ISCTE Business School
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A KNOWLEDGE-BASED DECISION SUPPORT SYSTEM FOR SUSTAINABLE CITY LIVABILITY EVALUATION

Inês Filipa Coutinho Reis

Project submitted as partial requirement for the conferral of
Master in Management

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Desenvolvimento De Um "Termómetro" De Habitabilidade Sustentável Para Apoio À Decisão No Mercado Imobiliário Urbano

RESUMO

O mercado imobiliário é um indicador importante das economias mundiais e é influenciado pelo ambiente em que opera. Muitos foram os países seriamente afetados pela mais recente crise financeira internacional, incluindo Portugal. Não obstante, este continua a ser uma área de investimento interessante, ainda que, hoje em dia, as cidades possam enfrentar desafios que influenciam a sua habitabilidade sustentável. Por essa razão, parece lógico o desenvolvimento e a aplicação de metodologias que permitam avaliar a sustentabilidade habitacional de uma área urbana. No entanto, limitações metodológicas comuns à maioria das aplicações (*e.g.* processo de seleção e ponderação dos critérios de avaliação) têm dificultado os progressos alcançados. Assim, a presente dissertação pretende desenvolver um "termómetro" de habitabilidade sustentável que, de forma informada e transparente, permita apoiar a tomada de decisão no mercado imobiliário urbano, através da combinação do uso integrado de técnicas de mapeamento cognitivo e da metodologia *Analytic Hierarchy Process* (AHP). As vantagens e as limitações do uso deste sistema integrativo de avaliação serão também analisadas e discutidas.

Palavras-Chave: Mercado Imobiliário; Avaliação da Habitabilidade Sustentável; Mapeamento Cognitivo; *Analytic Hierarchy Process* (AHP); *Multiple Criteria Decision Analysis* (MCDA).

An Evaluation "Thermometer" For Sustainable City Livability

ABSTRACT

The real estate industry is an important indicator of national economies and is influenced by the environment in which it operates. Several countries were seriously affected by the most recent international financial crisis, including Portugal. Nevertheless, it is still an interesting area to invest in, in spite of the challenges cities may face nowadays that influence their sustainable livability. For this reason, it seems logical to develop and apply methodologies aimed at evaluating sustainable city livability. It is worth noting, however, that there are methodological limitations typically associated with the majority of the current applications (*e.g.* how to select and weight criteria in the evaluation), which have been hampering the progress. Hence, this dissertation aims to develop a knowledge-based decision support system to evaluate sustainable city livability, in a transparent and informed way. To achieve this goal, it combines cognitive mapping techniques and the Analytic Hierarchy Process (AHP). The advantages and limitations of this integrative evaluation model are also analyzed and discussed.

Keywords: Real Estate; Sustainable City Livability Evaluation; Cognitive Mapping; Analytic Hierarchy Process (AHP); Multiple Criteria Decision Analysis (MCDA).

EXECUTIVE SUMMARY

The aim of the present dissertation is to construct a knowledge-based decision support system for sustainable city livability evaluation. The real estate industry is essential for the economic and social development of a region or country. To that extent, any change in this industry might influence the wellbeing of the population. Nowadays, the real estate industry – more specifically, cities – have been facing challenges concerning their sustainable livability. In fact, the crux of the present dissertation is how important and critical is to understand the advantages of evaluating sustainable livability. Furthermore, it is pertinent to bear in mind the determining factors for considering a neighborhood and/or city as sustainable and livable. When someone is looking for a place to live, the choice is the result of a complex function, including not only housing and location attributes, but also several other factors. Being knowledgeable and possessing this information – in an accurate, informed and transparent way – will help the decision-making process. Several studies, methods and/or techniques have been developed focusing on the evaluation of the sustainable livability of a neighborhood and/or city. However, the methodological limitations typically associated with the majority of the applications (*e.g.* the way criteria/determinants are selected and incorporated into the evaluation mechanisms and the way of calculating the weights of these determinants) have been hampering the progress. Therefore, the alternative approach one intends to implement should succeed in overcoming these methodological limitations, take into account the inherent subjectivity of the decision-making process, as well as contribute to expand the capabilities of sustainable livability formulation. By taking into consideration the limitations of these methodologies, adopting a set of cognitive mapping techniques and the Multiple Criteria Decision Analysis (MCDA) approach seems to be feasible – namely, JOintly Understanding, Reflecting and NEgotiation StrategY (JOURNEY) Making and Analytic Hierarchy Process (AHP) approaches –. The combination of these approaches enables the selection of the determinants and the way to calculate their weights. Also, it allows decision makers to structure and evaluate the issue at hand. Cognitive mapping uses qualitative data when structuring a problem, while the AHP is relevant to create supporting systems since it enables to weigh determinants through the organization of ideas of the decision-makers. Thus, both cognitive mapping and the

AHP proved to lend themselves to integrating quantitative and qualitative factors, allowing realistic decision support systems to be created. Taking into account the participative component of these techniques, it is imperative to refer that their application implied gathering a panel of decision-makers willing to cooperate in face-to-face group sessions. A panel of six decision-makers was put together (*i.e.* civil engineers, urban planners and real estate agents) to help define and analyze the problem. In the beginning of the first session, the following trigger question was announced: *"Based on your own values and professional experience, what are the mains reasons or factors that most influence sustainable city livability?"* This question enabled the panel to find the criteria through the sharing and discussion of their perspectives. Then, the "post-its technique" was carried out, in which each member was asked to write down the relevant criteria on post-its, from an individual perspective. Subsequently, it was possible to aggregate the criteria (*i.e.* post-its) into six clusters, namely: (1) *Building Infrastructures*; (2) *Services and Transportation*; (3) *Community and Surrounding Areas*; (4) *Political and Economic Environment*; (5) *Safety Aspects and Social Risks*; and (6) *Urban Infrastructures*. The last step of this technique consisted of defining hierarchies among the criteria inserted in each area of concern. After the first session, a collective map was developed using the *Decision Explorer software*. During the second session, the decision-makers were asked to focus their attention on the cognitive map and afterwards define a descriptor and respective levels of partial performance for each cluster. The last session focused on the application of the AHP methodology, where the aim was to obtain local and global performance scales for the CTR identified, as well as to get trade-offs (*i.e.* weights) between them. In order to analyze the results obtained and measure the applicability of the process adopted, it was necessary to "test" the new model for sustainable city livability evaluation. Therefore, the panel was asked to provide real information about eight neighborhoods to investigate the impact level, per neighborhood, in each of the criteria previously identified. In conclusion, the model developed made it possible to evaluate the sustainable livability of different neighborhoods and reinforced the conviction that the integrated use of cognitive maps and the AHP method is pertinent to the current evaluation context. For this reason, the model helps decision-makers to reach a decision in a more robust and transparent way.

GENERAL INDEX

INDEX OF FIGURES AND TABLES

FIGURES

TABLES

MAIN ABBREVIATIONS USED

AHP	− Analytic Hierarchy Process
ANP	− Analytic Network Process
BI	− Building Infrastructure
BPI	− Banco Português de Investimento
CI	− Consistency Index
CR	− Consistency Ratio
CSA	− Community and Surrounding Area
CTR	− Criterion/Criteria
DEA	− Data Envelopment Analysis
DM	− Decision Makers
EPV	− Elementary Point of View
EPsV	− Elementary Points of View
EU	− European Union
FPV	− Fundamental Point of View
FPsV	− Fundamental Points of View
GDP	− Gross Domestic Product
I_SUM	− Index Sustainable Urban Mobility
IMF	− International Monetary Fund
INE	− Instituto Nacional de Estatística
JOURNEY	− JOintly Understanding, Reflecting and Negotiation StrategY
MACBETH	− Measuring Attractiveness by a Categorical-Based Evaluation Technique
MAVF	− Multi-Attribute Value Function
MCDA	− Multiple Criteria Decision Analysis
MCDM	− Multiple Criteria Decision Making
OECD	− Organization for Economic Cooperation and Development
OR	− Operational Research
OSAC	− Overseas Security Advisory Council
PCA	− Principal Component Analysis
PCT	− Personal Construct Theory
PEE	− Political and Economic Environment

POLIS	− Programa de Requalificação Urbana e Valorização Ambiental das Cidades
PsV	− Points of View
PV	− Point of View
RI	− Random Consistency Index
SASR	− Safety Aspects and Social Risks
SDI	− Sustainable Development Indicator
SRR	− Strategic goal-Responsibility department-Response
ST	− Services and Transportation
TCS_SLTD	− Spatial, Logical and Time Dimensions
TOD	− Transit-Oriented Development
TOPSIS	− Technique for Order of Preference by Similarity to Ideal Solution
UAPS	− Urban Audit Perceptions Survey
UI	− Urban Infrastructures

INTRODUCTION

A. General Background

The real estate industry is one of the most important areas for the economic and social development of a region or country. For this reason, any change in this industry might yield hard impacts on the economy, influencing the wellbeing of the population. In addition, the real estate industry is affected by the environment in which it operates. Although this industry is mostly related to choosing a proper residence or its location, there are other economic and social factors that influence the decision-making process, such as the livability and sustainability conditions. In Portugal, even though the real estate industry has been affected by the international financial crisis, it has been a key factor in reducing the economic and social impacts. Yet, Portugal's inconsistencies in several sectors, such as wealth and education, mean that the country still has to recover lost ground in order to reach sustainable livability. As a way to sidestep the difficulties in obtaining information created by the inherent inequality of the real estate industry, its complexity and/or confidentiality, several studies, methods and/or techniques have been developed, aiming at evaluating the sustainable livability of a neighborhood or city. In practical terms, this attempt originates in the need felt by some professionals to incorporate and measure the tangible and intangible factors that dictate whether a city is considered livable and sustainable or not. This is useful to carry out a business strategy, to contribute for a better strategic planning and for further development of this market. However, the methodological limitations typically associated with the majority of the applications (*e.g.* the way criteria/determinants are selected in the evaluation mechanisms and the way of calculating the weights of these determinants) have been hampering the progress. For this reason, it seems logical to draw up an alternative approach intended to develop a knowledge-based decision support system for sustainable city livability evaluation. This approach should succeed in overcoming some of the existing methodological limitations and take into account the inherent subjectivity of the decision-making process, as well as contribute to expand the capabilities of sustainable livability formulation. Consequently, resorting to a set of cognitive mapping techniques and the Multiple Criteria Decision Analysis (MCDA) approach seems to be plausible, since it enables the selection of the determinants and also the way to calculate their weights.

B. Research Objectives

The real estate industry in Portugal is an appealing investment alternative, even though it is still in the recovering phase after going through a financial crisis that caused serious economic and social impacts. It is a fact that Portugal is a country of inequalities, namely when it comes to the uneven distribution of wealth, the high unemployment rate, the changes in the family structure and the low satisfaction rates regarding quality of life. These disparities will not be easily solved; however, considering that the decision-making process is even more complex and demanding — integrating several factors — it seems logical to develop new contributions in this field of research. They should be well-defined and coherent, adding transparency and simplicity to the decision-making processes.

Bearing in mind the scenario mentioned above, the present study aims to discuss a new approach leading to the construction of a knowledge-based decision support system for sustainable city livability evaluation. ***Therefore, this dissertation intends to develop a multiple criteria "thermometer", based on the integrated use of cognitive mapping techniques and the Multiple Criteria Decision Analysis (MCDA) approach, guaranteeing simplicity, transparency and well-founded principles in the decision-making framework.*** This entails a model that warrants constructing a system to evaluate sustainable livability of a neighborhood or city. In order to accomplish this objective, a literature review will be carried out to understand the current situation of the sector, as well as the current sustainable city livability evaluation systems. Specifically, it aims to: (1) promote discussion and debate among the members of the panel, who are experts in the real estate area, in face-to-face work sessions. The aim is to structure the problem through the elaboration of a collective cognitive map; (2) identify the evaluation criteria and calculate their weights; and (3) encourage reflection, the possibility of adjustments and recommendations.

C. Methodology

As stated in the previous section, this dissertation aims to construct an evaluation system to measure the sustainable livability of a city. Consequently, the model is based on the fundamental convictions of the MCDA approach. The construction of the model will make use of cognitive maps and the Analytic Hierarchy Process (AHP), which was developed by Saaty (1980). The AHP approach is one of the most widely used tools to solve complex decision problems. For this reason, this approach is relevant to create decision support systems since it enables to weigh evaluation criteria through the organization/structuring of ideas of the decision-makers.

In practical terms, the methodology will run through three phases: (1) review of the methods used, during the past years, to evaluate sustainable livability in a city, aiming to understand the current status of the real estate industry. Also, the methodologies and/or techniques to be used will be framed; (2) implementation of cognitive mapping integrated with the AHP approach. Moreover, it will be necessary to conduct face-to-face work sessions involving a group of professionals (*i.e.* civil engineers, urban planners and real estate agents). The objective is to structure the problem and define both the evaluation criteria and their trade-offs (*i.e.* weights); and (3) the model will be tested and analyzed.

D. Structure

In addition to the present introduction, conclusion, references and appendix, this dissertation is divided into two parts. The first part is composed of five chapters (*i.e.* chapters 1, 2, 3, 4 and 5), incorporating the theoretical and methodological background. The second part includes two chapters (*i.e.* chapters 6 and 7), which encapsulates the empirical component of the dissertation. In this segment, the methodologies explained in the first part are applied (*i.e.* cognitive mapping and the AHP approach).

Chapter 1 seeks to provide an overall description of the current situation of the real estate industry, in terms of its sustainability and livability conditions. For this reason, this chapter expounds the importance of strategic planning in urban infrastructure projects, as well as the need to guarantee sustainability. In addition, an overview of the Portuguese situation is presented. Subsequently, *Chapter 2* explores the reasons why it is necessary to evaluate cities in terms of their sustainable livability. On the whole, the most widely used methods to evaluate sustainable livability — including their main advantages and methodological limitations — are discussed. *Chapter 3* presents the MCDA approach, which aims to support the decision-making process; it is also the starting point to the construction of a system to evaluate sustainable city livability. It is suitable to weigh the criteria in a transparent, intuitive and fair way, making it possible to overcome some of the methodological limitations of the current methods. Moreover, the basic concepts, paradigms and fundamental convictions of this approach are explained, as well as their main contributions to the proposed framework. *Chapter 4* focuses on the JOintly Understanding, Reflecting and Negotiation StrategY (JOURNEY) *Making* approach, by explaining the importance of human cognition and presenting cognitive mapping as an useful tool to structure complex decision problems; it concludes with the explanation of the concept of point of view (PV). *Chapter 5* wraps up Part I of the dissertation and introduces the AHP approach which is known for its simplicity and ease of application when calculating the weighting of the criteria in a decision-making process. Not only are its fundamentals, characteristics and applicability explained, but also its major advantages and limitations. Part II of the dissertation begins with *Chapter 6* which describes how cognitive mapping is applied with the objective of identifying the criteria to be included in the new evaluation system. In this context, it is important to refer that the face-to-face work sessions were organized with an expert panel of six professionals of the real estate industry. Finally, *Chapter 7* elaborates on the technical procedures used to create preference scales and to calculate weights for the identified criteria, through the application of the AHP approach. In order to guarantee the consistency of the developed model, several tests and complementary analyses are conducted. Recommendations are also formulated based on the results achieved.

E. Expected Results

Having adopted the constructivist approach, the present dissertation aims to develop a multiple criteria “thermometer” to support the decision-making process geared to the evaluation of sustainable city livability in the Portuguese context. Taking into account the chosen methodological approach, which is characterized by direct participation of a panel of experts in the area, one of the expected results in this dissertation is to carry out a robust investigation. This implies understanding the potential of this approach in the real estate industry.

Likewise, it is expected that this multiple criteria approach can result in providing an increased simplicity and transparency in the process of evaluating a city in terms of its sustainability and livability conditions. This will bring added value to the agencies and mediators of the real estate industry in the strategic planning of their activity. Furthermore, publishing the results of this dissertation is another expected result.

PART I

THEORETICAL AND METHODOLOGICAL BACKGROUND

CHAPTER 1

STRATEGIC PLANNING AND SUSTAINABLE CITY LIVABILITY

Strategic planning is essential for the development of the real estate industry. It not only provides the guidelines for urban infrastructure projects, but also contributes to the accomplishment of the sector's strategic and operational goals. Nowadays, the increased use of strategic planning has profound impacts and results in sustainability, more specifically in urban sustainability. From this perspective, the importance of real estate and the need to guarantee its sustainability justify the required effort to develop an evaluation system for sustainable city livability. Taking this into account, this chapter aims to: (1) present the fundamentals of strategic planning and sustainability; (2) highlight the importance of sustainable city livability for the real estate industry; and (3) provide an overview of the Portuguese situation. The development of these topics is fundamental to understand the processes followed in the construction of a knowledge-based decision support system for sustainable city livability evaluation, which is the aim of this study.

1.1. Fundamentals of Strategic Planning and Sustainability

According to Porter (1996: 61), *strategy* is *"the creation of a unique and valuable position, involving a different set of activities"*. However, there is no clear, single and common definition of strategy. There are multiple approaches within this concept and one will notice that each organization can have its own strategy on how to run its business. To put it simply, strategy is a guide that sets a direction and allows corporations, businesses or organizations to go from point A to point B. In order to have a consistent strategy, companies must have their goals, vision and mission aligned in accordance with its operating environment. It is also important to have a coherent allocation of resources and capabilities as a way to stimulate the accomplishment of the strategy (Barney, 1991). The main goal of a company, as well as its biggest challenge, is to survive in the market. As such, according to Barney (1991), to achieve competitive advantage, companies should learn how to evaluate their performance. However, a great amount of companies fail to accomplish this goal, and die in the market due to the fact that the environment is neither constant nor stable. For this reason, strategy needs to be evolutionary as well. Therefore, more attention to the opportunities and threats that may arise is necessary, since any change in the environment can be detrimental to the strategy orientation. Additionally, according to Bouhali *et al*. (2015), following a defined strategy can be compromising, because companies, instead of anticipating and focusing on any unexpected change, spend their time waiting until it appears. Having considered these factors, it is extremely important to adopt a strategic plan.

As in the definition of strategy, there is no commonly and universally accepted definition of strategic planning. Bachmann *et al*. (2016: 297) refer that strategic planning *"sets the stage for subsequent action by influencing workplace conditions across all of a firm's hierarchies and units"*. This influencing process is important to guarantee the implementation and execution of strategic plans (*cf*. Elbanna, 2016). Strategic planning complements the definition of strategy since it integrates the evolutionary characteristic of the environment. In this regard, Nazemi *et al*. (2015: 2) state that companies need to implement modern and sophisticated strategic plans if their purpose is to survive and grow in a completely evolutionary environment. There are several reasons that should influence companies to set strategic plans, namely: (1) *"better awareness of needs and of the facilities related issues and environment"*; (2) *"sense of direction, continuity, and effective staffing and leadership"*; and (3) *"opportunity to influence the future, or assume a proactive posture"* (Bouhali *et al*., 2015: 74).

The use of strategic planning is an important tool adopted by companies, since it incorporates various techniques that help managers and leaders to perform specific tasks, to collect data and to engage in effective decision-making. By using these techniques it is not only possible to increase awareness of the environment, including opportunities and threats, but it is also possible to reduce the risk of failure (*cf*. Kalkan and Bozkurt, 2013: 1017). Nevertheless, during the process of implementation, firms and leaders may face different barriers. This way, the plan set may not turn out to be as expected because of the changes in the environment. For instance, the *"i) lack of consensus, understanding and transparency regarding the meaning of the enterprise mission and vision; ii) lack of relation between strategic content and strategic feedback;* […]; *vi) lack of involvement of the organization's management* […]*"* are some of the barriers that can lead a strategic plan to its end (Nazemi *et al*., 2015: 3). The occurrence of some obstacles is common during the implementation phase. Overall, strategic planning is the process of an organization to set a strategy. Its formulation and implementation need to be well defined and clear. By doing this, it becomes easier to change the direction of the strategy if the environment demands it. The process starts with the leaders at the top of the organizations, but it is easily spread to all stakeholders (Bouhali *et al*., 2015). So, strategic planning should be seen as a tool to organize the present, but always keeping in mind the projections for the future.

Regarding *sustainability*, Yigitcanlar *et al*. (2015: 36) state that it refers *"to maintain the existence of the ecosystem and its services, while also providing for human needs"*. Thus, it is possible to conclude that sustainability is a complex concept and it must integrate a set of interdependent variables, from economic and social questions to environmental and energetic matters. According to Pater and Cristea (2016), the terms "sustainability" and "durability" are similar and interchangeable. This means that being sustainable can also be thought of as being permanent, with a long-term perspective. In this sense, to ensure the possibility of reaching sustainability, it is imperative to integrate three main pillars: (1) economy; (2) society; and (3) environment. Nowadays, it is possible to observe an increasing will from companies to adopt sustainability-oriented values and strategies. In fact, as Lee and Jay (2015: 126) refer, *"many companies today are attempting to incorporate sustainability as a central principal of their strategies"*, since companies actually face demands and opportunities that are related to sustainability, in spite of their will.

