MCDM Problem-Structuring Framework and a Real Estate Decision Support Model

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Abstract

The real estate selection process might be regarded as a typical Multi-Criteria Decision Making (MCDM) problem. With current literature concentrating predominantly on institutional investment decision making, additional effort should be directed towards studying inexperienced homebuyers who want to buy a property in which to live. In this context, authors have described the decision environment as a complex decision process with restricted access to property data, high financial burdens partially due to the illiquid nature of the investment, the unfamiliarity with the decision task and low transparency in information aggregation. Consequently, this situation could benefit from a more structured approach that assists homebuyers in their actions.

In order to guide the decision making process and provide a suitable support mechanism, it is necessary to first structure the problem and extract the required information. A thorough literature review shows that little guidance is available for MCDM problem structuring. Consequently, this research first proposes an MCDM problem-structuring framework to decompose complex problems into smaller parts. Foremost, the application is intended for high-involvement consumer products and services. This framework is derived from MCDM and methodology literature, where the former provides the elements that need to be defined in any MCDM problem situation, and the latter suggests suitable data collection and analysis methods to obtain the information. As a result, the first contribution to existing literature is the introduction of an MCDM problem-structuring framework, which consists of a carefully designed sequential exploratory mixed method procedure.

Next, following the proposed structure, the real estate selection problem in Majorca (Spain) is defined. Whilst providing the inherent problem elements and establishing a comprehensive list of evaluation criteria to assess luxury properties, the fieldwork also offers behavioural insights, contributing and supplementing existing real estate research. In particular, major misunderstandings and false assumptions during real estate agent and client interactions are observed, stressing the need to optimise communication and targeting strategies.

On the basis of the relevant real estate evaluation criteria, a dataset of alternative houses is created and subsequently rated by prospective luxury-homebuyers. This provides the basis for the third research focus, the construction of a decision support model for real estate selection. In accordance to the problem features and model requirements, the Evidential Reasoning (ER) rule is identified to offer a powerful and transparent evidence aggregation process, with the potential to have a superior performance than other methods in addressing the selection decision. Due to the ER rule's short history (2013), application studies in general are practically non-existing and unprecedented in the real estate domain. Therefore, the use of a modified ER model can provide the real estate literature with a prescriptive multi-criteria decision support mechanism, whilst simultaneously offering an application study for the MCDM community and other relevant decision analysis domains. In closing, modelling a real problem using the ER rule highlights the method's advantages and might in turn increase awareness, leading to more applications.

Declaration

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

Dedication

This research is dedicated to the memory of my beloved grandad, Horst Otremba, who passed away unexpectedly during the course of my doctoral studies. He was, and will always be the best grandad, who I miss every day for the rest of my life.

Acknowledgement

I am thankful to my supervisory team, Prof. Jian-Bo Yang and my co-supervisor Dr. Nathan Proudlove, who have guided and critically evaluated the progress of this research project. Particularly the long academic relationship with my main supervisor assured a smooth and concentrated research project.

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List of Abbreviations

AHP	Analytic Hierarchy Process
ANN	Artificial Neural Network
BD	Belief Distribution
DM	Decision Maker
DS	Dempster-Shafer
DSS	Decision Support System
ER	Evidential Reasoning
MAE	Mean Absolute Error
MAI	Mean Accuracy Indicator
MCDM	Multi-Criteria Decision Making
MODM	Multi-Objective Decision Making
MRA	Multiple Regression Analysis
MSE	Mean Square Error
PSMs	Problem Structuring Methods
RMSE	Root Mean Squared Error
SCA	Strategic Choice Approach
SODA	Strategic Options Development and Analysis
SPSS	Statistical Package for the Social Sciences
SSM	Soft Systems Methodology
TLF	Taguchi Loss Function
WBDR	Weighted Belief Distribution with Reliability

1 Introduction

This introductory chapter gives an overview of the research by presenting the main research questions and linking them to the overall aims and potential contribution to existing knowledge. Additionally, the research space and adopted methodology are introduced.

1.1 Introduction

Everyone from the individual to the high ranked executive is confronted with decision problems on a daily basis. Many decisions are made with little deliberation as they are repetitive, routine exercises or may not pose large risks, in terms of negative consequences. However, in unfamiliar territories, with potentially high resource demand, it is generally beneficial to go a little deeper into analysing the problem at hand. Accordingly, the need and desire to make comprehendible decisions in complex situations has led to a vast amount of research in decision science. In the real estate industry, the comparison and evaluation of properties constitutes such complexity, and can be thought of as a Multi-Criteria Decision Making (MCDM) problem. Therefore, this decision environment, with restricted access to property data, multiple evaluation criteria, high financial burdens and low transparency in information aggregation, should be studied in great depth. It is the less experienced homebuyers, rather than investors, who demand a more structured approach for assessing real estate.

1.2 Research Background and Rational

At present, the decision making process in the real estate domain is frequently simplified using rules of thumb to deal with high complexity. In fact, a widely held view is that homebuyers are still greatly reliant on intuition, do not follow a structured approach and acknowledge a limited number of property criteria. In this context, Kasanen et al. (2000) found that unaided decision processes typically exclude reasonable decision alternatives and evaluation criteria, hindering informed decision making. Inevitably, these capital-intensive investment decisions deserve a more thorough analysis of available alternatives.

Real estate studies, particularly those assessing decision behaviour and interactions between stakeholders, have been limited in the past. Most attention in literature is directed towards real estate investment decisions. Or, to put it differently, the predominant focus is on institutions and is closely related to asset pricing and their investment strategies, where the main objective is to explain housing prices or maximise returns. Hence, existing decision support models across the industry are centred on price, where it is this variable that predicts the value or performance of a particular property. However, from a homebuyer's perspective, a real estate cannot simply be reduced to the predicted market price; there are multiple other criteria, alongside price that need to be taken into account when comparing and assessing alternatives. Thus, the objective is to determine a comprehensive list of relevant performance indicators that play a role in comparing properties (in particular for this

study ‘luxury’ properties on the Spanish island of Majorca), as well as using this information to construct a MCDM support model. In more detail, homebuyers confronted with a complex decision environment, with limited guidelines on how to proceed and what factors to consider, would most certainly benefit from a transparent decision model that facilitates the aggregation of all relevant factors to determine property performance. Here, the Evidential Reasoning (ER) rule offers many advantages and provides a powerful, transparent evidence aggregation process, with the potential to have a superior performance to other models in addressing the real estate selection decision. Besides, it constitutes a great opportunity for the investigated problem context to develop a procedure that incorporates decision maker (DM) preferences and information. This can promote more objective and consistent decision making within the real estate domain. Thus far, despite many beneficial features, no existing research has attempted to tackle and solve real estate decisions with ER.

Of course, the researcher’s personal motivation to conduct this study also played a role in the topic choice. First, the family business concentrates on real estate developments in numerous locations across Europe, triggering the interest in real estate from a young age. From predominantly investing in and constructing luxury residencies, it naturally emerged that on both sides of the transaction, buyers and real estate developers are concerned with multiple criteria, which need to be assessed and considered when making decisions. This caught the researcher’s attention and curiosity on what constitutes the best path to approach a real estate selection. Furthermore, since many in-depth investigations of a phenomenon are built on empirical research, the access to data was a key motivation in choosing the research site. More precisely, growing up in Majorca and being given many responsibilities in the family business over the years, the researcher had built-up a network in the Majorquin real estate market, which is beneficial and greatly facilitates answering the research questions described in the next section.

1.3 Research Questions

This section discloses the main research questions. A detailed discussion is offered in Chapter 4, including the justification for each question, with reference to applicable literature and relevant sub-questions.

1.3.1 Academic Research Focus

There are a number of research questions concentrated on enriching the academic literature and adding to existing knowledge. For instance, the first research question (RQ1), **‘How is an MCDM problem structured?’**, intends to develop a framework that can be applied by researchers to find adequate support mechanisms or build tailored solutions. Hence, this first research focus has the potential to benefit the MCDM community, and, in particular, researchers who investigate complex decision problems of high-involvement products and services. Here, high-involvement products and services represent consumption items that are generally associated with higher investments, involve more research and are generally bought on an infrequent basis (Anon., 2015).

The second research question (RQ2), **'What is the luxury-homebuyer's decision making process when selecting a property in Majorca?'**, does not in itself provide academic knowledge. Yet, sub-questions herein may contribute to the real estate literature in terms of proposing a comprehensive list of relevant evaluation criteria for luxury real estate and constructing a logical, hierarchical structure of these elements. Additionally, new insights may emerge that supplement real estate behavioural studies.

Next, the third research question (RQ3), **'How can the real estate selection problem be modelled to allow transparent and consistent criteria aggregation?'**, essentially provides an application study of the ER rule, with a modified evidence combination algorithm that accounts for interdependencies among criteria. Considering the short history of the ER rule, this offers an innovative insight into the applicability to a real-life, complex decision problem and potentially emphasises the method's advantages over competing approaches. Also, with regards to the real estate industry, this application is unprecedented.

1.3.2 Practical Implications of Research

This research also yields a number of practical implications. Particularly, research question two, 'What is the luxury-homebuyer's decision making process when selecting a property in Majorca?', investigates current behaviour and discovers possible conflicts between decision stakeholders. This can for instance suggest modifications and improvements to realtors' communication and marketing strategies. In fact, the findings can provide indications as to what content to display on websites. On the other hand, adapting property viewings to the specific requirements of clients eliminates unsuitable properties and correspondingly reduces the total number of viewings. These implications can essentially encourage more efficient agency services.

Also, by simply providing a comprehensive list of potentially relevant property criteria might, at the very least, draw the homebuyers' attention towards frequently neglected items. As a result, this could promote the deliberate inclusion of some additional factors in the property assessments, or acknowledging them when viewing alternatives, and ultimately enhance decision confidence and satisfaction (Kasanen, et al., 2000).

1.4 Research Objectives

As described in the previous section, there are several research avenues. Three key contributions were identified in line with the aforementioned research questions, forming the overall research objectives.

The first objective is to develop an MCDM problem-structuring framework for complex decision situations assessing consumption products purchased infrequently and of significant investment size. The intention is to clearly outline and describe a research design that can be adopted to efficiently identify MCDM problem elements and consequently

increase the understanding of model requirements. This can then help to either find an existing MCDM method that has the required capabilities to address the problem at hand, or to state exactly what needs to be adjusted or developed to allow an accurate analysis.

The second goal is to apply the aforementioned problem-structuring guide to define the real estate selection problem, simultaneously serving as a validation tool for the framework. This fieldwork phase additionally provides valuable behavioural insights into the real estate industry, which can benefit various stakeholders. In other words other likely contributions here include an understanding of the decision behaviour and practice in luxury real estate purchases. For instance, since no attempts were made in existing literature to uncover relevant criteria in a luxury house purchase, this investigation provides a comprehensive list and simultaneously illustrates their approximate level of importance. As described earlier, simply stating and defining those criteria can draw attention to frequently neglected items and potentially enhance the level of satisfaction from the decision upon reflection. Also, real estate agents may learn from the fieldwork findings about their current communication strategies with clients and recognise some conflicts that can be optimised.

Then, the last objective is to apply the ER rule to the real estate selection problem. With the identification of problem elements during the fieldwork, the ER rule with a modified algorithm has great potential in supporting the complex evidence aggregation task. The inference model is constructed to estimate the most probable performance of different properties in a transparent way. This application study is unique in existing literature and provides a practical demonstration of a modified ER rule. Whilst the developed model is predominantly limited to the application in the research location, means of generalising the model to a wider geographical region are suggested towards the end of this thesis.

1.5 Research Scope

Majorca serves as the research site, where the target population is defined and a research sample is drawn. For the purpose of this research, the data collection concentrates exclusively on experienced or directly involved stakeholders in the selection process of luxury holiday or secondary residencies. To set the scene prior to data collection, the research context is introduced in more detail in the Chapter 7.

1.6 Methodology

The research starts with an in-depth literature review of the real estate industry and modelling mechanisms to comprehend the current situation, thereby identifying gaps and research avenues. This allows formulating research questions and highlights potential contributions that the investigation can produce. Apart, the literature suggests that MCDM problems are composed of a number of elements that need to be defined. In conjunction with knowledge on different data collection and analysis techniques, the best tools emerge for combining the two spectrums and, subsequently, allow the development of an MCDM

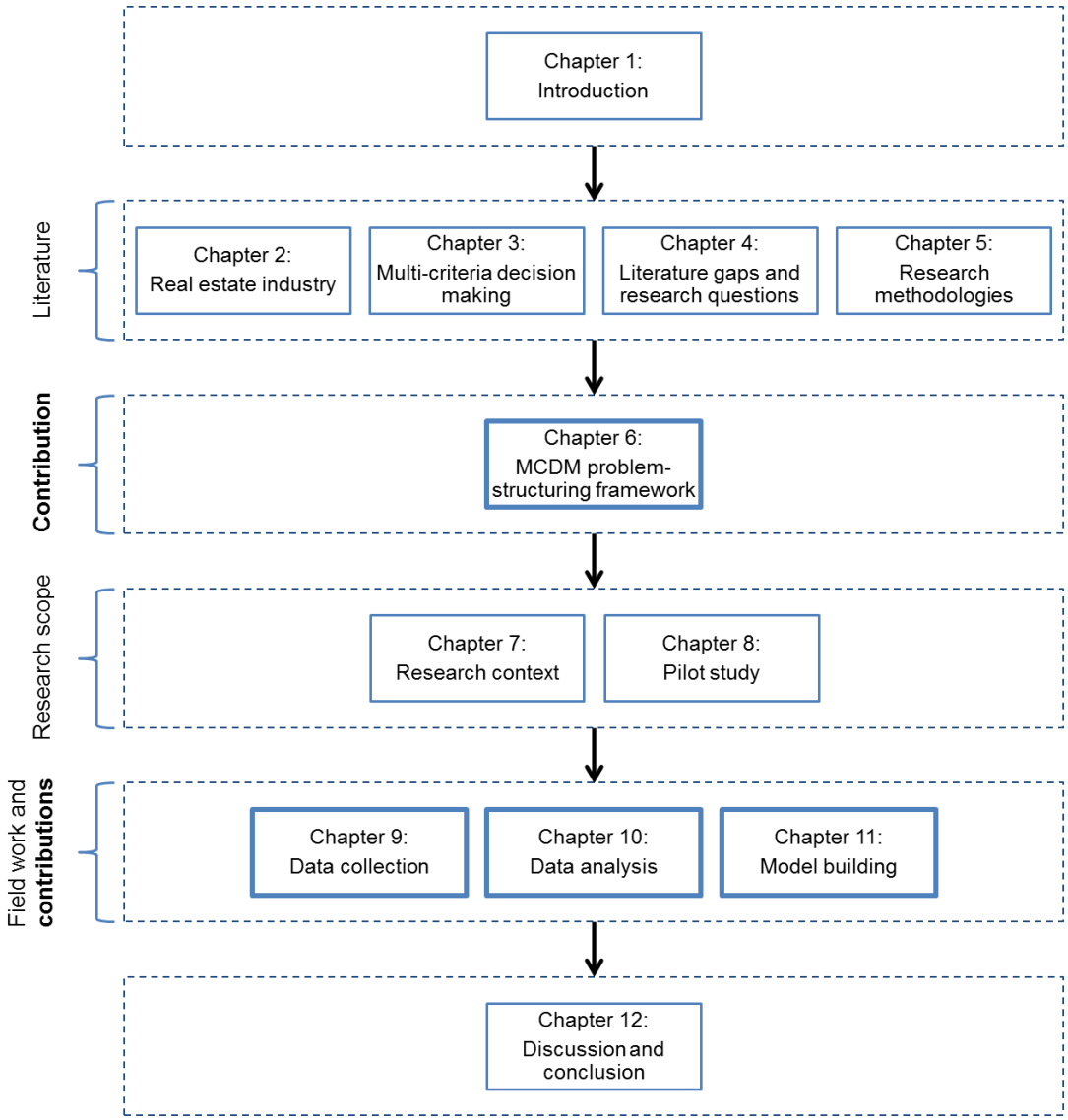
problem-structuring framework applicable for defining product or service evaluation processes. Whilst not limited to this purpose, the framework is foremost valid for various MCDM problems that focus on assessing high-involvement products and services. In sum, the proposed framework consists of a multi-stage, mixed method procedure to dissect an MCDM problem and extract relevant information to match or tailor a support method.

This proposed structure proves to be very useful in the field of real estate selection. Hence, after describing the research context and conducting a preliminary, small-scale pilot study, the researcher follows the outlined procedure during the fieldwork. In a nutshell, the data collection first comprises qualitative procedures: observation, in-depth, semi-structured interviews and a focus group (split into three sessions). With the obtained information, a quantitative online questionnaire can be designed and distributed. In the final stages of data collection, a finite set of alternatives to be assessed needs to be constructed. This involves databanks, real estate agencies and prospective DMs. The data gathered throughout the fieldwork then enables the construction of the ER rule model for decision support. With the introduction of the model, the final part of this research assesses the results and overall research findings, with the objective to extract and clearly present the research implications and contributions. The researcher also draws the attention to known research limitations and, with the concluding remarks, suggests possible future research avenues.

1.7 Thesis Structure

Whilst the previous section provides a good picture of the research progression, it is worth providing a graphical representation of the thesis structure. The succeeding figure describes the research project in six consecutive blocks and highlights the key thesis chapters (6, 9, 10 and 11) that produce the academic and practical contributions.

Figure 1, Thesis Structure



1.8 Summary

This introductory chapter emphasised the research motivations, focus and intended contributions. The second part then focused on the research methodology and provided the reader with an overview of the thesis structure. Correspondingly, the following four chapters review relevant literature, emphasise knowledge gaps and present the research questions defined in an attempt to provide both academic as well as practical industry contributes.

2 Real Estate Industry

This chapter reviews relevant literature in real estate, including decision making criteria and decision processes. Existing limitations are highlighted to justify and proceed with this research study.

2.1 Introduction

Great controversy exists among the various decision making techniques in real estate transactions. Throughout real estate literature, normative, descriptive and prescriptive theories are related to decision processes within the industry. In recent years, focus has shifted towards descriptive practices, which investigate actual actions undertaken by real DMs (Rapoport, 1994). Although many rational approaches are suggested, particularly emerging from the finance domain and with a focus on corporate real estate investment decisions, most authors draw attention to the violation of normative axioms during property evaluations. Following the discussion on decision making practices, it is necessary to investigate the criteria that have been associated and employed in property evaluations. Here, it is anticipated that literature concentrates on a few key factors, whilst neglecting to report a comprehensive list of influential decision criteria. Lastly, existing support mechanisms are reviewed and the connection to the MCDM field is established.

2.2 Decision Making Processes

Real estate acquisitions can be characterised as high-involvement goods that are accompanied by very complex processes with significant financial burdens (Daly, et al., 2003; Ratchatakulpat, et al., 2009; Anastasia & Suwitro, 2015), stressing the need to thoroughly study the decision making process. In particular, the heterogeneous nature of real estate requires the assessment of substantial information to determine a property's performance (Zheng, et al., 2006; Liu, et al., 2006). Sah et al. (2010) suggest that due to information deficiencies in the real estate sector, there is no evidence of a global normative model. In other words, the scarce data availability and imperfect information of property characteristics increase the relevance of the human element. For instance, the preference measurement models based on the normative utility theory seem inappropriate in the housing market, since decision problems are considered highly complex and DMs may exhibit certain cognitive limitations (French & French, 1997). French and French (1997), as well as Gallimore et al. (2000), concluded that final decisions are generally influenced by factors outside the boundaries of mathematical/normative models.

There are two distinctions within real estate decision making research. There are studies that focus on an investment perspective and there are studies that examine the decision making process of individual homebuyers, i.e. the end-users.

2.2.1 Real Estate as an Investment Opportunity

For investments in general, portfolio theory is probably the most prominent framework; however, for real estate investments, there is no widely accepted or applied normative model (Sah, 2011). In fact, a strong body of evidence exists claiming that the static normative models are rarely adopted in practice (Atherton, et al., 2008). Mostly, some practical techniques, such as return on investment or internal rate of return are computed and used in conjunction with investors' sentiment (Gallimore & Gray, 2002; Bispinck, 2012).

As described earlier, this research is motivated on providing insight into the decision making process of homebuyers, rather than investors, yet the immense literature on real estate investments should not be ignored. The most striking difference between an investor and a homebuyer is the purchase incentive. The former segment pursues the target of high returns on an initial investment, whereas the latter is more concentrated on tangible variables of a property. It is true that there are aspects that overlap in the two perspectives. The relevance of location may for instance be a good example. In this case, the location for the investor is key, since this aspect cannot be modified in any way and must be appealing to attract as many tenants or homebuyers as possible. Likewise, a homebuyer also tries to find the best location that suits his/her needs. Either way, both potentially put high significance on the location. This was confirmed by Ratchatakulpat et al. (2009), who compared property buyers with a motive to find investment opportunities to those wanting to buy a residential property to live in. Apart from indicating that location is essential for both buying groups, Ratchatakulpat et al. (2009) found investors assign even higher importance on excellent neighbourhoods, as well as other location related factors. Again, a possible explanation may relate to the invariable nature of location conditions, in contrast to other property components that can be changed. The evidence appears to support the assumption that investors usually prioritise fixed factors (i.e. location, age, structure), along with financial measures that indicate the efficiency of the investment, such as the net present value, inflation levels, payback time of investment and the internal rate of return, among others (Ginevicius & Zubrecovas, 2009; Sah, 2011). Here, the internal rate of return is often favoured as a return figure and is a widely used calculation in real estate context to measure the attractiveness of an investment (Atherton, et al., 2008; Bispinck, 2012).

2.2.2 Residential Real Estate

Compared to the investment decision above, it is anticipated that homebuyers are more emotionally involved with the property selection decision, carefully taking into consideration additional criteria. Also, from the end-user's perspective, the house purchase decision can be characterised as an infrequent task (Branigan & Brugha, 2013). A number of studies have investigated actual decision making in the real estate domain, highlighting key characteristics, difficulties experienced throughout the process and stakeholders involved, among others. The number of studies in this field is gradually growing, yet a predominant focus remains on investment decisions. Unfortunately, real estate behavioural studies of inexperienced individuals who want to buy a property, in which to live, are still relatively

scarce (Sah, 2011) and need additional attention in future. Particularly, investigations of prospective buyers' search behaviour need to be carried out (Zheng, et al., 2006). Evidently, this refers to descriptive decision theory (further discussed in section 3.2.2), studying real behaviour and providing a valid description of decision processes (Atherton, et al., 2008).

2.2.2.1 Decision Stakeholders

Unfamiliarity with a decision, accompanied by a substantial financial burden, often leads to consulting external sources to form one's opinion (Diaz & Hansz, 1997; Gallimore, et al., 2000). There are various parties involved in capital-intensive decisions. The most obvious contributor to search and selection tasks is the partner. Here, a household generally attends a high-involvement purchase jointly. Whilst this relationship is obvious, other stakeholders may play a smaller role. Real estate literature often refers to children, family members and friends, but also real estate brokers, valuers and lawyers.

2.2.2.1.1 Partner/Family Members

Frequently, the home purchasing decision is made jointly by a household/couple. Varying degrees of involvement were observed across different stages of the decision making process (Levy & Lee, 2004). This indicates that specific tasks may be more likely to be approached by either the wife or the husband, whilst there are also key stages that are reviewed together.

Levy and Lee (2004) investigated the roles individuals play in five separate stages. First, problem recognition is usually initiated by one family member who seeks a change. A product specification stage needs to follow to formulate the key choice criteria. Accordingly, whilst spouses primarily want to find an alternative that best meets their own preferences, they do simultaneously attempt to minimise conflict (Park, 1982). Key criteria that often include number of bedrooms, price and/or property type are most likely agreed upon prior to starting the property search process or contacting intermediary service providers, i.e. real estate agencies. Here, children often have an indirect influence, where the main DMs take their needs into account. Once agreement is reached, the information search phase to locate suitable properties begins. In upper-class families, it is believed that the woman may be more involved in this process. Alternatively, if one spouse does not work, he/she would have more opportunities to attend to the time consuming task appropriately. The information gatherer assembles knowledge from various sources and often initiates the first contact with a real estate brokerage firm. The fourth stage, alternative evaluation, is generally conducted jointly as it requires the inspection of chosen properties. Sometimes, other family members or friends are also invited to share their opinions at this point in time. Arguably, it is at this stage during which most of the disagreements emerge as individual's personal preferences are raised, creating conflicts. When progressing to property viewings, friction mostly occurs on salient subjective dimensions, like interior design. As a result, spouses need to resolve their differences through concessions, meaning the individual who puts lower intensity on

achieving their objective on the particular criterion compromises (Park, 1982). Finally, making a capital-intensive investment requires the consensus of both parties.

Although the research by Levy and Lee (2004) provides an insight into influence levels across different decision process stages and indicates that perhaps the woman plays a more important role in some stages whilst the majority of tasks are addressed together, it is questionable whether these findings are reliable. Concern is raised towards the study units (real estate agents) and sample size (nine). Agents, acting as the sole information source, might hold false assumptions about their clients. In fact, the authors stressed the need for further research that incorporates the actual decision making parties (Levy & Lee, 2004). Other observations suggest that family structures potentially dictate decision influences. Based on this argument, traditional arrangements have a higher tendency towards clearly defined feminine and masculine roles, with the husband generally dominating decision power. In contrast, modern families, or couples, usually share equal influence in important decisions. Another key indicator of the amount of influence a family member can exert on the decision is his/her interest in the purchase (Levy & Lee, 2004).

2.2.2.1.2 Real Estate Agents

In most countries, real estate agencies play a relevant role in the property selection process. Authors like Hardin (1999) and Zheng et al. (2006) emphasise this point. Frequently, open and easy access to the real estates is limited and individuals who wish to buy a property must go through an agent. Whilst this is part of the reason to involve the intermediaries, they also offer a range of services that ultimately aim to match a seller with a prospective buyer. These include, but are not limited to, the provision of property and location information, consultation, selecting suitable alternatives and arranging viewings (Urbanaviciene, et al., 2009). Evidently, there are many different occasions on which the agent directly interacts with the prospective homebuyer and is provided with the chance to assert influence (Kethley, et al., 2002). This raises concern considering intermediaries may purposely withhold information or deceive clients to score sales and obtain commissions (Zheng, et al., 2006), for instance by neglecting to inform clients of negative aspects. Often, the only resolution is to visit individual units to determine the quality in person, which inevitably increases search and selection time. Besides, inefficient communication and ignoring clients' preference, specifications when selecting a set of possible properties, can decrease consumer satisfaction and significantly increase search costs (Anglin, 1997).

