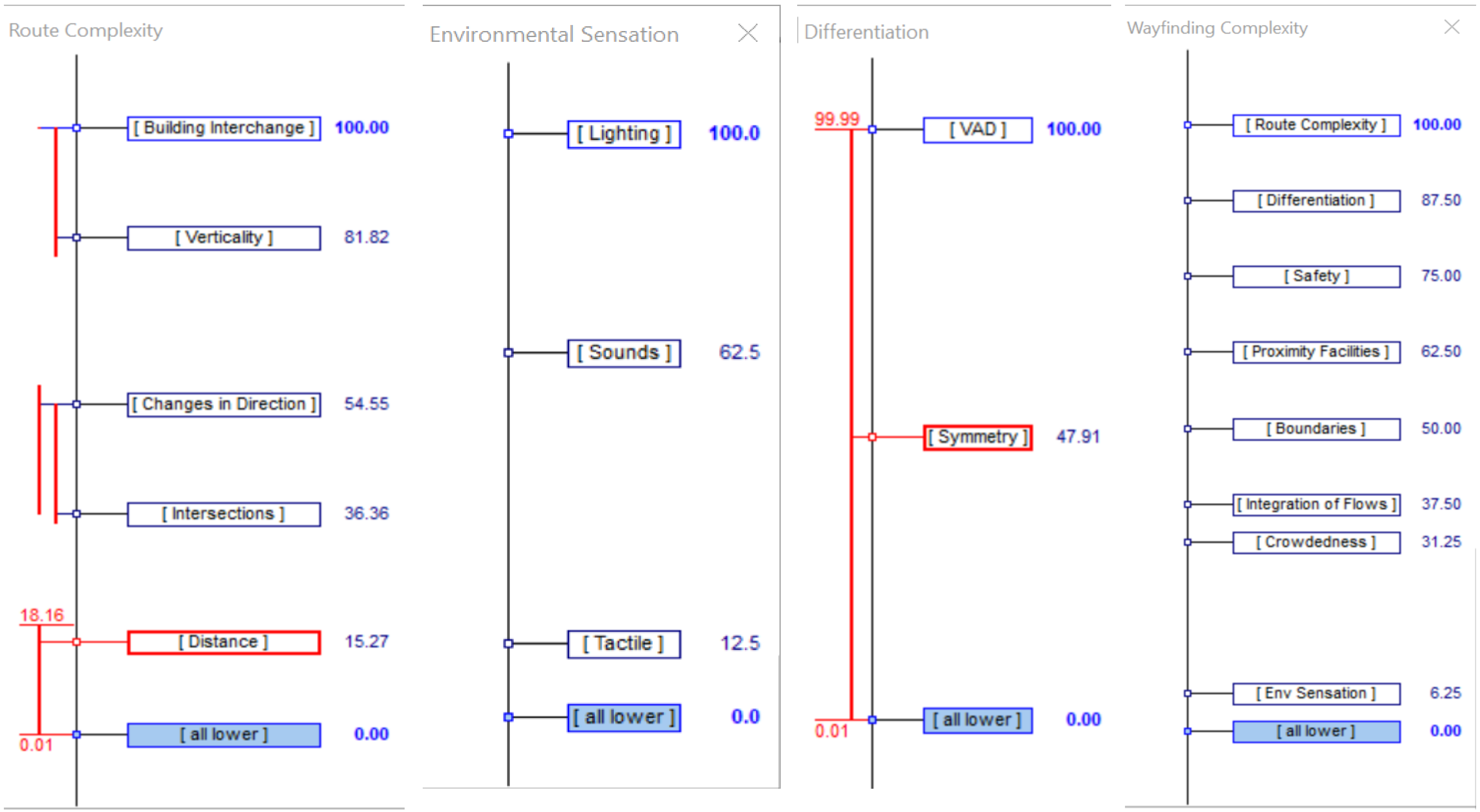
Figure G.8 and G.9: Example of constructed pairwise comparison matrices for the Environmental Sensation and Differentiation nodes, respectively.