The general concept of sustainability also applies to *city sustainability*. This specific concept emerged since *"urbanization has become an inevitable global trend"* (Zhang *et al*., 2016: 491). According to Zhang *et al*. (2016: 491), cities are *"inherently unsustainable"* because, although they are able to yield economic and social benefits, these are gained from "*consuming natural resources and exporting wastes*". Cities are causing large-scale pollution and scarcity of resources. As a means to control that, at the same time, there is an increase of ecological regulators in the cities which have a significant impact to achieve sustainability. In order to accomplish that, there are several criteria to help them evaluate sustainability, which will be developed in the next topic.

As it has already been pointed out, urban infrastructures influence the state of the environment, and thus *"processes of strategic planning* […] *are instrumental to materializing environmental sustainability visions"* (Malekpour *et al*., 2015: 67). In this sense, the need for long-term strategic planning becomes indispensable, since it creates the conditions to deal with future issues. Traditionally, the question people try to answer regarding long-term planning is: *"What does the future look like*?*"* However, according to Malekpour *et al*. (2016: 196), the real question should be: *"What do different futures mean for success or failure of a solution*?*"* In other words, instead of predicting future scenarios, one might wish to explore a set of different possibilities. By using this approach, the strategic plan is expected to be robust, which means that it will take care of present issues, predict future conditions and be ready for any unexpected changes. One of the challenges and changes that companies, including real estate ones, might face is related to the need to develop a sustainable environment. That is almost impossible without a well-defined strategic plan.

In keeping with this, strategic planning and sustainability are connected. Companies, by combining business with the environment, may benefit *"not just for day-to-day operational issues but for strategic issues that have a material impact on the medium- and long-term viability of the firm"* (Rosenberg, 2016: 56). In addition, according to Malekpour *et al*. (2015: 67), strategic planning is critical to *"operationalize environmental sustainability visions"*. From one point of view, general firms tend to have a short-term thinking and vision (three to five years), especially because of a set of factors including the *"time value of money, shareholder pressures, strategic planning cycles,* […]*"*. On the other hand, the majority of stakeholders tend to have a long-term thinking (decades), *"planning cycles or even imagination of many business leaders"* (Rosenberg, 2016: 55). As such, even though the relationship between strategic planning and sustainability is an open door for different types of development opportunities, it may bring subjectivity and ambiguity to the decision-making process (*cf*. Malekpour *et al*., 2015). Lastly, strategic planning is considered a useful tool to conceive sustainable urban infrastructures, being responsible for ensuring city livability in the real estate industry.

1.2. Real Estate and Sustainable City Livability

According to Uysal and Tosun (2014), the price of real estate is an economic indicator that reflects urban evolution mechanisms. It is worth noting, however, that there is variety of demographic, economic and social factors that also influence both the supply and demand of real estate holdings. Indeed, the real estate industry is mostly related to choosing a proper residence or its location. However, this choice is in fact a result of a *"complex function of a wide range of housing and location attributes"* (Uysal and Tosun., 2014: 322). It is considered a difficult endeavor, since it takes into account not only an economic decision, but also several social factors.

Presently, the real estate industry is not just about choosing the location of a residence, land or neighborhood. It demands searching for a livable/happy region/neighborhood, taking into account the promotion of a sustainable environment. Some of the most common characteristics when choosing a place to live include *"the location of the building relative to the center of town, the level of infrastructure, the presence of community facilities and shops"* (Nesticò and Bencardino, 2016: 410). This industry is complex and it is a result of livability and sustainability compounded. When livability is about the present ("*now*" or "*how to be*"), sustainability is an objective to aim for. On the one hand, livability seems to be easier to reach as it is tangible and immediate. Conversely, sustainability has a long-term perspective, becoming harder to reach. However, neither of these concepts exists without the other, since they are complementary. As a result, both are used as a guide process for the planning and the policy of a real estate industry project (*cf.* Ruth and Franklin, 2014).

Astell-Burt *et al.* (2015: 69) point out that the choice of neighborhood is a critical factor for defining it as livable, since its effects contribute to the health of the living community. The authors include, as characteristics of neighborhoods, the *"provision of food outlets, green spaces and other factors subsumed within the concept of "livability""*. According to Okulicz-Kozaryn (2013), livability has as its main goal to find objectively the quality of life, including infrastructure. The author defends that people living in livable cities are happy. So, when living in a livable city or neighborhood, people tend to feel happy. Also, according to Zanella *et al.* (2015), a livable city "*should be healthy, safe, harmonious, attractive and affordable*". As a matter of fact, planners and policy makers use this concept as a baseline condition for investments that have an impact on environment (*i.e.* urban, social, economic, physical and biological) (*cf.* Ruth and Franklin, 2014). However, what allows cities to become livable depends on the behavior of several components. There are essentially two elements – the so called "First Principles" – that help qualify a city as habitable or inhabitable: (1) characteristics of population and its demands (*e.g.* energy supply, education, transportation, safety and entertainment); and (2) biological and physical characteristics of the environment, such as infrastructures and ecosystems that are responsible for providing the goods and services (*cf.* Ruth and Franklin, 2014). This second principle also refers to the control of environmental impacts, such as water resources, waste generation, air quality and biodiversity. In addition, the second principle exists essentially in developed countries that have established the concept of *livability* in the context of achieving development goals and to improve neighborhood environments (*cf.* Setijanti *et al*., 2015).

Conceptually, a sustainable city can be defined as *"the spatial entity that maximizes the benefits in economic and social dimensions under relevant constraints on environmental limitations and socio-economic distributional equity"* (Mori and Yamashita, 2015: 10). Every stakeholder holds an important role in the construction of an urban project. For example, the government and local authorities can be crucial to develop sustainable practices among citizens. Cities are affected not only by positive agglomeration effects but also by negative ones, such as the concentration of knowledge and skills and housing costs. As pointed out by Mori and Yamashita (2015), for a city to be successful it must balance the trade-offs between benefits and costs.

In keeping with the above-mentioned, for a city to be considered livable, it needs not only to fulfill the quality of life indicators, but also the sustainability components. While there are authors that defend the existence of ten dimensions of livability, others claim that there are only four. Zanella *et al*. (2015), for instance, argue that initially there were 6 dimensions: (1) *wealth and income inequality*; (2) *unemployment*; (3) *education and training*; (4) *housing*; (5) *accessibility and urban design*; and (6) *health*. However, the Australian Government (*in* Zanella *et al.*, 2015) completed the list with four more in order to also assess sustainability. They are: (7) *equality*; (8) *safety*; (9) *affordability*; and (10) *community wellbeing*. On the other hand, Heylen (2006: 4) refers in his study that there are four dimensions around the concept of sustainable city livability, namely: "*(1) quality of dwelling/building; (2) quality of physical environment, including the level of services and facilities; (3)*

quality of the social environment; (4) safety of the neighborhood". In spite of the two different views regarding the number of dimensions, it is noteworthy that both perspectives include the same components, which are subdivided in different dimensions. Therefore, both visions take into account livability and sustainability components.

Recently, Foster *et al.* (2015: 150) came up with an innovative idea for the real estate industry, raising the question of whether a livable neighborhood meant a safer neighborhood. These authors defend the need of a new urbanism within the cities. This new urbanism includes the *"design of the compact, pedestrian-friendly, mixed-use developments"*, promoting walking, minimizing car dependence and creating a sense of community. The implementation of this new urbanism will enhance safety, decreasing criminal complaints. After all, the critical question is: *"why is sustainable city livability important?"* First of all, this factor *"is important for people,* […] *for businesses"* and *"for city governments* […]*"* (Okulicz-Kozaryn, 2013: 434). If cities are able to make their inhabitants happy, they will become better workers. As a consequence, good workers and new businesses will be attracted to these cities, contributing to their development. Secondly, sustainable city livability is about providing good accessibility, health, wellbeing, walkable environments and high amenity (Newman, 1999; Shamsuddin *et al.*, 2012; Zanella *et al.*, 2015). On the contrary, cities that do not provide goods and services are not chosen as places to live in. Finally, a livable city *"maximizes socio-economic benefits measured by economic and social indicators under relevant constraints measured by environmental indicators"* (Mori and Yamashita, 2015: 12). All things considered, it is important to assess the real estate industry in Portugal, more specifically in terms of sustainable livability dimensions.

1.3. The Portuguese Scenario

In general, the real estate industry is an important indicator of national economies and it is influenced by the environment in which it operates. Bearing in mind that Portugal is not any different in terms of sustainable livability, the dimensions referred to above will form the basis of a detailed look at its characteristics.

Firstly, in terms of (1) *wealth and income inequality*, Portugal is considered a country of unequal distribution of wealth. Since the mid-1990's, there has been a gradual increase in the number of Portuguese people living in poverty (Carmo and Cantante, 2010). It is possible to analyze the Portuguese distribution of wealth for the five subsets of the population, in which each quartile represents 20% of the population. The first quartile corresponds to the poorest 20% and the fifth quartile to the 20% richest. According to Observatório das Desigualdades (2010), in 2008 the poorest population in Portugal held 7.2% of the total wealth. On the contrary, the richest population held 43.2%. Furthermore, the income of the 10% wealthiest people was 10.7 times higher than the 10% least wealthy ones (*cf.* Carmo and Matias, 2014). Another useful variable is the Gini Coefficient, which helps to measure the degree of inequality in wealth. In 2011, the Gini Coefficient for Portugal was 34.5%, which was above the EU-27 average (30.4%). As a result, Portugal is one of the European countries with the highest unequal wealth distribution (Carmo and Matias, 2014). Two of the reasons which account for this are the very low wages (Carmo and Cantante, 2010), and the qualification levels of the Portuguese families (Observatório das Desigualdades, 2012). Moreover, Portugal shows strong disparities not only in wealth distribution in terms of Gross Domestic Product (GDP) per capita distribution, but also in the location of most company headquarters. The Greater Lisbon area stands out in these aspects, having a quality of life three times better than the Serra da Estrela region, which is the poorest region (*cf.* Ministério do Ambiente, Ordenamento do Território e Energia, 2015).

From the standpoint of Portugal (2008: 59), when (2) *unemployment* is concerned, "*a distinctive feature of the Portuguese labor market is the very high average duration of unemployment*". According to the Organization for Economic Cooperation and Development (OECD) (*cf.* OECD, 2016a) and Rosa (2016), Portugal is experiencing an improvement in both unemployment and employment rates. However, this phenomenon is not a consequence of an increase in employment, since it has been falling at a slow pace. On the contrary, it is a consequence of the increased rate of emigration and the escalating number of Portuguese people excluded from the labor market (*cf.* Rosa, 2016). In May 2016, unemployment in Portugal (11.6%) remained above the OECD average (6.3%) (OECD, 2016a). The situation becomes clearer when comparing the unemployed people for one year or more. In Portugal, for the same time frame, this rate is about 55%, while in the OECD the average is 33%

(OECD, 2016a). This *“reflects freezes in the minimum wage as well as a decline of the importance of collective agreements and extensions during the crisis”* (OECD, 2016a: 1). In regional terms, the employment situation in Portugal is not homogenous. Job offers, young and qualified people, higher bargaining power consumers and better transportation infrastructure are highly concentrated along the coastline of Portugal (Ministério do Ambiente, Ordenamento do Território e Energia, 2015).

Furthermore, with respect to (3) *education and training*, *“Portugal faces the challenges of ensuring that all students complete compulsory education, increasing attainment rates in upper-secondary and tertiary education, and offering the quality and inclusive education for all students”* (OECD, 2014: 4). On the one hand, the investment in education in 2013 by the Portuguese government was above the European Union (EU) average (6.8% of the GDP compared to 5% in the EU). On the other hand, in spite of the decreasing numbers, Portugal still has a high rate of school drop-outs. From 2009 to 2014, this rate decreased from 30.9% to 17%. However, *“this remains far above the Europe 2020 national target of 10”* (European Commission, 2015: 4). In addition, another critical aspect affecting Portuguese youths who complete higher education is the relatively low employment rate of tertiary graduates, which is about 73.6% — when in the EU it is approximately 80.5% (European Commission, 2015). Despite the increase in the indicators regarding lifelong learning in Portugal, in the period between 2000 and 2008, it was still below the EU average. In 2008, the population aged between 25-64 years old who received education and training was 5.3%, while in EU the rate was around 9.5% (Observatório das Desigualdades, 2010). According to the OECD (2014) and the European Commission (2015), Portugal has been investing in education, aiming to raise the overall equity and quality. This investment is based on the implementation of major reforms and on the introduction of an additional loan system, especially for the tertiary education.

When it comes to (4) *housing* and (5) *accessibility and urban design*, according to Instituto Nacional de Estatística (INE) (*cf*. INE, 2012), the housing stock in Portugal is 45% higher than the number of families, which means that the number of dwellings in the country exceeds the number of families by 1.8 million. The Portuguese urbanization process mainly occurs along the coastline of the country. As a consequence, *“the accessibilities, climate, quality of life and development of economic activities”* are intensifying the expansion of coastal living (Ministério do Ambiente, Ordenamento do Território e Energia (2015: 6)). According to the same source, the development of the accessibility system, resulting from a huge investment, helped to connect the main urban centers. Consequently, it enabled the access of people to businesses, goods and services, but also reinforced the link to international markets. In terms of urban designing, according to Guedes *et al.* (2009), architects and urban planners are responsible for reducing the environmental impacts through the implementation of environmental strategic plans. One of the programs developed in 2000 — named Programa de Requalificação Urbana e Valorização Ambiental das Cidades (POLIS) — was mostly intended to improve the quality of life in cities.

With regards to (6) *health*, *"Portugal possesses an impressive array of quality monitoring and improvement initiatives. It has a robust quality architecture which, unlike in many OECD countries, covers almost the whole health care system"* (OECD, 2015: 13). Also, the recent primary care reforms in Portugal are producing impressive improvements in certain aspects, such as efficiency, quality and satisfaction. However, Portugal has an ageing population, which results from the combination of a lower birth rate and an increase in life expectancy. Besides this, there are noticeable changes in the family structure (*e.g.* single-parent families, childless couples, elderly people living alone) that pose both economic and cultural challenges and impacts on urban systems (Ministério do Ambiente, Ordenamento do Território e Energia, 2015).

Regarding (7) *equality*, *"in Portugal, the average female employee earns 12.5% less than the average male employee"* (European Commission, 2013: 13). In order to reduce this gender gap, the 4th Plan for Equality postulates the introduction of equality plans within enterprises (European Commission, 2014).

With reference to (8) *safety*, according to the Crime and Safety Report from Overseas Security Advisory Council (OSAC) (*cf.* OSAC, 2015: 1), Portugal is mostly characterized by low-level street crime. This is most likely to happen in *"tourist locations, near beaches, and transportation hubs (subway, bus, train stations)"*. This report also enunciates that the areas deserving special attention are urban centers, such as Lisbon, Porto, Sintra, Coimbra and the Algarve.

Concerning (9) *affordability*, it is important to clarify this concept as *"the ratio of housing costs to income"* (Branco and Alves, 2015: 3). Indeed, housing affordability is a concept especially applicable to middle and low-income families, since there are concerns about their ability to make the payments inherent to housing. When comparing Portugal to the rest of Europe, one will notice that Lisbon and Porto — especially the latter — are two of the least expensive cities to live in (Deloitte, 2015). Also, from the perspective of Deloitte (2015: 27), real estate in Portugal is recovering after a tough period of deep decline in prices. Now, *"houses are starting to be sold for higher prices"*.

Lastly, as far as (10) *community wellbeing* is concerned, according to the Better Life Initiative of the OECD, *"life satisfaction in Portugal is the lowest in the OECD"* (OECD, 2016b: 3). On a scale of zero to ten, in which zero is "not satisfied" and ten stands for "totally satisfied", Portuguese people evaluated their life satisfaction as 5.1 while the OECD average is 6.5. Also, in terms of living in a close-knit community and experiencing civic participation, Portuguese people are below the average of the OECD. Only 85% of the respondents believe that they have someone to resort to when needed. The average of the OECD is 88%. Gaucher (2014) refers that Daniel Kahneman defends that the way a person experiences happiness is different from how he/she remembers it. For this reason, this can be a plausible reason for the OECD findings.

In Portugal, the real estate industry has been a key factor to reduce the economic and social impacts of the most recent international financial crisis. Although the crisis has had a huge and negative impact on the real estate industry, real estate is still an interesting investment alternative (*cf.* Pinto, 2013). According to Banco Português de Investimento (BPI) (2014: 3), the International Monetary Fund (IMF) says that Portugal is considered an economy in which the real estate industry is still in the recovery phase. The level of family debt and the procedures involved in the rent market are two of the factors that hinder a faster growth of the real estate industry in Portugal. In addition, in terms of sustainable livability, Portugal is not homogenous in most of the dimensions, as highlighted above. Hence, there is still a long road ahead and it is crucial to find a balance by applying correct planning in the real estate industry (Ministério do Ambiente, Ordenamento do Território e Energia, 2015). Nevertheless, it is not possible to conclude if Portugal is sustainable or not by just looking at some of its dimensions. City livability evaluation requires the use of some specific methods, which will be the focus of the next chapter.

SYNOPSIS OF CHAPTER 1

This first chapter aimed to provide an overview of the concepts of strategic planning and sustainability, and their contribution to the development of the real estate industry. Next, the importance of sustainable city livability and its dimensions were explained. Lastly, a brief review of the city livability in Portugal was presented. In general terms, the focal points were viewed as being of great importance to construct a knowledge-based decision support system for the evaluation of sustainable city livability. Through their lens, strategic planning and sustainability are two concepts that currently influence the real estate industry. On the one hand, strategic planning is the process that helps to define the goals and the direction for the present, although one must always keep the future in mind. Therefore, if the environment changes, it is possible to reformulate the strategy due to the evolutionary component of strategic planning. In the real estate industry, the use of strategic planning for urban infrastructures is becoming of extreme importance, especially to make cities sustainable. On the other hand, sustainability is one of the factors that have recently become relevant in this industry. As it was pointed out, people who live in sustainable cities tend to be happier than the other ones living in less inviting areas. The idea is to try to make the real estate industry more and more sustainable at a slow pace, with lower consumption of resources and balancing the trade-offs between benefits and costs. Lastly, this industry is the result of a complex interaction within a set of variables. It is not just about choosing a home, but more about what the environment can provide to its residents. As such, there is a set of dimensions to evaluate sustainable livability that includes quality of life and sustainability components. Through the analysis of the principal dimensions of sustainable livability, it was possible to notice that Portugal is a country of inequalities. In most of the dimensions, Portugal is constantly below the EU average. Although the Portuguese health system is one of the most impressive ones in the OECD, the configuration of the population does not help, since there are fewer children being born and people live longer. To make matters worse, the population distribution is uneven and the distribution of businesses is unbalanced across the country. This causes a large concentration of people along the coastal areas. In a nutshell, Portugal has a long road ahead to achieve sustainable livability; therefore, opting for strategic planning might be a good solution. In the next chapter, the importance of sustainable city livability evaluation will be discussed.

CHAPTER 2

SUSTAINABLE CITY LIVABILITY EVALUATION: FUNDAMENTALS

This chapter aims to explore the reasons that underpin the need to evaluate cities in terms of their sustainable livability. Accordingly, this second chapter intends to: (1) understand the importance of city livability evaluation; (2) identify some of the most used methods to evaluate city livability, as well as to analyze its advantages and shortfalls; and (3) present general methodological limitations of the current methods. These three points are essential to support the evaluation framework to be developed in this dissertation.

2.1. The Importance of City Livability Evaluation

Cities, as seen in the previous chapter, are responsible for providing socio-economic activities, offering jobs and creating the ideal living conditions for their residents. According to Zanella *et al*. (2015: 699), *"places with good livability must not only be economically successful, but also need to have a low environmental impact"*. However, when choosing a city, neighborhood and place to live, people make their choices based on the features they are looking for. After all, even cities have their own personality, and differ from one another. As such, the existence of indicators, ratings and indices help to evaluate a city's sustainability. Moreover, the challenges cities may face on a daily basis emphasize the importance of the city livability evaluation. This can be summarized in five aspects: (1) *complexity of a city's housing market*. Cities are characterized as being heterogeneous and multiple. Indeed, the variety of transportation problems, neighborhoods and arrangements may hamper finding a place to live (Uysal and Tosun, 2014). Furthermore, the problems and solutions available are different from place to place and demand proactivity from the main stakeholders involved (*cf*. Heylen, 2006); (2) *personal preferences. "Each person has a different pleasure and socio-economic properties"* (Uysal and Tosun, 2014: 393). The residential price, social facilities and location are instrumental in the decision-making process. However, these characteristics may be perceived and valued differently from one person to another; (3) *positive and negative effects of a city*. Cities are affected not only by the impacts of positive agglomeration, but also by negative ones, such as the concentration of knowledge and skills and housing costs. Similarly, cities have been contributing to global climate change. This means that the emissions of greenhouse gases are negatively impacting cities on a global environment basis (Mori and Yamashita, 2015); (4) *the role of urban planning and management*. The assessment of city livability and the comparison of how cities perform play an important role in urban planning and management. In fact, the evaluation of cities leads to *"better standards of human wellbeing without compromising environmental sustainability in the long-term"* (Zanella *et al.*, 2015: 696); and (5) *the influence of a strong tourism industry*. Cities are influenced by the tourism industry, which entails that one must ponder the correlation between not only the social and economic conditions, but also sustainable and livable ones (*cf*. Setijanti *et al.*, 2015). As a consequence, tourists choose their destination based on the performance of a city.