Literature repeatedly stressed the need to address the interaction between realtors and homebuyers in future research to eliminate behaviour restricting successful search activities and finalising transactions (Hardin, 1999; Zheng, et al., 2006). On a related note, Hemphill (2007) found that there are certain discrepancies between agents and property sellers. Misunderstandings and false assumptions that are observed during their interactions often lead to unsuccessful property listings (Hemphill, 2007). This in turn raises the question whether this phenomenon is also observable between the agent and client.

2.2.2.1.3 Other Stakeholders

As briefly described earlier, children usually play a minor role in strategic decisions. If anything, opinions of older children are taken into account (15 years and older) (Levy & Lee, 2004). Other family members and/or friends that potentially can express their opinions through experience may be consulted when viewing the properties and comparing alternatives. Familiarity with the decision process and knowledge of the local real estate market potentially provides a first source for information and recommendations of satisfying agencies. Financiers are sometimes involved when assessing the available means, whilst lawyers are generally approached at a later stage, when a definite estate has been selected.

2.3 Decision Making Criteria

Selecting and identifying appropriate criteria is a challenging task. The authors that addressed this issue generally present an incomplete list with high inconsistency across studies. Additionally, practically no study fully justifies the adoption of a chosen criteria system. Table 1 summarises key contributions and research on real estate assessment criteria. For each paper, a description and the number of adopted/identified criteria is given, plus the research methodologies, possible limitations and identified further research avenues.

Table 1, Literature Review of Real Estate Evaluation Criteria

Author	Study description (study site)	Nr. of criteria	Methodology (sample size)	Drawbacks/study limitations	Proposed areas for future research
Branigan & Brugha (2013)	Examination of behavioural biases in residential property purchase decisions and the use of decision tools to improve decisions (in Dublin, Ireland).	24	- Case studies (4)	- Based on small study sample (4 DMs) - Decision tree constructed on researchers' perception rather than consulting DMs - Some bottom level criteria were too broadly defined (e.g. good facilities)	None proposed
Torres, et al. (2013)	Research on the locational preferences of residents (in Santiago de Chile)	10	- Survey (123) to identify 8 attributes most relevant - Interviews (10) to provide variable definitions	- Only 8 bottom level factors were identified to assess location preferences for flats - All (except price) were transformed into dummy variables	None proposed
Mulliner & Maliene (2012)	Development of a criteria system for housing affordability by first identifying relevant criteria and then determining the level of importance (in Merseyside and Cheshire, UK)	20	- Literature and interviews (7) to identify variables - Survey with housing experts (337) to validate criteria and elicit weights	- Focused on housing affordability factors - Considered only experts to define housing criteria - Calculated and used mean weights	None proposed
Haddad, et al. (2011)	Investigation of factors influencing consumer's apartment buying behaviour (in Amman, Jordan)	23	- Questionnaire (81)	- No explanation on how the criteria were identified and on what grounds they were organised into 5 categories - Focused on apartment criteria	Create criteria categorisations for other real estate types
Ratchatakulpat, et al. (2009)	Comparison between the level of importance of pre-defined factors in property purchases for personal use in contrast to those acting as investment vehicles (in Queensland, Australia)	35	- Survey of property buyers (376) - Sampling through real estate agencies - Content analysis	- Relied on existing variable groupings rather than own investigations (pre-defined list of criteria) - No measures provided (e.g. the criterion appearance seems too subjective)	Establish a more accurate set of factors and study criteria interdependencies
Kaklauskas, et al. (2007)	Methodology application to define utility and market value of a real estate (in Lithuania)	28	- Questionnaire with experts (35) to determine the criteria system and weights	- Focused on prioritising criteria, not identifying or validating the list of 28 criteria - Based entirely on expert opinion rather than end-users	None proposed

Author	Study description (study site)	Nr. of criteria	Methodology (sample size)	Drawbacks/study limitations	Proposed areas for future research
Kauko (2006)	Cross-country study of location attractiveness. Uses AHP to examine different preference levels between housing and location attributes across various housing consumers (in Randstad, The Netherlands and Helsinki, Finland)	8	- Semi-structured interviews with real estate professionals (39)	- The list of attributes was kept very general - Criteria selection based on existing literature - Neglected cost attributes entirely - No consideration given to homebuyers	Broadening the analysis to further contexts, i.e. geographical locations
Kim, et al. (2005)	Development and application of a housing performance evaluation model for multi-family buildings. Uses existing models for the construction and AHP as weight eliciting method (in Korea)	32	- Assessment of existing valuation models to identify housing performance indicators - Interviews with experts to extend list - Questionnaire with experts	- Identified three levels, whereas the bottom level criteria were very broad and some should be further broken down (e.g. convenience or adaptability) - Neglected cost attributes entirely - Based entirely on expert opinion rather than homebuyers - The geometric mean value was taken for the individual weights, - Alternatives' criteria values had to be transformed into four performance grades one by one	None proposed
Daly, et al. (2003)	Exploration of attributes that influence the value of residential properties from a buyers perspective and investigation of valuation methods employed by professional valuers (cross-national research in the UK, Ireland and Australia)	20	- Pre-interview questionnaire - Interviews with residential consumers (30) and practising valuers (15) - Informal interviews	- Focused on predicting the most probable/accurate price for negotiation purposes (property performance is dictated entirely by estimated price) - The study did not intend to list all criteria with an influence on a property's value - Factor labels were broad and hard to measure consistently (e.g. location)	Development of a valuation approach that reflects consumer preferences
Mills & Reed (2003)	Identification of drivers that affect DMs' property purchase behaviour (in Melbourne, Australia)	25	- Survey as interview format with first homeowners (81) - Sample reached at display homes	- Pre-defined list of criteria with no justification on why they were included - Factors affecting purchasing decisions were not clearly defined, i.e. no precise measures were provided	None proposed

Author	Study description (study site)	Nr. of criteria	Methodology (sample size)	Drawbacks/study limitations	Proposed areas for future research
Theriault, et al. (2003)	Hedonic valuation model to estimate housing price using neighbourhood quality and property specifics (in Quebec, Canada)	31	- Secondary data of bungalows (4040) split into model building and test set	- Variables used and expected to have a contribution to price were selected from existing studies	Building similar models for different market segments
Kettani, et al. (1998)	Construction of a descriptive model for real estate evaluation (in Alberta, Canada)	11	- Case study using properties sold during the year (108) - Relevant criteria identified by consulting a group of real estate agents	- Selling price was viewed as a function of housing characteristics, i.e. the performance of a property is dictated by the estimated price - Criteria identification entirely based on real estate agents	Develop interactive decision support systems and method to decide which set of criteria need to be included in an evaluation
Adair, et al. (1996)	Identification of variables that potentially impact the valuation process	26	- Regression analysis - Criteria were sourced from property, environmental and census data	- Assumption of independent variables - No explicit explanation for including certain variables, whilst excluding others	Price assessments using multiple regression analysis and neural networks
Ball & Srinivasan (1994)	AHP to elicit relative importance and rank alternatives (in Boston, USA)	17	- Case study (1 buyer)	- Based on a small study sample (1) - No explanation on how the criteria system and hierarchy was derived - Some broad criteria (e.g. aesthetics)	None proposed
Adair & McGreal (1994)	Behavioural study of house purchasers with focus on buyer mobility, search behaviour and factors influencing decision making. Intention to segment market to define submarkets (in Belfast, Ireland)	25	- Survey of individuals who had moved recently (506)	- Did not list all 55 variables that were presented to the sample of buyers (only 25 factors were mentioned) - The criteria selection justification and process was not provided	None proposed

*number of criteria includes the categories/groupings/upper level criteria that are assessed on a set of measurable bottom level criteria

The list of scholars, who identified relevant property criteria, is by no means exhaustive, but rather serves as an indicator for major inconsistencies and no common ground on a comprehensive list of evaluation factors. Whilst this definitely emphasises a gap within existing literature, it is worth reviewing some of the above studies in more detail.

Ratchatakulpat et al. (2009), potentially provided the largest list of criteria. Yet, the authors simply reviewed and condensed the research findings published by Daly et al. (2003) and Adaire et al. (1996) and subsequently investigated the level of importance of these pre-defined factors. Therefore, the most in-depth research can potentially be attributed to Branigan and Brugha (2013). They proposed a criteria tree with three distinctions at the top, price, actual house and resale value. The researchers themselves identified the relevant criteria and clustered these. Actual house and resale value were broken down into:

- Actual house consisted of the house description (size, condition and character), outdoor description (ease of extension, overlooked and garden type) and surroundings (easy transport, suitable neighbours and facilities).
- Resale value was made up of comparable sales, neighbourhood (safe area, aging population and recent upgrades to other houses) and future developments in the area (new transport plans, building plans and parking changes).

Whilst they asked participants to approve with the set structure prior to collecting further data, it may have been more accurate in explicitly including individuals, confronted or familiar with the decision, to construct the criteria tree. Also, bottom level factors here are still relatively broad and often require various aspects to be considered. For instance, it was suggested that the house character is described, and ultimately measured, by property features such as fireplaces, ceiling plasterwork and front door, among others simultaneously. In respect to consistent measures, a cross-national study revealed that location, for instance, is interpreted differently across DMs (Daly, et al. 2003), making it difficult to use this broad term when evaluating a real estate. Hence, to provide a meaningful structure, it is recommended to clearly define criteria measures.

Belton and Stewart (2002) argue that the explicit inclusion of all criteria that have some degree of influence on the overall decision objective has the potential to significantly reduce the level of regret upon reflection. Kim et al. (2005) support this view by emphasising that a real estate assessment should always constitute a systematic process, incorporating a variety of performance indicators. Similarly, whilst Kettani et al. (1998) suggests that the estimation of real estate price is heavily dependent on the right selection of criteria, this can be generalised to overall property performance. In other words, several scholars agree it is essential to discover the relevant factors for a coherent assessment. These literature findings suggest that further effort needs to be made in co-operation with industry experts and prospective homebuyers to establish a comprehensive list of relevant property evaluation factors and, correspondingly, develop a coherent hierarchy structure. Creating logical clusters of criteria can be very beneficial for the decision analysis (Ratchatakulpat, et

al., 2009). Therefore, variables should be broken down into smaller, measurable sub-sets, to reduce ambiguity during the assessment process and assure consistent measurement.

Another research focus in relation to real estate criteria is their prioritisation. The widely accepted notion is that housing consumers have unique preference sets and it is extremely hard to make any generalising statements. For instance, Kauko (2006) found that the majority of real estate professionals in Helsinki and Amsterdam believed that location is far more important than the housing characteristics. In contrast to this, the author recorded the opposite when they questioned experts in Randstad, who prioritised the house-specific criteria. Evidence suggest that while location does play a substantial role in choosing among real estate alternatives, it is by far not the sole contributor to the decision making process. Authors like Ratchatakulpat et al. (2009), also questioned the significance and assumption of location being the utmost important variable in real estate assessments. They conjecture that people generally aspire to live in a specific location, or express strong preferences towards a certain locations with a number of neighbourhoods that are perceived close substitutes, but that there are other critical factors (Anglin, 1997).

External characteristics such as size and sunlight, i.e. direction of the property, are often highly valued by homebuyers, making it worth investigating these factors further. Similarly, findings from in-depth interviews in Dutch cities indicate that there is a growing importance on housing features compared to location (Kauko 2006). To address the huge differences in weights, authors tried to use demographic information to potentially cluster more alike individuals in terms of preferences. Accordingly, Levy and Lee (2004) studied gender differences and observed that men generally express their preferences towards garage and office space, whilst their counterparts focus more on safety and accessibility attributes. Continuing the discussion on different homebuyer segments, buying purpose was also reviewed, indicating that this may exhibit some impact on the relevance and importance of factors (Ratchatakulpat, et al., 2009). Herein, investors may concentrate more on location aspects, whereas evidence offered by Mills and Reed (2003) suggests first-time buyers perceive location related factors as least important. Overall, existing literature does not provide a clear situation on real estate criteria prioritisations. Perhaps one can argue that some intrinsic housing characteristics have received more attention in the past than other factors, but preferences still vary substantially across individual DMs.

In conjunction with the above, it is worth mentioning that there is a distinction between criteria types. Some criteria must explicitly meet the DM's requirements in order to at least consider an alternative in the decision process. These evidently are assigned high levels of importance. For instance, a DM may specify that an acceptable property must have a minimum of three bedrooms and a garden. Such requirements are generally pre-defined by the involved DMs as "must-haves" prior to engaging in the high involvement decision (Park, 1982). The set of usually three to five factors represents minimum requirements and helps to first narrow down the list of potential properties. Other factors are seen in terms of trade-off,

where the absence of one feature can be compensated by the presence or proficient performance of another (Park, 1982).

2.4 Difficulties associated with the Decision Making Process

Thus far, from sections 2.2 and 2.3, it is clear that the real estate selection constitutes a difficult, subjective process, with an unclear set of relevant criteria.

The identification of all decision influencing factors is a first, indispensable step when confronted with a real estate decision problem. The currently adopted simplified strategies that neglect relevant factors to make the construct manageable (Argiolas, et al., 2010) are a real concern. Yet, determining all variables is far from being a trivial exercise, and should receive sufficient attention during problem formulation and modelling (Stewart, 1992). Adding to the complexity, information deficiencies in the industry often require homebuyers to rely on local knowledge or diverse external sources to make a selection. Besides, in this decision making context, it must be respected that priorities are DM specific and must properly be included in any process intending to determine real estate performances. This last issue particularly directs attention towards the human element in real estate purchases.

To summarise, the following points precisely emphasise the key concerns that researchers, analysts and DMs encounter in real estate decision problems:

- High number of potentially relevant evaluation criteria (section 2.3).
- DMs have in the past found it overwhelming to acknowledge a large number of influences, which has led to simplified strategies where relevant information is ignored to make the problem solving process manageable (Argiolas, et al., 2010).
- Limited information processing capabilities frequently forces the DM to adopt cognitive shortcuts (developed over time, i.e. experience), which has led to an array of inconsistent decisions in the past (Ball & Srinivasan, 1994; Sah, 2011).
- No support is available for homebuyers to systematically reach a decision.
- Some criteria have obvious correlations (Lindberg, et al., 1988). For instance, it is anticipated that price is negatively correlated with neighbourhood condition.
- Criteria may not be evaluated independently of one another (Lindberg, et al., 1988). For instance, it can be assumed that the price of a particular property is dependent on the view, whilst the view would not change as a response to any price variations.
- Typically, interactions with other stakeholders are observed (section 2.2.2.1.2).
- Agents may not act in the best interest of their clients, creating longer search times and frustration (Zheng, et al., 2006).
- There is limited access to property and location information (Zheng, et al., 2006; Sah, et al., 2010).
- Preferences vary across DMs (Kauko, 2006), leading to distinct solutions across different DMs.

- The critical human element makes normative theories inapplicable (French & French, 1997; Gallimore, et al., 2000; Atherton, et al., 2008).
- Usually a very large set of heterogeneous candidates are considered, making it practically impossible to obtain an optimal solution as set out in the normative theory (Guitouni & Martel, 1998).
- Despite the knowledge of the above, behavioural studies of homebuyers are limited (Zheng, et al., 2006; Sah, 2011).

Evidently, this highly complicated situation often leads to unsatisfying results. Any applicable decision support mechanism must acknowledge and be capable of handling the above difficulties in order to improve the unstructured process.

2.5 Existing Support Mechanisms

This section reviews the most cited evaluation methods associated with the real estate industry. First, a significant proportion of research in this area was conducted on valuation methods, where estimated price is the ultimate indicator of property performance. Non-compensatory tools, on the other hand, are less researched, but are very evident in practice. These simply are filtering techniques to reduce a large pool of properties to a more suitable set. Then, a connection between real estate and MCDM literature is established.

2.5.1 Valuation Methods

The majority of assessment guidelines are heavily focused on price predictions, i.e. market value estimations. This tendency may be the result of a large number of market players, such as appraisers, assessors, mortgage lenders, real estate agents, property developers, investors and other specialists or consultant that require formal real estate valuations in terms of estimating the most probable trading price of a building (Pagourtzi, et al., 2003; Selim, 2009). Consequently, existing valuation methods assume that property price is a function of a number of property characteristics (Kettani, et al., 1998). This subsection briefly presents the most applied and researched methods within a real estate context.

2.5.1.1 Direct Capital Comparison

The direct capital comparison, also simply referred to as comparable method, is the traditional and still most widely accepted way in assessing a property (Pagourtzi, et al., 2003). To value a particular property, appraisers, investors as well as homebuyers often use a reference approach, which reviews similar properties that have been sold relatively recently. In fact, valuers have been known to include neighbourhood trends and houses that are currently listed for sale on real estate websites (Larraz, 2011). In any case, the property in question is related to comparable real estates on a number of critical factors, and at the same time necessary adjustments due to notable differences are made (Daly, et al., 2003). These differences can range from variations in construction quality or size to property age.

The market value of the subject property is therefore a product of the prices of comparable, competing houses (Kaklauskas, et al., 2007).

The approach's simplicity promotes the high adoption in the industry, although researchers have their reservations about its reliability. The quality of the valuation heavily depends on the availability of recent, accurate and complete transaction data as well as the selection of the most appropriate variables (Pagourtzi, et al., 2003). In situations where the subject estate is too dissimilar to any properties on the market, using the comparable method is inappropriate. Thus, an assessor would have to allude to other valuation techniques such as the cost method computing the replacement cost (Pagourtzi, et al., 2003).

2.5.1.2 Multiple Regression Methods

Regression models have also been observed in the real estate context. Typically using selling price as the dependent variable, researchers tried to construct a regression with a set of independent variables (i.e. housing characteristics) that best describe the price. Hence, Multiple Regression Analysis (MRA) identifies the contributing impact of the chosen independent variables on the dependent one (Adair, et al., 1996; Monson, 2009). This can particularly offer real estate developers with valuable information about which property attribute has the most significant impact on price.

MRA was applied in a real estate context by authors like Lindberg, et al., (1988), Wolverton (1997), Anglin (1997) and Nghiep and Cripps (2001), among others. For instance, Lindberg et al. (1988) used MRAs to determine the housing characteristics that contributed to the property value. Here, 12 variables entered the final regression equation. Similarly, Nguyen and Cripps (2001) determined six property features to predict housing value, including living area, number of bedrooms, number of bathrooms, age, quarter when the property was sold and presence of garage. They contrasted the MRA model results to the predictive performance of an Artificial Neural Network (ANN). Conclusions indicated that MRAs only outperform ANNs when the sample size of existing transactions is relatively low. In another study by Wolverton (1997), plot value was the dependent variable and quality of view, plot size and steepness of terrain were used as value indicators (Wolverton, 1997). The findings suggested that plot price per square foot diminishes when increasing plot size or view (in terms of increased angle width). A different perspective was taken by Anglin (1997), who employed MRA in the real estate context to determine search behaviour. He used regressions to estimate the search duration by a homebuyer looking at the time spent as well as the number of houses inspected. The statistically significant variables here included prior information and its quality.

In relation to the above, only very small number of independent variables were included in individual models. Often a stepwise regression was used on a larger number of explanatory variables to identify the most contributing variables (Lindberg, et al., 1988; Pagourtzi, et al., 2003). Whilst the number of independent variables needs to be considered when

constructing the regression equation, MRA is also constrained by the imposed linear functional form. In real estate, this assumption of linear relationship is not realistic. For instance, it is expected that a property's age has a non-linear relationship with the value (Nguyen & Cripps, 2001). Overall, this method seems relatively restricted in its powers compared to other, more advanced techniques.

Closely related to the traditional regression models, but more advanced, hedonic pricing models can determine the inherent value of each criterion used to explain the dependent variable (Monson, 2009). More precisely, this valuation approach attaches a value to property features and the sum then provides the overall property value (Argiolas, et al., 2010). It can provide an indication of price increase or decrease when considering individual housing characteristics. To exemplify, Larraz (2011) predicted that the presence of an elevator has a positive effect on price by an 8.1% increase, whilst the absence of an elevator reduces price by 11.1%. Limsombunchai, et al., (2004) also constructed a hedonic price model testing seven input variables that were hypothesised to influence property price. In addition to the identification of variables, the authors defined a priori the direction of the variables' relationship to the dependent one. Although hedonic price models may record superior performance to traditional MRA equations, they may still not provide the best prediction performance in real estate, where independent variable interactions and non-linearity of data is observed (Limsombunchai, et al., 2004). Respectively, Selim (2009), who developed a hedonic regression and an ANN to predict housing prices, concluded that ANNs are valid alternatives that potentially have greater predictive power.

2.5.1.3 Artificial Neural Networks

ANNs in real estate are a more recent phenomenon. ANNs, as well as the hedonic pricing methods (section 2.5.1.2), try to estimate the estate's market value by replicating the assessors' thought processes (Pagourtzi, et al., 2003). In this case, a non-linear data driven modelling tool uses interconnected nodes that replicate the human learning process (Larraz, 2011). The network consists of three principal components. First, in a real estate context, the input layer carries the housing characteristics that are passed onwards to the second layer. This second layer may constitute one or multiple hidden layers, wherein the weighted summations function and a transformation function relates the input data to the output measure (Pagourtzi, et al., 2003; Limsombunchai, et al., 2004). The output layer provides the hosing price estimation (Larraz, 2011). However, before conducting a valuation, an ANN needs to be sufficiently trained with a dataset of already valued or sold houses. The training of the ANN essentially establishes price cues to certain characteristics (Larraz, 2011). This inevitably means that the quality and availability of data is a key indicator of the resulting model's predictive power (Liu, et al., 2006).

Real estate researchers have noticed the applicability of ANNs to the field, resulting in multiple application studies. Most frequently, a feed-forward backpropagation network was adopted, which is not only the most common structure, but also seems to be the most

appropriate one in real estate problems (Basheer & Hajmeer, 2000; Nguyen & Cripps, 2001; Selim, 2009). Nonetheless, the number of hidden layers and nodes varied across studies. Pagourtzi et al., (2003) used a dataset of 271 previously sold residential properties over a period of three months with seven variables in the input layer and the sales price in the output layer. For this particular situation, the optimal network architecture was achieved with six hidden layer nodes, as it possessed the minimum mean absolute prediction error. Limsombunchai (2004), on the other hand, conducted a comparative study between hedonic models and ANN systems. Different to the structure proposed by Pagourtzi et al. (2003), the ANN included three hidden layers, each with six hidden nodes. The direct comparison of model performance showed the ANN was more accurate in estimating real estate price. However, the author also stressed that some other scholars reached different conclusions. This inconsistency observed in relation to ANN's performance was also recognised and supported by Zhang, Patuwo and Hu (1998). They believe that there is great flexibility in choosing the model parameters and structuring the network system, which can adversely effect performance. Therefore, even these advanced artificial intelligence methods have their limitations that may restrict their applicability to certain situations.

Besides the large number of model components that need to be decided, if the analyst or DM needs to be able to justify the final recommendation, the learning output of an ANN system cannot be interpreted due to the lack of transparency in the hidden layer (Rossini, 2000). It is important that an analyst assess whether for a certain problem the costs do not outweigh the benefits when adopting the ANN method. Nonetheless, due to their potential and already wide application in real estate, a more thorough analysis of ANNs is provided in the next chapter (see section 3.5.3.2).

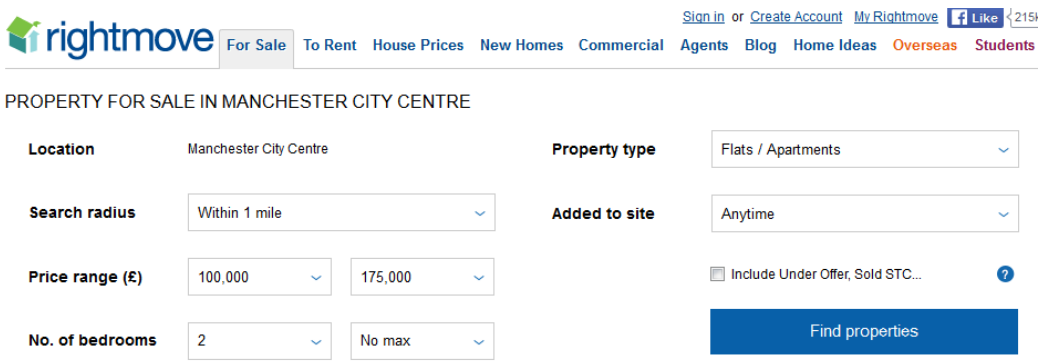
Undeniably, the described valuation techniques provide the homebuyer with important knowledge (i.e. the potential resale price) (Pagourtzi, et al. 2003); however, there are certainly other criteria that must be thoroughly addressed to identify the most suitable property to fully satisfy the DM's needs. In other words, the introduced models generally use price as the determinant of value, whilst "there are many exceptions to this reasoning" (Kim, et al., 2005, p. 1104), where acquisition price may well be a criterion among a list of others that define a real estate's overall quality. Homebuyers acquire a bundle of property characteristics (Lindberg, et al., 1988), where each combination provides unique benefit to different DMs. This again emphasises the human element that obviously plays a role in property assessments, generally ignored by the valuation mechanisms (Daly, et al. 2003). Correspondingly, French and French (1997) criticised the finance-orientated decision analyses for falling short in accepting human cognitive abilities. And Larraz (2011) suggested that even the existing price prediction methods are either lacking statistical soundness, or are far from being transparent.

2.5.2 Non-Compensatory Tools

Frequently used, and openly available to end-users, are filtering mechanisms provided by all major real estate agencies, as well as Internet platforms, to connect sellers with buyers. Some prominent platform based examples (also referred to as Multiple Listing Service systems), where multiple agents and sellers present their offerings (Kaklauskas & Gikys, 2005), are RightMove or Zoopla in the UK and ImmoScout24 or ImmoWelt in Germany. These methods are characterised as non-compensatory and aim to decrease the vast number of alternatives in the choice set.