Wayfinding Complexity

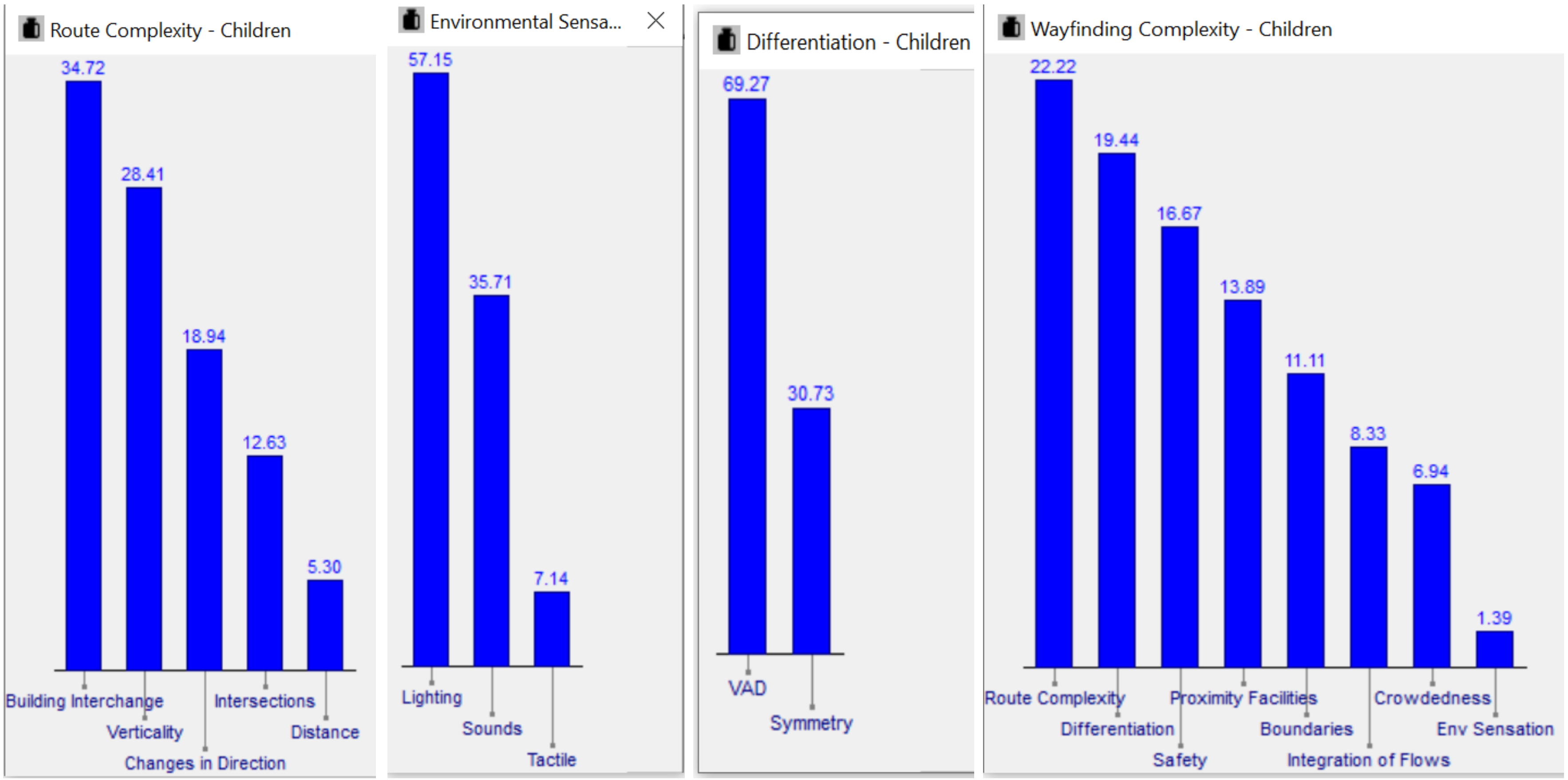
	[Route Complexity]	[Differentiation]	[Safety]	[Proximity Facilities]	[Boundaries]	[Integration of Flows]	[Crowdedness]	[Env Sensation]	[all lower]
[Route Complexity]	no	weak-mod	weak-mod	moderate	moderate	mod-strg	mod-strg	v. strong	positive
[Differentiation]		no	weak	moderate	weak-mod	moderate	weak-mod	strg-vstr	positive
[Safety]			no	weak-mod	moderate	weak-mod	moderate	mod-strg	positive
[Proximity Facilities]				no	weak-mod	weak-mod	weak-mod	mod-strg	positive
[Boundaries]					no	weak	weak	moderate	positive
[Integration of Flows]						no	very weak	moderate	positive
[Crowdedness]							no	moderate	positive
[Env Sensation]								no	positive
[all lower]									no