With this in mind, it is possible to understand the importance of the performance evaluation of livability in cities. *"The higher the benefits are, the better the performance of the city is"* (Mori and Yamashita, 2015: 12). As such, it is desirable to increase the benefits as a way to pursue economic growth, as long as cities fulfill a minimum of sustainability requirements. To ensure that, it is important to be knowledgeable about the current evaluation methods.

2.2. Evaluation Methods in the Context of Sustainable City Livability

In the light of what was previously discussed, cities may face problems that affect their sustainable livability. For this reason, it becomes essential to have methods and measures to evaluate cities. According to Heylen (2006), there are two different measures to solve these problems. They both have the purpose of reaching sustainable and livable cities. On the one hand, the solution to these problems is possible to achieve through residents' manipulation. This means that to change the direction of the path, measures should directly affect the behavior, perceptions and preferences of residents. On the other hand, another way to solve the problems that cities experience is by resorting to residents' structure modification. The effectiveness of these measures is possible via resident, environment or dwellings by assigning rules, for example. In this sense, the methods to evaluate city livability have been under scrutiny, contributing to the development of new approaches. Nevertheless, in accordance to Kashef (2016: 247), "*each approach tends to demarcate the idea of urban livability by either disciplinary/professional concerns or specific interests that are aimed at creating a convenient cultural understanding of a complex social construct*". Many studies have been developed using different methods that help to evaluate a city's sustainability. *Table 1* identifies some of these studies, highlighting their contributions and limitations.

AUTHORS	METHOD USED	CONTRIBUITIONS	METHODOLOGICAL LIMITATIONS
Marshall (2013)	▪ Use of Transit-Oriented Development (TOD) to evaluate transportation sustainability and livability.	▪ Linkage of the methodology with the concepts of sustainability and livability. ▪ Help city planners to recognize the most efficient cities and places to live with regards to transportation sustainability and livability.	▪ Not considering the variables selected for this assessment as proxy. ▪ Deviation from the real end goals.
Okulicz-Kozaryn (2013)	▪ Use of survey answers in Urban Audit Perceptions Survey (UAPS) and Mercer city ranking.	▪ Weak correlation between satisfied residents with livable cities and dissatisfied residents with unlivable cities. ▪ Importance of subjective variables, such as trust, to evaluate quality of life and city livability.	▪ Relationship between Mercer ranking and survey data when measuring perceptions is weak. ▪ Difficulty in measuring subjective measures of quality of life.
Ding *et al.* (2015)	▪ Use of the model of Spatial, Logical and Time Dimensions (TCS_SLTD) for the assessment and development of city sustainability, named *Trinity of Cities' Sustainability.*	▪ Guide the process of Sustainable Development Indicator (SDI) ▪ Provide a framework to assess sustainability in developing countries. ▪ Assist planners to formulate policies in developing countries to ensure a sustainable development and growth.	▪ The model is unsustainable when the goal is city development in developing countries. ▪ Need for multiple criteria introduction.
Marsal-Llacuna *et al*. (2015)	▪ Use of Principal Components Analysis (PCA) to determine the performance of cities.	▪ Representation of sustainable livability indicators in a synthetic index, combining subjective (qualitative) life-satisfaction and objective (quantitative) quality of life indicators. ▪ Reduce the number of variables, by combining them into smaller groups, the so-called principal components	▪ Low frequency update of real-time indicators. ▪ Summarizing indices.
Norouzian-Maleki *et al*. (2015)	▪ Use of Delphi method to determine which criteria were most important to define livability in two different countries.	▪ Introduction of additional variables, alterations to the wording and merger of others by benefiting from having a panel of expert members. ▪ Initial ideas can be tested for consensus since the Delphi method is characterized by having a participatory and interactive environment. ▪ Tools useful for building livable neighborhoods and sustainability.	▪ Tension to create a tool to determine and measure physical environments. ▪ Expert's cultural bias. ▪ Judgments are from the chosen panel and may not be representative as a whole. Results are not a final solution.
Silva *et al*. (2015)	▪ Use the outcomes from the constructed Index Sustainable Urban Mobility (I_SUM) to compare the mobility conditions within five Brazilian macro-regions.	▪ Wealthier cities tend to have a better performance. ▪ The size of a city affects their performance.	▪ Availability and quality of data affected by accentuated regional differences among cities. ▪ Number of indicators unequal when comparing the cities.

Zanella *et al*. (2015)	▪ Use of a conceptual model in order to determine livability of cities in Europe by considering two components of it: human wellbeing and environmental impact.	▪ Construction of a composite indicator using Data Envelopment Analysis (DEA) specified with a directional distance function. ▪ Used as a benchmarking: cities with low performance may learn with their peers (best practices). ▪ Help decision makers to define policies in order to improve the cities' performance.	▪ Some dimensions have more impact on the results than others.
Zhou *et al*. (2015)	▪ Use of a developed responsibility-based method, named *Strategic goal-Responsibility department-Response* (SRR), in order to select and model sustainable indicators.	▪ Empirical evidence that this method is effective for assisting the practice of finding and choosing sustainable indicators. ▪ Guidance to implement sustainable strategies.	▪ SRR method affected by the degree of specification of responsibilities and interdependence between departments. ▪ Tested in just one city within the Chinese context.

Table 1: Sustainable City Livability Evaluation Methods: Contributions and Limitations

In brief, the studies presented in *Table 1* use methods of great importance when the main objective is to evaluate sustainable city livability. In fact, this evaluation *"can be a contributory factor to the prosperity and development of cities because it reflects the real-life experiences of residents and can also affect the attractiveness of a city for well-qualified workers"* (Norouzian-Maleki *et al*., 2015: 263). Each one of these methods is based on indicators that help stakeholders in their decision-making process. However, stakeholders must choose the method that is the closest to the reality they seek, bearing in mind that each method measures quality of life differently and has its own methodological limitations.

2.3. Methodological Limitations of the Current Evaluation Methods

The literature review has shown a set of methodological limitations in the current evaluation methods, which have an impact on the contributions made by some individuals. Thus far, some of the current methods used to evaluate cities in terms of their sustainable livability have been presented. These methods are important to facilitate decision-making processes, since they combine certain indicators, enabling comparisons between cities. Although they make the stakeholders' lives easier, the current methods also have some shortcomings.

In practice, there are several identified limitations in methodological terms. First of all, there are studies that select their data based on surveys, such as the ones from Okulicz-Kozaryn (2013) and Silva *et al*. (2015). Secondly, considering certain variables and criteria depends on the availability and quality of the existing data. In addition, *"the larger availability of data in the short run does not guarantee the good quality of these data"* (Silva *et al*., 2015: 155). Also, there are other studies that recognize the need to integrate multiple criteria and/or efficiently measure both objective and subjective criteria in their evaluation, such as Okulicz-Kozaryn (2013) and Ding *et al*. (2015). Lastly, the definition of criteria weighting is unclear from study to study. According to Sahoo *et al*. (2016), there are two types of weighing methods: subjective and objective. The subjective weighing methods depend on the opinion of a panel of experts and the objective ones on a mathematical data evaluation. In this way, *"potential uncertainty in expert judgement is the main disadvantage of the subjective methods, while the objective methods do not benefit from the knowledge and* *experience of the decision-makers"* (Sahoo *et al*., 2016: 1304). In general terms, the limitations converge in two major domains: (1) the way variables/criteria are defined and integrated into the evaluation models; and (2) the way weights are calculated and attributed to the different criteria. Consequently, *"although these measures can improve the standards of living, they do not necessarily result in long-term implications for the well-being of life-long residents"* (Kashef, 2016: 252). In this sense, the search for new approaches is beneficial and advisable.

SYNOPSIS OF CHAPTER 2

This second chapter intended to explore the reasons for the need to evaluate cities in terms of their sustainable livability. In addition, another objective was to analyze some of the main methods used to evaluate city livability, reviewing the main contributions of the different methods, as well as their methodological limitations. These were considered the basic factors to adequately define the construction of a knowledge-based decision support system for sustainable city livability evaluation, which is the major aim of this dissertation. Accordingly, this chapter contributed to better understand the importance of evaluating city livability and how this is associated with the challenges cities may face. There are critical problems arising in cities. Each city has its own personality, meaning that the housing market is different from one city to another; it is complex and has a variety of positive and negative effects. Also, people have different personalities and personal preferences. Their personalities influence what they value when looking for a place to live, such as safety or transportation accessibility. Moreover, cities play an important role in terms of urban planning and management and are influenced by the tourism industry. These factors emphasize the importance of the evaluation of city livability. There are different methods to evaluate a city's performance. The studies analyzed vary from one another according to the method used, its main contributions and methodological limitations. From the analysis, it was possible to notice that there is a huge variety of methods to evaluate sustainable city livability. Also, one of the most common contributions of these methods is the possibility of using them as a guide to formulate policies to enhance sustainability and livable conditions. However, these methods present shortcomings as well. First of all, the selection and articulation of the evaluation criteria are unclear. In some of the studies, it is not clearly defined how criteria are identified and considered in the evaluation model. Secondly, the attribution of weights to the different criteria is not always well defined. For these reasons, even though the current methods can help to improve living standards, they are far from having long-term consequences in the wellbeing of the population. Looking for new approaches might become a suitable future strategy. The next chapter will provide a more detailed look at the Multiple Criteria Decision Analysis (MCDA) approach.

CHAPTER 3

MULTIPLE CRITERIA DECISION ANALYSIS (MCDA)

In the previous chapter of the dissertation, it was possible to conclude that there is a set of different methods to evaluate city livability. Every method has its own characteristics and methodological limitations. The present chapter aims to present the Multiple Criteria Decision Analysis (MCDA) approach, providing its general background to support the decision-making process. More precisely, this chapter intends to: (1) clarify the basic concepts underlying the MCDA approach; (2) specify its fundamental convictions; and (3) understand the connection between the MCDA approach and city livability evaluation. These three points are essential to explain the importance of this approach to evaluate cities and the real estate industry.

3.1. Basic Concepts of the MCDA Approach

Every day, people are confronted with decision-making problems, even though most of the time they are trivial and do not require a deep analysis. However, there are major decisions that can dictate the future path of any human being. For instance, when choosing a job, there is a combination of several aspects that will influence the decision. Some of the aspects are "*salary, advancement potential, working environment, living environment, and friendship possibilities with colleagues*" (Yu *et al.*, 1985: 1). For this reason, the decision-making process may be formulated in an MCDA framework, since this approach involves multiple criteria evaluation and its aim is to help decision makers in constructing solutions for their decision problems (*cf*. Wang and Chen, 2015).

Due to the necessity of dealing with complex problems, in the second half of the 1930s, Operational Research (OR) was created. By definition, OR is a tool of managerial decision science (*cf*. Agrawal *et al*., 2010), but it was developed, in its essence, during World War II as "*a means through which scientists and mathematicians contributed to the war effort*" (Kjeldsen, 2010: 184). After the war, this tool started to be used in the academic context, becoming important for research in operations (Agrawal *et al.*, 2010; Kjeldsen, 2010). Basically, the strategy behind OR is *"to build a model of the situation under scrutiny and use it in determining what should be done to solve the problem"* (Landry *et al.*, 1996: 443). According to Landry *et al.* (1996), the rapid growth of OR urged the proliferation of not only successes of this tool but also the failures. In this regard, new methodologies were developed to support decision-makers in their decisions.

In evolutionary terms, the support to the decision-making process was based on mathematical procedures up until the 1960s, known as being mono-criterion approaches and oriented to optimization. As a matter of fact, the *"incessant search for optimum solutions led to the assumption that any other solution would be worse, or at least equivalent, resulting in the disposal of many other good solutions"* (Ferreira *et al.*, 2011: 115). This approach became known as hard, traditional or orthodox (Roy, 1990). However, soon the limitations of the traditional approach in terms of resolution of real problems emerged. Mendonza and Martins (2006), Belton and Stewart (2010), Montibeller and Franco (2010), and Ferreira *et al.* (2011) refer the existence of two different branches: Multiple Criteria Decision Making (MCDM) and Multiple Criteria Decision Analysis (MCDA). *Table 2* allows these two branches to be compared.

CHARACTERISTICS OF THE MCDM AND MCDA APPROACHES	
MCDM	**MCDA**
▪ Hard paradigm	▪ Soft paradigm
▪ Descriptive approach	▪ Constructive approach
▪ Optimum solutions	▪ Non-optimal solutions
▪ Well-conceived mathematical problem	▪ Information often vague and changeable
▪ Something that pre-exists to achieve the best solution	▪ Build/create something that does not pre-exist
▪ Single actor or homogeneous group	▪ Heterogeneous and participative group
▪ Consensus	▪ Simplicity and transparency
▪ Rationality and objectivity	▪ Recognition of uncertainty and subjectivity
▪ Legitimacy to procedures	▪ Introduction of values and preferences

Table 2: Comparison between the MCDM and MCDA Approaches

Source: Bana e Costa et al. (1997: 30, adap.).

The MCDM approach is a research field within the OR that models a problem considering different criteria instead of using a single criterion, as it was in the traditional optimization techniques (*cf*. Ferreira *et al*., 2011). However, according to Roy (1990), this approach, being part of the OR, tries to reach optimum solutions since it assumes the pre-existence of something that enables decision makers to find the best solution to the problem. On the other hand, the MCDA appeared as a means to *"enhance the degree of conformity and coherence between the evolution of a decision-making process and the value systems and the objectives of those involved in this process"* (Roy, 1990: 324). Also, this approach is adequate for addressing complex problems that are influenced by human concerns. This means that it allows for a trade-off between objective and subjective criteria, which is common and inherent to the decision-making process. In this sense, it seems to be of high importance to present the basic concepts of the MCDA approach.

The decision-making process is a system composed by two main subsystems: (1) the subsystem of actions and respective characteristics; and (2) the subsystem of actors and respective objectives and values. Therefore, the choice of the decision maker is based on the consequences of the actions and/or the preferences of the actors (Neto, 1996; Pinheiro *et al*., 2008; Costa and Ensslin, 2011). The actors, usually known as stakeholders, are people or institutions that may have different roles based on their values, objectives and preferences and, thus, intervene directly or indirectly in the decision-making process (Pinheiro *et al*., 2008). According to Costa and Ensslin (2011), each actor has its own value system. *Table 3* presents the principal actors of a decision process.

TYPE OF ACTOR	POSITION TOWARD THE DECISION-MAKING	RELATION WITH A DECISION
Agents	The ones that do not have an active position in the decision, even though they can influence it indirectly.	The ones that suffer from the decision consequences in a passive way.
Intervenients	Actors that directly participate and influence the decision-making process. They are considered the negotiators.	All individuals or institutions that determine a decision, through direct intervention.
Decision Makers	The person or group to whom the decision-making process is intended. They are also intervenients actors.	The ones with power and responsibility to assume the consequences of the decision.
Facilitators	It is an external specialist, responsible of comprehending the problem, developing the aid activity and interacting with the rest of the actors.	This role is important in this process, since he/she helps to improve the communication among members and coordinate the information to reach a solution.
"Demandeur"	This actor appears occasionally to represent the decision maker in its absence.	This actor only exists when the decision maker has limited access, naming someone as intermediate.

Table 3: Classification and Characterization of Actors

Source: Neto (1996: 25-26, adap.).

According to Neto (1996), an action is considered a representation of an eventual contribution to the final decision. Rocha (2011) refers that they can be distinguished between *real* and *fictional* actions. On the one hand, they are considered *real* actions if it is possible to turn them into a final decision. On the other hand, they are considered *fictional* actions if they are present through the decision-making process, but do not have a real existence. Nevertheless, fictional actions can be divided into *realistic* or *unrealistic*, depending on whether or not they anticipate the viability of their existence. In this way, it is important to present the various stages of a decision support process. According to Bana e Costa *et al.* (1999), Dutra (2005), Belton and Stewart (2010), Amine *et al.* (2014) and Ferreira *et al.* (2015b), there are three steps/phases that complement the decision-making process. Bana e Costa *et al.* (1999), Dutra (2005) and Ferreira *et al.* (2015b) define these three steps as: (1) *structuring*; (2) *evaluation*; and (3) *recommendations*. Amine *et al.* (2014), instead of using this terminology, use the following terms: (1) *observation*; (2) *interpretation*; and (3) *results analysis*. Also, Belton and Stewart (2010) have their own terms when specifying the steps of the decision-making process. Despite the different designations, it seems clear that the steps advocated by the authors have the same functions. The first step may be considered the most important phase because it is concerned with the problem definition. For this reason, it aims to collect data/criteria on the decision problem at hand. According to Ferreira *et al.* (2015a: 2693), this phase includes *"the* *definition of the panel of decision makers and participants involved; the formulation of the "trigger question"; the construction and validation of the collective cognitive map; and the development of the tree of criteria* […]*"*. Additionally, Ensslin *et al*. (2000) refer that this phase is essential to establish a mechanism of communication among participants, promoting consensus through common understanding for debate and learning. As such, structuring the problem enables the identification of decision opportunities and new alternatives, but also the recognition of some evaluating actions (Bana e Costa *et al*., 1997). Regarding the second step, it is the phase when the trade-offs among evaluation criteria are obtained (*cf*. Ferreira *et al*., 2015b). As stated by Amine *et al*. (2014), the second step is when decision makers express their preference for each criterion based on the collected data from the first step. In a nutshell, Bana e Costa *et al*. (1999) and Ensslin *et al*. (2000) refer that the evaluation phase may be divided into 3 steps: (1) *construction of the preference value functions*, allowing to find the partial values to each alternative in analysis; (2) *identification of the compensation rates*, weighing each criterion; (3) *revision and analysis of the impact of the actions according to each criterion*. Lastly, the third step takes place when decision makers combine the outcomes obtained from the second step in order to determine the best alternative. Also, this phase helps to perform a visual interactive sensitivity analysis that allows "what if" questions to be answered (*cf*. Bana e Costa *et al*., 1999). Subsequently, it is possible to validate the multiple criteria used in the model.

Yu *et al*. (1985) refer that multiple criteria decision involves four important elements: (1) a set of alternatives, which is denoted by X (and each generic element by x), and may contain a small or infinite number of choices; (2) a set of criteria, which is denoted by $f(x) = (f_{1, \ldots,} f_q)$ and contains the criteria that are important to reach a good decision; (3) the outcome of each choice, which is denoted by $f(x) = (f_1(x), \ldots, f_q(x))$, measured in terms of the criteria. The totality of each outcome is represented by $Y = \{f(x) \mid x \in X\}$, y being the generic element. The outcome of each decision can be a single point or deterministic; and (4) the preference structures of the decision maker. In the case preferences over the possible outcomes are well specified, the decision problem will be easily reached.

This is in line with Malczewski *et al*. (2015), who defend the existence of three elements of multiple criteria approach. The first essential element is the decision maker. Decision makers can be individuals, group of individuals or organizations with an interest in the decision-making process. In some cases, decision makers prefer to reach multiple solutions for a decision, enabling them to embody high levels of information. However, in other cases they want to have a single optimal solution. When decisions are made by groups, *"the degree of consensus can be considered a major determinant of the nature of the decision making process"* (Malczewski *et al.*, 2015: 24). For this reason, the evaluation of the actions and choices need to be clearly defined, since the decision makers' interest must be demonstrated by the chosen criteria (*cf.* Bana e Costa *et al.*, 1997). The second major element is the set of criteria (Rezaei, 2016). Each criterion needs to be measurable and comprehensive, and a set of criteria needs to be: (1) complete; (2) operational; (3) decomposable; (4) non-redundant; and (5) minimal. Finally, the third element is the set of choice alternatives. It is the *"alternative courses of action among which the decision maker (agent) must choose"* (Malczewski *et al.*, 2015: 27).

Research conducted by Belton and Stewart (2010), Montibeller and Franco (2010) and Ferreira *et al*. (2011) refer another important element to take into account. This element is related to the uncertainties and complexity that characterize strategic decisions. According to Montibeller and Franco (2010: 26), strategic decisions involve *"a high degree of uncertainty, high stakes, major resource implications, and long-term consequences"*. Given the above, it seems useful to deepen the knowledge about the MCDA approach, by providing an explanation of its paradigms and fundamental convictions.

3.2. Fundamental Convictions

The hard and soft approaches are associated with the paradigms of OR. Even though the soft paradigm has its origins in the constant evolution of the hard paradigm, its characteristics differ from one another (Roy, 1990). *Table 4* shows the main characteristics of the soft paradigm.

CHARACTERISTICS	IMPLICATIONS IN THE DECISION PROCESS
Acceptance of uncertainty	Search also for qualitative analysis to keep options open, guaranteeing flexibility in managing future decisions.
Search for non-optimal solutions	Search for acceptable solutions on separate dimensions without trade-offs.
Reduced data demand	Search for avoiding problems of availability and credibility by integrating qualitative and quantitative data, but also social judgments.
Simplicity and transparency	Search for facilitate the problem comprehension clarifying the terms of conflict.
Inclusion of the human factor	Search for integrating people as active members in the decision-making process.
Bottom-up planning	Search for the necessary conditions to planning from the particular to the general.