Mainly the conjunctive method is applicable in this decision context, where candidates are eliminated from the choice set if they do not meet a set minimum level on the filtering criteria (Guitouni & Martel, 1998). To illustrate, Figure 2 below presents the prospective homebuyer with essentially five filtering options, namely the location and radius, price range, number of bedrooms and property type. The DM can then specify his/her requirements.

Figure 2, Search Engine RightMove.co.uk



Source: RightMove.co.uk (2016)

For the example above, using a realistic price range for a two bedroom apartment in the city centre of Manchester, the DM is still offered 208 alternative properties (on 31st of March 2016) that all fulfil the set standards (RightMove.co.uk, 2016). This is a relatively large set of decision options, requiring more thorough comparison. Clicking through each offering and trying to compare them is a daunting task with not much structure or consistency. Hence, the simple non-compensatory techniques account for some of the DM's requirements, yet neglect the inherent preferences and have limited power in providing valuable support for real estate selection (Argiolas, et al., 2010).

Noteworthy, in relation to non-compensatory methods in the real estate domain, Kethley et al., (2002) presented the Taguchi Loss Function (TLF) approach, which can actually create a ranking of alternatives that fall within set boundaries. Accordingly, TLF requires the DM to define a target value of each filtering variable, plus a limit that cannot be exceeded. For the properties that do meet the minimum requirements, a percentage loss from the target performance of each criterion is calculated. Lower variation from the set target is clearly preferred to large losses. Having obtained the Taguchi loss value, criteria weights are added

to derive a property's weighted loss value. This is a simple way to rank alternatives on a relatively low number of key property characteristics, enabling a more efficient selection of alternatives to be included for further analyses. Unfortunately, this technique is limited to filtering dimensions measured on a continuous scale, such as selling price.

2.5.3 Multi-Criteria Decision Making Methods in Real Estate

The link between real estate and MCDM becomes very clear when considering industry characteristics, current decision practices and the heterogeneity of real estate assets with the numerous criteria affecting an evaluation (Guo, 2010).

MCDM methodologies mostly take a prescriptive stance, offering guidance to increase search effectiveness and promote an efficient structure in order to sustain a degree of consistency (Stewart, 1992). Prior to conducting a formal multi-criteria analysis, non-compensatory methods are often a preliminary stage to create a suitable pool of candidates that meet extreme preferences (Ball & Srinivasan, 1994). All remaining alternatives can then be assessed on a multitude of identified and weighted variables to find the house that best meets a DM's preferences

In the real estate literature, the Analytic Hierarchy Process (AHP) is most applied, with other MCDM method applications practically non-existing. AHP promotes consistency by initially decomposing the problem into a hierarchical structure and assessing criteria directly competing with each other on a particular level in a pairwise comparison exercise (Ball & Srinivasan, 1994). Ball and Srinivasan (1994) for instance demonstrated how AHP can assist a DM in formalising a house purchase decision depending on a set of qualitative and quantitative factors. Similarly, Kauko (2006) used AHP in a cross-country analysis to elicit DMs' preference systems. He found that in Helsinki, location was perceived more important than the house-specific factors, whilst the situation was vice versa in Randstad. Kim et al. (2005) also did an extensive study and developed a model to improve housing performance analyses. They identified an extensive list of criteria from existing industry models and applied AHP to derive weights for each indicator. Then, they created a credit system (where weights were transformed into credit scores), enabling an alternative to yield a single performance score (with the maximum attainable credit being 1000). Prior to computing the final value, the alternatives' criteria were assessed on an overall performance grading scheme and it was determined to what degree each unit attained the performance levels. This last task however seems extremely time consuming and involves a lot of effort, potentially limiting the practicality of this approach. Finally, even AHP applications in the real estate investment domain were observed, where Fang and Yan (2011) built an evaluation index system.

Obviously, these numerous examples illustrate that AHP has been used extensively to deal with real estate issues. Yet, there are still other decision practices that dominate research efforts. Furthermore, the application of other MCDM techniques that may constitute a viable

or superior alternative to existing, applied approaches falls short in literature. Johnson (2005) is a proponent for further development of MCDM methods in real estate. Kaklauskas et al. (2007) share the same belief that MCDM studies with applications in this industry are still rather limited. In fact, MCDM provides a great opportunity for developing interactive procedures that successfully incorporate DM preferences and information into the decision making process. In summary, whilst there are definitely MCDM methodologies inappropriate for real estate decision making problems, there are most certainly other approaches to AHP that carry high potential in supporting such selection situations.

2.5.4 Decision Support Systems

Focusing less in this research project on the development of a Decision Support Systems (DSS), it is still useful to portray the current situation in the real estate industry. In general, the usage of information technologies is still extremely low compared to other sectors (Urbanaviciene, et al., 2009). Although different DSS software packages have been developed in the past for large-scale real estate modelling to improve investment decisions, little is known about their applicability, ease of use and consequently, their success within the industry (Trippi, 1990). Moreover, the behavioural biases eminent in such decisions possibly explain observed resistance towards applying decision tools (Branigan & Brugha, 2013). Therefore, although not central to this research project, a potential future research avenue includes the development of computer-aided systems, to effectively and efficiently support the real estate decision making process in practice (Kettani, et al., 1998).

2.6 Summary

This chapter introduced the reader to the real estate industry and existing literature on decision making behaviour and processes. Herein, key characteristics and challenges that are inherent to real estate selection were identified, including a large number of evaluation criteria, indication of strong interdependencies among criteria and very unique preferences across DMs. Also, an initial linkage, and the great potential of MCDM was presented. It is for this reason that the next chapter focuses on MCDM. Methods are described that can cope with the identified requirements and satisfy the researcher's objective in providing a transparent assessment model.

3 Multi-Criteria Decision Making

A real estate constituting a bundle of criteria, it is only natural to review MCDM literature. Consequently, in relation to the problem investigated, this chapter examines relevant MCDM methods that have already been applied, but also those portraying great potential in the real estate context.

3.1 Introduction

The beginning of MCDM, as a distinctive field, dates back to the 1960s and 70s (Xu & Yang, 2001; Belton & Stewart, 2010). Particularly during the 1980s and early 90s, its development accelerated substantially with an exponential increase in interest experienced in more recent years from researchers, as well as practitioners (Mardani, et al., 2015). This trend can, to a degree, be explained by the large number of decisions, which fit the multi-criteria conception (Dodgson, et al., 2009). Essentially, an MCDM method searches for the best alternative among a set of alternatives, frequently with the objective of generating a ranking of the decision options (Sönemez, et al., 2002). Alternatively, analysts appreciate the support in making comparisons among alternatives to justify a selection (Cinelli, et al., 2014). Due to today's increasing multifaceted choices and complex decision problems, MCDM methods have been promoted by influential authors, such as Zopounidis and Doupos (2002), Steuer and Na (2010), as well as Belton and Stewart (2010), who believe the available evaluation techniques are gaining popularity and are applied in practically every discipline today.

Prior to addressing MCDM in terms of core features, problem structuring and relevant decision methods, it is worth reviewing the decision theory and placing MCDM within this grand field.

3.2 Decision Theory

Decision theory has been examined extensively in the past. It studies decision behaviour and approaches, which aim to explain and assist decision making. Over time, three distinctive domains evolved, namely normative, descriptive and prescriptive decision theory. Normative theory, also known as statistical decision theory, presents ideal decision processes that should be used by the rational individual to attain an optimal solution (Brown & Vari, 1992). Descriptive theory, on the other hand, concentrates on behaviour observation and highlights actual practices. Prescriptive theory uses a combination of normative theoretical foundations and descriptive discoveries to develop decision support models, which aim to improve current decision practices by offering some structure whilst permitting flexibility to incorporate DM specific characteristics.

3.2.1 Normative Decision Theory

Normative decision theory is the focus of many investigations assuming structured decision behaviour (French & French, 1997; Baron, 1985). They provide rigid rules that should be

followed in order to act rationally (Over, 2004). Hence, normative models are developed on the notion of rationality in the economic sense (i.e. utility maximisation), as well as optimality (i.e. maximising or minimising a measurable outcome) (Einhorn & Hogarth, 1981). Many theoretical model developments resulted from these assumptions (Wierzbicki, 1997) and have the main goal of finding the absolute best option in terms of measurable performance (Baron, 2007). Based on this argument, the best option refers to the choice that does the most good (Baron, 2004). One of the most significant developments within the normative decision domain is potentially the utility theory, introduced by Neumann and Morgenstern in 1944 (Larichev, 1999). The main message conveyed by utility theory is that any DM chooses the decision option that maximises his/her utility. That is, the overall or expected utility is computed using the probability of a state or outcome occurring and its respective utility (Baron, 2004).

Rationality, being at the centre of the normative decision theory literature, presumes that all relevant and accessible data is known, well defined preferences exist and DMs are fully informed and have unlimited computational capabilities. Thus, normative theory concentrates on how idealised, rational DMs should behave in a precisely defined context (Rapoport, 1994); eliminating any cognitive aspect that may play a role in decision processes (Bell, et al., 1988). Criticisms of this rationality notion are widely evident. For instance, Simon (1955) reviewed the concept of 'the economic man' of classical decision theory and argued actual decision processes are far from any normative rule. Foremost, he suggests that the term rationality has been ill defined and is not suitable as a foundation for theory or model development. Fishburn (1981) supported Simon's view by acknowledging DMs often violate normative theories, such as the expected utility decision rules. In fact, the utility theory never obtained a descriptive or even prescriptive status. In general, the conditions or assumptions on which normative models are constructed are often far from reality, questioning their effectiveness. Likewise, Saaty (2005, p. 346) argued that once normative techniques are introduced to solve an array of decision problems, they "are likely to become obsolete" over time, stressing the importance of acknowledging emerging trends, as well as the "biology and psychology of people". Above all, circumstances are generally far from ideal and human actions deviate significantly from set norms (Weber & Coskunoglu, 1990; Rapoport, 1994; Weirich, 2004). The imposed frameworks by normative models limit individuals' flexibility and instinct (Tsoukiàs, 2008). Evidently, these concerns question the validity of the rational approaches.

3.2.2 Descriptive Decision Theory

Whilst "normative models are an idealisation" (Baron, 2004, p. 26), descriptive decision theory presents actual practices adopted by DMs and analysts. Or put differently, a descriptive theory implies how decisions are made under specific conditions (Rapoport, 1994). The descriptive domain is therefore concerned with DMs' thinking and reasoning processes (Over, 2004), providing some insight into how people may behave in sufficiently precise defined environments without decision aids (Keller, 1989; Rapoport, 1994). In fact,

researchers recognising this perception know the importance or presence of subjective judgements and intuitive thinking (Panagiotou, 2008).

The rational approach to decision making proposed by normative theory has increasingly been challenged by behavioural decision theory. For instance, Kunreuther et al. (2002), as well as Samuelson and Zeckhauser (1988), presented various cases in which DMs depart from the recommended normative rules. Herein, they describe how DM have an excessive focus on short term consequences, follow established social norms, prefer status quo and/or are influenced by emotions at the time of decision making (Samuelson & Zeckhauser, 1988; Kunreuther, et al., 2002). In this context, Kahneman and Tversky (1979) established the prospect theory that acknowledges the effect of different risk attitude levels when facing possible gains or losses. In other words, a DM's risk appetite is said to vary depending on the decision situation and the potential outcomes. Furthermore, the two authors identified the certainty effect, describing how individuals have a tendency to put more weight on sure outcomes rather than probable ones. Empirical work highlighted that this preference pattern frequently resulted in a different choice compared to expected utility calculations (Kahneman & Tversky, 1979). Also interesting, Wierzbicki (1997) found in situations where the DM acts as an expert in the field, he/she is more likely to mistrust and, in turn, violate standardised decision rules.

As a response to the definition of rationality under the normative theory, Simon (1955) introduced 'bounded rationality' as a new means of thinking about the DM. In contrast to the normative concept, bounded rationality accepts certain limitations associated with the DM and problem situation, such as computational capabilities, information access and processing and time constraints (Panagiotou, 2008). Consequently, under Simon's definition, a DM truly acts rationally in light of his/her capabilities (Simon, 1955). This perspective evidently provides greater flexibility to decision model developers. Nonetheless, consulting descriptive theories does not offer assistance in decision making, since there is no explicit guidance on how to improve decision processes, it merely describes actual observations (Keller, 1989; Weber & Coskunoglu, 1990).

3.2.3 Prescriptive Decision Theory

Prescriptive theory takes into account that it is often hard or even impossible to determine what is the ideal solution and its corresponding rules, which ought to be followed (Over, 2004). In essence, Baron (2004, p.21) regarded the prescriptive theory as an "applied field, which tries to design and test ways of curing psychological disorders". Hence, prescriptive models or rules have the aim to provide guidance to approximate normative ideals, and are arguably more applicable to today's complex decision problems. In this sense, final recommendations are essentially not optimal due to various conflicts, but rather adopt a satisfactory condition (Guitouni & Martel, 1998; Panagiotou, 2008). Respectively, DMs are 'satisficer', who have a set target in mind and aspire to reach the desired level (Köksalan, et

al., 2013). Once a solution satisfying all demands is found, a DM accepts it and terminates further effort to attain the optimal condition.

Overall, prescriptive frameworks are specifically designed for a particular situation, bearing in mind normative constructs and descriptive reasoning patterns. The focus is on developing a decision support model in form of a human activity system that can be used by 'real' people and specifically requires DM involvement, rather than a static algorithm (Brown & Vari, 1992; Baron, 2007). Continuing the discussion, when constructing prescriptive tools it has been emphasised to use normative foundations to approximate ideal solutions in combination with behavioural insights gained looking through the descriptive lens. It is believed that both extremes provide valuable insights to construct and enrich decision theory (Rapoport, 1994). Observing and understanding the currently preferred way in solving a decision problem is key to identify and overcome some of the human shortcomings involved in the process.

With regards to the willingness of using proposed prescriptive instruments, it is assumed experienced DMs often follow their intuition and reject normative rules or prescriptive strategies (Wierzbicki, 1997), whilst individuals confronted with a high-stake decision or new to a specific task would appreciate prescriptive guidance to come close to an ideal solution. To promote adoption and assure satisfaction, French and French (1997) propose that a prescriptive support methodology should, among others, have clear model assumptions acceptable to the intended users, be transparent to comprehend the process steps and be compatible with the DMs' philosophy.

Having established a foundation of the three decision theories, it can be suggested that there is an increasing relevance of applicable prescriptive models. Thus, MCDM techniques, with a primarily prescriptive nature, aim to support and tackle complex problems including numerous conflicting criteria, which have to be considered simultaneously (Hallerbach & Spronk, 2002; Belton & Stewart, 2002). Xu and Yang (2001) suggest that, with further technological advancements, MCDM as a discipline further increases in importance for prescriptive decision aids. Finally, it should be noted that there are some models, such as multi-objective programming or goal programming, trying to maximise or minimise multiple objectives subject to certain quantitative constraints that are located within the normative frame.

3.3 MCDM Problem Elements

All MCDM problems have some key elements in common, which need to be discussed prior to presenting problem structuring techniques and describing individual methods. First of all, the prevailing aim of any methodology within this domain is to offer guidance to DMs in determining the most suitable courses of action in accordance to his/her needs and underlying beliefs (Stewart, 1992). Thus, MCDM problems essentially assess alternatives (i.e. decision options) on a set of criteria (Triantaphyllou, 2000; Hallerbach & Spronk, 2002).

The alternatives are viewed as the courses of action a DM can pursue (Corner, et al., 2001). One differentiation exists in that some problems cover a finite number of alternatives and others are associated with an infinite number of decision options (Dodgson, et al., 2009; Branigan & Brugha, 2013). Mostly, addressing decision problems intended to generate an assessment or create a ranking, constitute a predetermined choice set. The latter description of an infinitive list refers to multiple objective optimisation problems, which are not further examined as it is beyond the scope of the current research project.

Evidently from the name, all MCDM problems are characterised by multiple criteria. Corner et al. (2001) define this concept as the means by which alternatives can be judged. For the purpose of this research, the term criteria is used interchangeably with attributes, variables, pieces of evidence, performance indicators or decision factors. Criteria enable an insightful assessment of alternatives and determine the degree to which these satisfy established objectives (Corner, et al., 2001; Keeney & Gregory, 2005). The various decision aids within the MCDM domain decompose a complex problem into smaller pieces to facilitate the analysis (Barfod, 2012; Branigan & Brugha, 2013; Mardani, et al., 2015). Grouping criteria may greatly enhance transparency and the understanding of decision components in light of the overall objective, especially if a decision problem constitutes a large number of different criteria (Dodgson, et al., 2009). Accordingly, criteria are commonly organised in a hierarchical format, with broad criteria potentially being further broken down into sub-criteria (Stewart, 1992). A set of basic or lower/bottom level criteria that can be measured are used to describe the performance of the associated general/upper criterion in the level above (Yang & Xu, 2002a). Across a variety of MCDM problems, pieces of evidence often stand in conflict to each other (Xu & Yang, 2001). In addition, they are of hybrid nature; meaning criteria may have incommensurable units, i.e. different measurements (Mustajoki & Hamalainen, 2005). For instance, evaluating a house, the garden size is expressed in square meters, whereas the maintenance costs are measured in pounds or euros. In fact, there is usually a mixture of qualitative and quantitative attributes.

Adding to the complexity, criteria have different level of importance in assessing the overall performance of an alternative. It is the DM's task to define criteria weights to infer relative importance on the decision. In most cases, this is a subjective scoring procedure, with different levels of importance across analysts. Accordingly, in almost all MCDM methods the DM is required to act as an active contributor to solve the decision problem and to derive the most appropriate compromise for him/her (Guitouni & Martel, 1998; Ishizaka & Nemery, 2013). As a result of incorporating individuals in the structuring and analysis process, and particularly by adding preference information, multi-criteria assessments may not be conclusive, contrasting heavily to the normative science. Another common feature in MCDM problems is uncertainty. Naturally, evidence in itself is uncertain as it may be incomplete, possibly completely or partially incorrect and/or the knowledge source potentially has a restricted view on the whole situation leading to reduced reliability (Guo, et al., 2008; Lowrance, et al., 2008). Essentially, uncertainties can arise from imprecise, incomplete,

vague, and/or missing data, or be a result of subjective judgements (Xu & Yang, 2001). Finally, a condition that has not been widely incorporated into MCDM methods, yet frequently observed in real-life problems, is the relationship among evaluation criteria. Currently, dependencies and correlations are rarely acknowledged in decision analyses, probably significantly affecting the outcomes and respective recommendations.

3.4 Problem Structuring

Selecting the most relevant MCDM approach out of the large pool of available methods is often a challenging task. Each technique has its own unique theoretical background, properties and abilities to assess criteria, compute weights, describe the DM's preference set and cope with uncertain parameters among others. On the other spectrum, different decision problems also have very unique requirements. For these reasons, it is obvious that both the problem and the methods need to be fully understood to match them together (Cinelli, et al., 2014).

The problem formulation needs to be very precise in combination with a focused selection of a suitable MCDM method. The implementation of these two tasks must be to the highest standards possible to derive a truthful recommendation (Ozernoy, 1992). Nonetheless, most publications within the MCDM literature focus on selecting appropriate methods by assessing the techniques themselves on a number of quality criteria (De Montis, et al., 2004), rather than to first dissect and understand the decision problem fully (Baron, 2007). For instance, De Montis et al. (2004) explore the differences between MCDM methods by determining a set of criteria to assess approaches and determine the strengths and weaknesses (De Montis, et al., 2004). Whilst this may give an insight into the elements and capabilities of MCDM methodologies, researchers and practitioners often eliminated methods from the selection pool based on time constraints and the nature of the input data; hence, ignoring the significance of problem formulation (Franco & Montibeller, 2009). Even more concerning is that they often adapt the decision situation to a particular approach, rather than the other way around, and the resulting problem definition is the consequence of the available method (Guitouni & Martel, 1998; Hanne, 1999). In this context, Cinelli et al. (2014, p.146) stated "the selection of MCDM method is dependent on the familiarity and affinity with the approach rather than on the decision making situation under consideration". Also, in situations where non-experts engage with MCDM models, the ease of use is a key selection criterion (Hanne, 1999). As a result, analysts are frequently incapable of clearly justifying their method choice (Guitouni & Martel, 1998).

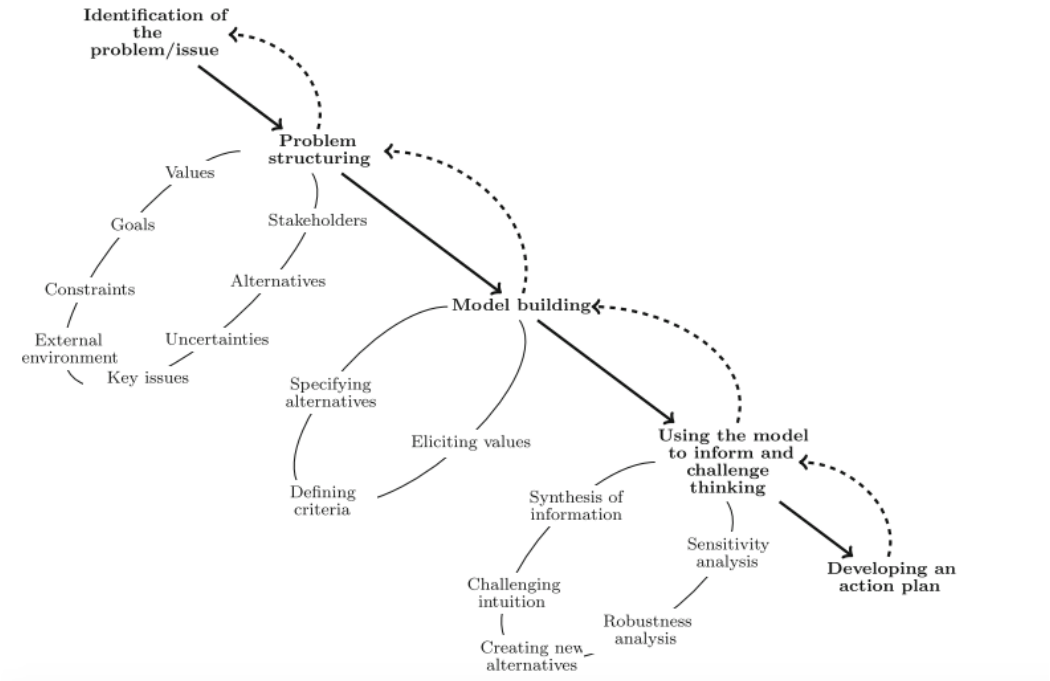
3.4.1 MCDM Problem Structuring

Potentially one prominent problem structuring approach within the MCDM domain was defined by Saaty (1990) in the early 1990s. He demonstrated a top-down approach, which consists in first outlining an overall-objective, connected to assessment criteria to assess the decision alternatives listed at the bottom (Maier & Stix, 2013). Hence, he directly associates

problem structuring with deriving a hierarchical or network structure (Saaty & Shih, 2009). Despite Saaty's proposition presented along with the AHP, around that time there was relatively low emphasis on focused problem structuring in an MCDM context (Franco & Montibeller, 2009). More recently, increasing attention has been devoted towards this necessary and key task. Baron (2007), Franco and Montibeller (2009), as well as Belton and Stewart (2010), stress the importance of first understanding a problem before attempting to solve it. Corner et al. (2001), as well as Von Winterfeldt and Fasolo (2009), also note that defining the initial problem clearly to facilitate decision modelling and analysis is the hardest, but most important task in decision making.

Belton and Stewart (2002) refer to the problem structuring as an integral part of MCDM, and developed a graphical representation of a typical MCDM process with five stages (Figure 3). The framework, presented hereafter, again emphasises some of the generic MCDM characteristics presented previously.

Figure 3, Problem-Structuring Framework



Source: Belton and Stewart (2002)

Considering the framework, Belton and Stewart (2002) attach eight aspects to the problem structuring task. However, reviewing the loop connected to model building, it is debatable whether some of the three tasks (specifying alternatives, defining criteria and eliciting values) may not better be placed under the heading 'problem structuring'. Arguably, the identification of criteria is important in the course of problem structuring (Keeney & Gregory, 2005). Also, it is unclear if the authors adopted an alternative-focused thinking, meaning a fixed set of decision alternatives leads to the definition of evaluation criteria, or whether they acknowledge that alternatives and criteria are interlinked, as suggested by Corner et al. (2001). With regards to the five stages identified by Belton and Stewart (2002), scholars

such as Ozernoy (1992), as well as Guitouni and Martel (1998), also previously suggested that the MCDM methodology is best divided into individual steps; firstly, focusing on structuring the decision problem, then formulating a preference model and finally assessing the options to provide recommendations for a rational decision. Thus, whilst it is clear that problem structuring is acknowledged as a separate part of the MCDM process, understanding the tasks to be performed and the specific data that needs to be collected to structure the MCDM problem is relatively imprecise.

Focusing now exclusively on the problem structuring stage, the decomposition of a complex problem into separate smaller parts has the potential to increase transparency and processing capabilities (Maier & Stix, 2013), and should therefore be the focus of problem structuring literature. Some authors point towards three key phases to obtain required information. Generally, brainstorming with stakeholders is proposed as the first step. Franco and Montibeller (2009) and Barfod (2012) see the importance of integrating all stakeholders in the problem structuring process. As a next step, Belton and Stewart (2010) suggest representing the issue graphically, which is then reviewed by the analyst and the stakeholders in the final stage. Similarly, Franco and Montibeller (2009) also proposed a three phase process to frame an MCDM problem most effectively. As noted above, they too believe the first step is to concentrate on defining and acknowledging key stakeholders. Subsequently, focus shifts towards identifying basic attributes using a bottom-up or top-down approach, whilst simultaneously recognising the decision options to be assessed. The evaluation process, including the provision of an overall performance score, is thought to be the final phase of the decision analysis (Franco & Montibeller, 2009). Whilst the first two phases intend to structure the decision problem, it is believed the last phase may already be outside the structuring exercise.

Research presented by Maier and Stix (2013) potentially provide the most detailed step-by-step process in structuring an MCDM problem, however their focus is exclusively on the criteria definition and the hierarchical display using card sorting procedures, ignoring other key components. Corner et al. (2001) also contributed to problem structuring literature by identifying that criteria and alternatives interactively generate each other. Principally, greater transparency of an investigated decision problem and the corresponding process, places the DM or analyst in a better position to identify the required modelling and support mechanisms (Kasanen, et al., 2000).