Consistent judgements

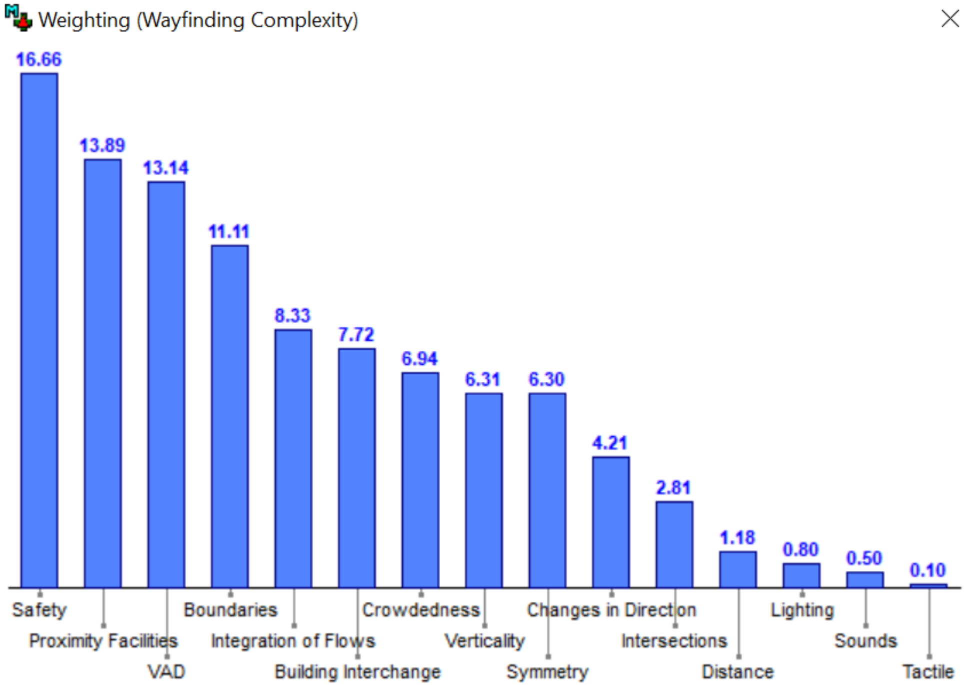
Figures G.10: Example of a constructed pairwise comparison matrix for the Wayfinding Complexity (global node).

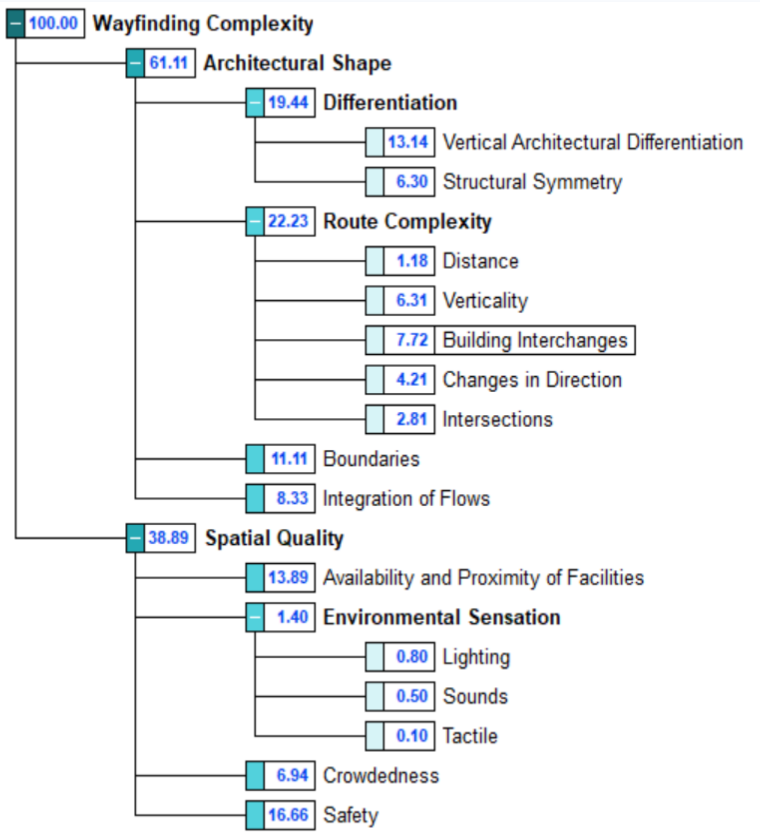


Figures G.11 to G.14: Example of interval scales obtained for the Route Complexity, Environmental Sensation, Differentiation and Wayfinding complexity (global) nodes, respectively. **Note:** The first and third scales were adjusted as per indication of the participant who expressed interest in increasing the weights of the subcriteria ‘distance’ and ‘symmetry’.



Figures G.15 to G.18: Example of criteria weights obtained for the Route Complexity, Environmental Sensation, Differentiation and Wayfinding complexity (global) nodes, respectively. **Note:** In the first three scales, the weights are represented in a local scale. The global weights for each subcriterion present in these scales can be derived by multiplying the local weight by the global weight of their parental node.





Figures G.19 and G.20: Example of global criteria weights obtained for one participant in form a histogram (on the left) and in the value tree with their correspondent node (on the right).