Table 4: Characterization of the Soft-OR

Source: Mendoza and Martins. (2006: 17, adap.).

According to Montibeller and Franco (2010: 35), the soft paradigm is *"a particularly useful tool, as the means-end structure permits the analyst to ladder-up the decision-makers' values and find their fundamental and strategic objectives, helping to structure a value tree"*. In a nutshell, as indicated by Mendoza and Martins (2006: 18), the difference between both paradigms is that decision makers, by following the soft approach, *"not only provide input to the model, but they also contribute to the modelling process by being involved in identifying model components, dynamics or processes between and among model components, and their relationships"*.

In keeping with this, there are three fundamental convictions of the MCDA approach: (1) *constructivism*; (2) *interrelationship among objective and subjective elements*; and (3) *learning through collaborative participation*. The MCDA is considered a constructivist approach since it provides decision makers with essential tools that facilitate their decision-making process. With these tools, decision makers have arguments to help them reflect, readjust and/or validate their own perspectives and thoughts (Ferreira, 2013). Therefore, the idea is to construct guiding principles without pre-conditions. Concerning the interrelationship between objective and subjective elements, Bana e Costa *et al.* (1997: 35) state that this conviction means seeking *"to build a more-or-less formal representation integrating the objective environmental components of the decision context, with the subjective and context-dependent points of view, concerns or objectives, in such a way that the value-systems of actors or stakeholders are made explicit"*. Also, according to Ferreira (2013), subjectivity is inherent in all decision-making processes. For this reason, by making the decision makers' preferences and opinions explicit, transparency is ensured in this process. Regarding learning through collaborative participation, as the MCDA includes preferences in its processes, their articulation will lead to one solution that is the most preferred among all decision makers (Mendoza and Martins, 2006). Moreover, decision makers are one of the key players to the MCDA's success, since *"they are responsible for assisting the facilitator (i.e. researcher, scientist) in the design and implementation of the evaluation mechanisms"* (Ferreira *et al*., 2015b: 284). Although it is possible to separate the three fundamental convictions, they are closely connected since the constructivist perspective also means a learning process by implementing both objectivity and subjectivity that are inherent to all decision-making processes. Dutra *et al.* (2005) summarize this linkage in four critical abilities: (1) to provide different types of information, whether they are quantitative, qualitative, verbal or non-verbal; (2) to capture the objectives of decision makers in an explicit way; (3) to allow decision makers to reflect on their goals, priorities and preferences; and (4) to provide a set of conditions to inform decisions that depend on what decision makers consider the most appropriate. In conclusion, these three fundamental convictions enable a better structuring of the decision-making process. Thus, it seems to be of the utmost importance to understand and clarify the potential contribution of the MCDA approach to the process of city livability evaluation.

3.3. MCDA and City Livability Evaluation

The real estate industry is a sector of great importance for the development of a country, economically and socially speaking. However, this sector is also influenced by new trends that change the direction of the housing market. Factors such as economic crisis, purchasing power of the population, liquidity status or lending situation, may dictate strong volatility of this market (*cf*. Canas *et al*., 2015). For this reason, *"the use of structuring techniques and multiple criteria evaluation methods seems to make sense"* (Canas *et al*., 2015: 368).

In addition, as concluded in the previous chapter, city livability and quality of life are essential in determining a city's attractiveness. It is a vicious cycle because by attracting people the sustainable development of a city will be accelerated (*cf*. Chiang and Liang, 2013). In the light of this reasoning, it is important to evaluate city livability, and there are several methods to do so.

The reasons why researchers and scientists choose the MCDA approach to evaluate cities can be summarized in four points. First of all, according to Chiang and Liang (2013), it is because quality of life indicators are characterized by having two dimensions: objectivity and subjectivity. This means that quantitative and qualitative indicators should be included. Second, to properly evaluate urban livability and its effects, it is important to have a public opinion in order to obtain feedback about their feelings regarding various factors (*cf.* Mendoza and Martins, 2006). Third, and in addition to the previous one, it is important to take into account not only livability preferences, but also the changes in *"individual values, life style, social conditions, and historical backdrops"* (Sakamoto and Fukui. 2004: 177). As pointed out by Sakamoto and Fukui (2004), people usually have consistency and certainty regarding their preferences. However, uncertainty also plays a role in the decision-making process since people have unconscious preferences. Finally, the purpose of city livability evaluation is to provide decision makers with useful tools to reflect upon and facilitate their decision-making process. According to Chiang and Liang (2013: 5230), *"the proposed method can be used by city administrators to inform and direct their improvements policies"*. Bearing this in mind, it is possible to conclude that the MCDA seems to be a useful approach to evaluate city livability.

SYNOPSIS OF CHAPTER 3

The present chapter had as its main purpose to explore the inherent concepts of the multiple criteria decision analysis (MCDA) approach. Thereafter, its origin and fundamental convictions were presented. Lastly, some of the potential contributions of the MCDA for city livability evaluation were described. To begin with, during World War II, the *Operational Research* (OR) was developed as a tool to support the decision-making process. It has evolved throughout the years from a hard paradigm to a soft paradigm. This means that OR moved from a more traditional view to a new perspective of dealing with complex decision problems. In this line of thought, two evolutionary branches were presented, namely: (1) MCDM, which tries to obtain optimal solutions; and (2) MCDA, which is strongly linked to a constructivist view, helping decision makers to reflect, readjust and/or validate their own perspectives and thoughts. To complement this process, there are three phases in the decision making process that should be taken into account: *structuring*; *evaluation*; and *recommendations*. Additionally, the elements that characterize this approach are essentially four: decision-makers; criteria; alternatives; and uncertainty. Decision-makers can be individuals or a group. However, when decision-making is processed by a group, reaching a consensus is not always easy. The third element, alternatives, provides the decision makers with courses of action. Finally, uncertainty and complexity stand for the fourth element. The next point intended to provide the characteristics of the soft-OR, as well as to present the fundamental convictions of the MCDA approach, namely: *constructivism*; *interrelationship among objective and subjective elements*; and *learning through collaborative participation*. The last point of this chapter intended to observe the potential contributions of the MCDA approach for city livability evaluation. On the one hand, the real estate industry is complex and changeable. On the other hand, city livability is central for the development of a city. Thus, it needs to be attractive. A set of reasons explaining why MCDA should be used to evaluate cities in terms of their livability was presented. In the next chapter, the methodological aspects of the JOURNEY Making approach will be presented, giving particular attention to human cognition, cognitive mapping and variables selection.

CHAPTER 4

JOURNEY MAKING

The present chapter aims to introduce the *JOintly Understanding, Reflecting and NEgotiation StrategY* (JOURNEY) *Making* approach, which plays a fundamental role in helping decision makers structure complex problems. In order to contextualize this methodology, the following points will be detailed: (1) human cognition and decision aid; (2) cognitive mapping; and (3) variables selection. In a nutshell, the concepts presented in this chapter will allow for a better understanding of the procedures adopted during the structuring phase. The points developed in this chapter are also important to establish the basis for the construction of a knowledge-based decision support system for sustainable city livability evaluation.

4.1. Human Cognition and Decision Aid

Eden (1994: 258) defends that *"formal and scientific model-building activity is aimed at helping people tackle real-world problems"*. To accomplish that, Eden (1994) adds that language is considered the currency for solving problems in organizations. Citing Pettigrew (*in* Eden,1994: 260), *"language is not just a means of expressing thoughts, categories and concepts: it is also a vehicle for achieving practical effects"*. As such, when problem solving is required, it is important to understand cognition and its relation with language. Human cognition has been thought of as a structure individually created, although at the organizational level it is an area of extreme importance in strategic management (Tan and Hunter, 2002). Actually, as Klein and Cooper (1982) argue, human decision processes occur in the subjective world of each individual. Also, Marquardt and Hoeger (2009: 159) confirm that there is *"evidence of both spontaneous decisions and intuitive processes affect deliberative decision-making"*. In fact, by definition, human cognition is *"(a) the behaviour of whole embodied people and their interaction with their environment and others around them* […] *and (b) people's subjective experiences, goals, and beliefs"* (Kingstone *et al.*, 2008: 327). In other words, humans' preferences, values and beliefs are strongly linked with the decision-making process. For this reason, they should be seen as an interconnected causality system (Eden, 1994). In a similar way, Morselli (2015) refers that in the decision-making process the role of intuition and the effect of the emotions are important aid aspects to take into account. *Figure 1* presents this conception.

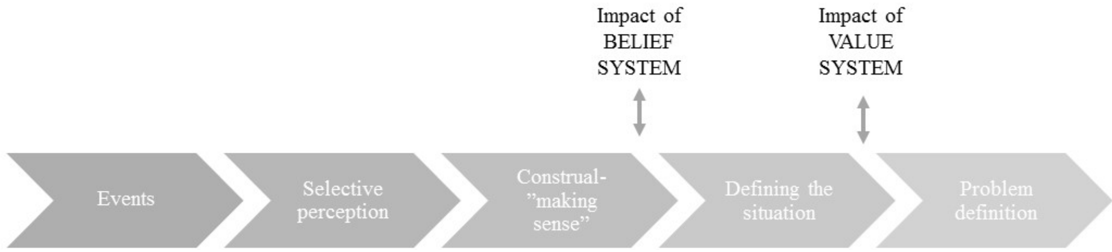

Figure 1: Cognition as the Interaction between a Value System and a Belief System

Fonte: Eden (1994: 263, adap.).

Figure 1 is a useful model that represents the understanding between cognition and its relation to language. Beliefs and values need to be understood as an interconnected causality system since without them actors would be impotent to solve decision-making problems (*cf*. Eden, 1994). According to Eden (1994: 263), *"the separation of perception and construal reflects a view of problem solving that follows Kelly's (1955) theory of personal constructs in supposing that we "make sense" of our world in order to "predict and control""*. Indeed, as stated by Hardison and Neimeyer (2007), George Kelly developed, in 1955, the Personal Construct Theory (PCT). The assumption underlying this theory is that *"humans literally construct the meaning of their own lives by devising, testing, and continuously revision personal theories to make sense of the world around them and anticipate future experiences"* (Hardison and Neimeyer, 2007: 286). These personal theories are called construct systems that help the integration, differentiation and prediction of life events (*see again Figure 1*). In order to do that, information is structured in a repertory grid technique, which is also known as cognitive mapping. Cognitive maps are considered to be, according to Klein and Cooper (1982: 63), a *"representation of the perceptions and beliefs of an individual about his own subjective world"*. Thus, given the importance of cognitive mapping in the context of this dissertation, the next point is dedicated to the presentation of this type of maps.

4.2. Cognitive Mapping

Cognitive mapping is a method for problem structuring based on the Personal Construct Theory, which counts on human beings as key problem solvers (Eden, 1994). It is this theory that defines the rules for formal mapping, where individuals share and assess the personal construct systems from one another (Tan and Hunter, 2002). By definition, cognitive mapping is *"the task of mapping"*, through a graph, similar to a diagram, *"a person's thinking about a problem or issue"* (Eden, 2004: 673). Through bipolar linkages, it uses qualitative data from the cognitive structure of the members of the organizations to represent and structure decision problems (*cf*. Eden, 1994; Eden, 2004). This data is retrieved from *"the beliefs, values and expertise of decision makers relevant to the issue in hand through interview or through the analysis and coding of documents"* (Eden and Ackermann, 2004: 616). Each idea is supposed to be *problem-oriented,* which means that every suggestion made by the panel needs to result in an option for an action (*cf*. Eden (1994)). In general, a cognitive map is *"composed of concept nodes of a target problem, signed directed arrows, and causality value between the nodes"* (Xue *et al.*, 2010: 228). To put it differently, cognitive mapping is composed of: (1) *elements*, that represent objects of interest within the domain of investigation, such as people or activities, and are considered systems analysts or systems of development projects, respectively (Tan and Hunter, 2002); (2) c*onstructs*, which are considered concept nodes and represent the interpretation from the participants regarding the elements (Tan and Hunter, 2002; Nassreddine, 2016); and (3) *linkages*, which are represented by signed directed arrows connecting the elements and the constructs. For this reason, cognitive maps are also known as causal maps since *"the direction of the arrow implies believed causality"* (Eden, 2004: 673). Therefore, *"a statement at the tail of an arrow is taken to cause, or influence, the statement at the arrowhead"* (Eden and Ackermann, 1992: 310).

As stated by Eden (2004), cognitive maps are designed in a hierarchical structure in the form of means/ends, in which the goal statements are represented at the top of the hierarchy. When linking the nodes with the arrows, the cause-and-effect relationship is defined by attributing a sign, either positive (+) or negative (–), in the arrow head (*cf*. Klein and Cooper, 1982; Eden, 2004; Ho, 2015). As pointed out by Ho (2015: 739), *"a + sign (e.g. A – (+) → B) means that an increase in variable A leads to an increase of variable B, whereas a – sign (e.g. A – (–) → B) indicates the* *opposite, that is, an increase of variable A leads to a decrease in variable B". Figure 2* illustrates an example of a cognitive map, showing the causality between concept nodes.

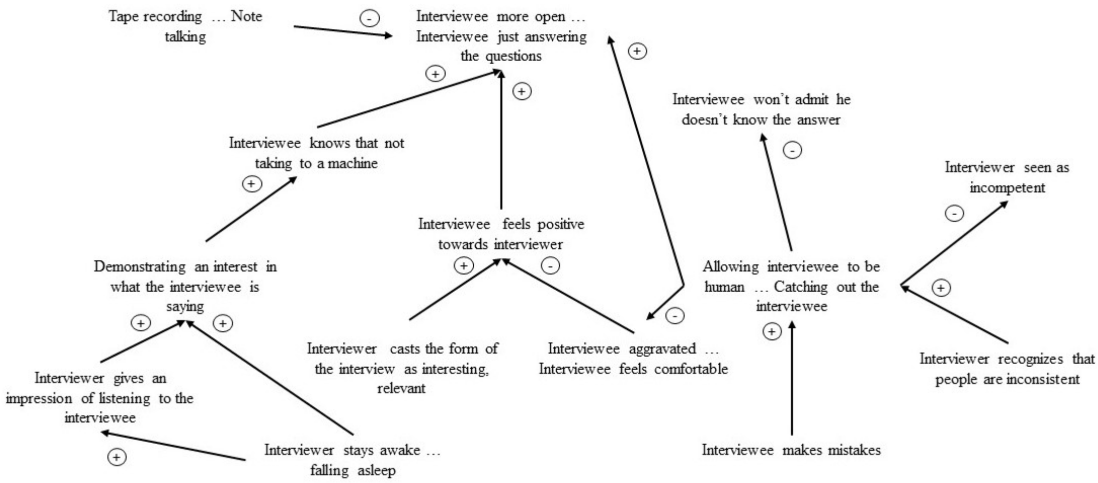

Figure 2: Example of a Part of a Cognitive Map

Source: Eden and Ackermann (1992: 311, adap.).

As Eden and Ackermann (1992) and Eden (1994) state, the dots separating two sentences in a construct (node) should be understood as *rather than*. By doing that, it is possible to segregate two contrasting poles. Yet, to ease the reading, the second part of the sentence is frequently omitted.

According to Sun and Zhang (2004) and Marquardt and Hoeger (2009), there are two different approaches when working with cognitive maps: the *top-down* and the *bottom-up* approaches. The top-down approach is based on the definition of constructs of superior value and, from that, the exploration of concept nodes of inferior levels. On the contrary, the bottom-up approach starts from defining constructs of inferior level and finishes by obtaining the fundamental/goals concept nodes. In this context, it is important to point out that a cognitive map has a pyramid shape: (1) *goals*, at the top; (2) *central concepts/strategies*, in the center; (3) *possible options to solve the key questions*, at the bottom (Eden, 2004; Eden and Ackermann, 2004). As Eden (2004) defends, most of the maps place an emphasis on the top of the pyramid, where the desired outcomes are represented. For this reason, *"an exploration of top-down shape* *is more appropriate because tails represent an elaboration in further detail of the means or options"* (Eden, 2004: 684).

Gonçalves *et al*. (2016) believe that cognitive mapping is a tool of great importance because it not only improves the understanding of the problem under discussion, but it also allows for breadth in the criteria used in the system. Additionally, due to the fact that cognitive mapping is strongly linked with the constructivism conviction, Ferreira *et al*. (2016) agree in recognizing cognitive maps as *"well-established and interactive visual tools, which allow for the structuring and clarification of complex decision situations"*. Lastly, both Ferreira *et al*. (2016) and Nassreddine (2016) emphasize the great power of discussion, communication and negotiation related to this methodology. Yet, *"the conception of a cognitive map is always dependent on the decision circumstances, the experts involved, facilitator skills and/or session durations"* (Ferreira *et al*., 2015b: 287). This can be seen as a methodological limitation. However, the direct involvement of the group and the discussion involved counterbalance this pitfall (*cf*. Ferreira *et al*., 2015b). Overall, Eden (1994: 264) claims that *"a cognitive map includes both a description of a problem situation and, by implication or explication, an understanding about what can and cannot be done about a problem"*. Underlying the structuring phase is the concept of Fundamental Points of View, which will be discussed in the next section.

4.3. Variables Selection

Once the problem is defined, the next decision aid step is to define and structure the Points of View (PsV), by analyzing potential impacts and the attractiveness of the options. According to Bana e Costa *et al*. (1999: 317), a Point of View (PV) is *"any aspect within a specific decision context that at least one actor considered relevant to the evaluation"*, and can reflect the interaction between: (1) concerns and objectives of the actors; and (2) the characteristics of alternatives. This interaction assumes a complementary relationship that enables the definition of PsV (Bana e Costa and Beinat, 2010).

Bana e Costa and Beinat (2010) stress the importance of analyzing the impacts of each PV and the attractiveness of the options. At this stage, points of view can be classified in: (1) Fundamental Point of View (FPsV); and (2) Elementary Point of

View (EPsV). Therefore, as indicated by Bana e Costa *et al.* (2000), a FPV can be a single point of view or composed of several interdependent EPsV. Moreover, *"FPsV are ends, while EPsV are means to achieve ends"* (Bana e Costa *et al.*, 1999: 317). The distinction of "means" and "ends" in problems of greater complexity is enabled by the use of cognitive mapping, which is considered an intermediate step in the identification of FPsV (Bana e Costa *et al.*, 1999; Bana e Costa and Beinat, 2010). However, for an "end" PV to be considered fundamental, it needs to accomplish the "isolation hypothesis". In other words, a specific PV should enable the ordering of the proposals in terms of their FPV, regardless of the impacts on other PVs (Bana e Costa *et al.*, 2000). That is why sometimes some PsV classified as "ends" need to be aggregated in the same evaluation criteria. Each FPV will be an evaluation criterion in the multiple criteria model and, as a consequence, an *area of concern* (Bana e Costa *et al.*, 1999). All things considered, a FPV is therefore *"a key PV that, first, the actors desire to isolate from the other PsV, as an evaluation axis, and second, verifies the necessary preference independence conditions"* (Bana e Costa *et al.*, 1999: 317).

In order to create a family of FPsV, besides being independent, an FPV needs to be consensual, operational, non-redundant and exhaustive (Bana e Costa *et al.*, 1999). When dealing with complex problems, it is usual to organize the areas of concern, and the FPsV into a tree structure, frequently known as *value tree.* According to Pinheiro *et al*. (2008), the construction of a value tree (*i.e.* a set of interrelated PsV) is made easier with the support of a cognitive map. The value tree allows the visualization of several levels of specification of the different PsV, which is why it is alternatively called a hierarchy (Bana e Costa and Beinat, 2010). In order to implement the FPsV, descriptors should be constructed, allowing for the performance measurement of different alternatives. From the technical point of view, Bana e Costa *et al*. (1999: 319) define a descriptor as *"an ordered set of plausible impact levels in terms of a FPV, intended to serve as a basis to describe, as much as possible objectively, the impacts of alternatives* […] *with respect to that FPV"*.

The descriptors can be classified into three dimensions: (1) *quantitative* and *qualitative* (*i.e.* quantitative descriptors are numbers, while the qualitative ones represent semantic expressions); (2) *discrete* and *continuous* (*i.e.* discrete descriptors are composed of a finite number of impact levels, while continuous descriptors consist of a continuous mathematical function); and (3) *direct*, *indirect* and *constructed* (*i.e.* direct descriptors have a common interpretation, measuring direct effects; the indirect ones indicate more causes than effects, used as an index of several indicators; and the constructed ones are considered an alternative for problems in which there are no direct descriptors) (Bana e Costa *et al*., 1999; Pinheiro *et al*., 2008; Bana e Costa and Beinat, 2010). Once the descriptors have been constructed, the structuring phase/cycle is considered complete (*Figure 3*).