3.4.2 Other Problem Structuring Methods

Traditional problem structuring methods (PSMs) frequently mentioned in operational research literature include, most prominently, strategic options development and analysis (SODA), soft systems methodology (SSM) and strategic choice approach (SCA) (Von Winterfeldt & Fasolo, 2009). All of which include visual maps to capture stakeholders' interpretations (Lami, et al., 2014). Hence, PSMs are primarily concerned with group decision making, where multiple perspectives need to be drawn together to derive a

collective understanding and single formulation of the problem (Mingers & Rosenhead, 2004); they are techniques to assist negotiation and achieve agreement (Eden & Ackermann, 2006).

The first step in SODA, SSM and SCA has the purpose of probing for the real problem and understanding the inherent purpose attached to the problem by the various stakeholders (Von Winterfeldt & Fasolo, 2009). Differences between the three methods are recognised within the visualisation process. SODA uses 'cognitive maps' as a modelling device, capturing concepts that the DMs associate with the problem (Lami, et al., 2014). In contrast to SODA, SSM requires the analysts to draw 'rich pictures' to illustrate DMs' views (Mingers & Rosenhead, 2004). And SCA constitutes a planning approach that originally provided an interactive decision medium by generating graphs and grid drawings on flip charts. Whilst all PSMs introduced herein are widely applied in practice and facilitate the exploration of a problematic situation, they have been criticised for being too 'artistic' (Maier & Stix, 2013) and have not directly been developed to handle the complexity involved in MCDM problems. Thus, visual maps may in some situations offer powerful tools to provide initial understanding, emphasis key areas of concern, highlight element interactions and agree on the problem focus, but when confronted with large MCDM problems, visualisation often gets too messy and difficult.

3.4.3 Research Gap

Overall, there is the need to go deeper into the topic and explore potential techniques in identifying and extracting all the decision problem components. In particular, multi-criteria problems are generally messy and the various elements need to be defined within the particular decision context (Belton & Stewart, 2010).

In the early 90's, Brown and Vari (1992) already acknowledged the urgency of exploring problem structuring techniques in greater depth. They emphasised the need to establish assessment frameworks for specific context situations in order to avoid solving wrong problems (Brown & Vari, 1992). Similarly, Corner et al., (2001) stressed that existing structuring approaches are inadequate to define complex situations. Reviewing their interpretation of the situation, this process "remains as much art as it does science" (Corner, et al., 2001, p. 130). Despite increasing research devoted to MCDM models over the last century, still limited contributions are found on guiding multi-criteria problem structuring. Sure, all publications attending an MCDM problem chose certain mechanisms to gather data relevant to derive decision recommendations, but, to the researcher's knowledge, there is no suggestion put forth on a standardised framework that has the ability to extract required information for several problems in a selected context. In other words, there is no straightforward process that can be adopted by researchers or practitioners to clearly identify elements, decompose the problem and achieve greater transparency (Maier & Stix, 2013).

A more recent publication by Franco and Montibeller (2009) claims this area of research has still fallen short in current literature. They insisted further research should be conducted on tailored problem structuring tools for the MCDM domain. The focus herein should be on portraying particular procedures suitable to extracting information, which ultimately helps understand and structure the problem, and allows for focused decision analysis to obtain the best results and recommendations possible (Franco & Montibeller, 2009). More specifically, Maier and Stix (2013), as well as Keeney and Gregory (2005), raise awareness that not much attention has been devoted on how to obtain a comprehensive list of evaluation criteria and organise these in a coherent structure. On the whole, literature falls short of providing systematic, context related, step-by-step guides that are repeatable and reliable to identify and formulate diverse problem. Finally, a beneficial side-effect when extending current knowledge with more rigour problem modelling mechanisms may be that an analyst is more likely to see when none of the existing MCDM methods is appropriate (Hanne, 1999), potentially promoting the development of new, improved and more tailored MCDM tools.

3.5 MCDM Methods

It is key to highlight the great scope of methodologies within MCDM (Dodgson, et al., 2009; Cinelli, et al., 2014). Whilst all methods have to account for the basic properties identified in section 3.3, some do a better job than others in their ability to cope with certain conditions. Hence, different methods are more appropriate in specific situations than others (Guitouni & Martel, 1998). To distinguish between the vast amounts of approaches, their capabilities are often reviewed in light of the problem features, allowing the formation of broad MCDM groups. One such categorisation is between methods attending decision problems with infinite alternatives, i.e. Multi-Objective Decision Making (MODM), and those that address finite decision spaces (Multi-Attribute Decision Making) (Mendoza & Martins, 2006). For the purpose of this research, only those approaches that lie within the latter are examined, rendering any further discussion of MODM unnecessary.

Next, there is the differentiation between non-compensatory and compensatory methods. Non-compensatory methods, as described in the previous chapter, do not allow trade-offs among criteria (Xu & Yang, 2001). Basically, criteria are viewed as stand-alone factors. A non-compensatory technique, such as the conjunctive method, is often used as a pre-screening of alternatives to eliminate any that do not meet a set standard on all criteria (Guitouni & Martel, 1998). A major drawback relates to the idea of setting cut-off values to eliminate options, but not taking into consideration that an alternative with a very minor distance from the cut-off is excluded, despite being better on all remaining aspects. Thus, there are no trade-offs accepted in these methods, viewing each criterion as a stand-alone factor (Xu & Yang, 2001). Alternatively, the dominance method can be employed to determine dominated alternatives that perform worse on all criteria in comparison to competing options. Evidently, when it comes to evaluating a large number of alternatives assessed on a large number of criteria, it is practically impossible to identify dominating

options. Nonetheless, as discussed in the real estate literature chapter, these non-compensatory tools often narrow down the choice set to a more suitable pool of alternative. On the contrary, the compensatory approaches intend to mitigate the emphasised problems by allowing one criterion to compensate for the bad performance of another (Xu & Yang, 2001). Obviously, this second class is the more demanding and accurate way in addressing complex multi-criteria problems.

Although the two classification schemes (finite versus infinite alternatives and non-compensatory versus compensatory methods) may provide a better idea of individual methods and enable a superficial separation, the key differentiation between approaches lies in their core abilities, such as accounting for uncertainties, handling interdependencies among pieces of evidence and their information aggregation procedures to solve problems (Mardani, et al., 2015). The following subsections review the most popular and relevant methods to the current decision making context.

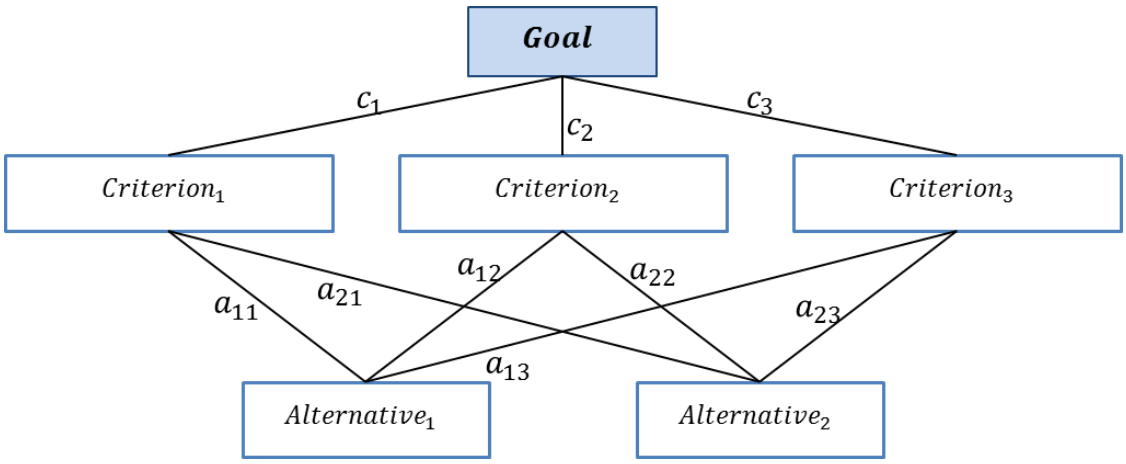
3.5.1 Analytic Hierarchy Process

In the late 1960's, Saaty developed the AHP. The approach is frequently referred to as the theory of prioritisation, or theory of measurement (Saaty, 2005). Accordingly, its main aim is to compute performance scores for decision options using pairwise comparison judgements for all competing elements in the problem domain (i.e. evaluation criteria and alternatives) (Xu & Yang, 2001). There are two justifications for including AHP in this research project. First, the previous chapter demonstrated AHP is potentially the most applied method in real estate context that stands under the MCDM umbrella. Second, Xu and Yang (2001, p. 12) make the connection between AHP and ER, proposing AHP "will help to better understand the ER approach" as they both use hierarchical representation in modelling a multi-criteria problem. The authors essentially compare AHP to ER and highlight key differences. Considering the next section goes into great depth on ER, this part provides a description of AHP, including features, applications and limitations. Hence, differences between the two methodologies automatically emerge when proceeding through this chapter.

3.5.1.1 Analysis Process

The AHP method requires four basic steps. First, the problem is decomposed into the decision target (goal), situated at the top of the hierarchy, multiple, measurable criteria at the middle level and explicit decision options that are being contemplated at the lowest level (Ball & Srinivasan, 1994; Xu & Yang, 2001; Saaty, 2008). The most simplified version of the AHP hierarchy is demonstrated in Figure 4.

Figure 4, Simple AHP Hierarchy



A hierarchy serves as a simplifier of a complex problem into a structured format, providing an overall view of problem elements' relationships (Saaty, 1990). Therefore, the first stage is generally viewed as the problem modelling or structuring process attended by DMs before assessing alternatives in accordance to this construct (Ishizaka & Labib, 2011). It is advised to pay close attention to this non-trivial task, as the chosen structure has a significant impact on the final ranking.

The second step consists in constructing a set of decision matrices (Saaty, 2008). Here, it was proposed that articulating one's opinion on two competing factors is easier and more accurate, rather than simultaneously viewing one criterion in relation to all others (Ishizaka & Labib, 2011). Accordingly, pairwise comparison judgments are made, typically using a 9-point scale, on competing criteria organised on the same hierarchical level. This 9-point scale adopted for AHP systematically depicts the degree to which a criterion dominates another (Kettani, et al., 1998; Kauko, 2006). Whilst there are other numerical scales to choose from, Saaty's proposed one to nine scale is the most applied tool (Ishizaka & Labib, 2011). The score one indicates that both factors contribute equally to the performance of the upper criterion or overall goal. On the contrary, an intensity score of nine portrays absolute importance of the evidence over the competing one. Comparisons need to be done at all levels across the hierarchy, resulting in $\frac{(n^2-n)}{2}$ judgements for n elements in a matrix (i.e. criteria and alternatives) (Saaty, 2005). Evidently, in situations with a high number of criteria and alternatives, this can lead to an excessive number of comparison questions (Ishizaka & Labib, 2011). Sometimes, analysts avoid this time consuming task by allowing incomplete matrices.

Now, supposing there are i competing criteria on the same hierarchical level that need to be assessed, producing the pairwise comparison matrix as a reciprocal matrix shows the relative importance of one criterion over the other (Ball & Srinivasan, 1994):

$$\begin{bmatrix} & c_1 & c_2 & \cdots & c_i \\ c_1 & {w_1}/{w_1} & {w_1}/{w_2} & \cdots & {w_1}/{w_i} \\ c_2 & {w_2}/{w_1} & {w_2}/{w_2} & \cdots & {w_2}/{w_i} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_i & {w_i}/{w_1} & {w_i}/{w_2} & \cdots & {w_i}/{w_i} \end{bmatrix}$$

where w_2/w_1 is the comparison between two pieces of evidence c_1 and c_2. If the element on the left of the matrix is perceived less important than the one at the top, the reciprocal value is entered in the corresponding place (Saaty, 2005). The dominated element is used as the unit, whilst the more important one is given by the multiple of that unit. If the above matrix would have missing comparisons, at the very least there must be $i-1$ judgements, recording a number in each row or column (Ishizaka & Labib, 2011). The missing numbers are dispensable as they mainly serve as inputs in the consistency check, and can simply be computed using the transitivity rule. Nonetheless, if possible, a complete matrix is beneficial in terms of providing the opportunity to assure and improve accuracy.

The eigenvector approach is used in step three to obtain the criteria priorities. Here, first the matrix is squared and then each row is aggregated. To normalise the results and obtain the eigenvector, row totals are divided by the overall sum. Subsequently, a consistency check determined by CR (consistency ratio), assures the rationality of the matrix of i elements:

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - i}{i - 1}$$

where λ_{max} represents an approximation of the maximum eigenvalue and RI is a Random Consistency Index given for different values of i. The computation must yield a minimum consistency score to obtain meaningful priorities (Ishizaka & Labib, 2011). If $CR < 0.1$, then the decision matrix passes the consistency check and the general ranking exercise can start (Saaty, 1987). In contrast, if $CR > 0.1$ then it is necessary to revise or repeat comparisons (Triantaphyllou & Mann, 1995).

The ranking obtained for the competing elements on one level must also be done for all remaining elements in the hierarchy, including possible sub-criteria and the alternatives at the lowest level. Essentially, the priorities obtained from a comparison matrix are used to weigh the priorities in the next level down (Saaty, 2008). For instance, alternatives are weighed by the previously identified relative weight score of the criterion above.

Finally, in the synthesis phase (step four), the priorities are fused to obtain a single global score for each alternative $(a_l,\ l = 1, \dots, M)$ achieved by computing:

$$\begin{bmatrix} & c_1 & c_2 & \dots & c_i \\ a_1 & a_{11} & a_{12} & \dots & a_{13} \\ a_2 & a_{21} & a_{22} & \dots & a_{23} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_l & a_{l1} & a_{l2} & \cdots & a_{li} \end{bmatrix} * \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_i \end{bmatrix}$$

The analysts can then easily rank the obtained scores to determine the preferred action. A numerical example follows, further clarifying the necessary computational steps.

Demonstrating the above theory, suppose there are two properties a_1 and a_2 that are assessed on three criteria, i.e. location (c_1), property itself (c_2) and costs (c_3). The hierarchy structure for this simple illustration is identical to Figure 4. Next, to derive priorities, it is assumed that (1) the property itself is two times as important as the location, (2) location is three times as important as costs, and (3) the property itself is four times as important as costs. These verbal judgments can be transformed into the pairwise comparison matrix:

$$\begin{bmatrix} & c_1 & c_2 & c_3 \\ c_1 & 1/1 & 1/2 & 3/1 \\ c_2 & 2/1 & 1/1 & 4/1 \\ c_3 & 1/3 & 1/4 & 1/1 \end{bmatrix}$$

To obtain priorities, the eigenvector approach is used. First, the fractions are converted into decimals and the matrix is subsequently squared:

$$\begin{bmatrix} & c_1 & c_2 & c_3 \\ c_1 & 1.0000 & 0.5000 & 3.0000 \\ c_2 & 2.0000 & 1.0000 & 4.0000 \\ c_3 & 0.3333 & 0.2500 & 1.0000 \end{bmatrix}^2$$

Resulting in:

$$\begin{bmatrix} & c_1 & c_2 & c_3 \\ c_1 & 3.0000 & 1.7500 & 8.0000 \\ c_2 & 5.3332 & 3.0000 & 14.000 \\ c_3 & 1.1663 & 0.6667 & 3.0000 \end{bmatrix}$$

To compute the eigenvector, the rows are aggregated to derive the following:

$$\begin{aligned} c_1 &= 12.7500 \\ c_2 &= 22.3332 \\ c_3 &= \ 4.8333 \\ \hline & 39.9165 \end{aligned}$$

Normalising the above, for instance $c_1 = \frac{12.7500}{39.9165} = 0.3194$, provides the relative importance of the three criteria (also referred to as eigenvector). However, this process must be repeated until no change is observed in the eigenvector, giving us the final result of $c_1 = 0.3194$, $c_2 = 0.5584$ and $c_3 = 0.1220$, which implies that the property itself is the most important criterion. Prior to constructing the next pairwise comparison matrix, it is advised to

make a consistency check. This means multiplying the initial judgements by the eigenvectors for each criterion:

$$c_1 = (1.000 * 0.319) + (0.500 * 0.558) + (3.000 * 0.122) = 0.964$$
$$c_2 = (2.000 * 0.319) + (1.000 * 0.558) + (4.000 * 0.122) = 1.684$$
$$c_3 = (0.333 * 0.319) + (0.250 * 0.558) + (1.000 * 0.122) = 0.368$$

Then, each result is divided by the corresponding eigenvector:

$$c_1 = \frac{0.964}{0.319} = 3.022$$

$$c_2 = \frac{1.684}{0.558} = 3.018$$

$$c_3 = \frac{0.368}{0.122} = 3.016$$

The mean score of these values is 3.019, which is the estimation of the maximum eigenvalue λ_{max}. Note, if the estimate is less than i (in this case $i = 3$), it indicates that there is a computational error. The CR for the matrix above is then calculated as follows:

$$CI = \frac{3.019 - 3}{3 - 1} = 0.0095$$

The Random Consistency Index for $i = 3$ gives the RI value of 0.58, therefore:

$$CR = \frac{0.0095}{0.5800} = 0.016$$

Since the CR of $0.016 < 0.1$, the judgments pass the consistency check.

Following this exercise, the DM must address the set of alternatives in the same way, assessing each option in terms of individual attributes. In this case, creating another three pairwise comparison matrices, each producing two scores. The aggregated performance of the alternatives for all three criteria can then be multiplied by the criteria weights to obtain the final ranking:

$$\begin{bmatrix} & c_1 & c_2 & c_3 \\ a_1 & 0.363 & 0.669 & 0.540 \\ a_2 & 0.637 & 0.331 & 0.460 \end{bmatrix} * \begin{bmatrix} c_1 & 0.319 \\ c_2 & 0.558 \\ c_3 & 0.122 \end{bmatrix} = \begin{matrix} 0.555 \\ 0.445 \end{matrix}$$

From the above information, alternative a_1 has an overall better performance than a_2. Although this illustration example is straightforward, in general decision problems are more complex and have more elements in the hierarchy, with multiple levels of sub-criteria.

Hence, in reality, a lot of pairwise comparisons are necessary to derive a final score for each alternative, which consequently identifies the rank order.

3.5.1.2 Applications

Among the various MCDM methods, AHP is one of the most popular techniques (Cinelli, et al., 2014). It has been applied to practically all industries. Particularly for resource management, corporate strategy and planning exercises, AHP offers a straightforward decision analysis (Velasquez & Hester, 2013). Also, in real estate literature it is frequently chosen for weight eliciting and alternative assessments (Ball & Srinivasan, 1994; Kim, et al., 2005; Kauko, 2006; Fang & Yan, 2011). The wide adoption is potentially attributed to the method's ease of use and transparent procedure of obtaining weights (Velasquez & Hester, 2013). Over the years, specially designed software packages for AHP, like Expert Choice, further facilitated and promoted its application (Triantaphyllou & Mann, 1995; De Montis, et al., 2004; Cinelli, et al., 2014).

3.5.1.3 Limitations

Whilst AHP may generate a ranking to support decision making, caution must be taken (Stewart, 1992). There are limits to this approach, such as its inability to handle interdependencies between upper and lower hierarchy levels, or among elements competing on the same level, which is frequently observed in real-life decision problems (Velasquez & Hester, 2013). As in the case of real estate assessments, interdependencies between criteria are anticipated, generally rendering the AHP that functions under the assumption of uncorrelated and independent variables less fitting. Another criticism lies in the rank reversal issue. Here, adding additional decision options retrospectively can flip or reverse the final ranking (Velasquez & Hester, 2013). Especially, in real estate, where frequently new alternatives become available, this is a serious constraint and may further discourage analysts from using the AHP.

3.5.2 Evidential Reasoning

The ER approach falls into the MCDM domain and addresses the analysis of complex decision problems accompanied with various uncertainties to derive a reliable result and enabling the DM to make an informed choice (Xie, et al., 2008; Guo, et al., 2007). The latest version, the ER rule, is a general probabilistic reasoning process that facilitates the combination of multiple independent pieces of evidence and acknowledges the role of evidence weight and reliability scores to enhance decision making under uncertainties (Zhu, et al., 2015). Considering the evolution of the ER framework for evidence combination, it was first introduced by Yang and Singh in 1994 derived from an evaluation analysis model and the Dempster-Shafer (DS) theory (Yang & Singh, 1994; Yang, 2001; Lowrance, et al., 2008). Hence, it is only logical to first attend the DS theory.

3.5.2.1 Dempster-Shafer Theory

The DS theory was originally established by Shafer in 1976 to analyse situations with incomplete and uncertain information, but rooted in Dempster's work on the theory of

probabilities with upper and lower boundaries (Beynon, et al., 2000). Herein, the upper and lower boundaries represent the value range resulting from uncertainty. Dempster essentially identified that more flexibility was needed when assigning probabilities, proposing that probability assignments should not have to sum unity (Dempster, 1968). In addition to Dempster's research, Shafer added to his work by attending the notion of belief functions (Beynon, et al., 2000). Therefore, the DS theory is viewed as a generalisation of Bayesian theory of subjective probability able to deal with incomplete information (Deng & Chan, 2011). It is these two pillars of (1) using belief functions to account for imprecision and uncertainty, and (2) Dempster's evidence combination rule allowing to pool multiple pieces of independent evidence, that are central to the DS theory (Shafer, 1992).

3.5.2.1.1 Analysis Process

Now, the first step in evidence theory is to define a finite set of N propositions θ representing the frame of discernment Θ (Shafer, et al., 1987; Deng & Chan, 2011). Here, the terms propositions, hypotheses and grades are used interchangeably to describe all possible outcomes of the analysis (Zhu, et al., 2015). The frame of discernment is denoted by:

$$\Theta = \{\theta_1, \dots \theta_n, \dots, \theta_N\}$$

and must consist of mutually exclusive (distinct) and collectively exhaustive (complete) propositions (Wang & Elhag, 2007). Evidence can occupy a single proposition, as observed in traditional probability theory, or can be distributed over a set of propositions using belief degrees (Sentz & Ferson, 2002). This flexibility allows a piece of evidence to be presented by a belief distribution defined on the power set of the frame of discernment Θ. The power set $P(\Theta)$ is composed of 2^N subsets of Θ:

$$P(\Theta) = \{\emptyset, (\theta_1), \dots, (\theta_N), (\theta_1, \theta_2), \dots, (\theta_1, \theta_N), \dots, (\theta_1, \dots, \theta_{N-1}), \Theta\}$$

where $\emptyset$ represents the empty set (Deng & Chan, 2011). The N subsets that hold only one element are referred to as singletons. Furthermore, an important concept in the DS theory is the basic probability assignment (bpa). Herein, the mass of belief in an element of the frame of discernment, where the unit mass is distributed between the elements of the power set (Deng & Chan, 2011). The basic probability assignment is a function:

$$m: P(\Theta) \rightarrow [0,1]$$

Subject to:

$$m(\emptyset) = 0$$

$$\sum_{\theta \subseteq \Theta} m(\theta) = 1$$

where θ is any subset of Θ and $m(\theta)$ is a bpa exactly assigned to a proposition θ, showing the support strength of the evidence m for θ. Note, there is no belief left in the empty set and the bpas are fully assigned to the subsets of Θ, summing unity, where the precisely assigned probability to the frame of discernment $(m(\Theta))$ represents the degree of global ignorance (Yang & Xu, 2013). In addition, there are two other key functions completing the DS theory. For each bpa, a belief measure $Bel(\theta)$ and a plausibility measure $Pl(\theta)$ are defined (Wang & Elhag, 2007). The belief measure, i.e. the lower bound, expresses the confidence of the proposition θ being true, i.e. the exact support to θ:

$$Bel(\theta) = \sum_{B \subseteq \theta} m(B)$$

for all $\theta \subseteq \Theta$

where θ and B are subsets of Θ.

On the other hand, the plausibility measure, i.e. the upper bound, describes the degree of doubt in θ:

$$Pl(\theta) = \sum_{B \cap \theta \neq \emptyset} m(B)$$

for all $\theta \subseteq \Theta$

The plausibility function counts all propositions that at least partially intersect proposition θ. Bel and Pl are non-additive, meaning their individual sum does not have to add up to one (Sentz & Ferson, 2002), yet the measures can be computed from each other, $Bel(\theta) = 1 - Pl(\neg\theta)$ and $Pl(\theta) = 1 - Bel(\neg\theta)$, where $(\neg\theta)$ is the compliment of θ. Also, $Bel(\theta) + Bel(\neg\theta) \leq 1$ and $Pl(\theta) + Pl(\neg\theta) \geq 1$. These relationships indicate a major departure from traditional probability functions in Bayesian theory (Beynon, et al., 2000). However, DS theory being a generalisation of Bayes' rule, the latter is a special case of the DS theory (Yang & Xu, 2013). Accordingly, the DS theory reduces to traditional probability theory where $Bel(\theta) = Pl(\theta)$, implying that probability is uniquely determined (Sentz & Ferson, 2002).

With the above measures, the DS theory applies Dempster's combination rule that offers an orthogonal sum method for aggregating multiple pieces of evidence (Wang & Elhag, 2007). It combines various independent and fully reliable information sources with different assessments (i.e. several mass functions) for the same frame of discernment (Beynon, et al., 2000; Sentz & Ferson, 2002). To clarify, a piece of evidence is independent when its information does not depend on the information of other evidence (Yang & Xu, 2013). Now, Dempster's combination rule is often written as:

$$m(\theta) = m_1 \oplus m_2 \oplus \ldots \oplus m_L$$

where $\oplus$ denotes the orthogonal sum operator of combining L pieces of independent evidence m. Thus, if two pieces of evidence m_1 and m_2 are pooled to obtain the combined $bpa\ \ m(\mathrm{C})$, the function $m_1 \oplus m_2 : 2^{\Theta} \rightarrow [0,1]$ is mathematically written as follows (Beynon, et al., 2000):

$$m(\theta) = [m_1 \oplus m_2](\theta) = \begin{cases} 0 & \theta = \emptyset, \\ \frac{\sum_{B \cap C = \theta} m_1(B) m_2(C)}{1 - \sum_{B \cap C = \emptyset} m_1(B) m_2(C)} & \theta \neq \emptyset, \end{cases}$$

where the denominator represents the normalisation factor, often written as k, measuring the degree of conflict between the two pieces of evidence (Beynon, et al., 2000; Deng & Chan, 2011). Noteworthy, Dempster's rule of evidence combination is regarded as commutative $(m_1 \oplus m_2 = m_2 \oplus m_1)$ and associative $((m_1 \oplus m_2) m_3 = m_1 (m_2 \oplus m_3))$, allowing evidence to be combined in any order (Sentz & Ferson, 2002; Wang & Elhag, 2007).