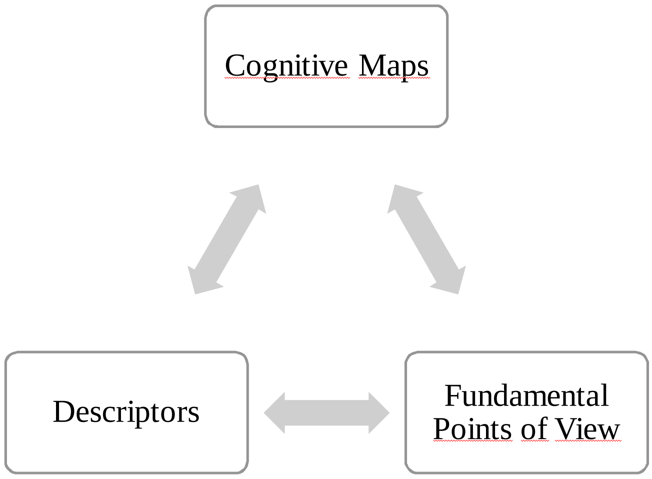

Figure 3: The Structuring Cyclic Process

Source: Bana e Costa et al. (1999: 317, adap.).

Considering the constructivist approach adopted in the present study, which combines cognitive mapping and the AHP method, the next chapter will deal with the evaluation phase and the AHP method.

SYNOPSIS OF CHAPTER 4

The present chapter aimed to present the fundamental concepts associated with the JOURNEY Making approach, which is a valuable tool to structure complex problems. In this way, some inherent concepts, namely human cognition and decision aid, cognitive mapping and fundamental points of view were presented. JOURNEY Making is used as a tool to facilitate and structure the organizational strategic objectives in a shared environment. It was demonstrated that human cognition has a role in the decision-making process. There is evidence that spontaneous and intuitive processes influence this process. Therefore, humans' preferences, values and beliefs should be taken into account, as well as the personal constructs that humans develop to make sense of the world and predict future events. For that reason, cognitive maps were created as a tool to structure, in the form of a diagram, the perceptions and beliefs of a person regarding a specific problem/issue. Cognitive maps are designed in the form of means/ends, including three important components: elements, constructs and linkages. All of these are set in a pyramid shape where goals are at the top, central concepts/strategies in the center and the possible options to solve the key questions at the bottom. The person in charge of structuring and elaborating the map is the facilitator who may intervene in a polite manner, not interfering in the model of the decision-making process. Underlying this analysis is the concept of Point of View (PV), which allows the interaction between concerns and objectives of the actors and the characteristics of alternatives. These can be classified as Fundamental Point of View (FPV); and (2) Elementary Point of View (EPV). While an FPV is considered an end, an EPV is a means to achieve that end. In this process, cognitive maps, which are an intermediate step in the identification of FPsV, assumes an important structuring role. Furthermore, a family of FPsV is possible to be constructed into a value tree structure if each FPV is independent, consensual, operational, non-redundant and exhaustive. Finally, in order to implement the FPV, it is necessary to use descriptors and levels of impact. As discussed in this chapter, a descriptor is an ordered set of plausible impact levels, with an intention to serve as a basis for describing the impacts of the alternatives on a FPV. Considering that this dissertation adopts a constructivist approach, the combination of cognitive mapping and the AHP method holds great potential in the context of this dissertation. The AHP method is presented in the next chapter.

CHAPTER 5

THE AHP/ANP APPROACH

This chapter presents the Analytic Hierarchy/Network Process (AHP/ANP) approach, which is one of the most widely used MCDA tools to deal with complex decision problems. Because the empirical component of this dissertation will make use of this approach, the provision of its principles and guidelines is of a great importance. Therefore, this chapter intends to: (1) explore the fundamentals of the AHP/ANP approach, its characteristics and applicability; and (2) expose the method's principal advantages and limitations. Overall, this chapter is important to justify our methodological choice as a way to build a knowledge-based decision support system for sustainable city livability evaluation.

5.1. Fundamentals of the AHP/ANP Approach

The decision-making process depends on the choices among a certain number of alternatives. In order to make the best choice, decision makers need to have the following abilities: "*(1) having a clear definition of design objectives and requirements; and (2) being able to evaluate or predict the performance of the proposed alternatives*" (Amine *et al.*, 2014: 497). However, as concluded in the first chapters, the real estate industry and its sustainability imply the existence and influence of multiple variables and/or factors, which are characterized by inherent heterogeneity and subjectivity. That is why some of them are difficult and complex to measure. For this reason, it is important to select the "right" methodology to structure the decision-making process (Santos *et al.*, 2002; Amine *et al.*, 2014).

The MCDA approach turned out as an appropriate tool to analyze complex problems and help reach the best solution to them. As previously described, the MCDA can deal with quantitative and qualitative data, with uncertainty and subjectivity and also with the participation of multiple experts' opinion (Mendoza and Martins, 2006). In fact, there are several MCDA methods to support decision-making. As stated by Singh and Nachtnebel (2016: 46), the objective of the different methods is *“to be able to compare alternatives that have different performance levels for various criteria, to create a more formalized and better informed decision-making process”*. However, a critical issue inherent to the choice of the most suitable MCDA method is the fact that methods may yield different solutions for the same problem (*cf.* Amine *et al.*, 2014). Russo and Camanho (2015), Dweiri *et al.* (2016), Karanik *et al.* (2016), and Singh and Nachtnebel (2016) agree in claiming that one of the most widely used and trusted methods of MCDA is the Analytic Hierarchy Process (AHP).

Thomas L. Saaty formulated the AHP as a result of several years of attempts to use normative theories. In the early 1970s, Saaty (1980) wondered how ordinary people make a decision bearing in mind all the information needed. The answer to this question was made possible through the creation of the AHP in 1971 (*cf.* Saaty, 1980), considering *“hierarchies and networks, paired comparisons, ratio scales, homogeneity and consistency, priorities, ranking”* (Saaty, 1994a: 37). The AHP allows multiple complex decision problems to be resolved by capturing not only objective variables, but also subjective factors from a group of decision makers. Quoting Jovanovic *et al.* (2015: 226), *“the main purpose of the AHP method was to help the decision-makers to, based on the information available, make the best decision possible”*. Indeed, in accordance with the procedural steps of the MCDA approach, there are three main functions/principles of the AHP (*cf.* Saaty and Vargas, 1998; Russo and Camanho, 2015), namely: (1) *structuring complexity*; (2) *measurement of preferences*; and (3) *synthesis*. *Figure 4* presents the conceptual proposal of the AHP method, where, during the structuring phase, the problem is decomposed in a hierarchical structure.

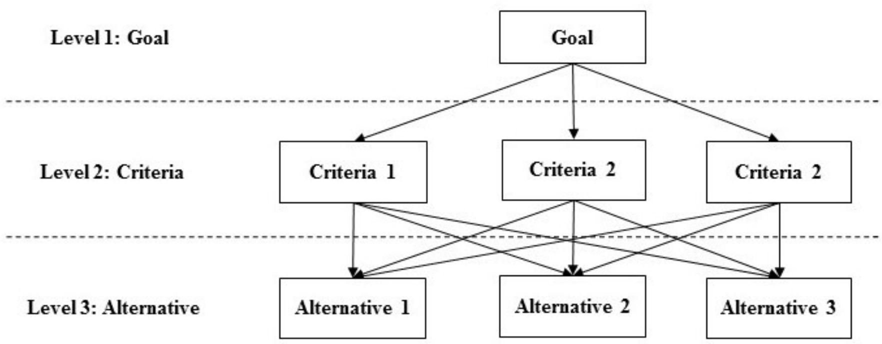

Figure 4: Basic Hierarchical Structure of the Application of the AHP Method

Source: Dweiri et al. (2016: 274, adap.).

As shown in *Figure 4*, the AHP uses different hierarchical levels, breaking down the complexity of the problem (Jovanovic *et al.*, 2015; Dweiri *et al.*, 2016; Morano *et al.*, 2016). Saaty (1994b: 428) refers that *"the structure of hierarchies is linear and proceeds downward from the most general and less controllable (goals, objectives, criteria, subcriteria) to the more concrete and controllable factors terminating in the level of alternatives"*. As such, in the hierarchy of the AHP, factors are distributed as follows: (1) the objective/goal of the decision process at the highest level; (2) the criteria and sub-criteria represented at the mid-level; and (3) the alternatives of decision presented at the bottom level (*cf.* Singh and Nachtnebel, 2016). Saaty (1990) and Karanik *et al.* (2016) believe that the construction of this structure has two essential objectives. On the one hand, it enables the integral visualization of relationships within the whole situation. On the other hand, it provides a system to compare factors by levels, using the same magnitude order. In addition, in the opinion of Saaty (1994b: 429), *"hierarchies structures are fundamental to planning and to the analysis of risk"*. Accordingly, when constructing hierarchies, it is important to guarantee the introduction of the following detailed information: (1) faithful characterization of the problem; (2) consideration of the sorrounding environment of the problem; (3) identification of the criteria that contribute to the resolution of the problem; and (4) consideration of the expertize of the panel members (Saaty, 1990). A certain hierarchy structure is called *complete* if every element, no matter at which level, relates or influences every element in the level below. However, most of the times, structures are called *incomplete* since this influencing process is not always observable (*cf.* Ramanujam and Saaty, 1981).

Besides this linear structure, in the form of a hierarchy, there is also another framework, which is the network one. It is in this form of structure that resides the difference between the AHP and ANP approaches. According to Saaty (2008), the ANP is a generalization of the AHP. It involves functional dependence, allowing interaction between clusters. While the AHP represent *"the simplest type of functional dependence of one level or component of a system on another in a sequential manner"*, the ANP involves interaction and dependence between elements (Saaty, 1994b: 428).

In the evaluation phase, the measurement of the preferences is needed. Instead of being based on absolute measurement, which is the *"comparison of some value on a scale with the unit value of the scale"*, the AHP is based on a relative measurement.

In other words, the AHP is a method that derives a scale from pairwise comparisons (Saaty, 1994b: 430). Quoting Dweiri *et al*. (2016: 274), *"this pairwise comparison allows finding the relative weight of the criteria with respect to the main goal"*. From that, a comparison matrix is constructed, being translated into a scale of values (Jovanovic *et al*., 2015). This matrix compares pairs of elements, either criteria or alternatives, in order to determine the priorities and the relative rankings for each level of the hierarchy (Jovanovic *et al*., 2015; Karanik *et al*., 2016). As such, to quantify the preferences of the decision-makers, Saaty (1980) set a 9 point-scale. As shown in *Table 5*, this scale varies between "1" (equal importance of both elements) and "9" (absolute importance of one of the elements over the other) and comparisons are made through discussion of judgments.

SCALE	DESCRIPTION
1	Equal importance of "i" and "j"
3	Weak importance of "i" over "j"
5	Strong importance of "i" over "j"
7	Demonstrated importance of "i" over "j"
9	Absolute importance of "i" over "j"
Note: 2, 4, 6 and 8 are intermediate values.	

Table 5: Importance Scale of Factors in Pairwise Comparison

Source: Dweiri et al. (2016: 53-55, adap.).

In practical terms, according to Davies (1994), the matrix structure is determined by the total number of elements (*n* columns and *n* rows). The number of rows, represented by *i*, and the number of columns, represented by *j*, show the relative importance of given criteria C_i over another criteria C_j. This relationship is presented in the matrix (1):

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1j} \\ \frac{1}{a_{12}} & 1 & a_{23} & \dots & a_{2j} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 & \dots & a_{3j} \\ \dots & \dots & \dots & 1 & \dots \\ \frac{1}{a_{1j}} & \frac{1}{a_{2j}} & \frac{1}{a_{3j}} & \dots & 1 \end{bmatrix}. \quad (1)$$

One of the characteristics of a pairwise comparison matrix is the reciprocal property. According to Davies (1994) and Saaty (1994a), if each level of the hierarchy includes *n* elements, then for a matrix of *n* x *n* it is only necessary $n\,x\,\frac{n-1}{2}$ pairwise comparisons. As such, *"only ½ of the potential cells of each matrix require completing because the other half will be the reciprocals"* (Davies, 1994: 64). Therefore, Saaty (1990), Karanik *et al.* (2016) and Singh and Nachtnebel (2016) refer that this procedure must comply with the following conditions (2):

$$\begin{cases} \text{If } a_{ij}=\alpha \text{, then } a_{ji}=\frac{1}{\alpha}\text{, } \alpha\neq 0 \text{ and } ij=1, 2, 3, \ldots, n; \\ \text{If } C_i \text{ is equally important as } C_j\text{, then } a_{ij}=1\text{, } a_{ji}=1 \text{ and } a_{ii}=1\text{, } \forall\, i. \end{cases} \tag{2}$$

As stated before, the AHP is based on relative measurement. This is particularly useful when considering elements that possess intangible properties. Quoting Saaty (1990: 12), *"measurements in a standard ratio scale are transformed to measurements in a relative scale by normalizing them"*. In this way, the next step is known as normalization and the objective is to find the relative weight of each element by dividing them by the sum of the column where each of them belongs. Formulations (3) and (4) represent the normalization procedures:

$$N = \begin{bmatrix} w_{11} & w_{12} & w_{13} & \cdots & w_{1j} \\ w_{21} & w_{22} & w_{23} & \cdots & w_{2j} \\ w_{31} & w_{32} & w_{33} & \cdots & w_{3j} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ w_{i1} & w_{i2} & w_{i3} & \cdots & w_{ij} \end{bmatrix}, \text{ where } w_{ij}=a_{ij}; \tag{3}$$

$$w_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}. \tag{4}$$

The scores obtained in (3) are then *"each weighted by the priority of its criterion and summed to derive a total ratio scale for the individual"* (Saaty, 1994a: 34). In brief, in order to obtain the relative weight of each row, it is necessary to divide the sum of the values of each row by *n*. This technique is known as eigenvector and its expression is shown in equation (5):

$$W_i = \left(\sum_{i=1}^{n} w_{ij}\right)^{\frac{1}{n}} = \frac{\sum_{i=1}^{n} w_{ij}}{n}. \quad (5)$$

When using the AHP approach, it becomes necessary to assure the quality and consistency of the decision makers' judgments (Karanik *et al*., 2016). Accordingly, it is important to take certain procedures into account. First of all, in order to test the consistency of the decision maker's judgment, the maximum eigenvector (λ *max*) needs to be estimated, being given by the expression (6):

$$\lambda_{max} = \sum A.W. \quad (6)$$

Secondly, it is necessary to calculate a consistency index (CI), which is represented by equation (7), where *n* represents the size of the matrix:

$$CI = \frac{\lambda_{max} - n}{n-1}. \quad (7)$$

Finally, *"the validity of comparisons can be evaluated through the consistency ratio"* (Jovanovic *et al*., 2015: 227). For the consistency ratio (CR) calculation, the consistency index will be needed, as well as the random consistency index (RI). By definition, RI is a random index that was constructed resorting to Saaty's scale values (1980), obtained from 500 randomly designed positive reciprocal matrices (Karanik *et al.*, 2016). According to Saaty (1994a), Jovanovic *et al*. (2015), Karanik *et al*. (2016) and Singh and Nachtnebel (2016), when CR is 10% or less it means that the pairwise matrix is consistent. On the contrary, when CR is over 10%, there are other methods to improve this index, through revision and adjusting, although the matrix needs to be complete. The equation of CR is represented in formulation (8) and the RI in *Table 6*:

$$CR = \frac{CI}{RI} \quad (8)$$

N MATRIX DIMENSION	RANDOM CONSISTENCY INDEX
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49

Table 6: Random Consistency Index

Source: Jovanovic et al. (2015: 227, adap.).

It is important to clarify that, besides the reciprocal property, the AHP is based on three other axioms. According to Karanik *et al*. (2016) and Singh and Nachtnebel (2016), the additional axioms may be defined as: (1) the *homogeneity axiom*, meaning that the elements that are compared should not differ too much; (2) the *dependence axiom*, which creates connections among elements in each level in order to establish external dependencies; and (3) the *expectation axiom*, which enables the complete visualization of the problem.

In the last phase, which is the recommendation one, it becomes essential to synthesize the AHP process. The goal of this phase is to identify the possible actions to be taken in the future. Through the use of mathematical procedures to synthesize information, the AHP *"produce*[s] *the overall rank of the alternatives,* […] *fix*[es] *a structure to model a problem* […] *that captures all expectations"* (Saaty, 1994b: 439-440). However, as in any other approach, the AHP method has its own contributions and limitations.

5.2. Advantages and Limitations of the AHP/ANP

As pointed out before, the AHP method enables the users to reach a solution by *"breaking a problem down and then aggregating the solutions of the sub-problems* *into a conclusion"* (Saaty, 1994a: 21). In spite of providing benefits in solving complex problems, it also has some pitfalls.

As far as the contributions of the AHP are concerned, they can be summarized in 5 points: (1) *simplicity and ease of application* – indeed, according to Saaty (1994b) and Dweiri *et al*. (2016), the AHP organizes feelings, perceptions and judgments into a hierarchy that helps people to make effective decisions (as stated by Morano *et al*. (2016: 959), the AHP is a *"technique of operational simplicity and clarity of the logical-mathematical process"*); (2) *flexibility and capability of the combination of variables* – as pointed out by Davies (1994), the AHP can integrate not only objective and subjective variables in a single ratio scale, but also both qualitative and quantitative data; (3) *reliable weight calculation*, meaning that establishing the weightings of the criteria is often done with respect to the main goal and independently from the alternatives; and (4) *ability to capture inconsistency in the judgments*, considering that the *"eigenvector is associated with the idea of dominance of judgements"* (Saaty, 1994b: 438).

Conversely, the limitations of the AHP approach may also be detailed. Some authors, such as Davies (1994) and Saaty (1994a), point out that there are essentially two expressed technical disadvantages: (1) *rank reversal*, which is associated with the question *"what happens to the synthesized ranks of alternatives when new ones are added or old ones deleted?"* (Saaty, 1994a: 36) (*i.e.* rank reversal can be considered an undesirable and/or unpleasant property, since a slight change in the situational context, may shift to another choice); and (2) *expressive comparison between elements*, meaning that, when the size of the elements is too large, the analysis of the results is a time-consuming task and the accuracy level is very low. As a consequence, according to Saaty (1994a: 36), *"in AHP* […] *the number of elements compared should not be too large in order to obtain priorities with admissible consistency"*.

Weighing the pros and the cons, it is worth noting that, when dealing with complexity, rationality is necessary and, according to Saaty (1994a: 40), the AHP is *"best manifested in the analytical approach"*. Additionally, in the opinion of Ramanujam and Saaty (1981: 97), the AHP is considered a potent approach due to the fact it integrates *"judgements and facts with models, methods, and theories"*. Therefore, there seems to be considerable scope for the application of this approach in the construction of a knowledge-based decision support system for sustainable city livability evaluation.

SYNOPSIS OF CHAPTER 5

This last chapter from the first part aimed to provide an overall perspective of the AHP approach within the multiple criteria analysis context. In that way, it was possible to identify not only the origins, characteristics and applicability of this approach, but also its contributions and limitations. This chapter has contributed to a better understanding of how multiple criteria methodologies enable the construction of evaluation models, and why are they considered important tools for the decision-making process. The evaluation models are supported by hierarchies that are based on the association, organization and aggregation of decision-makers' preferences. In fact, the AHP was developed in the early 1970s, after several years of attempts to use normative theories and the intrinsic limitation of these techniques when dealing with complex problems. The main purpose of the AHP approach is to help decision makers reach the best solution to the problem. This is possible since the AHP is based on mathematical procedures and includes both objective and subjective elements in the analysis. There are three main functions/principles of the AHP: *structuring complexity*; *measurement of preferences*; and *synthesis*. These steps may be subdivided in five steps, which are: (1) *hierarchical structure of the problem*; (2) *preferences definition,* through the elaboration of a pairwise matrix that compares elements of one level of the hierarchy in relation to the immediate level above; (3) *determination of the eigenvector of relative weights,* to each preference matrix; (4) *analysis of preferences consistency*; and (5) *valuation of the relative importance of each alternative in relation to the larger objective*. Therefore, it is considered an approach of great simplicity, flexibility, reliability and ability to deal with inconsistent judgments from the decision makers. However, this approach also has some limitations that can be summarized in two essential disadvantages: (1) *rank reversal*, meaning that the eigenvector and the random consistency index are also target of criticism; and (2) *expressive comparison between elements*, meaning that, in order to obtain priorities with consistency, the number of elements should not be too large. *Chapter 5* concludes the theoretical and methodological background that composes the first part of this dissertation. The next chapter will start the empirical component, where a multiple criteria information system will be built to support the construction of a knowledge-based decision support system for sustainable city livability evaluation.

PART II

AN EVALUATION "THERMOMETER" FOR SUSTAINABLE CITY LIVABILITY

CHAPTER 6

THE STRUCTURING PHASE

The present chapter introduces the second part of the dissertation which emphasizes the developed empirical component. Accordingly, this chapter focuses on structuring the problem, which is, perhaps, the most important phase in a decision-making process, through the application of cognitive mapping. In this case, the problem is based on the main aim of the dissertation, *i.e.*, the construction of a knowledge-based decision support system for sustainable city livability evaluation. Basically, this chapter intends to explain how cognitive mapping was used to identify the evaluation criteria, as well as the way the value tree, the descriptors and the impact levels were constructed.

6.1. Mapping Sustainability City Livability

As previously stated, the structuring phase is, perhaps, the most important phase in a decision-making process (Bana e Costa *et al.*, 1997). Barfor (2012: 810) refers that, besides being a crucial part of an OR analysis, it is also the hardest step. In other words, the structuring phase implies "*shaping general statements by the DMs* [Decision Makers] *about their goals, concerns and uncertainties and turning these statements into a clear and transparent representation of the decision problem*". As such, to structure the intended model, whose objective is constructing a knowledge-based decision support system for sustainable city livability evaluation, it is essential to use cognitive mapping techniques, through the JOURNEY Making approach. Therefore, taking into account the participative component of these techniques, it is imperative to refer that their application implied gathering a panel of decision makers willing to collaborate in defining and analyzing the problem in face-to-face group sessions. Considering the high degree of availability/dedication demanded, a panel of six decision makers was composed (*i.e.* civil engineers, urban planners and real estate agents). To this end, even though there is not a fixed number of participants required to form a panel, Eden and Ackermann (2004) state that ideally the panel should consist of six to ten key individuals. Two facilitators (*i.e.* researchers) also participated in the sessions, being responsible for the facilitation, negotiation and communication processes.

The structuring phase of the problem occurred during two work sessions, which in total represented 7.5 hours of work (*i.e.* 4 + 3.5). The first session started with a brief introduction of each member of the panel and further clarification of methodological aspects. Subsequently, the trigger question was presented to the panel (see next section), as a means to guide them in the sharing and discussion of ideas and to form the basis for the application of the "post-its technique" (Ackermann and Eden, 2010). By using this technique, the construction of the cognitive map was made possible as it enabled the identification of the necessary criteria. The second session had as its primary goal the construction of descriptors and subsequent levels of impact for the criteria previously identified. The next section will focus on that.

6.2. Criteria, Descriptors and Impact Levels

The determinants/criteria of the model were defined, as previously pointed out, during the first work session, in which the objective of the study, as well as the inherent concepts and procedures of the JOURNEY Making methodology, were presented. The session moved on to focus on pulling the decision makers in and have them address the issues revolving around the creation of sustainable livability in a city/residential area. To achieve that, the following trigger question was announced: *"Based on your own values and professional experience, what are the main reasons or factors that most influence sustainable city livability?"* This question enabled the panel to find the criteria through the sharing and discussion of their perspectives. After this starting point was clarified, the "post-its technique" was carried out. Each member was asked to write down the relevant criteria on post-its, from an individual perspective. There are two essential rules: (1) one criterion per post-it; and (2) place a negative sign (–), in the upper right corner, whenever the cause-effect relationship is negative (*cf.* Ferreira *et al.*, 2015a; Martins *et al.*, 2015). Each post-it is then stuck on a board/table and this process should be repeated until the panel is satisfied with the number of criteria identified. At this point, the decision makers were worried about the possibility of repetition of some criteria. However, they were reassured that the second stage of this technique involves tweaking and helps to detect possible overlapping; consequently, the repeated criteria would be eliminated. *Figure 5* shows some of the moments of the application of the "post-its technique".

Figure 5: Snapshots of the First Group Session

The aim of the second part of the technique was to reorganize and divide the post-its into different clusters/areas of concern. By doing that, it was possible to identify six different groups of related criteria and analyze them individually following a means-end-based logic. The last step of this technique aimed to obtain a consensus within the panel regarding the form and content of the cognitive structure. As they discussed, their purpose was to primarily focus on the internal analysis of each cluster in order to verify the cause-and-effect relationships between criteria (*i.e.* defining hierarchies among the criteria inserted in each area of concern).

After the application of the “post-its technique”, a collective cognitive map was developed using the *Decision Explorer software* (http://www.banxia.com), which supported the discussion of how the problem was structured. Decision-makers were given the possibility of inserting and/or changing criteria, restructuring the clusters and/or starting over again in case of disagreement with the content and/or form of the map. *Figure 6* represents the final version of the group cognitive map, after validation by the panel of decision-makers.

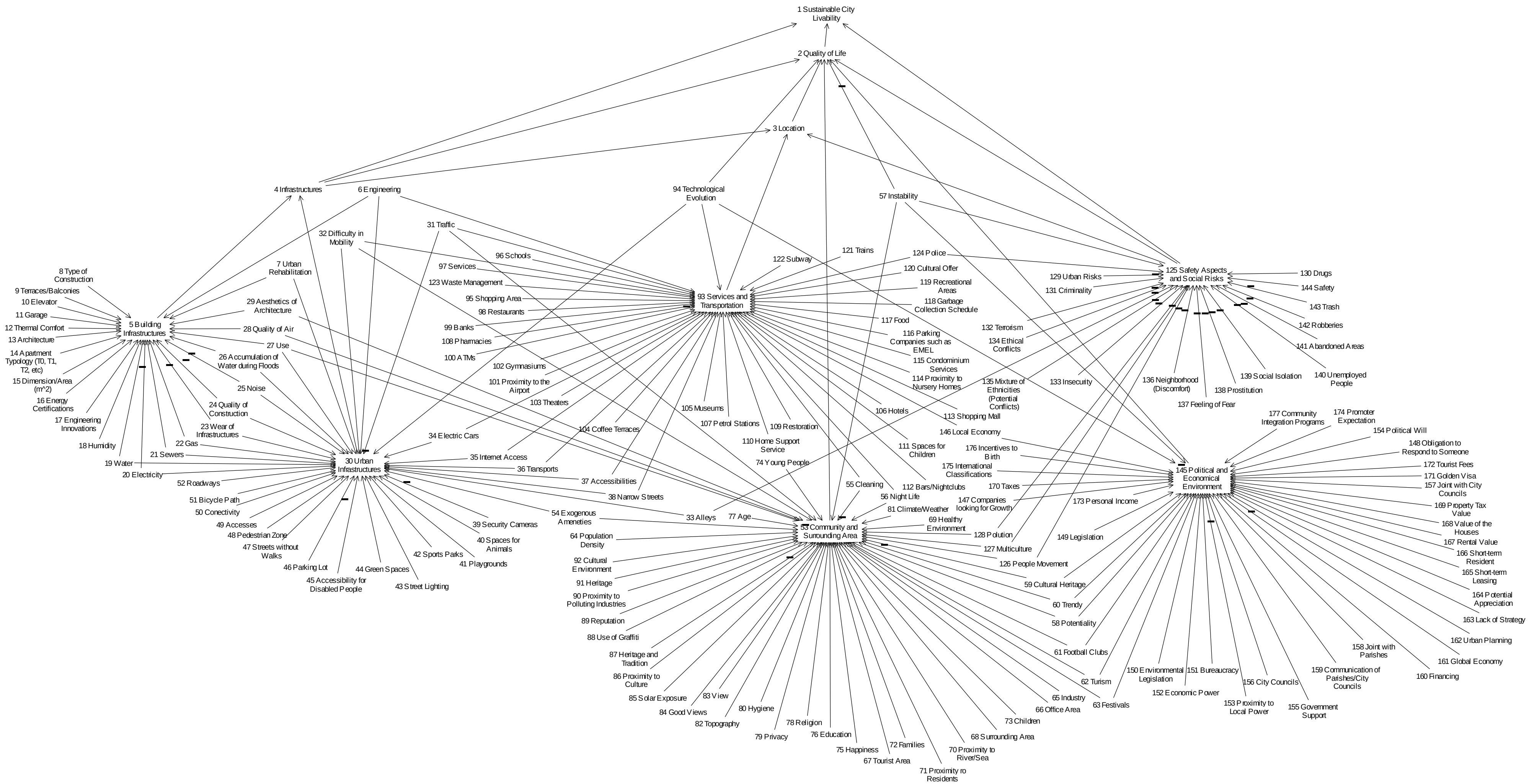

Figure 6: Collective Cognitive Map

The construction of a value tree was the next step of the problem structuring process. Considering the methodological orientations of Eden (1994) and Ackermann and Eden (2010), the areas of concern were defined by the panel of decision makers, which helped to support the selection of criteria (CTR). The different areas of concern can be identified as: *Building Infrastructures*; *Services and Transportation*; *Community and Surrounding Areas*; *Political and Economic Environment*; *Safety Aspects and Social Risks*; and *Urban Infrastructures*. *Figure 7* shows the identified determinants.

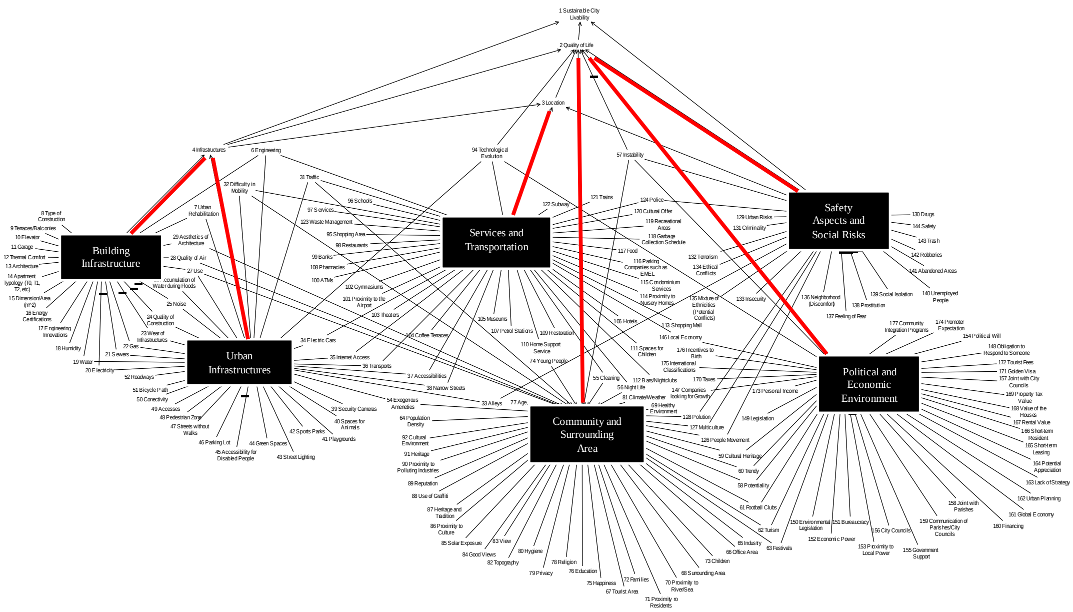

Figure 7: Identification of the Cognitive Branches and the Lines of Thinking

Although *Figure 7* has illustrative purposes, it represents the most important factors to construct a knowledge-based decision support system for sustainable city livability evaluation. As such, six clusters were identified and led to the creation of the value tree presented in *Figure 8*.

Figure 8: Value Tree

The panel members agreed on the importance of clarifying the following: CTR1 – *Building Infrastructures* (BI) – includes all the characteristics and factors related to the building itself (*e.g.* existence of water, dimension/area, building typology, quality and type of construction); CTR2 – *Services and Transportation* (ST) – includes characteristics in terms of offer and quality of different services and transportation (*e.g.* schools, restaurants, coffee terraces, waste management, transport network, services and cultural events); CTR3 – *Community and Surrounding Area* (CSA) – integrates characteristics of the community nearby the residential area (*e.g.* solar exposure, topography, hygiene, reputation, education, population density and climate/weather); CTR4 – *Political and Economic Environment* (PEE) – refers to aspects of political and economic nature that might influence the sustainable city livability (*e.g.* house market value, legislation, personal income, urban planning, global economy, future prospects and property taxes); CTR5 – *Safety Aspects and Social Risks* (SASR) – includes a set of factors or situations that affect the classification of a city livability (*e.g.* neighborhood, social isolation, trash accumulation, criminality and insecurity levels); and CTR6 – *Urban Infrastructures* (UI) – includes a set of characteristics related to the area surrounding the building and what it offers (*e.g.* street lighting, parking lots, green spaces, roadways and accessibilities).

Even though the value tree is considered a useful tool when structuring a decision problem, it is not perceived as the final goal of the facilitator or the structuring process. Therefore, generating descriptors was essential so that the panel could proceed and operationalize the CTR previously defined. For this reason, during the second session, the decision makers were asked to focus their attention on the cognitive map and the value tree and afterwards define a descriptor and respective levels of partial performance for each CTR (*cf.* Bana e Costa *et al.*, 1999). *Figure 9* shows some of the moments of the second work session.

Figure 9: Snapshots of the Second Group Session

The decision makers identified the criteria which they believed were the most relevant in each cluster. Then, by using an adaptation of the Fiedler's scale (1965; 1967), they were able to define the reference levels to use in each descriptor. Knowing that descriptors can be described differently (Bana e Costa *et al.*, 1999), this scale was the one suggested and it became easy to apply. In practical terms, the impact level L_1 corresponds to the best possible partial performance, while L_n is a performance clearly less successful. *Figures 10* to *15* represent the descriptors and respective levels of partial performance constructed for the clusters.

As shown in *Figure 10*, CTR01 – *Building Infrastructures* (BI) – was operationalized through a BI index, which includes the characteristics of the building that, in the opinion of the panel of experts, are the most important ones (*i.e.* existence of water and adequate plumbing, typology of the building, dimensions/area, type and quality of the construction). The impact level L_1 represents the best possible performance, including the residential areas whose index (*i.e.* sum of the points given to each criterion) belongs to the range of practicable maximum values. On the contrary, the impact level L_5 is a performance clearly negative, which includes residential areas classified with minimum values.

Descriptor CRT01 - Building Infrastructure [BI]			Level	Description
Inexistence of Potable Water or Extremely Inadequate Plumbing	1 2 3 4 5 6 7 8	Existence of Potable Water, with Extremely Adequate Plumbing and Excellent Pressure	**L1**	Index BI ∈ [36-40]
Very Poor Distribution of Space	1 2 3 4 5 6 7 8	Excellent Distribution of Space	**Good**	Index BI ∈ [29-35]
Excessively Small Areas	1 2 3 4 5 6 7 8	Excellent Areas	**Neutral**	Index BI ∈ [20-28]
Extremely Inadequate Functional Construction	1 2 3 4 5 6 7 8	Extremely Adequate Functional Construction	**L4**	Index BI ∈ [11-19]
Very Poor Quality of Construction	1 2 3 4 5 6 7 8	Excellent Quality of Construction	**L5**	Index BI ∈ [5-10]

Figure 10: Descriptor and Levels of Local Performance of CTR01

Figure 11 shows the descriptor of CTR02 – *Services and Transportation* (ST) – which was operationalized through an ST index. The same procedure of the previous CTR was followed.

Descriptor CRT02 - Services and Transportation [ST]			Level	Description
Total Absence of Schools	1 2 3 4 5 6 7 8	Great Offer and Variety of Schools	**L1**	Index ST ∈ [50-56]
Inexistence or Very Poor Restoration Offer	1 2 3 4 5 6 7 8	Very Wide Offer and Variety of Restoration	**Good**	Index ST ∈ [42-49]
Inexistence or Very Poor Waste Management	1 2 3 4 5 6 7 8	Excellent Waste Management	**Neutral**	Index ST ∈ [35-41]
Total Absence of Coffee Terraces	1 2 3 4 5 6 7 8	Excellent Offer of Coffee Terraces	**L4**	Index ST ∈ [27-34]
Inexistent or Inadequate Transport Network	1 2 3 4 5 6 7 8	Excellent Offer and Variety of Transport Network	**L5**	Index ST ∈ [16-26]
Total Absence of Services	1 2 3 4 5 6 7 8	Excellent and Diverse Offer of Services	**L6**	Index ST ∈ [7-15]
Total Absence of Cultural Offer	1 2 3 4 5 6 7 8	Excellent and Diversified Cultural Offer		

Figure 11: Descriptor and Levels of Local Performance of CTR02

Regarding the CTR03 – *Community and Surrounding Area* (CSA) – it was operationalized using a CSA index, which combines characteristics of the community nearby the residential area and are, according to the panel, essential to define the sustainable livability of a city. *Figure 12* shows the descriptor of CTR03.

Descriptor CRT03 - Community and Surrounding Area [CSA]			Level	Description
Very Poor Solar Exposure (Shaded Area)	1 2 3 4 5 6 7 8	Excellent Solar Exposure	L1	Index CSA ∈ [51-56]
Area with Extreme Topographic Variations	1 2 3 4 5 6 7 8	Area with Insignificant Topographical Variations	Good	Index CSA ∈ [43-50]
Extreme Lack of hygiene	1 2 3 4 5 6 7 8	Excellent Hygiene	Neutral	Index CSA ∈ [34-42]
Very Poor Reputation	1 2 3 4 5 6 7 8	Excellent Reputation	L4	Index CSA ∈ [26-33]
Very Poor Education	1 2 3 4 5 6 7 8	Excellent Education	L5	Index CSA ∈ [15-25]
Extremely Densified Area	1 2 3 4 5 6 7 8	Population Density Clearly Adjusted to Area	L6	Index CSA ∈ [7-14]
Very Poor Weather	1 2 3 4 5 6 7 8	Excellent Weather		

Figure 12: Descriptor and Levels of Local Performance of CTR03

Figure 13 represents the descriptor of CTR04 – *Political and Economic Environment* (PEE) – in which a PEE index includes aspects of political and economic nature in the surroundings that, according to the panel of experts, might influence the sustainable city livability.

Descriptor CRT04 - Political and Economic Environment [PEE]			Level	Description
Value of Houses Extremely Inadequate	1 2 3 4 5 6 7 8	Value of Houses Extremely Adequate	L1	Index PEE ∈ [52-56]
Inexistence or Inadequate Legislation	1 2 3 4 5 6 7 8	Extremely Adequate Legislation	Good	Index PEE ∈ [44-51]
Extremely Low Personal Income	1 2 3 4 5 6 7 8	Very High Personal Income	L3	Index PEE ∈ [36-43]
Inexistence or Inadequate Urban Planning	1 2 3 4 5 6 7 8	Excellent Urban Planning	Neutral	Index PEE ∈ [28-35]
Severe Global Crisis	1 2 3 4 5 6 7 8	Very High Economic Growth	L5	Index PEE ∈ [18-27]
Inexistence of Potentialities	1 2 3 4 5 6 7 8	Numerous and Diverse Potentialities	L6	Index PEE ∈ [7-17]
Extremely High, Diverse and Inadequate Taxes	1 2 3 4 5 6 7 8	Extremely Adequate Taxes		

Figure 13: Descriptor and Levels of Local Performance of CTR04

The SASR index is a set of factors that influence the quality of life and the wellbeing. It operacionalizes the descriptor of CTR05 – *Safety Aspects and Social Risks* (SASR) – (*Figure 14*), and includes characteristics such as the neighborhood, social isolation, trash accumulation, criminality and insecurity levels.

Descriptor CRT05 - Safety Aspects e Social Risks [SASR]			Level	Description
Bad Neighborhood	1 2 3 4 5 6 7 8	Excellent Neighborhood	L1	Index SASR ∈ [38-40]
Extreme Social Isolation	1 2 3 4 5 6 7 8	Very High Social Integration Index	Good	Index SASR ∈ [30-37]
Extreme Trash Accumulation	1 2 3 4 5 6 7 8	Total Absence of Trash	Neutral	Index SASR ∈ [22-29]
Extremely High Criminality Level	1 2 3 4 5 6 7 8	Total Absence of Crime	L4	Index SASR ∈ [15-21]
Extremely High Level of Insecurity	1 2 3 4 5 6 7 8	Extremely High Level of Security	L5	Index SASR ∈ [5-14]

Figure 14: Descriptor and Levels of Local Performance of CTR05

Finally, CTR06 – *Urban Infrastructures (UI)* – was operationalized using an UI index, which combines characteristics related to the surrounding area of the building (*e.g.* street lighting, parking lots, green spaces, roadways and accessibilities). In the opinion of the decision makers, these have implications when the goal is to evaluate sustainable city livability (*Figure 15*).

Descriptor CRT06 - Urban Infrastructures [UI]			Level	Description
Inexistence or Weak Street Lighting	1 2 3 4 5 6 7 8	Excellent Street Lighting	L1	Index UI ∈ [36-40]
Inexistence or Inadequate Parking Lot Offer	1 2 3 4 5 6 7 8	Very High and Adequate Parking Offer	Good	Index UI ∈ [29-35]
Inexistence of Green Spaces	1 2 3 4 5 6 7 8	Extremely Adequate Green Space Offer	Neutral	Index UI ∈ [20-28]
Inexistence or Inadequate Offer of Roadways	1 2 3 4 5 6 7 8	Excellent and Adequate Offer of Roadways	L4	Index UI ∈ [11-19]
Inexistence or Inadequate Offer of Accessibilities	1 2 3 4 5 6 7 8	Excellent and Adequate Offer of Accessibilities	L5	Index UI ∈ [5-10]

Figure 15: Descriptor and Levels of Local Performance of CTR06

The structuring phase of the problem ended when a descriptor was clearly defined for each CTR. The next chapter will focus on the second phase of the process, which is the evaluation one. Through the use of the AHP methodology, it was possible to obtain value functions for the descriptors, as well as the trade-off between CTR.