3.5.2.1.2 Limitations

Dempster's and Shafer's research on evidence combination allowed the fusing of two bodies of evidence, i.e. belief functions, to create new evidence (Voorbraak, 1991; Lowrance, et al., 2008). However, whilst the DS theory offered a powerful evidence combination rule, plus its relaxed requirement for the basic probability assignment (Yang & Singh, 1994), it still suffers from several limitations. It is mostly criticised for completely ignoring conflict.

First noted by Zadeh (1986), the normalisation factor is a controversial subject. In situations where the measure of conflict approximates one, the combination of the conflicting evidence yields questionable results (Beynon, et al., 2000). In other words, significant conflict leads to counter-intuitive results. Consequently, various scholars questioned and examined the validity and consistency of the DS theory when combining highly or fully conflicting evidence, rendering the approach to some extent inapplicable in these situations (Dezert, et al., 2012). Yang and Xu (2013, p.2) argue that Dempster's combination rule "accumulates consensus support only and rejects a proposition completely if it is opposed by any evidence". Another concern is that the DS theory does not differentiate between global and local ignorance when assigning residual support specifically to the frame of discernment (Yang & Xu, 2013). Here, the former is an intrinsic property of the evidence with no linkage to other criteria, whilst the latter is its extrinsic feature incurred due to its relative weight in comparison to other evidence. Local ignorance represents the probability mass assigned exactly to a subset of Θ, except for any singleton proposition or the whole frame of discernment.

For instance, considering three singleton propositions $\{A\}\{B\}\{C\}$, in the DS theory any residual support is assigned to the whole frame of discernment, i.e. $\{A, B, C\}$, whilst not considering any subsets of Θ such as $\{A, B\}\{A, C\}$ or $\{B, C\}$. As a result, allocating all unassigned belief degree to the whole frame and not making a distinction between global and local ignorance means that, even if all pieces of evidence point exactly towards a

proposition (i.e. no ignorance is present in the pieces of evidence), Dempster's rule still introduces global ignorance and consequently generate imprecise combined support (Yang & Xu, 2013). This inevitably changes the distortion of the evidence. A simple example of this phenomenon is provided in Appendix A. At last, Voorbraak (1991) examined the requirement of independent sources of evidence. He noted that pieces of evidence have to meet very firm constraints to achieve the so called DS-independence, resulting in limited application of the DS theory since this assumption is not always realistic in complex decision problems.

Often, the DS theory in literature is presented as a general mechanism for evidence reasoning, with universal application, yet it is acknowledged that its restrictions limit the appropriateness in certain situations (Dezert, et al., 2012). The limitations along with the theory's advantages motivated research in this field to provide other decision analysis options. Particularly, its ability to cope with uncertainties and approach in dealing with subjective assessments from multiple information sources was adopted in the ER approach introduced by Yang and Singh (1994).

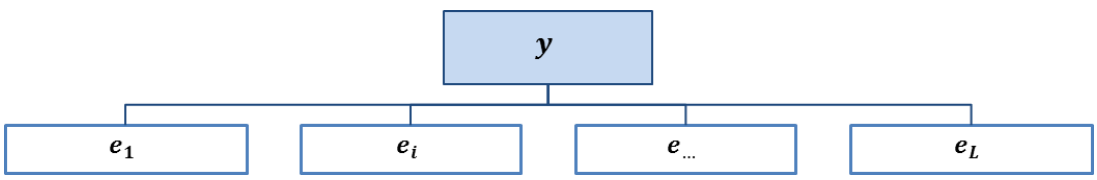
3.5.2.2 ER Approach

Since the first appearance of the ER approach in 1994 (Yang & Singh, 1994), significant research has been conducted, contributing to this area. Numerous application and comparison papers were published, often leading to modification proposals (Xu, 2012). This section addresses one of the first versions of the ER approach, by reviewing the individual steps involved to attain an overall assessment of a decision option. Then, key extensions and revisions of the ER approach over the last two decades are highlighted, which have ultimately led to the introduction of the ER rule, investigated hereafter.

3.5.2.2.1 Analysis Process

Step one constitutes the MCDM problem representation (Yang & Xu, 2002b). Generally, parameters of a complex problem are defined into upper and lower level criteria, creating a hierarchical structure. The hierarchy is made up of a set of L basic criteria e_i $(i = 1, \dots, L)$ that define the general criterion y at the top of the hierarchy, i.e. the overall goal. A simple two-level hierarchy is illustrated in Figure 5 below. Note, within the ER framework, criteria are generally referred to as pieces of evidence.

Figure 5, Simple Hierarchical Structure



Once the problem has been defined and structured, relative weights w_i $(i = 1, \dots, L)$ are assigned to the pieces of evidence competing on the same level, where $0 \leq w_i \leq 1$ and

$\sum_{i=1}^{L} w_i = 1$ (Xu & Yang, 2001). Weight estimating methods, such as pairwise comparison (as discussed in light of AHP) exist to facilitate the allocation of relative weights (Yang & Xu, 2002a). Direct assignment methods are also used to obtain absolute or relative weights that represent the importance of one piece of evidence in comparison to the competing pieces of evidence that jointly feed into the same upper level criterion.

Next, N evaluation grades θ_n $(n = 1, \dots, N)$ to assess M alternatives a_l $(l = 1, \dots, M)$ on all pieces of evidence $e_i (i = 1, \dots, L)$ are defined. The finite set of grades form the frame of discernment Θ and need to be mutually exclusive and collectively exhaustive (Yang, 2001). Basic probabilities can be assigned to any subsets of propositions, forming the Belief Distribution (BD). In essence, a number between $[0\ 1]$ indicates the degree to which a piece of evidence supports proposition θ_n. The belief structure, which is a key concept in the ER approach, originally described the subjective expectation that an alternative yields one or more of the possible assessment grades to a certain degree (Yang, 2001). This tool is particularly powerful if subjective judgements are collected using a survey. Here it can simply represent the proportion of responses that voted θ_n and the remaining percentage that supported θ_{n+1} (Xu, 2012). Overall, an assessment for evidence e_i of a single alternative a_l is expressed as a BD:

$$S\big(e_i(a_l)\big) = \big\{\big(\theta_n, \beta_{n,i}\big), \quad n = 1, \dots, N; \quad \big(\Theta, \beta_{\Theta,i}\big)\big\} \quad i = 1, \dots, L, \ \ l = 1, \dots, M$$

where $\beta_{n,i}$ represents the degree of belief. Essentially, it states that e_i for alternative a_l is assessed on the evaluation grade θ_n with a degree of belief $\beta_{n,i}$ (Yang & Xu, 2002a). Note, $\beta_{n,i}(a_l) \geq 0$ and $\sum_{n=1}^{N} \beta_{n,i}(a_l) \leq 1$, where a complete assessment would constitute $\sum_{n=1}^{N} \beta_{n,i}(a_l) = 1$. Both complete and incomplete assessments can be aggregated to derive an overall performance score (Yang, 2001).

The belief structure is an extension to the traditional probability distribution in that it can assign probability to a number of propositions, rather than to only a single one (Xu, 2012). Distributed assessments across the possible propositions are repeated for all pieces of evidence, which then have to be aggregated to derive the overall assessment for each alternative. Here, the evidence combination uses the ER algorithm to aggregate belief degrees and compute decision options' assessments that can be compared and ultimately ranked. This algorithm was established on the basis of decision theory and Dempster's evidence combination rule (Xu & Yang, 2001).

To illustrate the aggregation process using the ER algorithm, we consider two criteria assessments that are defined using four propositions θ_n $(n = 1, \dots, 4;\ N = 4)$. Correspondingly, the two BDs are expressed as follows:

$$S\big(e_1(a_1)\big) = \big\{\big(\theta_1, \beta_{1,1}\big), \big(\theta_2, \beta_{2,1}\big), \big(\theta_3, \beta_{3,1}\big), \big(\theta_4, \beta_{4,1}\big)\big\}$$

$$S(e_2(a_1)) = \{(\theta_1, \beta_{1,2}), (\theta_2, \beta_{2,2}), (\theta_3, \beta_{3,2}), (\theta_4, \beta_{4,2})\}$$

Step two consists in transforming these distributed assessments into basic probability masses $m_{n,i}$ for e_i $(i = 1)$. Hence, the weighted belief degrees are generated by incorporating relative weights w_i and the belief degrees $\beta_{n,i}$:

$$m_{n,i} = w_i \beta_{n,i}$$

$$m_{\Theta,i} = 1 - w_i \sum_{n=1}^{N} \beta_{n,i}$$

$m_{\Theta,i}$ can then be decomposed into:

$$\bar{m}_{\Theta,i} = 1 - w_i \qquad \text{and} \qquad \tilde{m}_{\Theta,i} = w_i(1 - \textstyle\sum_{n=1}^{N} \beta_{n,i})$$

with:

$$m_{\Theta,i} = \bar{m}_{\Theta,i} + \tilde{m}_{\Theta,i}$$

where $\bar{m}_{\Theta,i}$ is the residual support of e_i that cannot be assigned by e_i alone considering its weight w_i; hence it is allocated to any individual and/or subsets of evaluation grades, subject to the weights of the other pieces of evidence (Yang & Xu, 2002b; Yang & Xu, 2013). Then $\tilde{m}_{\Theta,i}$ is the second part of the remaining probability mass unassigned to single propositions, which is the result of any incomplete assessments (Yang & Xu, 2002b). Overall, the basic probability mass represents the extent to which the criterion is assessed to the n th evaluation grade θ_n (Xu & Yang, 2005). The above calculations are repeated for the second evidence e_i $(i = 2)$.

Step three presents the recursive ER algorithm to aggregate two probability assignments at a time for a joint upper level criterion (Wang, et al., 2006). In sum, basic probability masses are joined to attain combined probability masses for θ_n and Θ:

$\{\theta_n\}$:

$$m_{n,e(2)} = k\left[\, m_{n,1} m_{n,2} + m_{\mathrm{n},1} m_{\Theta,2} + m_{\Theta,1} m_{\mathrm{n},2}\right] \quad (n = 1, \ldots, 4)$$

$\{\Theta\}$:

$$m_{\Theta,\mathrm{e}(2)} = \bar{m}_{\Theta,\mathrm{e}(2)} + \tilde{m}_{\Theta,\mathrm{e}(2)}$$

$$\tilde{m}_{\Theta,\mathrm{e}(2)} = k\left[\tilde{m}_{\Theta,1}\tilde{m}_{\Theta,2} + \bar{m}_{\Theta,1}\tilde{m}_{\Theta,2} + \tilde{m}_{\Theta,1}\bar{m}_{\Theta,2}\right]$$

$$\bar{m}_{\Theta,\mathrm{e}(2)} = k\left[\bar{m}_{\Theta,1}\bar{m}_{\Theta,2}\right]$$

where:

$$k = \left[1 - \sum_{t=1}^{N} \sum_{\substack{j=1 \\ j \neq t}}^{N} m_{t,1} m_{j,2}\right]^{-1}$$

k representing a normalisation factor resulting in $\sum_{n=1}^{N} m_{n,e(2)} + m_{\Theta,\mathrm{e}(2)} = 1$. Dissecting the equations $m_{n,e(2)}$, the multiplication of $m_{n,1} m_{n,2}$ measures the degree of the two pieces of evidence supporting the upper criterion y to be assessed to θ_n, whilst the term $m_{\mathrm{n},1} m_{\Theta,2}$ describes the level e_1 supports y assessed to θ_n (same for $m_{\Theta,1} m_{\mathrm{n},2}$). Then $\widetilde{m}_{\Theta,1} \widetilde{m}_{\Theta,2}$ measure the extent to which y cannot be assessed to a single grade owing to incomplete assessments of the two pieces of evidence, whereas $\widetilde{m}_{\Theta,1} \overline{m}_{\Theta,2}$ shows the amount to which y cannot be assessed due to the incomplete assessment for e_1 only (same fore $\overline{m}_{\Theta,1} \widetilde{m}_{\Theta,2}$). The last computation $\overline{m}_{\Theta,1} \overline{m}_{\Theta,2}$ gives the degree to which the upper criterion has not yet been assessed to individual grades caused by the relative weight of the pieces of evidence after these have been aggregated (Yang & Xu, 2002b). So $\overline{m}_{\Theta,\mathrm{e}(2)}$ gives the residual support that is not assigned to Θ as global ignorance and consequently not being a part of $\widetilde{m}_{\Theta,\mathrm{e}(2)}$ (Yang & Xu, 2013). Note, that if no ignorance is observed in the assessment, then $\widetilde{m}_{\Theta,\mathrm{e}(2)} = 0$ (Wang, et al., 2006).

If there are more criteria to be pooled, a third assessment $m_{n,3}$ and $m_{\Theta,3}$ for evidence e_3 can be added to the combined probability masses of the first two criteria $m_{n,e(2)}$ and $m_{\Theta,\mathrm{e}(2)}$. This can be repeated until all pieces of evidence e_i $(i = 1, \ldots, L)$ explaining an upper criterion are combined recursively using the ER algorithm. Ultimately, this then derives the final combined probability mass $m_{n,L}$. The results of $m_{n,L}$ and $m_{\Theta,L}$ are not affected by the order in which bpms are aggregated (Yang & Xu, 2002a).

The fourth step takes the overall combined probability mass for e_i $(i = 1, \ldots, L)$ of a decision option a_1 to compute the combined degree of belief β_n that the upper criterion y is assessed to proposition θ_n (Wang, et al., 2006):

$\{\Theta\}$:

$$\beta_\Theta = \frac{\widetilde{m}_{\Theta,\mathrm{e(L)}}}{1 - \overline{m}_{\Theta,\mathrm{e(L)}}}$$

$\{\theta_n\}$:

$$\beta_n = \frac{m_{n,e(L)}}{1 - \overline{m}_{\Theta,\mathrm{e(L)}}} \quad n = 1, \ldots, 4$$

Hence, β_n represents the degree of belief to which L pieces of evidence are assessed to the proposition θ_n, whereas β_Θ denotes the incompleteness in the overall assessment, i.e. the remaining belief unassigned to any θ_n (Yang & Xu, 2002a). Therefore, $\sum_{n=1}^{N} \beta_n + \beta_\Theta$ for alternative a_l should always sum to unity (Wang, et al., 2006).

Note, Yang (2013) more recently suggested that the equations outlined in steps three and four can be equivalently rewritten. Accordingly, for e_i $(i = 1, \dots, L)$ and $L = 2$:

$m_{n,e(2)} = \hat{m}_{n,e(2)}$:

$$\hat{m}_{n,e(2)} = \left[(1 - w_2)m_{n,1} + (1 - w_1)m_{n,2}\right] + (m_{n,1}m_{n,2} + m_{n,1}m_{\Theta,2} + m_{\Theta,1}m_{n,2})$$

$m_{\Theta,e(2)} = \hat{m}_{\Theta,e(2)}$:

$$\hat{m}_{\Theta,e(2)} = \left[((1 - w_2)m_{\Theta,1} + (1 - w_1)m_{\Theta,2}\right] + (m_{\Theta,1}m_{\Theta,2})$$

$$\beta_{\Theta,e(2)} = k_1\hat{m}_{\Theta,e(2)}$$

$$\beta_{n,e(2)} = k_1\hat{m}_{n,e(2)}$$

$$k_1 = \left(\sum_{t=1}^{N} \hat{m}_{t,e(2)} + \hat{m}_{\Theta,e(2)}\right)^{-1}$$

This rewritten format allows separating the bounded sum of individual support given by $\left[(1 - w_2)m_{n,1} + (1 - w_1)m_{n,2}\right]$ from the orthogonal sum of collective support $(m_{n,1}m_{n,2} + m_{n,1}m_{\Theta,2} + m_{\Theta,1}m_{n,2}$. Both terms are more thoroughly reviewed when explaining the ER rule. The fifth and final step is the representation of the final assessment for alternative a_1 as a distribution:

$$S(a_1) = \{(\theta_n, \beta_n), \quad n = 1, \dots, N; \quad (\Theta, \beta_\Theta)\}$$

This BD offers a "panoramic view about the overall performance" of a decision option with level of its strength and weakness embodied by the propositions θ_n directly measured by the degrees of belief β_n (Yang & Xu, 2013).

Another concept that deserves brief mentioning at this point is the utility-based method proposed by Yang (2001). Having computed the assessment for all alternatives, utility scores for the evaluation grades may be added to allow precise comparison (Yang & Xu, 2002b). Utility functions are created for the criteria assessment grades to reflect a DM's subjective preference towards one grade over another (Xie, et al., 2008). Here, $u(\theta_n)$ describes the utility of the grade θ_n. Accordingly, the expected utility of an alternative a_1, if the overall assessment is complete (i.e. no unassigned degrees of belief), is calculated by:

$$u(a_1) = \sum_{n=1}^{N} u(\theta_n)\,\beta_n$$

A utility interval, with maximum and minimum utilities of a_1 is established when facing incomplete assessments (Yang & Xu, 2002b). Here, β_n reflects the lower bound of the probability that alternative a_1 is assessed to θ_n and the upper bound is given by $\beta_n + \beta_\Theta$ (Yang, 2001). In situations where preference information, in forms of grade utility, is not

available or difficult to attain, utility functions are assumed to be linear with the worst grade denoted by zero and the most preferred grade by one.

3.5.2.2.2 ER Development

Overall, the very first ER approach, introduced in 1994 by Yang and Singh (1994), had restricted capabilities, particularly in comparison to the ER rule available today. As a result, major modifications and improvements were achieved over the years to successfully address complex decision problems in a structured approach. For instance, some features that were not yet fully elaborated and implemented in the first version included the failure to explicitly handle incomplete information and the assumption of measuring alternatives' performances with qualitative criteria only, among others (Xu, 2012).

In 2001, Yang proposed the introduction of rule and utility-based methods to systematically transform assessment information into a unified format, and hereby handle both qualitative and quantitative evidence in a consistent way (Yang, 2001). An extended decision matrix allowed criteria aggregation with distributed assessments, providing the basis to model both precise data and capturing different types of uncertainties (Guo, et al., 2008). Additionally, the process to normalise weights was added, which then received more attention and was further expanded in 2002 along with a new scheme for basic probability assignments (Yang & Xu, 2002a). Also, Yang and Xu (2002) developed a new aggregation process with the aim of satisfying four synthesis axioms that were not met by the original ER algorithm, i.e. independency, consensus, completeness and incompleteness. Any rational probabilistic reasoning process ought to meet these four synthesis axioms (Yang & Xu, 2013). Further modifications, such as the establishment of the weighted belief distribution and its extension considering reliability, among others, followed and led to the ER rule presented in the next section.

3.5.2.3 ER Rule

The ER rule 'constitutes a generic conjunctive probabilistic reasoning process to combine independent pieces of evidence with associated weights and reliabilities' (Yang & Xu, 2013, p. 2). To illustrate the ER rule, the ER properties and the conjunctive probabilistic reasoning process is presented in this section.

3.5.2.3.1 Analysis Process

Again, to apply any decision support or inference mechanism, the logical initial step is to identify and understand the MCDM problem by defining key components such as evaluation criteria, alternatives and decision stakeholders, among others. Next, to recap from the DS theory and correspondingly the ER approach, the alternatives are assessed on L pieces of evidence e_i $(i = 1, \dots, L)$ with a common set of N mutually exclusive and collectively exhaustive propositions θ_n $(n = 1, \dots, N)$ that form the frame of discernment Θ (Yang & Xu, 2013; Yang & Xu, 2014). The L pieces of evidence are generally organised into a hierarchical formation (Sönmez, et al., 2001), where the upper criterion represents the

overall goal defined by various levels of sub-criteria. At the very bottom are basic criteria for which the evaluator can provide an assessment. Also, in a multi-level structure, mid-level criteria receive a performance score based on their corresponding lower variables, which can provide a pretty good estimate on how the decision option performs in terms of the frame of discernment. Nonetheless, the hierarchical construct is not a requirement to perform the decision analysis using the ER rule, as it is inherently associative, i.e. $(e_1 \oplus e_2) \oplus e_3 = e_1 \oplus (e_2 \oplus e_3)$ and commutative, i.e. $e_1 \oplus e_2 = e_2 \oplus e_1$, allowing the combination of multiple pieces of evidence in any order without affecting the final result (Yang & Xu, 2013; AbuDahab, et al., 2016). In fact, the hierarchy may primarily serve as a simplification of the problem by proposing a logical reasoning pattern and enhance transparency for the DM(s).

Next, as belief can be assigned to singleton propositions and corresponding subsets of the frame of discernment, a BD is defined on the power set $P(\Theta)$ containing 2^N subsets of the frame of discernment (AbuDahab, et al., 2016):

$$P(\Theta) = \{\emptyset, (\theta_1), \dots, (\theta_N), (\theta_1, \theta_2), \dots, (\theta_1, \theta_N), \dots, (\theta_1, \dots, \theta_{N-1}), \Theta\}$$

with ∅ representing the empty set. The power set was previously introduced in the DS theory, but unlike the procedure in the ER rule, any residual support was assigned to the frame of discernment. In this context, the ER rule claims it is neither rational to assign any residual belief specifically to the frame of discernment, nor to a singleton proposition. Besides, the empty set, which is located outside the frame of discernment, also isn't worth considering. Therefore, the rational solution is to commit residual support to propositions without any prior specification, i.e. making unassigned belief assignable to the power set of the frame of discernment (Yang & Xu, 2013). That way, the power set for three propositions A, B and C would consist of $\{\emptyset, (A), (B), (C), (A, B), (A, C), (B, C), (A, B, C)\}$.

Then, considering independent pieces of evidence, the BD for a single evidence e_i is expressed as follows:

$$e_i = \left\{ \left(\theta, \beta_{\theta,i}\right), \quad \forall \theta \subseteq \Theta, \quad \sum_{\theta \subseteq \Theta} \beta_{\theta,i} = 1 \right\}$$

where $\left(\theta, \beta_{\theta,i}\right)$ is an element of evidence e_i, and is referred to as a focal element of e_i if $\beta_{\theta,i} > 0$ (Yang & Xu, 2013). The equation then reads that the evidence points to proposition θ, which can be any subset of the frame of discernment or any element of the power set except for the empty set, to a belief degree of $\beta_{\theta,i}$ (Yang & Xu, 2014). Important, the BD equation acknowledges both global and local ignorance, whereas the BD $S\left(e_i(a_l)\right)$ in the ER approach only accounts for global ignorance (Yang & Xu, 2013).

In the ER rule, every piece of evidence is associated with a reliability score r_i and a weight w_i (Yang & Xu, 2013; Fu, et al., 2015; Zhu, et al., 2015). The reliability and weight of a criterion may potentially not measure the same property of the evidence, which implies that they need to be treated individually in an inference process (Yang & Xu, 2013). Reliability measures the quality of the information source, inevitably identifying evidence's ability to provide the correct assessment of a proposition (Yang & Xu, 2014; Fu, et al., 2015; Chen, et al., 2015). As a matter of fact, the reliability r_i of e_i is an inherent property of the evidence and occupies a score between $0 \leq r_i \leq 1$, where $r_i = 1$ indicates a fully reliable and $r_i = 0$ a completely unreliable piece of evidence (Yang & Xu, 2013). Most MCDM techniques do not consider reliability as it is assumed that experts, DMs and/or information sources are completely trustworthy. However, as described earlier, any source is only bounded rational (Simon, 1955) and the level of reliability varies substantially, which in turn significantly affects the decision analysis outcomes (Fu, et al., 2015). Generally speaking, even very small reliability deficiencies play a huge role in inference, as they have a great impact on the generated probabilities. Unreliability may sometimes be caused by subjectivity, human error, system failures, recording faults and/or poor data management. Under these circumstances and in a practical sense, when a piece of evidence e_i has a reliability r_i of 80%, e_i alone could only provide a tendency towards a particular proposition. Meanwhile, the missing reliability of one piece of evidence allows another piece of evidence to play a role in providing stronger support for, or against, propositions (Yang & Xu, 2014).

Weights differ from reliabilities when diverse information sources are sought and pieces of evidence are measured in different ways (Yang & Xu, 2013). Here, weight reflects the importance of a body of evidence (Chen, et al., 2015; Zhu, et al., 2015), which is the result of a subjective assessment determined by the DM who uses the evidence (Yang & Xu, 2014). The weight concept also introduces a modification to the ER approach, in that the former uses absolute weights, whilst the latter supposes normalised weights ($\sum_{i=1}^{L} w_i = 1$) (Yang & Xu, 2013). Weights may be elicited using direct preference assignment or by applying specifically developed techniques (Guo, et al., 2007) to obtain a weight $0 \leq w_i \leq 1$. A $w_i = 1$ symbolises extremely important evidence, whilst $w_i = 0$ would correspondingly stand for no importance at all and would imply that the piece of evidence does not play any role during evidence combination (Yang & Xu, 2013).

The two key parameters in the ER rule, weight and reliability are used to compute the Weighted Belief Distribution with Reliability (WBDR). First, the degree of support for θ from evidence e_i with the associated r_i and w_i is computed ($\widetilde{m}_{\theta,i}$), assigning the basic probability masses for e_i as follows:

$$\widetilde{m}_{\theta,i} = \begin{cases} 0 & \theta = \emptyset \\ c_{rw,i} m_{\theta,i} & \theta \subseteq \Theta, \theta \neq \emptyset \\ c_{rw,i}(1 - r_i) & \theta = P(\Theta) \end{cases}$$

Here, $c_{rw,i} = \frac{1}{(1+w_i-r_i)}$ is a normalisation factor requiring $\sum_{\theta \subseteq \Theta} \widetilde{m}_{\theta,i} + \widetilde{m}_{P(\Theta),i} = 1$. Also, $m_{\theta,i} = w_i \beta_{\theta,i}$ and $\sum_{\theta \subseteq \Theta} \beta_{\theta,i} = 1$. The term $m_{\theta,i}$ refers to the degree of support for proposition θ from e_i. In situations where all pieces of evidence are measured in a joint space, then $w_i = r_i$ or $m_{\theta,i} = r_i \beta_{\theta,i}$. For now, assuming in the above equation $w_i \neq r_i$, the unreliability of e_i is denoted by $1 - r_i$, again allowing other pieces of evidence that are combined with e_i to play a role in providing stronger support for, or against, propositions (Yang & Xu, 2014). When $r_i = 1$ then $\widetilde{m}_{P(\Theta),i} = 0$, ruling out any θ by e_i if $\widetilde{m}_{B,i} = 0$ for any $B \cap \theta = \theta$, whatever support θ may receive from other pieces of evidence (Yang & Xu, 2013). Yang and Xu (2013) equivalently rewrote the equation above:

$$\widetilde{m}_{\theta,i} = \begin{cases} 0 & \theta = \emptyset \\ \widetilde{w}_i \beta_{\theta,i} & \theta \subseteq \Theta, \theta \neq \emptyset \\ 1 - \widetilde{w}_i & \theta = P(\Theta) \end{cases}$$

where $\widetilde{w}_i = c_{rw,i} w_i$. The term $c_{rw,i} m_{\theta,i}$ in the previous equation is equivalent to $\widetilde{w}_i \beta_{\theta,i}$ and $c_{rw,i}(1 - r_i)$ is substituted by $1 - \widetilde{w}_i$. In fact, $\widetilde{w}_i$ can be interpreted as the adjusted weight of e_i, or as a hybrid weight and reliability coefficient for e_i to find the amount of support from the piece of evidence e_i given that $0 \leq \widetilde{w}_i \leq 1$ (Yang & Xu, 2013). Hence, weight and reliability have to be considered simultaneously to derive the hybrid weight (Chen, et al., 2015).
Now, with the basic probability masses, a piece of evidence can be denoted by the WBDR:

$$m_i = \left\{ \left(\theta, \widetilde{m}_{\theta,i}\right), \quad \forall \theta \subseteq \Theta; \quad \left(P(\Theta), \widetilde{m}_{P(\Theta),i}\right) \right\}$$

This equation ultimately takes into account the three focal elements of the ER rule: BD, reliability and weight, to measure the degree of support for θ from e_i (Yang & Xu, 2013; Chen, et al., 2015). Furthermore, contrary to the DS theory, in the ER rule the original specification $\beta_{\theta,i}$ of the BD of e_i is strictly retained because $\beta_{\theta,i} = \frac{\widetilde{m}_{\theta,i}}{1 - \widetilde{m}_{P(\Theta),i}}, \forall \theta \subseteq \Theta$ always holds. It becomes clear that now the level of unassigned support $\widetilde{m}_{P(\Theta),i}$ is earmarked to the power set $P(\Theta)$ for redistribution (Yang & Xu, 2013).

Subsequently, the ER rule can be applied to obtain the combined degree of belief $\widehat{m}_{\theta,e(2)}$ to which two independent pieces of evidence e_1 and e_2 (profiled by BDs and WBDRs) jointly support proposition θ, represented by $(\beta_{\theta,e(2)})$.

$$\beta_{\theta,e(2)} = \begin{cases} 0 & \theta = \emptyset \\ \frac{\widehat{m}_{\theta,e(2)}}{\sum_{D \subseteq \Theta} \widehat{m}_{D,e(2)}} & \theta \subseteq \Theta, \theta \neq \emptyset \end{cases}$$

$$\widehat{m}_{\theta,e(2)} = \left[(1 - r_2) m_{\theta,1} + (1 - r_1) m_{\theta,2}\right] + \sum\nolimits_{B \cap C = \theta} m_{B,1} m_{C,2} \quad \forall \theta \subseteq \Theta$$

$\widehat{m}_{\theta,e(2)}$ consists of two parts; the bounded sum of the evidence individual support $\left[(1-r_2)m_{\theta,1}+(1-r_1)m_{\theta,2}\right]$ and the orthogonal sum of the collective support $(\sum_{B\cap C=\theta} m_{B,1}m_{C,2})$ (Yang & Xu, 2013). Considering the first part, if evidence e_1 is said to be fully reliable, i.e. $r_1=1$ so that $(1-r_1)=0$, then automatically the individual support of e_2 is not counted at all, i.e. $(1-r_1)m_{\theta,2}=0$ (Chen, et al., 2015). Similarly, when e_1 is fully unreliable, then the individual support of e_2 would be counted completely. The second part of the equation, the orthogonal sum of collective support, measures the level of all intersected support on proposition θ (Yang & Xu, 2013; Yang & Xu, 2014). Principally, if two pieces of evidence both play limited roles, restricted by their weights besides their joint support, then individual support from any evidence should be regarded as part of the combined support; whereas if each identical piece of evidence offers a high degree of support for a proposition, it reinforces this support more than proportionally (Yang & Xu, 2013). On the other hand, if a single piece of evidence dominates, then the individual support from the other only reinforces the propositions that have already been supported by the dominant evidence. Importantly, the ER rule overcomes the limitation of the DS theory of deriving counter-intuitive results when combining conflicting evidence. The ER rule simply redistributes conflicting assessments to the power set of the frame of discernment (Zhu, et al., 2015).

3.5.2.3.2 ER Rule Axioms

Having illustrated the ER rule, it should be noted that the ER rule is a prescriptive mechanism for rational and rigorous reasoning to combine multiple pieces of evidence whilst satisfying four key axioms. Despite frequent descriptive violations of the axioms (Durbach & Stewart, 2012), the ER rule does not intend to represent a descriptive model of human behaviour and therefore the axioms serve as a rigorous rationality check.

Whilst the four synthesis axioms were briefly mentioned in the previous ER approach section, they deserve more attention. Consequently, to show the ER rule does combine multiple pieces of independent evidence in accordance to the axioms, they are restated and defined hereafter:

- Axiom 1 (Yang & Xu, 2002a; Yang & Xu, 2013): the independency or no support axiom states that if multiple pieces of evidence do not support a proposition at all, then there should not be joint support for that proposition. Basically, the general criterion y should not be assessed to an evaluation grade θ_n if none of the basic criteria e_L is assessed to that particular grade θ_n. In short, if $\beta_{B,i}=0$ for $i=1,\dots,L$ and $B\subseteq\Theta$ with $B\cap\theta=\theta$ then $\beta_{\theta,i}=0$.
- Axiom 2 (Yang & Xu, 2002a; Yang & Xu, 2013): the consensus axiom requires complete joint support for a proposition if all pieces of evidence fully support that proposition. For instance, the general criterion y should be fully assessed to the evaluation grade θ_n if all basic criteria e_L are fully assessed to that grade θ_n.
- Axiom 3 (Yang & Xu, 2013): the locality or completeness axiom says that if all pieces of evidence are completely assessed to a set and the corresponding subsets

of propositions, then the joint support should also be assessed to the same set and subsets. Thus, there should be no joint support for any other proposition.

- Axiom 4 (Yang & Xu, 2013): the non-dominance axiom refers to the situation where no evidence is dominant and at least one piece of evidence points to the proposition; then there should be some combined support for that proposition. Herein, if $\beta_{\theta,i} > 0$ for at least one $(i = 1, \dots, L)$, then $\beta_{\theta} > 0$.

In real-life, violations of these axioms are evident, yet these do not invalidate the ER rule as a prescriptive decision support. In fact, all existing decision models are either based on axioms that are frequently violated in a descriptive sense or do not consider any axioms at all (Durbach, 2012). In turn, the ER rule offers a rational way in combining multiple pieces of evidence to provide the DM with recommendations or some indications that can be further examined through complementary decision analysis.

3.5.2.3.3 Special Cases

Finally, to complete the review on the ER rule, its relationship with Bayesian inference, the ER algorithm and Dempster's rule must be assessed. Starting with Bayesian inference, Yang and Xu (2014) examined the relationship between Bayes' rule ant the ER rule. The latter reduces to probability theory if all pieces of evidence are profiled by a BD without local or global ignorance (Chen, et al., 2015). This is evident considering that BDs are regarded as a flexible generalisation of probability distributions, where the belief structure allows inexact reasoning by assigning belief to multiple propositions (Yang & Xu, 2013). In summary, when basic probabilities are exclusively allocated to singleton propositions, $\alpha_i = (\theta_n, 1)$, and pieces of evidence are fully reliable, Bayes' rule is a special case of the ER rule (Xu, 2012; Yang & Xu, 2014).

Next, whilst Dempster's rule generalises Bayes' rule, Dempster's rule and the ER rule are also closely related as both originate from the orthogonal sum generated on BDs and WBDRs respectively (Yang & Xu, 2013). In turn, Dempster's combination rule is another special case of the ER rule when each piece of evidence is fully reliable, i.e. $r_i = 1$ $(i = 1, \dots, L)$, causing $(1 - r_2)m_{\theta,1} + (1 - r_1)m_{\theta,2} = 0$ (Chen, et al., 2015). Yet, it must be noted that the ER rule corrects the counter intuitive problem existent in Dempster's rule (Yang & Xu, 2014).

Lastly, since the ER rule was developed to generalise the original ER algorithm, it is natural to conjecture that the ER algorithm is a special case of the ER rule (Yang & Xu, 2013). Based on this argument, if reliability and weight share the same definition, i.e. $r_i = w_i$ for $i = 1, \dots, L$ where weight is normalised, then the ER algorithm is a special case of the ER rule (Yang & Xu, 2014; Chen, et al., 2015).

3.5.2.3.4 Applications

Due to the fact that the ER rule has only been introduced in 2013, application research has been almost non-existing up to date. Merely Yang and Xu (2014) and Zhu et al. (2015) published application studies. Herein, Yang and Xu (2014), a year after they introduced the new approach, show how imprecise experimental data of a population can be used to determine the probability a person already has AIDS given the first HIV test is positive. This study predominantly aims at demonstrating the generalisation of Bayesian inference to ER. Zhu et al. (2015) explained how the ER rule could be adopted to aggregate peer review information with reliabilities. Contrary to the low number of publications, the forerunner (i.e. ER approach) found wide adoption, spanning various fields. It is anticipated that the ER rule too is applicable to diverse decision problems. That is to say, despite the limited application, the ER rule's merits and advances from previous methods make it a powerful reasoning tool that is expected to cover many industries.

Under current circumstances, this shortage of application research essentially establishes a research gap. Accordingly, keeping in mind the ER rule's properties, it offers a very promising procedure for real estate selection. The method has the potential to incorporate more evaluation criteria and aggregate the pieces of evidence in a consistent manner.

3.5.2.3.5 Limitations

The ER rule overcomes many of the difficulties found in Bayesian theory, DS theory and the ER approach. It acknowledges and defines local and global ignorance separately; it does not change the specificity of evidence and it fixes the counter-intuitive problem of Dempster's combination rule, to name a few. However, one assumption is even upheld in the ER rule examined in this chapter, referring to the requirement of independent criteria. To accurately reflect the reality, the aim should be to incorporate criteria relationships in the process of aggregating evidence.

Particularly for the present research project, criteria dependencies and correlations are expected, requiring a decision analysis method that can account for this condition. Given these points, Yang et al. (2015) recently suggested a modification to the ER rule, which ticks all other boxes in terms of solving a complex multi-criteria problem. In more detail, it was proposed to adjust the ER rule by adding an alpha-index (α) for coping with the independency proposition (Yang, et al., 2015):

$$\widehat{m}_{\theta,e(2)} = \left[\left((1-r_2)m_{\theta,1} + (1-r_1)m_{\theta,2}\right) + \sum_{B\cap C=\theta} m_{B,1}m_{C,2} * \alpha\right] \quad \forall\theta \subseteq \Theta$$

Here, a large dataset can be used to identify interdependencies among pieces of evidence (Yang, et al., 2015). This then accounts for criteria relationships and offers more reliable outcomes to support decision making. To date, as expected, application of this modified format are still to be undertaken.

3.5.3 Alternative Methods

Alternative methods are frequently employed to solve multi-input decision problems. Researchers in the past have published papers comparing and contrasting the performance of the ER approach to alternative models such as the well-established MRA, and the more recent developments in ANNs (Wang & Elhag, 2007). Many application studies also exist that specifically compare the performance of MRA versus ANN models (Rossini, 2000). Whilst the two techniques are predominantly employed for price predictions, applications overlap. Basically, interchanging these methods to address identical MCDM problems, as well as their presence in the real estate industry, justifies reviewing them at this point.

3.5.3.1 Multiple Regression Analysis

MRAs are used worldwide to address decision problems by modelling the cause-and-effect relationship of independent variables on a dependent one. Acknowledging that MRA has been applied in the real estate sector, its scope and features should briefly be identified.

3.5.3.1.1 Features

First, the independent variables that help predict a dependent variable need to be defined (Chatterjee & Hadi, 2015). Reviewing existing studies or data records often assists the process of choosing the most appropriate explanatory items. The regression analysis requires a predefined function. Assuming a linear relationship and having identified all the model parameters, a linear MRA can be expressed by:

$$Y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n + \cdots + b_N x_N + \varepsilon$$

Here, Y denotes the dependent variable, b_0 is a constant determining the intercept, x_n $(n = 1, \dots, N)$ are N independent variables and b_n $(n = 1, \dots, N)$ are the corresponding beta coefficients (Wang & Elhag, 2007). At last, ε represents the random error following a normal distribution with zero mean and constant variance.

Using existing records, the coefficients can be estimated, a process referred to as model fitting (Chatterjee & Hadi, 2015). These essentially provide the influence level of individual variables onto the output. The beta value b_n shows how much a change is achieved in Y when changing x_n by one unit, holding all other independent variables constant (Keith, 2015). This relationship can easily be demonstrated with a scatter diagram. Ultimately b_0 and b_n are typically estimated using the least squares method to minimise the sample data's sum of squared errors (Wang & Elhag, 2007; Chatterjee & Hadi, 2015). In practice, this procedure is typically conducted in statistical software packages such as SPSS.

Once this relationship between the chosen independent variables and the dependent variable is identified, predictions can be made for unassessed cases. To determine the performance, the dataset is usually split into training set for estimating the model

parameters, and a test set, which can review the difference between an actual and a predicted value for Y (referred to as residual error).

Before moving on, it is worth mentioning that MRAs are functioning under certain assumptions. Some of the most prevailing ones are (Adair & McGreal, 1988; Wang & Elhag, 2007; Montgomery, et al., 2012; Chatterjee & Hadi, 2015):

- predefined functional form (in the case explained herein, a linear relationship between the independent variables and the dependent variable is assumed)
- variables have normal distributions
- independent variables
- errors need to be spread out consistently between the variables, referring to homoscedasticity of the errors
- no or little multicollinearity across parameters
- high quality, validity and suitable size of the dataset

3.5.3.1.2 Applications

The long history and ease of use of the MRA ensures to date high adoption in every industry and across different problem settings. To show the scope of application, predictions have been observed in agriculture, industrial relations, environmental issues, production and demand forecasting, cost estimations and in many more areas (Adair & McGreal, 1988; Chatterjee & Hadi, 2015). Of course, extensive applications within a real estate context can also be found (Adair & McGreal, 1988; Adair, et al., 1996; Wolverton, 1997; Nguyen & Cripps, 2001; Larraz, 2011)

3.5.3.1.3 Limitations

Whilst MRA is a widely applied technique, it is accompanied by major restrictions that are typically associated to the rigid model and imposed data assumptions. First, like most data driven methods, the data quality, and often also the quantity, is crucial in obtaining a powerful model. Missing data and outliers herein can significantly impact the model's performance. In application studies, analysts generally try to avoid this problem by excluding entire cases. Another limitation restricting the application to a small number of real-life situations is the requirement to predefine a functional form. More precisely, analysts need to specify the relationship between the independent variables and the dependent variable. Considering a linear multiple regression for instance, not many decision problems experience that each additional unit in an independent variable, all others held equal, contributes the same amount to the dependent variable's value (Adair, et al., 1996). Besides these restrictions, MRAs also assume independent and uncorrelated model parameters. Sure, some solutions have been proposed in regards to this, by for instance combining correlating variables into one, yet MRAs largely fail to mirror the complex situations an analyst has to deal with. Although there are a handful of other limitations, this goes beyond the scope of the current research. MRA is merely introduced as it has frequently been used in real estate price predictions. This focus may in some cases be justifiable, whereas the

inherent characteristics and assumptions of the conventional MRA stress their limited power in homebuyers' real estate selection.

3.5.3.2 Artificial Neural Networks

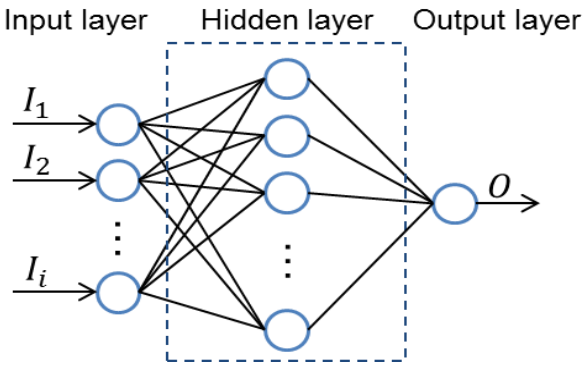
In response to major criticism of the traditional MRA, a multitude of researchers and authors have opted for more advanced, non-linear methods such as ANNs. Linked to research of the human brain, literature indicates a long history of ANNs, but its present popularity potentially dates back no longer than the mid-1980s (Jain & Mao, 1996), where explicit conferences and ANN societies were formed (Basheer & Hajmeer, 2000). This section introduces the method's key features and uncovers eminent restrictions.

ANNs are information processing systems that attempt to replicate or simulate the biological central nervous systems (Graupe, 2013). The artificial intelligence, non-linear analytical models essentially identify patterns in existing data (historical records) to later mimic these relationships to predict new cases (Zhang, et al., 1998). It describes the way in which ANN learn from existing examples, similarly to how humans learn from experience (Basheer & Hajmeer, 2000). Prior to explaining the ANN structure, it is worth noting that unlike regression analysis, ANNs do not require a predetermined functional form (Nguyen & Cripps, 2001) and in contrast to MCDM models discussed in this chapter, ANN systems neither rely on expert knowledge, nor active DM contributions, as they learn underlying rules and compute weights when studying the input-output relationships of past cases (Jain & Mao, 1996). Depending on the decision problem, this may be viewed as a strength, or weakness. Regardless, the data-driven network models benefit from very few a prior assumptions (Zhang, et al., 1998).

3.5.3.2.1 Features

To construct an efficient and effective ANN system, Basheer and Hajmeer (2000) suggest six phases. Phase one consists in defining and formulating the decision problem. Here, analysts should have a clear understanding of ANNs' benefits over other methods. In phase two, the analyst must design the network architecture. All ANNs consist of three layers, input, hidden and output. A simple network format with only one hidden layer and one output variable is shown in Figure 6 below.

Figure 6, Simple ANN Structure



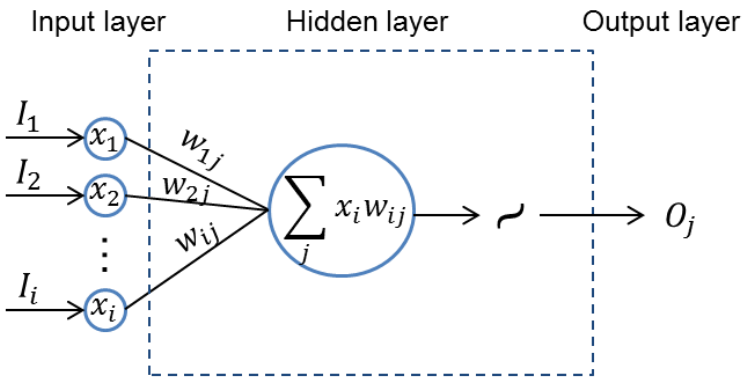
For the input layer, the number of nodes needs to be specified in relation to the problem formulation. Nodes refer to a set of input parameters that the DM considers relevant in assessing the dependent variable. The input variables are then connected to a 'black-box', which consists of one or more hidden layers. The 'black-box' concept is frequently used in relation to ANNs, as the DM is not able to comprehend the processing steps that relate a number of inputs to an output (Basheer & Hajmeer, 2000).

Continuing the discussion on hidden layer(s) and nodes, they capture the input-output relationship and must receive considerable attention from the network developer. Essentially, the structure impacts the model's performance along with other parameter settings, such as learning rate, selection of training set and number of training cycles (Nguyen & Cripps, 2001; Limsombunchai, et al., 2004). Arguably, the absence of any guidance on the non-trivial network design task, challenges the construction of a valid and efficient model. Respectively, it has been suggested that a network with too many hidden units, constitutes a lower training error, but has the potential to overfitting the data, decreasing generalisation power (Nguyen & Cripps, 2001). Meanwhile, too few nodes possibly limit the model's power in learning the data and differentiating between complex patterns (Zhang, et al., 1998). Trial-and-error may be the most viable way in establishing the optimal structure (Limsombunchai, et al., 2004). At last, a system is completed with an output layer, representing the dependent variable(s).

There are many different network types. The most commonly used backpropagation system (Zhang, et al., 1998; Basheer & Hajmeer, 2000; Nguyen & Cripps, 2001) is further investigated herein. These designs are also referred to as feedforward error-backpropagation, implying that each iteration constitutes a forward activation to first provide a result, whilst in a second step the computed error is transmitted backward through the hidden layer to the input layer to make weight adjustments. Prior to training the network system in phase three, a dataset is divided into training and test set, where the former is used to build the network, learn relationships and compute appropriate arc weights, whilst the latter measures the generalisation power of the network design (Zhang, et al., 1998). Sometimes a third set, i.e. validation set, is also included. In any case, these sets should aim to be a close representation of the study population (Zhang, et al., 1998).

Using the training set, the input nodes transmit the received external information forward to the hidden nodes. In Figure 6, each connection (the arcs/lines connecting the nodes) is associated with a weight (Wang & Elhag, 2007). They express the connection strength between the neurons. In the first instance, the connections are assigned random weights, which are later adjusted to minimise the error. Input values x_i are multiplied by the connection weight w_{ij} to allow the weighted sum of all inputs to be accumulated when entering a hidden node ($\sum_j x_i w_{ij}$) (Pagourtzi, et al. 2003). The collective effect is then passed onward through an activation/transfer function ($\sim$) to convert the total signal into the output value(s) O_j. The process can be graphically demonstrated as follows:

Figure 7, Process of Inputs reaching one Hidden Node



For the activation function, the sigmoid transformation function is predominantly used in software packages available for ANN analyses. Then, arriving at the output value, the backpropagation starts. This process describes the supervised learning of the system, where it is provided with existing relationships between inputs and output(s). The learning rate, which must be determined by the network developer, defines the magnitude of weight changes (Zhang, et al., 1998). The error, representing the difference between the actual and predicted outcome, offers an indication of the model's performance. In sum, the weights are iteratively modified with the objective to minimise the error between predicted and actual outputs (Zhang, et al., 1998). ANNs' learning abilities allow analysts to alter and adapt internal structures in accordance to the performance of the test set, as well as any emerging external stimuli, i.e. decision environment changes (Basheer & Hajmeer, 2000). This completes the system realisation phase of the ANN development (phase three).

Next, system verification is an optional phase that plugs the validation set into the best network structure resulting from the training and test set (Basheer & Hajmeer, 2000). It indicates the system's generalisation power of accurately inferring the outcome of unseen cases (Zhang, et al., 1998). High capabilities allow the system to be implemented in the real world (phase five), often requiring the network to be embedded in a suitable computer program. Finally, phase six relates to system maintenance, such as updating the system when new data becomes available (Basheer & Hajmeer, 2000).

3.5.3.2.2 Applications

The advantageous features promoted the application in numerous disciplines (Basheer & Hajmeer, 2000). Its suitability to solve very complex, ill-defined, non-linear problems raised its relevance in decision theory, prediction, data-mining, pattern recognition, clustering and other related areas (Graupe, 2013). Prediction/forecasting in particular are frequent goals when applying ANNs (Zhang, et al., 1998). This was also evident in real estate literature, where several stakeholders employed ANNs to predict a property's market value.

3.5.3.2.3 Limitations

Despite its successful application in many fields, ANNs offer extremely low transparency to DMs, making it less attractive as a decision support model where the DM wants to understand the process and justify his/her course of action. Put differently, whilst the results may be highly accurate, they are difficult to interpret (Zopounidis & Doupos, 2002). This, and the fact that weights are learned from the data rather than including the DM's preferences, poses significant challenges for adopting ANNs for real estate selection issues. Additionally, being data-driven, ANNs require a large dataset that holds information on existing relationships covering the possible variations in the problem (Zhang, et al., 1998). Especially the size of the sample is important, since ANNs require the dataset to be partitioned into training and test sets. Respectively, the success of any given ANN model is highly correlated with the quality and quantity of the data (Basheer & Hajmeer, 2000). This means, like in MRAs, that data inspection is crucial and often requires the elimination of outliers. Furthermore, whilst there are numerous comparison studies with conventional statistical methods like MRA, findings are inconclusive on the superiority of the ANN method (Zhang, et al., 1998). For instance, Nguyen and Cripps (2001) argue, based on their in-depth assessment, that ANN perform better if a moderate to large data sample size is available, whilst MRA outperform ANNs on small samples.

In sum, the review of the two alternative methods (MRA and ANN) seemed appropriate considering their applicability in the real estate sector. It followed the discussion of the ER framework, which had previously been investigated alongside MRA and ANN by Wang and Elhag (2007), using all three approaches to model the same problem. Based on this evidence, it may be suggested that they have overlapping abilities.

3.6 Decision Support Systems

Most of the above methods have been facilitated through DSS, which are interactive computerised systems that aim to enhance decision outcomes by facilitating the collection and analysis of data (Power, et al., 2011). They significantly increased in importance over the years, with more and more DMs relying on DSS for decision support (Eom, et al., 1998). The origins date back approximately 60 years, but due to the steady technological advances, updates are required regularly to always have the most adequate technique to tackle a decision problem (Velasquez & Hester, 2013). Accordingly, new capabilities constantly emerge and are offered to specialists, but also in some cases to the public. The latter frequently comes in form of World Wide Web-based DSS (Eom, et al., 1998).