SYNOPSIS OF CHAPTER 6

This first chapter of the second part of the dissertation aimed to introduce the structuring phase of the decision-making process. It elaborated on how the cognitive mapping techniques were applied in the structuring phase of the problem. As previously explained, this phase is, perhaps, the most important phase of the decision-making process. In practical terms, it described how the techniques to construct a cognitive map were applied, using the guidelines of the JOURNEY Making approach to define the main criteria of the model. From these, the definition of a value tree and the construction of descriptors and respective impact levels were also achieved. Therefore, taking into account the nature of these techniques, it was necessary to gather a group of decision makers for face-to-face sessions. This phase took place during two work sessions. The first work session had as a starting point the following trigger question: "*Based on your own values and professional experience, what are the mains reasons or factors that most influence sustainable city livability?*. This key question guided the group through discussion and sharing of ideas, using the "post-its technique". This approach enabled the panel to adopt their own perspective and jointly identify the most influential determinants/criteria when it comes to evaluating the sustainable livability of a city or residential area. By the end of this session, the panel had developed and agreed upon a collective cognitive map which led to the construction of a value tree. The second session was important to define descriptors and impact levels for each CTR. To achieve this, they used the information included in the collective cognitive map. In this context, the collaboration of the panel of experts was considered tremendously important, ensuring the consistency, reality and functionality of the descriptors created. Once a descriptor and respective impact levels were defined for each CTR, the structuring phase was concluded. Thus, after having guaranteed the necessary conditions, the evaluation phase — the second phase of a decision-making process — could take place. This stage of the process will provide the opportunity, through the application of the AHP methodology, to define priorities and preferences, as well as to assign weights to each CTR. Also, by using the AHP it is possible to measure relative and global performances. The next chapter will focus on this evaluation phase.

CHAPTER 7

EVALUATION AND RECOMMENDATION PHASES

The present chapter aims to introduce the evaluation and recommendation phases once the problem structuring phase is complete. As such, this last chapter presents the technical procedures of the AHP methodology, in terms of creating preference scales and assigning weights to the identified criteria. These procedures are the means to evaluate relative and global performances. The last part of the chapter emphasizes the need to conduct complementary tests and further analysis in order to validate the results and put together the recommendations.

7.1. The Evaluation Phase

After the conclusion of the structuring phase, the group moved on to the evaluation phase. This phase is an important step in the decision-making process since it allows, by means of performing pairwise comparisons, to determine the weights among criteria, leading to the construction of a knowledge-based decision support system for sustainable city livability evaluation.

This second phase of the process occurred during the last work session with the panel of experts, which lasted approximately 2 hours. In the first part of the session, after a brief period of explanations about the AHP methodology, the panel was asked to fill in a comparison matrix for each of the defined descriptors. In other words, the idea was, by discussing the opinions put forth, to compare pairs of elements between the identified levels for each descriptor and to complete the matrix. The definition of these priorities and relative rankings was based on the fundamental scale of Saaty (see *Table 3*). Taking into account one of the advantages of the AHP methodology, it is important to refer that, during this process, a consensus was not always reached; however, discussions among the decision makers helped to overcome the obstacles. *Figure 16* shows some of the moments of the last work session.

Figure 16: Snapshots of the Third Group Session

The information given by the panel of experts was used to fill in the matrices of the descriptors defined in the structuring phase and, consequently, obtain the local preference scales. Through the use of the *Super Decisions* software (http://www.superdecisions.com/), the application of the AHP methodology was made easier. However, it is important to point out that minor adjustments were made in cases where there were inconsistencies.

Figure 17 shows the process of filling in the matrix regarding CTR01 – *Building Infrastructures* – as well as the numerical scale obtained. This was presented to the panel for validation, in which the inconsistency index needs to be lower than 0.10 and it is for CTR01 (*cf.* Saaty, 1994a; Jovanovic *et al.*, 2015; Karanik *et al.*, 2016; and Singh and Nachtnebel, 2016). A partial score of 44.759% was obtained for L_1 (taken as the best level) and a weight of 3.251% for the worst level (*i.e.* L_5). For the levels *Good* and *Neutral*, decision makers assigned the weights of 32.756% and 14.600%, respectively. When analyzing the scale, one notices the weak preferencial difference between level L_1 and level *Good*, as well as between level L_4 and level L_5.

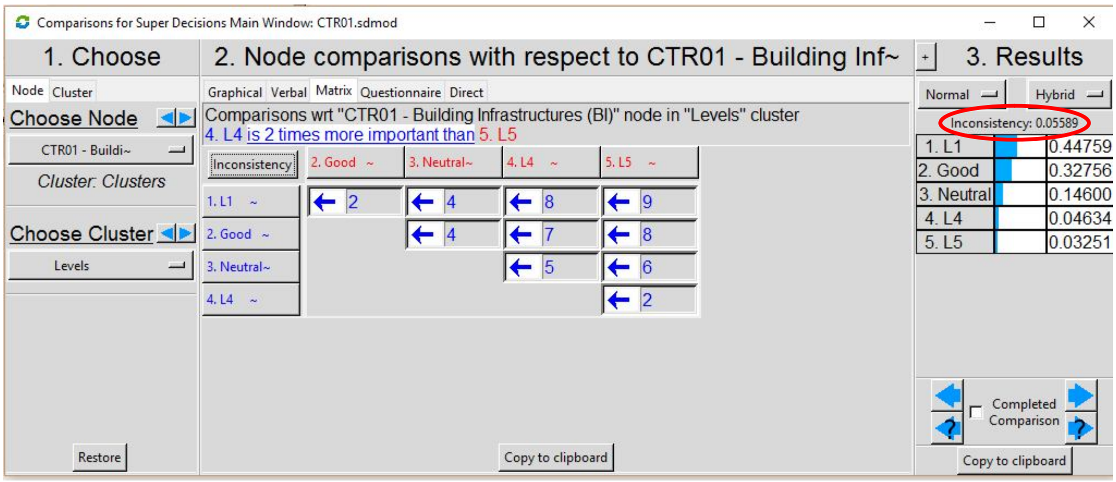

Figure 17: Judgments and Value Scale for CTR01

Figure 18 shows the judgments and the partial scale obtained for CTR02 – *Services and Transportation*, in which the inconsistency index is lower than 0.10. For the best level (*i.e.* L_1) a partial weight of 39.887% was obtained, while for the worst one (*i.e.* L_6) just 2.215%. These results clearly demonstrate how much decision makers favor the upper levels (*i.e.* L_1, L_2 and *Neutral*).

It is important to emphasize that consensus among the panel members was not achieved at all times. In some cases, it was necessary to engage in further discussion/negotiation among the panel in order to achieve agreement.

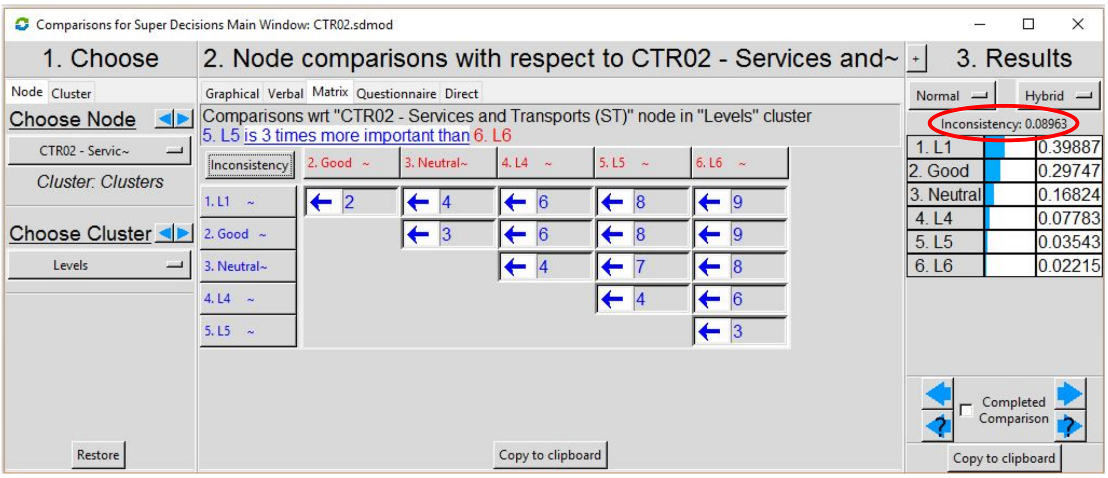

Figure 18: Judgments and Value Scale for CTR02

By taking a closer look at *Figure 19*, which is the matrix and value scale of CTR03 – *Community and Surrounding Area* – one can observe a small difference in terms of preference between the two upper levels (*i.e.* L_1 and *Good*) and the two bottom levels (*i.e.* L_5 and L_6). While the best level (*i.e.* N_1) scored 39.239%, the following level of impact (*i.e. Good*) obtained a score of 32.570%. Similarly, the difference between both impact levels L_5 and L_6 was of just 1.397%. This analysis clearly shows an inconsistency index below 0.10.

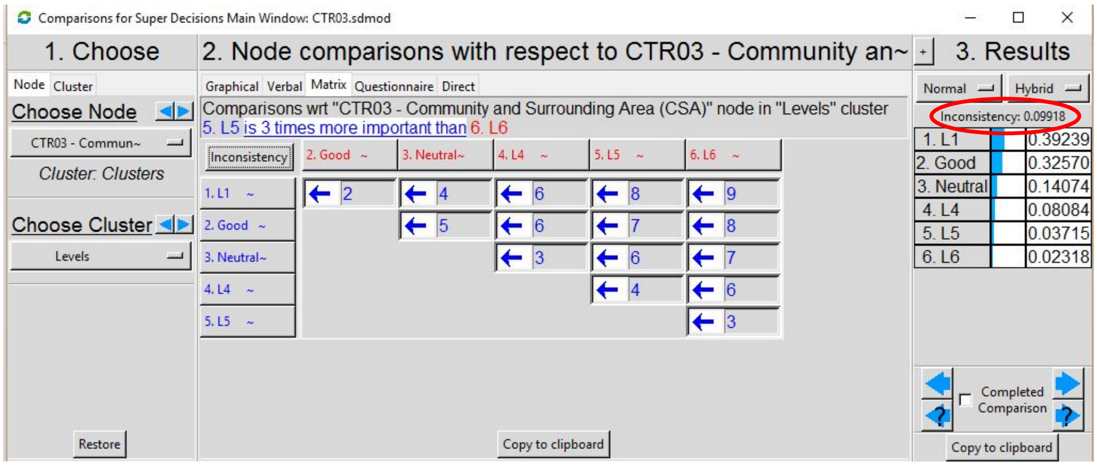

Figure 19: Judgments and Value Scale for CTR03

CTR04 – *Political and Economic Environment* – is, in a similar way, another descriptor with six levels of impact. *Figure 20* shows the partial performance scales, where the best level (*i.e.* L_1) scored 42.497% and the worst level (*i.e.* L_6) only 2.309%. It is important to stress that the inconsistency index was 0.09293 (*i.e.* lower than 0.10).

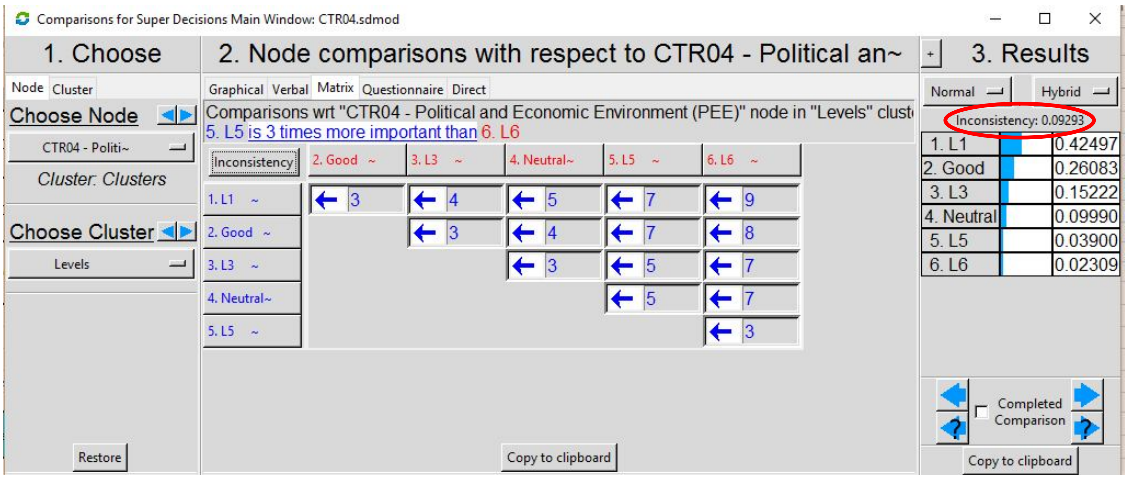

Figure 20: Judgments and Value Scale for CTR04

Figure 21 represents the judgments and the value scale of CTR05 – *Safety Aspects and Social Risks*. In this case, CTR05 is a descriptor with five impact levels, where it is possible to detect the evident importance for the panel of living in a neighborhood without any or with low levels of criminality and insecurity. The application of the AHP methodology resulted in a score of 54.445% in the best level (*i.e.* L_1). Conversely, the worst level of impact (*i.e.* L_5) scored only 3.290%. Once again, the inconsistency index of CTR05 is lower than 0.10.

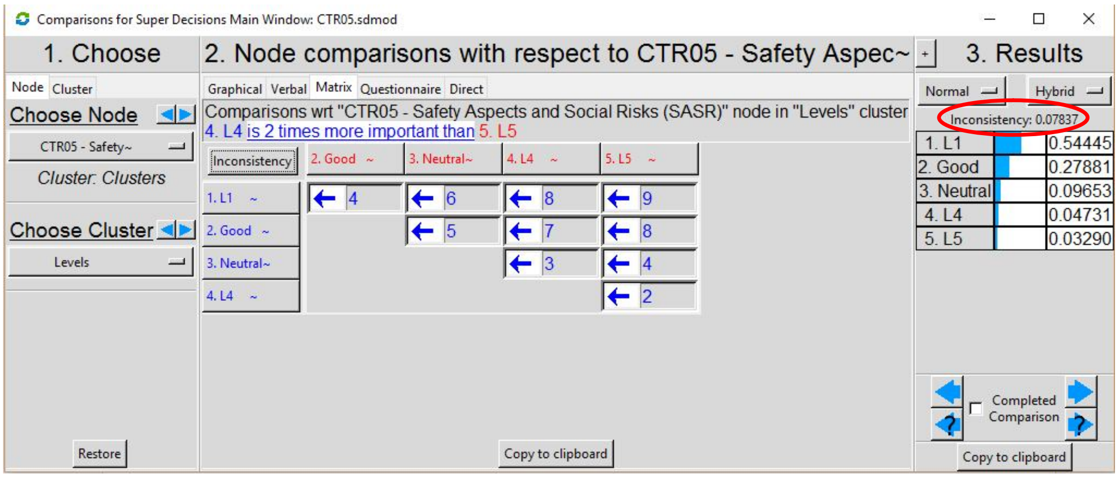

Figure 21: Judgments and Value Scale for CTR05

Lastly, regarding CTR06 – *Urban Infrastructures* –, *Figure 22* shows that the application of the AHP methodology resulted in a score of 44.221% in the best impact level (*i.e.* L_1) and 3.276% in the worst level (*i.e.* L_5). From this analysis, the proximity between the upper levels (*i.e.* L_1 and *Good*), as well as between the bottom ones (*i.e.* L_4 and L_5), is noteworthy. Once again, the inconsistency index was 0.07180, which is less than 0.10.

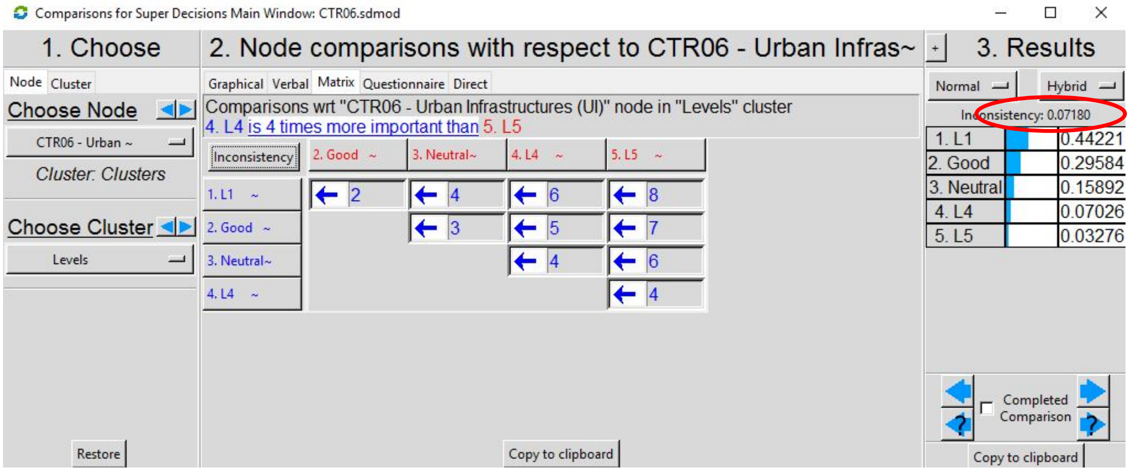

Figure 22: Judgments and Value Scale for CTR06

After obtaining a local performance scale for each of the six CTR identified in the model, the first part of this process ended. The following step was to obtain trade-offs (*i.e.* weights) between the six CTR defined. Accordingly, the panel was asked to focus their attention on the identified CTR and rank them based on their global preference. In practical terms, a matrix of ordering criteria was filled in based on their scoring, either "1" or "0". The idea was to assign "1" whenever one CTR was globally preferred over another and "0" otherwise. The final ranking was defined based on the sum of the values resulting from the comparisons. The CTR awarded the first place was the one with the highest sum, while the last one placed corresponded to the CTR with the lowest sum obtained (*Table 7*).

		CTR01	CTR02	CTR03	CTR04	CTR05	CTR06	TOTAL	R
Building Infrastructures	**CTR01**	--	1	1	1	1	1	**5**	**1**
Services and Transportation	**CTR02**	0	--	1	0	0	1	**2**	**4**
Community and Surrounding Areas	**CTR03**	0	0	--	0	0	1	**1**	**5**
Political and Economic Environment	**CTR04**	0	1	1	--	1	1	**4**	**2**
Safety Aspects and Social Risks	**CTR05**	0	1	1	0	--	1	**3**	**3**
Urban Infrastructures	**CTR06**	0	0	0	0	0	--	**0**	**6**

Table 7: Matrix of Overall Preferences

By obtaining the ranking of CTR and the approval from the panel, the next step consisted of building a pairwise comparison matrix in order to obtain the trade-offs. The panel followed the same procedure used to construct the matrices showing the impact levels and the aim was for them to express their opinion about the preferential difference between the identified CTR. The AHP methodology made it possible to complete the judgments matrix and calculate the trade-offs among the CTR, as shown in *Figure 23*. The result was shown to the decision makers for further discussion and validation. Once these results were validated, it was consensual that the highest weight (*i.e.* 35.608%) was assigned to CTR01 – *Building Infrastructures*. At the other end of the spectrum, the lowest weight (*i.e.* 2.948%) was allocated to CTR06 – *Urban Infrastructures*. The inconsistency index was 0.04773, which is lower than 0.10.

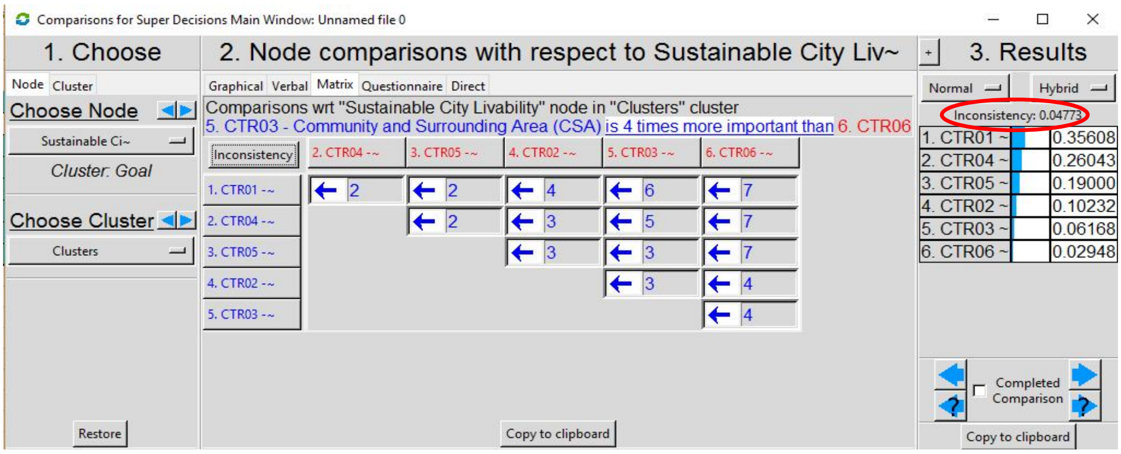

Figure 23: Judgments Matrix and Trade-Offs between CTR

Having validated the trade-offs, the next step consisted of the application of a simple additive model in order to obtain the global performance of four "artificially" alternatives created. Therefore, the technical procedure started by calculating the global performance of the four fictional neighborhoods (designated as "Alphas"), which were the starting point to evaluate sustainable city livability. *Table 8* shows the partial and global weights of each Alpha.

	OVERALL	CTR01	CTR02	CTR03	CTR04	CTR05	CTR06
Alpha 1 | Excellent	**0.45155**	0.44759	0.39887	0.39239	0.42497	0.54445	0.44221
Alpha 2 | Good	**0.29679**	0.32756	0.29747	0.32570	0.26083	0.27881	0.29584
Alpha 3 | Neutral	**0.12693**	0.14600	0.16824	0.14074	0.09990	0.09653	0.15892
Alpha 4 | Bad	**0.02850**	0.03251	0.02150	0.02318	0.02309	0.03290	0.02948
WEIGHTS		**0.33958**	**0.09066**	**0.05440**	**0.21063**	**0.18101**	**0.02731**

Table 8: Impact Levels and Overall Performance per Alpha

As shown in *Table 8*, it is important to draw attention to the fact that Alpha 1 corresponds to a "fictional" neighborhood (designated as "Excellent"), which integrates the best levels of all CTR. In the same way, Alpha 2 is a neighborhood, called "Good", which assembles the level *Good* from all CTR. Alpha 3 represents the "Neutral" neighborhood as it joins the *Neutral* levels from all CTR. Lastly, Alpha 4 is a neighborhood designated as "Bad" since it aggregates all the worst levels from the CTR identified. The creation of these Alphas enables cognitive comparisons and helps to evaluate sustainable city livability.

In order to validate the evaluation system created, it was necessary to test its practical applicability, through the development of a sensitivity analysis whose purpose would be to evaluate the consistency of the results.

7.2. Sensitivity Analysis

In order to analyze the results obtained and measure the applicability of the process adopted, it was necessary to "test" the new model for sustainable city livability evaluation, through the assessment of a set of different neighborhoods in Lisbon.

Therefore, the panel was asked to provide real information about neighborhoods to investigate the impact level, per neighborhood, in each of the CTR previously identified (*see* Appendix). *Table 9* represents the information regarding a sample of eight neighborhoods (identified as Delta 1 to Delta 8).

	CTR01	CTR02	CTR03	CTR04	CTR05	CTR06
Delta 1	0.14600	0.16824	0.14074	0.15222	0.09653	0.07026
Delta 2	0.04634	0.16824	0.08084	0.03900	0.09653	0.07026
Delta 3	0.14600	0.29747	0.14074	0.09990	0.27881	0.15892
Delta 4	0.32756	0.29747	0.32570	0.09990	0.09653	0.15892
Delta 5	0.44759	0.39887	0.39239	0.26083	0.27881	0.29584
Delta 6	0.14600	0.29747	0.32570	0.15222	0.27881	0.15892
Delta 7	0.14600	0.29747	0.14074	0.09990	0.27881	0.15892
Delta 8	0.14600	0.16824	0.14074	0.03900	0.27881	0.15892

Table 9: Partial Performance of Delta 1 to Delta 8

After the identification of the partial performances of each Delta, the next step implied the application of a simple additive aggregation model in order to calculate the global value of each Delta (see Martins *et al.*, 2015). *Table 10* shows the global weights of the neighborhoods under analysis as well as their respective ranking.

	OVERALL SCORE	RANKING
Delta 5	0.35402	1
Delta 4	0.21621	2
Delta 6	0.19982	3
Delta 3	0.17478	4
Delta 7	0.17478	4
Delta 8	0.14570	6
Delta 1	0.13794	7
Delta 2	0.06927	8

Table 10: Overall Score and Ranking of Alternatives (Deltas)

The ranking of the eight neighborhoods displayed in *Table 10* is ordered in terms of overall scores of the Deltas. Accordingly, one may conclude that Delta 5 is the neighborhood with the best performance, while Delta 2 is the worst performer. *Table 11* shows the relative position of each Delta according to the Alphas previously created.

ALPHA/DELTA	GLOBAL INDEX
Excellent	**0.45155**
Delta 5	0.35402
Good	**0.29679**
Delta 4	0.21621
Delta 6	0.19982
Delta 3	0.17478
Delta 7	0.17478
Delta 8	0.14570
Delta 1	0.13794
Neutral	**0.12693**
Delta 2	0.06927
Bad	**0.02850**

Table 11: Deltas' Positioning Taking into Consideration the Alphas Created

As shown in *Table 11*, only Delta 5 stands between *Excellent* and *Good*. There are six other neighborhoods that are in between *Good* and *Neutral* in terms of their sustainable livability. The last neighborhood (*i.e.* Delta 2) scores between the levels *Neutral* and *Bad*. Finally, based on this sample, there are no neighborhoods below the *Bad* level.

This phase of the process was essential to consolidate the results obtained, generating a feeling of satisfaction among the panel members. Indeed, the decision makers recognize the importance and potential of the techniques applied to construct the model, considering them an asset to evaluate sustainable city livability. Nevertheless, taking into account the inherent subjectivity of this process, the development of sensitivity analyses was important. This allowed the possibility of variations in terms of the ranking of the alternatives to be analyzed.

For instance, *Table 12* shows the sensitivity analysis in relation to CTR01. The created system seems to be stable when changing the weights. In other words, the higher the weight attributed to the criterion is, the less are the changes verified in the Deltas ranking. For this reason, there is stability in the model created.

CTR 01 WEIGHT	PRIORITIES							
	DELTA 1	DELTA 2	DELTA 3	DELTA 4	DELTA 5	DELTA 6	DELTA 7	DELTA 8
0.050090	0.093444	0.056293	0.131944	0.112196	0.214522	0.158102	0.131944	0.101554
	7	8	3	5	1	2	3	6
0.150070	0.093497	0.054194	0.128938	0.120055	0.220399	0.153018	0.128938	0.100962
	7	8	3	5	1	2	3	6
0.20060	0.09353	0.053154	0.127448	0.123949	0.223310	0.150499	0.127448	0.100669
	7	8	3	5	1	2	3	6
0.250050	**0.093548**	**0.052120**	**0.125968**	**0.127820**	**0.226204**	**0.147995**	**0.125968**	**0.100378**
	7	**8**	**4**	**3**	**1**	**2**	**4**	**6**
0.300040	0.093574	0.051092	0.124496	0.131668	0.229081	0.145506	0.124496	0.100088
	7	8	4	3	1	2	4	6
0.350030	0.093599	0.050071	0.123033	0.135492	0.231940	0.143032	0.123033	0.099513
	7	8	4	3	1	2	4	6
0.400020	0.093625	0.049055	0.121579	0.139294	0.234783	0.140572	0.121579	0.099513
	7	8	4	3	1	2	4	6
0.450010	**0.093650**	**0.048046**	**0.120133**	**0.143073**	**0.237608**	**0.138128**	**0.120133**	**0.099229**
	7	**8**	**4**	**2**	**1**	**3**	**4**	**6**
0.500000	0.093675	0.047042	0.118696	0.146829	0.240417	0.135697	0.118696	0.098946
	7	8	4	2	1	3	4	6
0.549990	0.093720	0.045243	0.116120	0.153566	0.245454	0.131339	0.116120	0.098438
	7	8	4	2	1	3	4	6
0.599980	0.093764	0.043462	0.113570	0.160232	0.250438	0.120727	0.113570	0.097936
	7	8	4	2	1	3	4	6
0.649970	0.093808	0.041701	0.111047	0.166827	0.255369	0.122761	0.111047	0.097440
	7	8	4	2	1	3	4	6
0.699960	0.093852	0.039958	0.108551	0.173353	0.260248	0.115839	0.108551	0.096948
	7	8	4	2	1	3	4	6
0.749950	0.093895	0.038233	0.106081	0.179811	0.265077	0.114361	0.106081	0.096462
	7	8	4	2	1	3	4	6

Table 12: Sensitivity Analysis for CTR01

Upon concluding the phase of the sensitivity analysis, it is important to validate the model, reflect on its limitations and suggest some future recommendations, which will be the focus of the next section.

7.3. Validation, Limitations and Recommendations

The model developed made it possible to evaluate the sustainable livability of different neighborhoods. It is grounded on the perceptions and convictions of experts in the real estate industry. The way the sessions unfolded, the testing of the different criteria and the satisfaction expressed by decision makers contributed to view the obtained results as relevant. Indeed, the AHP methodology allowed for the calculation of trade-off among CTR, giving the experts a more informed and transparent vision of the evaluation system developed. Therefore, it can be concluded that the model created reinforces the conviction that the integrated use of cognitive maps and the AHP methodology is pertinent to the current evaluation context.

Although the results are encouraging, it is worth noting that this proposal was based on a learning and constructivist position, in which results came from the discussion among the panel members. For this reason, and despite the versatility of the technical procedures used, the developed model is not intended to dictate a definitive or optimal solution, but instead be regarded as a negotiation and learning tool. Furthermore, since the model has idiosyncratic characteristics (*i.e.* the results depend on the context and actors involved), it is not prudent to extrapolate the results without taking proper precautions. Therefore, this might be considered a limitation of the model. However, the AHP methodology lends itself to some additional adjustments, which will increase the potential of the system created, always under the recommendation of conducting additional sensitivity analyses.

SYNOPSIS OF CHAPTER 7

The present chapter aimed to introduce the last two phases of the decision-making process, which are the evaluation and recommendation ones. Hence, it presented not only the technical procedures of the AHP methodology in the evaluation phase, but also the sensitivity analyses conducted and the validation of the model. The evaluation phase occurred during the last work group session, which was characterized by discussion and negotiation among the panel members. At the beginning, by use of the AHP methodology, the idea was to fill in the judgments matrices between the levels of each descriptor. From that, it was possible to reach a local performance scale in each of the six CTR identified. The judgments were inserted in the *Super Decision*s software and it was necessary to make some adjustments when the inconsistency index was above 10%. In the second part of the session, it was possible to rank the six CTR identified, through their global preference, and then construct a pairwise comparison matrix. With this matrix, the trade-offs between criteria were obtained and approved by the panel of experts. This allowed for the applicability of a simple additive model to obtain the overall score of four "fictional" neighborhoods (*i.e.* Alphas), which were the starting point to evaluate sustainable city livability. The panel was asked to give real information about eight neighborhoods (designated as "Deltas") to analyze the impact level, per neighborhood, in each of the CTR previously identified. It then became possible to rank the eight Deltas among the four Alphas. In order to verify the consistency of the developed model, sensitivity analyses were conducted by using the *Super Decisions* software. As a result, the stability of the values in relation to variations and in terms of the weighting coefficients was proven. After the model validation, the limitations and future recommendations became the focus of the last part of the chapter. Although the panel of experts expressed their satisfaction with the results obtained, one must bear in mind that it does not dictate definitive and final solutions; instead, it should be seen as a negotiation and learning tool. Furthermore, given the idiosyncratic characteristics of this model, the results should not be extrapolated without exercising proper precaution. Nevertheless, the integrated use of cognitive maps and the AHP methodology made it possible to reach a well-informed and transparent model, reinforcing the evaluation of the sustainable livability in an urban area. Naturally, improvements and updates are welcome.

CONCLUSION

A. Results and Limitations

The present study corroborated the conviction that, ***by following the MCDA approach, it is possible to build a robust and transparent knowledge-based decision support system for sustainable city livability evaluation***. With this objective in mind and having adopted a constructivist epistemological stance, the dissertation was divided into two parts.

In the first part — the theoretical and methodological background —, it was possible to: (1) have an overview of the current situation of the real estate industry, especially in Portugal; (2) understand the need to guarantee sustainable and livable conditions in urban spaces; and (3) clarify the techniques and approaches used in the empirical component of the dissertation, which are cognitive mapping and the AHP. The analysis enabled the conclusion that the real estate industry is an important area for the economy of a country, seen as a market of great heterogeneity. Being a performance indicator of an economy, the real estate industry in Portugal is recovering, after having experienced the effects of the most recent international financial crisis. Nevertheless, it seems evident that Portugal is a country of inequalities in several dimensions of sustainable livability, such as wealth distribution, education and community wellbeing. Considering both these facts and the analysis made to several evaluation models, it was possible to recognize the research problem of this dissertation as a complex decision problem. Its resolution was only reachable by resorting to the MCDA approach, specifically by using cognitive mapping, which enabled to organize the ideas and reduce the number of omitted criteria in the decision-making framework; and the AHP approach, which was used to calculate the weights of the criteria identified during the structuring phase.

The second part — the empirical component — dealt with the definition, structure and evaluation of the decision model. First, cognitive mapping techniques were employed as a way to identify the criteria; second, the AHP approach was used to obtain the weights for each criterion identified. For this reason, it was necessary to invite a group of experts in the area of real estate who then participated in face-to-face group work sessions. At a later stage, in order to verify the consistency of the model, additional tests and complementary analyses took place, giving the experts the opportunity to adjust the final results and, in this way, reflect upon the effects of their judgment evaluation. Once the consistency and robustness of the model had been tested and validated, the decision-makers agreed that the methodologies applied in the study helped to increase the clarity and simplicity of the decision-making process, allowing recommendations to be put together.

With respect to the limitations that could be identified, the methodologies applied proved to have an impact on the scope of the study. First of all, it is worth noting the inherent difficulty in the selection of a group of decision makers due to constraints in terms of availability. Indeed, it was extremely hard to find experts in the area, with experience and available to participate in the group meetings.

In terms of the application of the JOURNEY Making approach and the elaboration of the cognitive map, the limitations became clearer during the sessions. They are: (1) initial uncertainty regarding the real contributions of the developed system; (2) uncertainty concerning the identification of the criteria based on their ideas, values and thoughts; (3) difficulty in writing just one criterion per post-it; and (4) insecurity in terms of the hierarchy of criteria. In addition, the application of the AHP approach demonstrated other type of limitations, namely in the construction of the descriptors and when projecting preferences, due to divergent opinions among the panel members.

All things considered, from the model created it is possible to identify several contributions. Indeed, it is a learning process, in the sense that the constructivist approach is conducive to reflecting on the evaluation made and to suggest adjustments. For this reason, the model makes it easier to measure the sustainable livability of a city, enabling future decisions that are well-thought out and more transparent. Nevertheless, it is important to emphasize that the model designed in this dissertation possesses idiosyncratic characteristics; this is why results cannot be extrapolated without proper precaution.

B. Managerial Implications and Concluding Remarks

The present dissertation corroborated how important the real estate industry is to the development of an economy, in both economic and social terms, revealing the high potential of this field of research. To this end, several methods commonly used to evaluate sustainable city livability were analyzed, even though they were mostly applied in an ambiguous and/or poorly transparent way. Nevertheless, these methods and their contributions were important to understand that there is not a perfect method. In light of this reasoning, it was considered logical and pertinent to complement the evaluation under study with the introduction and/or implementation of new approaches, which allow the limitations of the current methodologies to be counterbalanced. Therefore, the present study helped to confirm that it is possible to create a multiple criteria system to support the evaluation of the sustainability and livability conditions of a city, through the combined use of cognitive mapping and the MCDA approach. This study also adds value to the processes of formulating the model, via simplicity and transparency, which benefits real estate agents in terms of their strategic planning.

In practical terms, the model created enables to identify the best neighborhoods to live in, regarding its sustainable livability conditions. Additionally, it helps to identify which are the points of improvement. For instance, by analyzing the sustainable livability conditions of the eight Deltas, it was possible to conclude that Delta 2 is the neighborhood with the worst performance. For this reason, it is important to have a look into its partial evaluation regarding the different CTR. In this case, it seems clear that Delta 2 needs to improve the conditions of the following clusters: (1) *Building Infrastructures*; (2) *Political and Economic Environment*; and (3) *Urban Infrastructures*. Improvement initiatives can be formulated based on the information contained in the cognitive map developed.

C. Future Research

In hindsight, based on the results obtained with the present dissertation, the great potential of the multiple criteria approaches seems to be quite evident. Specifically, the incorporation of the decision makers' experiences into the evaluation mechanism enables the model to be robust, transparent and realistic. For this reason, real estate agencies — and, consequently, the economy — may also benefit from the MCDA approach, since it improves the strategic planning of their activity. Future inquiry and research may explore and highlight the advantages of carrying out similar studies resorting to different multiple criteria methods, such as Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), Multi-Attribute Value Function (MAVF) or Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), as well as doing comparative studies.

The need to expand the methodological approach used in this dissertation to other contexts is another interesting future course of action. Lastly, it would also be advisable to improve the model created within the framework of this study or its adaptation for online platforms, thus enabling the decision makers to evaluate, in a quicker, transparent and intuitive way, the sustainable and livable conditions of a neighborhood and/or city. In truth, any adjustment in the model will be seen as a step forward to support the evaluation of sustainable city livability.

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APPENDIX

APPENDIX

EVALUATION FORM OF SUSTAINABLE CITY LIVABILITY

Sustainable City Livability

Alfa ______

1. Classify, marking with a ball (O), sustainable development:

1.1. Regarding Bulding Infrastructures:

Inexistence of Potable Water or Extremely Inadequate Plumbing	1 2 3 4 5 6 7 8	Existence of Potable Water, with Extremely Adequate Plumbing and Excellent Pressure
Very Poor Distribution of Space	1 2 3 4 5 6 7 8	Excellent Distribution of Space
Excessively Small Areas	1 2 3 4 5 6 7 8	Excellent Areas
Extremely Inadequate Functional Construction	1 2 3 4 5 6 7 8	Extremely Adequate Functional Construction
Very Poor Quality of Construction	1 2 3 4 5 6 7 8	Excellent Quality of Construction

1.2. Regarding Services and Transports:

Total Absence of Schools	1 2 3 4 5 6 7 8	Great Offer and Variety of Schools
Inexistence or Very Poor Restoration Offer	1 2 3 4 5 6 7 8	Very Wide Offer and Variety of Restoration
Inexistence or Very Poor Waste Management	1 2 3 4 5 6 7 8	Excellent Waste Management
Total Absence of Coffee Terraces	1 2 3 4 5 6 7 8	Excellent Offer of Coffee Terraces
Inexistent or Inadequate Transport Network	1 2 3 4 5 6 7 8	Excellent Offer and Variety of Transport Network
Total Absence of Services	1 2 3 4 5 6 7 8	Excellent and Diverse Offer of Services
Total Absence of Cultural Offer	1 2 3 4 5 6 7 8	Excellent and Diversified Cultural Offer

1.3. Regarding Community and Surrounding Area:

Very Poor Solar Exposure (Shaded Area)	1 2 3 4 5 6 7 8	Excellent Solar Exposure
Area with Extreme Topographic Variations	1 2 3 4 5 6 7 8	Area with Insignificant Topographical Variations
Extreme Lack of Hygiene	1 2 3 4 5 6 7 8	Excellent Hygiene
Very Poor Reputation	1 2 3 4 5 6 7 8	Excellent Reputation
Very Poor Education	1 2 3 4 5 6 7 8	Excellent Education
Extremely Densified Area	1 2 3 4 5 6 7 8	Population Density Clearly Adjusted to Area
Very Poor Weather	1 2 3 4 5 6 7 8	Excellent Weather

1.4. Regarding Political and Economical Environment:

Value of Houses Extremely Inadequate	1 2 3 4 5 6 7 8	Value of Houses Extremely Adequate
Inexistence or Inadequate Legislation	1 2 3 4 5 6 7 8	Extremely Adequate Legislation
Extremely Low Personal Income	1 2 3 4 5 6 7 8	Very High Personal Income
Inexistence or Inadequate Urban Planning	1 2 3 4 5 6 7 8	Excellent Urban Planning
Severe Global Crisis	1 2 3 4 5 6 7 8	Very High Economic Growth
Inexistence of Potentialities	1 2 3 4 5 6 7 8	Numerous and Diverse Potentialities
Extremely High, Diverse and Inadequate Taxes	1 2 3 4 5 6 7 8	Extremely Adequate Taxes

1.5. Regarding Safety Aspects e Social Risks :

Bad Neighborhood	1 2 3 4 5 6 7 8	Excellent Neighborhood
Extreme Social Isolation	1 2 3 4 5 6 7 8	Very High Social Integration Index
Extreme Trash Accumulation	1 2 3 4 5 6 7 8	Total Absence of Trash
Extremely High Criminality Level	1 2 3 4 5 6 7 8	Total Absence of Crime
Extremely High Level of Insecurity	1 2 3 4 5 6 7 8	Extremely High Level of Security

1.6. Regarding Urban Infrastructures:

Inexistence or Weak Street Lighting	1 2 3 4 5 6 7 8	Excellent Street Lighting
Inexistence or Inadequate Parking Lot Offer	1 2 3 4 5 6 7 8	Very High and Adequate Parking Offer
Inexistence of Green Spaces	1 2 3 4 5 6 7 8	Extremely Adequate Green Space Offer
Inexistence or Inadequate Offer of Roadways	1 2 3 4 5 6 7 8	Excellent and Adequate Offer of Roadways
Inexistence or Inadequate Offer of Accessibilities	1 2 3 4 5 6 7 8	Excellent and Adequate Offer of Accessibilities

Thank you for participating!