3.6.1 Features

Whilst DSS have many advantages and can provide strong support in a complex decision making situation, their adoption and acceptance rate is highly correlated with the provision of a user-centred design (Power, et al., 2011). Clearly, it is advisable to establish a design portraying the collaboration between developer and DM.

Ideally, systems feature a logical and clear interface to input necessary data to make a decision more transparent and robust, and allow efficient data analysis. With regards to user interfaces, visuals are often incorporated to simplify or allow DMs to better comprehend individual process steps. Also, when constructing a DSS for a specific purpose, the extent of information accessible to the DMs should be taken into account (Brown & Vari, 1992). Overall, there are a large variety of DSS with unique designs and requirements. To avoid adoption barriers and promote acceptance in the target audience, it is crucial to study the DMs' needs and expectations. Once these have been identified, it provides the DSS developer with a fairly good idea on the features and applications that are most desirable, and can ultimately make, or break, the success of a given system.

3.6.2 Applications

In the past, application studies have been conducted across different fields, such as operations management, marketing, finance, strategic management, accounting and others (Eom, et al., 1998). As a result, the computerised systems are extensively studied, reaching a multidisciplinary status within the literature (Power, et al., 2011). Clearly, the opportunities in real estate are vast. DSS, if constructed for users that are non-experts and in accordance to DMs logical thought processes, have huge potentials in supporting homebuyers' to make a more informed decision. In this context, Eom et al. (1998) agree that DSS, with all their proven benefits, should be solving more strategic decisions.

3.7 Summary

This chapter began by reviewing decision theory and placed the MCDM field within prescriptive theory. Subsequently, common MCDM problems elements were presented, explicitly highlighting the information needed to define a multi-criteria decision. Problem structuring literature revealed that there is little guidance on how to best extract the required decision components that allow a researcher to select or build a suitable MCDM support model. Next, most relevant MCDM approaches (to the real estate selection) were explained. Put differently, there are obviously a multitude of other MCDM methodologies, such as the different outranking techniques, yet in accordance with the purpose of this research project, the most capable and promising methods to the real estate context were presented in greater detail. Here, AHP, MRA and ANN did already find some adoption, whilst the ER rule has been identified to meet the problem characteristics set out in Chapter 2. Herein, most noticeable is the large number of evaluation criteria required to assess alternatives, which automatically introduces a high level of complexity. For this reason, the ER section offered a thorough analysis, providing the ER rule's evolution from the DS theory and the ER approach. It was emphasised that the ER rule is exceptionally advantageous to maintain transparency, when contrasting its aggregation procedure to ANN's 'black-box'. Also, as an addition to the ER rule, a modification recently proposed by Yang et al. (2015) further advanced the evidence combination method by addressing the frequently observed condition of dependent and correlated criteria. To conclude, a small review on DSS was

provided, as the practical implementation of any decision support mechanism is highly reliant on usable software.

4 Research Questions

This chapter presents the research questions and a brief description on how to address these during the research process.

4.1 Introduction

The research questions presented herein are directly linked to the aforementioned literature gaps and the researcher's knowledge and experience in the real estate industry. Shortcomings in existing literature are again summarised to justify the corresponding research question. Then, the expected strategy on how to answer each individual question completes this chapter.

4.2 Research Questions and Justifications

The researcher defined the research questions in an attempt to provide both academic as well as practical industry contributions. In respect to the former, contributions are made to the MCDM (RQ1 and RQ3) and real estate (RQ2 and RQ3) literature. Practical implications (RQ2) relate to potentially optimising communication and marketing strategies of real estate agents. Finally, a forth research question (RQ4) was added with the idea to provide an initial insight into DSS requirements and facilitate future research.

4.2.1 Research Question 1

An MCDM literature gap emerged during the previous review of existing research. As emphasised by Belton and Stewart (2002), problem structuring is an integral part of MCDM. Although viewed in light of MCDM, problem structuring needs to be addressed separately to MCDM methods or their applications. Respectively, despite increasing research devoted to MCDM models over the last century, still limited contributions are found on guiding multi-criteria problem structuring. Current understanding of the tasks involved in specifying and eliciting the MCDM parameters remains vague. Literature shortcomings were already highlighted in the early 90's, where Brown and Vari (1992) suggested that problem structuring techniques for specific context situations need to be explored in future research to avoid solving wrong problems. Yet, even in more recent publications, authors including Corner et al., (2001), Keeney and Gregory (2005), Franco and Montibeller (2009) as well as Maier and Stix (2013) point towards a literature gap that needs to be filled by developing a problem structuring tool for MCDM. Therefore, this research formulates the first research question as follows:

RQ1: How is an MCDM problem structured?

This relatively broad question deserves to be broken down into defined sub-questions:

- **RQ1.1**: What decision problem elements need to be known to select, modify or build an appropriate MCDM support mechanism?
- **RQ1.2**: How are required problem elements defined and information extracted?

Ultimately, establishing a clear process that can be adopted to define MCDM components has the power of deriving an adequate representation of the decision problem. It is proposed that with the resulting increase in problem transparency and the corresponding process, the DM or analyst is in a better position to identify the required modelling and support mechanisms (Kasanen, et al., 2000). Also, this provides the basis for a solid justification on the decision support method choice, which analysts are frequently incapable of providing (Guitouni & Martel, 1998).

4.2.2 Research Question 2

The heterogeneous nature of real estate indicates the complexity of making comparisons. Thus, a vast amount of information is required to determine a property's overall performance (Zheng, et al., 2006; Liu, et al., 2006). Whilst real estate investigations are steadily growing, the focus remains predominantly on investment decision making. In other words, current literature falls short of providing a framework for inexperienced individuals who want to buy a property to live in (Sah, 2011). There are different research avenues proposed to complement existing knowledge. Levy and Lee (2004) stress the need to investigate influence levels of DMs, in terms of female and male roles, during the decision process and on the final selection. Other authors such as Hardin (1999), as well as Zheng et al. (2006), propose that a focused assessment on agents' and homebuyers' interactions should be conducted to discover any barriers that hinder a smooth search and decision making process. Hemphill (2007) observed major misunderstandings and false assumptions during realtors and property sellers' interactions, potentially indicating a similar situation between agent and homebuyer. Generally speaking, it is worth investigating whether agents have certain prejudices about their clients, and vice versa, that affects a smooth interaction. Outcomes here have the potential for practical implications with regards to adapting agencies' marketing strategies and enhancing the communication with clients.

A different topic within real estate concerns the failure of establishing an accurate set of relevant evaluation variables, including appropriate categorisation, criteria interdependencies and prioritisations (Ratchatakulpat, et al., 2009; Haddad, et al., 2011). As identified by Kettani et al. (1998), Belton and Stewart (2002), as well as Kim et al. (2005), including all criteria that have some degree of influence has an effect on the decision and can potentially reduce regret and/or increase the level of satisfaction with the final outcome upon reflection. Currently however a rather low level of consideration is given towards assessing alternative houses on multiple criteria, neglecting many that are anticipated to play a role, whilst overemphasising others (Gibler & Nelson, 2003). Consequently, this demands further research efforts towards identifying a comprehensive list of criteria in co-operation with industry experts and prospective homebuyers. In summary, despite the knowledge that DMs need support in the highly complex real estate decision making process, there are very limited behavioural studies (Zheng et al., 2006; Sah, 2011) and particularly none that thoroughly address the issues just highlighted.

Ultimately, these potentially interlinked literature gaps were addressed under a broad research question:

RQ2: What is the luxury-homebuyer's decision making process when selecting a property in Majorca?

This, according to the literature, requires asking various questions:

- **RQ2.1**: Who is directly and indirectly involved in the decision making process?
- **RQ2.2**: What are influence levels of the various decision stakeholders?
- **RQ2.3**: How is the interaction between homebuyers and agents?
- **RQ2.4**: What are the criteria that are relevant in the luxury real estate evaluation process in Majorca?
- **RQ2.5**: What is an appropriate categorisation of the identified criteria?
- **RQ2.6**: Are criteria correlations and interdependencies observable?
- **RQ2.7**: How are individual criteria perceived in terms of level of importance in the decision framework?

4.2.3 Research Question 3

The next research question is aimed at addressing gaps that emerged within both real estate and MCDM literature. On the one hand, in publications originating from the real estate domain it has been suggested that MCDM studies with applications in the industry are limited despite their proven abilities to handle and solve complex decision making problems (Kaklauskas, et al., 2007). In support of this, Johnson (2005) argued that future work should investigate suitable MCDM methods that have the potential to facilitate real estate comparison. In this context, and in contrast to experienced DMs who frequently reject normative or prescriptive rules and strategies (Wierzbicki, 1997), it is anticipated that homebuyers who are confronted with an infrequent decision situation would appreciate prescriptive guidance in the high-stake, strategic decision of selecting a real estate.

On the other hand, in operational research and MCDM related journals, almost no application studies of the ER rule were identified. This practically non-existing area of research does not imply the method's limited applicability to real-life decision problems, but rather its short history, being introduced only in 2013 (Yang & Xu, 2013). Therefore, its highlighted merits and advances from previous support mechanisms (see section 3.5.2.3) provide strong evidence for a powerful reasoning tool that may potentially achieve a superior performance than other models in addressing the real estate selection problem. This conception led to the following research question:

RQ3: How can the real estate selection problem be modelled to allow transparent and consistent criteria aggregation?

This question essentially focuses on how the ER rule performs as a support mechanism for the real estate selection problem. More specifically, in accordance with the literature review, the applicability of the methodology to the real estate selection emerged. Having reviewed

other techniques such as AHP and ANN in greater depth, which were applied in the past, directed the research towards a potentially superior method to solve the current problem.

By including the above research question, this research project can provide the real estate literature with a prescriptive multi-criteria decision support mechanism, whilst also offering an application research for the MCDM community.

4.2.4 Research Question 4

DSS are known to facilitate decision making processes by offering a computerised system that dictates the required input parameters and conducts necessary computations. Nonetheless, within real estate, the availability is extremely low (Urbanaviciene, et al., 2009), mainly concentrating on project evaluation or investment appraisal spreadsheet based DSS. Even if specific DSS exist for real estate selection for the end-user, the behavioural biases eminent in real estate decision making and restricted accessibility may have prohibited the use within the general population (Branigan & Brugha, 2013). Additionally, as pointed out by Power et al. (2011), the adoption and acceptance of such computerised systems is highly dependent on the design. He suggested that in order to increase the probability of successfully developing a suitable DSS for a particular context, it is recommended to involve the DM directly in the design process, creating a user-centred construct. Consequently, to provide insight into system requirements, demanded by homebuyers that may eventually initiate further research extending the current project's findings, the fourth research question is enclosed:

RQ4: What factors influence the adoption and acceptance rate of a real estate decision support system among homebuyers?

4.3 Proposed Strategy to Address the RQs

The intended additions to existing knowledge are clearly emphasised in the previous section. These are essentially created in Chapter 6, 9, 10 and 11 as previously highlighted in Figure 1.

The first research question, which involves the construction of an MCDM problem-structuring framework, requires input from two academic bodies, the MCDM literature (Chapter 3) and research methodologies literature (Chapter 5). The second research question entirely relies on the field work that directly examines prospective homebuyers' decision making behaviour (using observations, interviews and surveys) (Chapters 9 and 10). The third research question is addressed by merging knowledge from various sources, including MCDM literature with focus on ER (section 3.5.2.3), data collection findings (Chapter 10) and model building expertise (MATLAB). Finally, research question four can be answered using the data obtained from homebuyers and agents in semi-structured interviews and surveys (sections 10.2 and 10.4).

4.4 Summary

This chapter explicitly presented the research gaps previously identified in a thorough literature review. This resulted in three key research questions that were broken down into a number of more precise sub-questions in the first two instances, i.e. research question one and two. Further, this was expanded with a forth research question that is predominantly aimed to facilitate any future research efforts in this area.

5 Research Methodologies

The purpose of this chapter is to outline the different research methodologies. This provides awareness of features, advantages and limitations to justify the selection of individual techniques for the hereafter presented MCDM problem-structuring framework.

5.1 Introduction

The selection of an appropriate research methodology is crucial to obtain valuable and meaningful results that can successfully answer research questions. Within academia, there are two overriding fields from which techniques can be adopted, i.e. quantitative and qualitative. Each domain has unique features, which come with certain benefits and limitations. These need to be discussed prior to choosing one over the other, or deciding to use a mixture of both. With respect to the latter option, the use of multiple methods now classifies a third, distinct approach to research. Either way, the choice needs to be justified to fit the particular research context, as well as ensure high validity and reliability of the final results. Given these points, existing data collection and analysis methods are examined to design the most suitable strategy in extracting the MCDM elements associated with high-involvement product or service decision situations.

5.2 Quantitative Approaches

5.2.1 Quantitative Paradigms

Prior to examine main features of quantitative methods, it is necessary to identify possible worldviews (I.e. conception of reality) a researcher may follow during an investigation. Herein, there are a number of paradigms that can be adopted, such as positivism, post-positivism, constructivism and interpretivism. The philosophical orientation followed by an individual is believed to guide actions throughout the research (Creswell, 2013). Many authors suggest positivism has predominantly become associated with quantitative research studies, since it is closely aligned with objectivity and emphasises a common reality among humanity (Howe, 1988; Newman & Benz, 1998; Mackenzie & Knipe, 2006; Suter, 2012; Creswell, 2014).

Furthermore, positivism ontology, referred to as realism, assumes there is a single world that is formed apart from human existence and interaction, and which can be captured using appropriate means (Guba & Lincoln, 1994; Sale, et al., 2002; Gibbs, 2007). Generally, quantitative investigators' objective is to test hypotheses with standardised measuring instruments (often in artificial constructed environments) to then generalise the findings to the larger population. The focus of positivists therefore lies in empirical verification, rather than understanding individuals' subjective perspectives (Suter, 2012). More recently, post-positivism gained popularity among researchers, which challenges the notion of the absolute truth and acknowledges the fact that it is not always certain to discover one truth when studying human phenomenon (Creswell, 2014). Despite the observed shift towards post-

positivism, Suter (2012) argues that the majority of quantitative still believe in the discovery of the objective truth.

5.2.2 General Features

In terms of describing quantitative research approaches, numerical data is collected, which can be statistically analysed to reveal significant relationships among variables (Muijs, 2011; Creswell, 2014). The objective of the quantitative data is to answer pre-defined research questions or test hypotheses. Hypotheses are always formulated as a null and alternative hypothesis, where the condition expected to be true is represented by the alternative and the null states the opposite (Muijs, 2011).

Key in quantitative studies is to achieve objective results of a representative statistical sample to enable generalisation of the research findings to the whole population (Onwuegbuzie & Collins, 2007). This emphasises the importance of sampling in terms of randomly selecting individuals that replicate the target population. In sum, the principal benefit of quantitative tools is their ability to make generalisation statements to other members of the studied population, leading to potentially high external validity (Onwuegbuzie & Collins, 2007). Another advantage is the relative low level of intervention by the researcher in the data, and typically a minimal level of personal contact with study subjects, which reduces various validity threats (Taylor, 2005). Here, the standardisation of data collection instruments increases the protection against bias (Creswell, 2014). It is also a widely held view that research reliability is high, because structured quantitative procedures can most certainly be replicated or repeated by other researchers to allow comparison across data, time and settings (Maxwell, 2005). This creates opportunities for further research in a particular area. Despite these evident benefits, quantitative methods do not come without limitations. For instance, they fail to incorporate any contextual aspect, which is claimed to be an important contributor to human behaviour. Other concerns are method specific and are discussed accordingly.

5.2.3 Data Collection Methods

Complementing the above section that introduced common features across quantitative research, different options for gathering data are discussed in more detail. Among the most utilised techniques are experimental studies in artificial environments and questionnaires with closed-end answers, nowadays often distributed online. Method specific benefits and limitations need to be explored and acknowledged by a researcher when developing the research strategy.

5.2.3.1 Questionnaires

In the quantitative context, questionnaires are viewed as non-experimental research (Muijs, 2011). They are employed to reach and collect data from a large number of respondents with the objective to make inferences from the study sample to the population (Creswell, 2003). Commonly, standardised questions are followed with predefined closed-end answers.

Whilst this format greatly facilitates data analysis, it runs the risk of not providing all possible or desired answer options. Also, in choosing the questions, the researcher must carefully consider the research objectives and the data required to test hypotheses (Muijs, 2011). Often pilot tests are conducted to ensure clear formulation and ultimately determine the questionnaires' reliability (Marshall & Rossman, 2006).

In terms of distribution channels, technological advances offered new opportunities and facilitated data collection. Administering a survey online, compared to traditional paper-based questionnaires, immediately expanded the geographical reach. This triggered many cross-country studies and substantially increased academic knowledge. In relation to this, the cost efficient distribution channel and the fast turnaround add to the advantages of surveys (Creswell, 2014). Nowadays, researchers have access to various sophisticated survey platforms offering many question layouts, integrated display logics and monitoring applications. Display logics allow programming the survey based on previous responses, in a way tailoring the questionnaire (Muijs, 2011). Monitoring applications refer to tracking participants' progress (Cole, 2005), but also pointing out the portion of the sample who did not yet start the questionnaire. In some cases, sending a reminder to these individuals can increase the response rate. Another valuable aspect of the online format is that response data is already in an electronic form, avoiding time-consuming data processing (Cole, 2005).

In terms of disadvantages, although the response rate might be increased to the traditional paper-based formats, a serious issue with online surveys is that the researcher is unsure whether it is completed by the target (Marshall & Rossman, 2006). Also, in order for this approach to be effective, the study population must have unrestricted access and happily use the Internet. This often limits the applicability to certain consumer segments. Regarding the pencil-and-paper questionnaires, a major disadvantage often eliminating the data collection method from further consideration is the time consuming data entry for the analysis process (Muijs, 2011). On the whole, all questionnaires might have the ability to collect a great amount of data, yet often lack depth and provide little knowledge on the context.

5.2.3.2 Experimental Research

Muijs (2011, p. 11) defined experimental research as "a test under controlled conditions that is made to demonstrate a known truth, or examine the validity of a hypothesis". Hence, experimentation studies concentrate on cause-and-effect relationships by manipulating the independent variables (Creswell, 2014). The investigator usually creates an artificial environment to compare an experimental and controlled group. This makes the random assignment of study subjects to either of the two groups crucial (Creswell, 2003). Essentially, it allows studying a phenomenon in isolation, examining connections and behaviour of variables, whilst controlling unwanted, external influences (Taylor, 2005; Muijs, 2011). The independent variables are usually identified and controlled for, such that gender influences or age differences can be ruled out to have caused any reaction in the dependent

variable (Creswell, 2014). Some major drawbacks of conducting an experimental study include the resource and time requirements.

5.2.3.3 Documentation and Data Banks

Using documents for an investigation usually refers to accessing existing data banks, i.e. considering secondary sources. Existing data obviously eliminates the time consuming data collection process accompanied with questionnaires or experimental research (Muijs, 2011). Secondary data can include very different information and come in numerous formats, ranging from financial or managerial reports to online platforms that provide information on different consumer products. Inevitably, it is crucial the investigator bears in mind that data was initially collected for a very specific purpose and should consider the applicability of the fixed concepts and measures used in the existing dataset (Muijs, 2011). Typically, however, documentation is used to support other data collection methods, or to complement a dataset obtained through primary research.

5.2.4 Data Analysis Methods

In quantitative research all data needs to be collected and organised prior to the analysis (Suter, 2012). This involves transforming data into a usable format and cleaning the dataset from errors and outliers. Following these principal steps creates the basis for descriptive and statistical analyses.

5.2.4.1 Descriptive Statistics

A descriptive analysis provides a general idea about individual responses and an overall summary or description of the dataset. A number of computer packages, such as Microsoft Excel and SPSS can be employed to support this analysis process. It focuses on computing measures of central tendency and measures of dispersion. In other words, descriptive statistics specify the mean, median, mode, range, standard deviations and variance for the dependent and independent factors (Creswell, 2003; Onwuegbuzie & Leech, 2006). These measures can highlight any emergent patterns that can be further examined with inferential statistics.

5.2.4.2 Inferential Statistics

Inferential statistics, also referred to as statistical analysis, concentrates on relationships among the variables. Statistical tests are the logical successive action after descriptive analyses. Foremost, they are required to make conclusions beyond the data and allow testing hypotheses. Most prominently, the T-test is used to check whether the means of two samples are statistically different. Another frequently conducted statistical test includes the one-way analysis of variance (ANOVA). Generally speaking, the results from a statistical analysis allow the analyst to make inference statements about the study population. In fact, inferential statistics have the potential to highlight differences between samples or sub-samples and specify whether findings are expected to be observed in the population. Again,

statistical computer programs are being used to facilitate correlation analysis and hypotheses testing.

5.3 Qualitative Approaches

5.3.1 Qualitative Paradigms

Similar to the typical quantitative paradigm, qualitative researchers are likely to follow an interpretive or constructivism approach to research. These two are fundamentally different to the quantitative paradigms introduced previously (Muijs, 2011). The qualitative philosophical stance stresses the importance of the human element in research (Howe, 1988; Creswell, 2014). The human element stems from the active involvement of the researcher in the data collection and analysis process as either interacting with the study participants or interpreting the dataset. The focus here is predominantly on human perception and experiences. Hence, it is not about identifying one truth, but rather trying to understand the subjective meanings individuals create and live by (Suter, 2012; Creswell, 2014). In this respect, qualitative investigators believe in the concept of multiple realities (Gibbs, 2007; Suter, 2012), where all views are equally valid and reality can be seen as a social construct (Newman & Benz, 1998). Accordingly, a researcher adopting an interpretive/constructivism orientation would never claim to be able to describe the real world; he/she is more interested in portraying how various individuals perceive it (Gibbs, 2007).

5.3.2 General Features

Qualitative approaches aim to get a deep insight into a particular phenomenon. Whilst quantitative mechanisms try to gather a clearly defined set of data points from a substantial sample size, qualitative methods concentrate on a relatively small number of individuals to receive very detailed information and understand a situation within the context. It emphasises that researchers explore meanings individuals assign to constructs and concepts (Creswell, 2014). This focused approach may result in the discovery of new ideas, new perspectives or areas that should be addressed in future investigations. In fact, qualitative methodologies are said to be emergent (Creswell, 2003). This evidently also stresses the great degree of flexibility, where evolving findings during data collection can directly influence subsequent actions (Suter, 2012). Respectively, researchers especially acknowledge newly gained insight during the process to optimally understand the phenomenon and create a holistic picture, derived from multiple perspectives. Moreover, it has frequently been observed that investigators, throughout the research progression, revise and adjust previous decisions, including research questions. As a consequence of these features, a qualitative researcher often follows an inductive approach, where data collection serves as input to develop a theory (Gibbs, 2007; Creswell, 2014). In other words, rather than starting with an explicit theory in mind, the research aims to discover a new theory from his/her investigation (Thomas, 2006; Suter, 2012).

Another common characteristic shared by qualitative methods is reflexivity. This concept stresses the active involvement of the researcher by interacting with the participants and interpreting their actions (Eriksson & Kovalainen, 2008). Unfortunately, this relationship between the research and the members of the target population during the data collection process may result in biased and subjective research findings. Regardless, it is often argued that the access to rich, detailed data compensates this weakness. Particularly, the investigation of a phenomenon in its natural environment has been identified as one of the great benefits of qualitative research (Kaplan & Duchon, 1988; Suter, 2012).

Qualitative approaches, whilst very powerful on the one hand, have also been criticised for a number of reasons. For instance, assuring reliability is often difficult since qualitative studies are hard to replicate. Another limitation, and often the main criticism, is its restricted ability of generalising the research results. Statistical generalisation can never be achieved, making research results only applicable to a very specific case and across the particular context. Attention is also repeatedly directed towards the issue of validity. Within the qualitative spectrum, researchers often refer to validity in terms of trustworthiness or credibility (Suter, 2012). Generally, qualitative findings are scrutinised for their validity, requiring researchers to recruit third parties or ask the informants to check whether interpretations of the raw data represent the truth (Suter, 2012).

5.3.3 Data Collection Methods

Within the qualitative domain, there is an extensive number of research methods available that intend to discover underlying meanings, deep insights and/or emerging themes and concepts (Cassell & Symon, 1994; Suter, 2012). Due to a large pool of methods, they may be differentiated in terms of level of analysis and/or stakeholder focus, i.e. individual, group or organisational case studies. The data originating from these mechanisms are usually non-numerical (Creswell, 2003), mainly portraying any type of communication in written, audio or visual format (Gibbs, 2007). To facilitate qualitative data analysis, this information is frequently transcribed or transformed into text.

5.3.3.1 In-depth Interviews

In general, one-on-one interviews are very powerful in obtaining rich data of participants' past experiences, attitudes, motives and opinions on a chosen topic (Barriball & While, 1994). Additional advantages include the superior response rate to questionnaires and the certainty of receiving information from the intended participant, without any intervention from others (Barriball & While, 1994). Along with the obvious interview features, it must be highlighted that there are diverse approaches to in-depth interviewing. For instance, the researcher first needs to clarify whether a structured, semi-structured or unstructured style is adopted. This basically refers to the amount of prior formulated questions and interview structure (Marshall & Rossman, 2006). In semi-structured and structured interviews, the researcher frequently creates an interview protocol to avoid missing important points. Guidelines for semi-structured interviews often include the opening statement of the

interviewer, the key questions, any probes if a more detailed answer is required and a section for notes (Creswell, 2003).

Interview type can also be differentiated between face-to-face and telephone/skype conversations (King, 2004; Eriksson & Kovalainen, 2008). Herein, face-to-face interviews allow the researcher to additionally capture non-verbal behaviour during the questioning, specifically facial expressions or voice tone. This data, typically captured in field notes, may provide additional insight and consequently contribute to the research. Equally important, respondents may provide more accurate and detailed information in a face-to-face situation, when they directly interact with the investigator and feel comfortable in the setting (Barriball & While, 1994). The environment created by the researcher is essentially a key influencer on the effort individuals are willing to put into their answers and their openness towards certain topics (Marshall & Rossman, 2006). Alternatively, telephone interviews are often more convenient for the interviewees, as well as the interviewer. Despite the various distinctions between styles, all interviews are generally tape recorded to avoid losing data and allow transcribing the dialog for analysis purposes.

5.3.3.2 Focus Groups

Focus groups are also a type of interviewing, yet the researcher attends multiple participants simultaneously. Prospective informants are generally selected purposefully to assure they can substantially contribute to a certain topic (Rabiee, 2004). The objective here is often to initiate a discussion and trigger brainstorming, or observe the interaction between members (Kitzinger, 1995; Morgen, 1996). This technique encourages participants to reflect on the responses of their peer group (Marshall & Rossman, 2006). Attention in such group settings needs to be directed towards the participant selection process. Researchers must avoid selecting a group where one person is dominating the conversation, whilst the others answer to social norms, rather than expressing their own opinions and experiences. Although focus groups reduce time by interviewing a number of people at the same time (Marshall & Rossman, 2006), similar to experimental studies, it may be difficult to coordinate the availability of participants to a single point in time and assure the access to a particular location. Furthermore, in some instances data analysis is extremely demanding, since the context plays a key role when interpreting the comments (Marshall & Rossman, 2006).

5.3.3.3 Observations

Another qualitative data collection technique involves observing the study subjects, often in a natural setting, whilst taking field notes on behaviour or ticking items of an observation checklist (Marshall & Rossman, 2006; Muijs, 2011). This type of data collection is required when exploring sensitive topics that people may not wish to discuss directly with the researcher (Creswell, 2003). Also, in situations where a process or the interaction between individuals is being investigated, observations are often the sole possibility of collect the required data (Muijs, 2011). Generally, it is essential that the researcher avoids influencing the natural environment or the subjects in any way, since individuals may alter their normal

behaviour if they realise they are being observed. In opposition, there are other occasions where the investigator actively participates with the observed individuals (Creswell, 2003). Overall, the intrusive nature of this data collection method, in terms of the observed and the researchers influence in the situation, is frequently cited as a key disadvantage, along with significant resource and time requirements (Muijs, 2011). Nonetheless, observations often play some role in other qualitative inquiries, for instance researchers taking notes on interviewees' facial expressions and tone (Marshall & Rossman, 2006).

5.3.3.4 Documents

Obtaining information about individuals may require a qualitative analysis of private documents such as diaries, letters, minutes of meetings, logs, statements or emails (Marshall & Rossman, 2006). Whilst documents are also consulted in quantitative inquiries, in this context they simply are recorded conversations or thoughts in a written format. Frequently, these documents already exist and the researcher simply needs to search, access and organise a considerable amount of records. This exercise, however, is often very challenging when the researcher has not deliberately instructed the participants to keep a journal, or similar, over a specific period of time. On a more positive note, if the data originates from such secondary sources, the researcher has no impact on the participants and may only introduce bias during the interpretation stage. Additionally, the required time is also reduced, since transcribing is eliminated (Creswell, 2003).

5.3.4 Data Analysis Methods

The principal objective of qualitative data analysis is to reduce or condense the volume of raw information, plus identifying recurring patterns to develop a conceptual framework and derive conclusions (Thomas, 2006; MacQueen, et al., 2008). Herein, despite the goal to summaries and condense the large volume of data, often reviewing and exploring qualitative material initially results in an enhanced and bulkier dataset.

Contrary to quantitative data analysis, the qualitative interpretation should always start at the same time as data collection. Taking notes of possible themes or codes emerging during the fieldwork can reduce the complexity and consequently facilitate the entire analysis process (Gibbs, 2007). In short, data collection and analysis are often attended simultaneously (Suter, 2012). It provides the investigator with an initial structure and serves as a data analysis starting point (MacQueen, et al., 2008). Besides, this strategy encourages and increases flexibility by allowing changes during data collection if new insights arise (Gibbs, 2007). Once the data collection process is finalised, taped conversations need to be transcribed for an inquiry. Often, further categories or codes evolve when listening to tape recordings and transcribing the dialog, which are then added to the coding scheme draft (Creswell, 2003). Although qualitative analyses mainly identify relevant sections or words that are assigned to appropriate categories and suggest potential links or relationships between codes (Thomas, 2006), the exact process varies across the different techniques. Here, content and thematic analyses are further explained.

5.3.4.1 Content Analysis

Content analysis consists in counting the occurrences of identified codes or words, which suggests a quantitative analysis of the qualitative data (Hsieh & Shannon, 2005; Priest & Roberts, 2015). It is assumed to provide an objective approach in explaining the content of discussions or verbal passages (Marshall & Rossman, 2006). Repetition and frequency imply the significance of a certain theme (MacQueen, et al., 2008). The codebook, with potentially numerous levels of sub-codes, often arises from the interview schedule or protocol and allows for coherently organising and counting evidence. For a coding scheme to be of high quality, the researcher must carefully define words that are expected to be used in relation with a particular category. In addition, in some cases, a researcher might want to include latent objects, referring to words or phrases that share the same meaning of a particular code or are associated attributes of the keywords (MacQueen, et al., 2008). Including latent phrases may however add some degree of ambiguity to the analysis, since the researcher needs to interpret the participants' sentences.

Regardless, content analysis minimises researcher bias and sometimes even allows the analysis to be replicated by other researchers (MacQueen, et al., 2008). Beneficial is also that the examination can be undertaken using computer software packages that are specially designed to elicit meaning from text (Priest & Roberts, 2015). On the contrary, a major criticism of addressing qualitative data from a quantitative perspective is the potential conflict with the overall philosophical approach taken by the researcher. In fact, the overemphasis on standardisation possibly distracts from the highly valued contextual meaning in qualitative research studies (Priest & Roberts, 2015).

5.3.4.2 Thematic Analysis

Thematic analysis is more time consuming than content analysis, yet provides a more dense examination of the information (MacQueen, et al., 2008). It involves organising the data content of the text into relevant, often pre-defined themes or categories (Cassell, et al., 2005). Usually, very broad categories are defined as upper level codes to add some sub-codes on lower levels. Here, it is in the interest of the researcher, and simultaneously the quality of the research study, to develop themes that accurately and honestly represent the interviewees' experiences and perspectives. Correspondingly, the final index structure is often the result of continuous adjustments to the initial template throughout data collection and analysis. De facto, if codes are identified in the text that cannot be allocated to a pre-defined section, a new theme may simply be added. At the time of analysis, interview parts are reviewed, sentences or concepts underlined and subsequently allocated according to the developed coding scheme (Gibbs, 2007). This process reduces the raw information to facilitate interpretation and correspondingly draw conclusions. Again, the subjectivity involved in interpreting the data is a major drawback of the analysis and greatly decreases reliability (MacQueen, et al., 2008). Difficulties also arise in multi-language studies, where no real guideline or simple strategy exists on how to translate and analyse textual data

(Marshall & Rossman, 2006). Despite these criticisms, this data analysis procedure has been widely adopted to make sense of qualitative research.

5.4 Mixed Methods Research

Leech and Onwueguzie (2009, p. 267), having extensive experience in this field, defined mixed methods research as “research that involves collecting, analysing, and interpreting quantitative and qualitative data in a single study or in a series of studies that investigate the same underlying phenomenon”. A similar definition, provided by Ivankova et al. (2006, p. 3), states that “mixed methods is a procedure for collecting, analysing, and “mixing” or integrating both quantitative and qualitative data at some stage of the research process within a single study for the purpose of gaining a better understanding of the research problem”. The main message these definitions convey is that both approaches discussed in the previous two sections are combined. In practice, mixed methods research found wide application and deserves separate consideration.

Applying a multistage format has been recognised as the third major research approach (Johnson, et al., 2007) and recent trends led to an increase in mixed methods research, despite the greater complexity. Some authors in support of this strategy claim choosing only one approach is comparable to viewing the world through one specific instrument such as an X-Ray machine (Mingers & Brocklesby, 1997). They infer that it is beneficial to adopt a mixed methods approach to obtain a wider, more comprehensive view of a phenomenon and enhance completeness of data by overcoming shortcomings of individual methods. In other words, the use of several tools most certainly expands the data, with a likely positive effect on research findings (Onwuegbuzie & Collins, 2007). As a result, the complementing, rather than competing nature of the two methodologies has been accepted for a more robust analysis (Ivankova, et al., 2006). For instance, quantitative data supporting qualitative findings may increase generalisable power, whilst qualitative information can facilitate the interpretation of quantitative results (Johnson, et al., 2007). Evidently, the combination of multiple sources of information has the potential to increase validity (Suter, 2012). This, in the mixed methods domain, refers to data or methodological triangulation (Thurmond, 2001; Johnson, et al., 2007). Sometimes theory triangulation also result from this research design, which attempts to reveal diverse perspectives, whilst considering a number of theories to interpret research findings (Johnson, et al., 2007). Above all, triangulation has the potential to increase confident in research results.

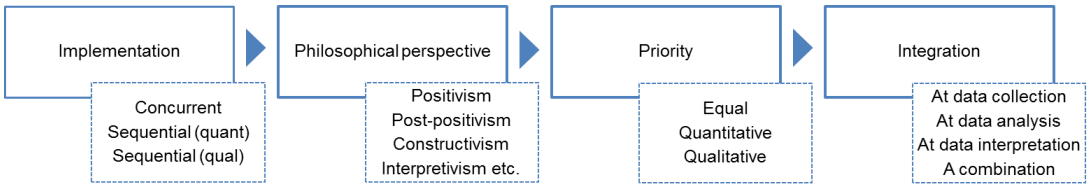
Contrary to the many benefits of adopting a mixed method strategy, there are scholars that criticise this approach to research, claiming there is a conflict or incompatibility with contradictory philosophical frameworks (Creswell, 2011; Muijs, 2011). A counter argument is raised by Mackenzie and Knipe (Mackenzie & Knipe, 2006), who believe that an investigator placing the research problem at the centre, follows a pragmatic paradigm, rather than being loyal to a specific framework (Johnson, et al., 2007). Along these lines, others suggest a shift of worldviews between the various paradigms as fieldwork progresses (Newman &

Benz, 1998; Creswell, 2011). For instance, when using a qualitative method prior to employing a quantitative tool, it would be expected that the investigator would adopt a constructivist view in the initial phase, to value multiple perspectives and deepen the understanding of the phenomenon, whilst in the later stage this shifts to post-positivism, where variables are measured and trends are identified statistically (Creswell & Clark, 2010). A different, undeniable drawback of multi-methods strategies is the extensive resource demand in respect to time, money and effort.

5.4.1 Mixed Methods Designs

In situations where it is appropriate and required to adopt a mixed methods strategy of inquiry, the researcher is confronted with four consecutive decisions (Creswell, 2014). First, the implementation sequence needs to be identified. A researcher must choose between conducting the quantitative and qualitative research at the same time (concurrently) or in different, subsequent phases (sequentially). The latter is frequently employed when certain information needs to be obtained to support subsequent research stages (Johnson, et al., 2007; Onwuegbuzie & Collins, 2007). Next, the overall theoretical perspective must be addressed, which partially indicates the prioritisation of either method or alternatively, the allocation of equal weight to both (Ivankova, et al., 2006). Whilst the selection herein often depends to a degree on the researcher's philosophical perception, the study population and the research questions are also important considerations (Creswell, 2003). With regards to the philosophical perception, this also needs to be reviewed in light of the mixed methods design phase. Then, the researcher must decide at what stage the two data sources are connected and integrated. Clearly, a number of different combinations can be pursued looking at Figure 8.

Figure 8, Mixed Method Procedures



Source: Adapted from Creswell (2003, p. 211)

In that respect, an investigator always needs to evaluate the various options carefully and act in accordance with the research objectives and resources to justify the mixed methods design. This is a challenging task, especially considering there are currently up to forty different mixed methods strategies being discussed in literature (Ivankova, et al., 2006). Some of the most popular are sequential explanatory and exploratory designs. Whilst there are variations within the two in respect to the data collection methods chosen, they are frequently adopted to exploit certain advantages and simultaneously avoid specific disadvantages.

5.4.1.1 Explanatory Design

The explanatory sequential design is popular among researchers who prefer conducting quantitative investigations prior to any in-depth qualitative research (Ivankova, et al., 2006). Here, researchers frequently prioritise the quantitative phase (Ivankova, et al., 2006). Complementary, the qualitative information is added to explain, refine and/or enhance the numerical data. In particular, this mixed methods design is regarded as very powerful in situations where the quantitative analysis resulted in unexpected conclusions and further insight is required.

5.4.1.2 Exploratory Design

An exploratory mixed methods strategy is also conducted in two consecutive phases. This requires the investigator to employ any qualitative research approach first to explore the unit of interest in great detail. The qualitative data analysis then provides valuable information to support a second quantitative phase (Creswell, 2014). This design is frequently preferred when the research problem has received little attention in literature and some insight needs to be generated to develop an appropriate quantitative research instrument.

5.5 Sampling

Selecting appropriate study participants is a key task in any research process as it determines the quality of research findings and is directly linked to the inference strength to the wider population (Onwuegbuzie & Collins, 2007). However, as previously highlighted, the sampling techniques differ depending on the research approach chosen. Regardless of the sampling methods, as an initial step it is crucial to define the target population and ideally create a sample frame that lists all members. Once a clear understanding exists regarding the study units, depending on the research aim, the researcher needs to decide whether random or non-random sampling is most suitable.

5.5.1 Random Sampling

Random sampling, also known as probability sampling, is usually adopted to allow statistical generalisations from the investigated to the population. More precisely, random sampling schemes are generally associated with the quantitative paradigm that aims at examining a large representative statistical sample on carefully defined variables (Onwuegbuzie & Collins, 2007). Particularly in such situations where random sampling is preferred, it is ideal to have a sampling frame, such as a telephone list from which respondents can be drawn randomly. Systematic random sampling can be employed that selects every k^{th} individual on the list (Onwuegbuzie & Collins, 2007). A list representing the entire population enables the researcher to assure equal (independent) likelihood of each individual to be chosen for the study (Creswell, et al., 2003; Muijs, 2011). In other words, probability sampling means each member of the population has a non-zero chance of being selected (Maxwell, 2005). However, it must be noted that the demonstrated situation, where an investigator can claim to have included the entire population, is problematic. For instance, considering the

telephone list, the contact details may be outdated, or households may simply not have a fixed telephone line and are therefore not included in the list from the start.

5.5.2 Non-random Sampling

Non-random sampling is frequently adopted in qualitative research projects, aiming to obtain an in-depth understanding and examination of a low number of specific candidates. Herein, the sampling strategy is commonly purposive, deliberately targeting and recruiting informants for the purpose of answering the research questions (Maxwell, 2005; Onwuegbuzie & Collins, 2007; Suter, 2012). These individuals are generally selected on a pre-defined set of criteria that are of interest or suggest a fairly good representation of the study population. Accordingly, a researcher may opt to stratify the population by selecting a number of subjects meeting certain characteristics with the objective to exactly mirror the proportions within the population (Creswell, 2003). For example, if the target population is male dominated, with a ratio four to one, the objective is to replicate this proportion in the sample. As a result, it may strengthen the generalisation power. A different selection technique within the non-random sampling scheme is snowball sampling, which is frequently used when the researcher has restricted access to the desired study group. Under such conditions, the investigator only needs to recruit some initial members, who can then be asked, post-participation, to provide the contact to other individuals that meet the criteria (Onwuegbuzie & Collins, 2007). Another approach is convenience sampling, which is evidently one of the least complex procedures. Here, individuals are simply chosen based on their availability (Eriksson & Kovalainen, 2008).

Coming back to the sample size, in qualitative research the focus is directed towards achieving high quality, rather than quantity. Therefore, data collection often terminates once data saturation has been reached, referring to the diminishing value of adding another informant to the study (Francisa, et al., 2010; Suter, 2012). On a related subject, whilst the significant time effort associated with qualitative data collection often limits the number of informants; non-random sampling actually has more opportunity to reach a high response rate. That is to say, individuals who are intentionally approached by a researcher are possibly less likely to decline an invitation to participate in a research study.

In sum, any technique selected, random or non-random, the choice must be justified and valid for reaching the overall goal. It should be noted here, that if a mixed methods approach is used, multiple sampling techniques may be required to select appropriate respondents for each phase (Onwuegbuzie & Collins, 2007). This can involve the same or different individuals from a single population, relating to an identical or parallel relationship between the sample of the qualitative and quantitative research parts respectively. Sometimes, members may also be drawn from diverse populations for different study phases.

5.6 Summary

This chapter reviewed the three methodologies to research, highlighted their most prominent methods and discussed individual features, advantages and limitations. Sampling, being considered an important part of any fieldwork, was discussed in the last section of this chapter. The following chapter is closely linked. It combines the MCDM insight gained, in section 3.3, and the knowledge on data collection and analysis methodologies, presented above, to develop a highly accurate problem-structuring framework.

6 MCDM Problem-Structuring Framework

This chapter provides an MCDM problem-structuring framework that is not specifically designed for the real estate selection problem, but rather presents a generic framework that can be adopted to define an MCDM problem assessing high-involvement goods. Further, explanations and justifications for the final design and individual process steps are given.

6.1 Introduction

Problem structuring is perhaps the most crucial task in decision processes (Corner, et al., 2001). Putting little effort and time towards identifying and organising decision components can substantially increase decision failure rates. Thus, all complex decision situations should first be attended by determining the problem components and formulating a logical structure, prior to proposing support mechanisms (Guitouni & Martel, 1998).

The literature review in section 3.4 indicted a lack of available MCDM problem-structuring guidelines for researchers and practitioners who intend to modify existing methods to address a problem appropriately or build tailored decision support models. Enhancing problem understanding can therefore facilitate the suitable adoption or construction of a support mechanism that can handle the nature of available input data (Guitouni & Martel, 1998; Kasanen, et al., 2000). So, the new framework is the result of a literature gap in MCDM problem structuring for decision support model development and, ultimately, emerged from two domains. First, a thorough examination of MCDM literature, with the focus on problem elements, played a key part in identifying the data required. Second, the design and sequence of process steps was established by reviewing different data collection and analysis methods, and determining the best procedures to elicit this information. As a result, the proposed framework consists of a mixed methods research procedure carefully designed to understand and extract essential elements. Worth mentioning in this context, it is necessary to actively include the potential DMs as information sources and possibly any other decision stakeholders during problem structuring to develop the human construct.

6.2 Assumptions

Although the framework is presented as a generic one to problem situations associated with the comparison or evaluation of high-involvement consumer products or services, it obviously may not be ideal in every situation. To clarify, the framework was developed on a number of assumptions:

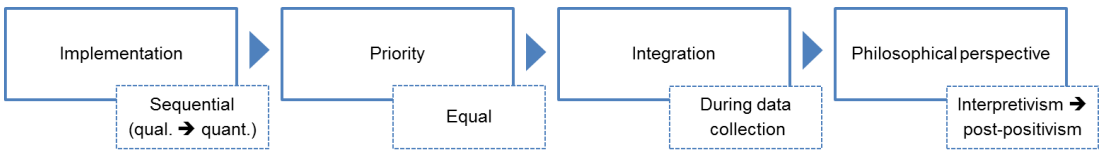
- Existing literature provides limited insight into the decision problem and its various components. This may also refer to inconsistent and vaguely defined decision environments across academic journals.
- Related to the above assumption, the current decision process ignores the supposedly large number of relevant assessment criteria, or they are simply unknown.

- Decision outcomes are subjective, i.e. different DMs have different views or perceptions on what is the best alternative.
- The final goal of structuring the problem is to review existing MCDM methods and, subsequently, match one to the defined problem. Where there is no appropriate method, the problem structuring provides the necessary insight to build a tailored decision support model to assist DMs in their actions.

The objective was to design a problem structuring strategy, which assured the collection of true information relevant to tackle a research problem (Taylor, 2005). Correspondingly, a purely qualitative or quantitative design seemed insufficient to define all MCDM problem parameters (identified in section 3.3). A key benefit of employing both, instead of choosing one extreme, is the enhanced completeness of data (Mingers & Brocklesby, 1997; Johnson & Turner, 2002).

Defining an MCDM problem with limited existing literature, a sequential exploratory design was adopted. This consisted of using qualitative data collection and analysis techniques for full understanding of the phenomenon, prior to developing and employing a quantitative approach in a subsequent phase (Creswell & Clark, 2010). Essentially, the qualitative methods offer an effective way of coping with the absence of existing research in the area of interest. It enables the collection of extensive information to understand the research population and the occurring phenomena in its natural setting in greater depth (Newman & Benz, 1998). Respectively, the qualitative research methods' aim is to capture certain data to define the problem, as well as support the development of an accurate quantitative research instrument. Quantitative methods in this context also follow two objectives, being able to generalise initial findings, as well as expanding the information (Onwuegbuzie & Collins, 2007). Part of the whole process, the data integration occurs at the intermediate stage, meaning the collected data always needs to be analysed to contribute and support the next stage (Ivankova, et al., 2006). Figure 9 graphically depicts the discussed concepts of the mixed methods procedure followed by the developed framework.

Figure 9, Problem-Structuring Framework Mixed Methods Procedure



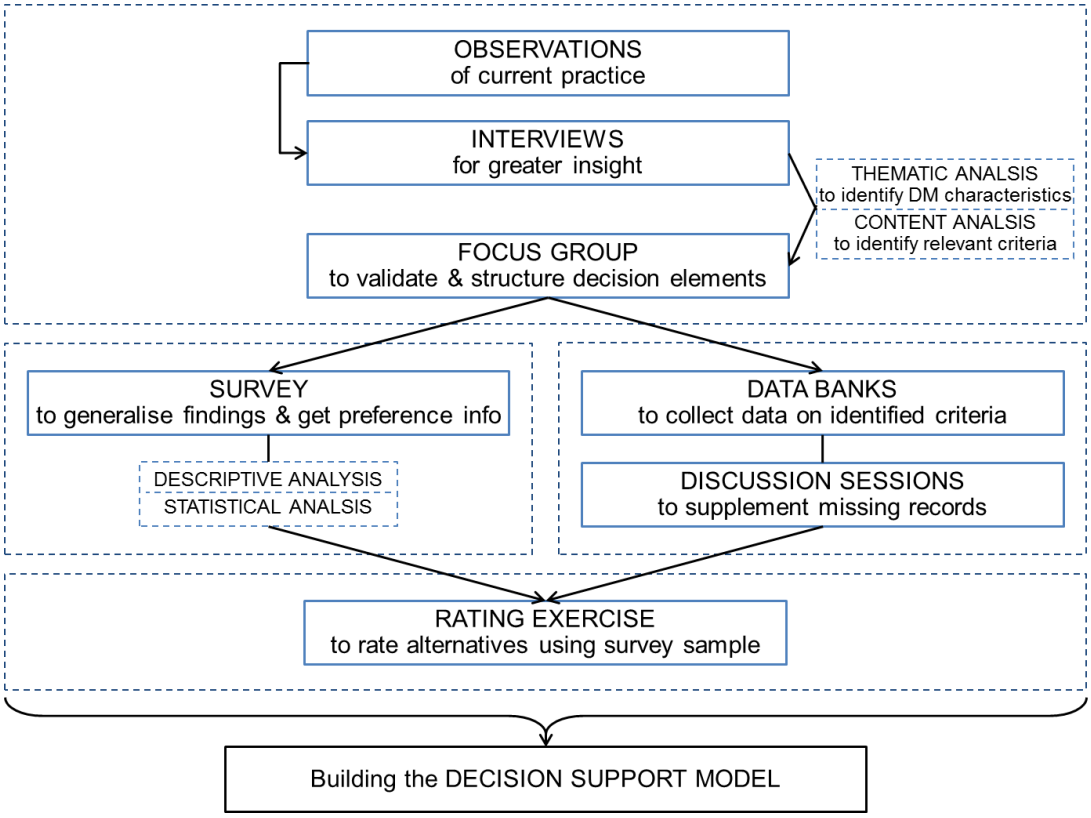
Source: Adapted from Creswell (2003, p. 211)

6.3 MCDM Problem-Structuring Framework

Having provided the general procedure adopted herein, Figure 10 displays the complete MCDM problem-structuring framework with multiple data collection and analysis stages. Explanations and justifications for the chosen sequence, adoption of individual approaches

and particularly their unique contribution to the problem definition are discussed in great detail in the corresponding subsections.

Figure 10, MCDM Problem-Structuring Framework



In contrast to existing literature on problem structuring, this framework outlines specific actions that can be taken by researchers to define the decision environment and extract the required information to find an appropriate support mechanism. More precisely, each stage was carefully designed to obtain necessary input data for a decision support model and assist DMs in high-involvement product selection situations.

6.3.1 Qualitative Phase

A pilot study may first be conducted to become more familiar with the decision environment. This was not included in the final framework, but can improve the way of initiating the problem structuring process.

6.3.1.1 Observations

In order to first appreciate the problem situation, current decision practices should be understood through observations in the field. Whilst it is not feasible to observe the entire decision process from problem recognition to decision making, it would be recommended to observe prospective DMs in the early stages of the decision problem. For instance, the initial search process and defining the finite set of alternatives can offer invaluable insights. In some situations, this may also include interactions with other decision stakeholders that influence the list of decision options (Muijs, 2011).

This preliminary stage functions as an addition to a pilot study with the objective to increase researchers understanding of the current situation. This in turn can highlight some problems DMs face, and ultimately justifies the research into applicable decision tools that can support DMs in their actions. Also, this first qualitative research stage can be regarded as a pre-requisite for the semi-structured interviews that follow. The greater the researcher's knowledge of the decision problem, the better he/she can formulate adequate interview questions and avoid missing crucial information. Regarding possible interactions with other stakeholders, such as market intermediaries, the observations may point towards inefficient or misleading communication. More precisely, if different perspectives and assumptions between the involved parties clash, it is worth investigating these discoveries further in upcoming data collection rounds. In sum, observations identify the target audience for in-depth interviews, which generally includes the prospective DMs, but also any additional sources that play a role in the decision problem environment.

6.3.1.2 Interviews

A number of possible research methods were evaluated for the second stage. In the end, semi-structured, ideally fact-to-face, in-depth interviews were chosen to best achieve the goal of gathering in-depth information on decision making problems. In-depth interviews are widely viewed as the best tools to address complex decision making situations (Levy & Lee, 2004) and obtain a broad impression of the problem (Belton & Stewart, 2010). Therefore, they are at the heart of the framework's qualitative research phase.

At this point, face-to-face data collection is recommended as it is generally superior to telephone interview sessions. Benefits of direct contact include higher response rate, non-verbal feedback, the possibility to encourage informants to provide more detail in certain areas and making them feel more involved in the study (Levy & Lee, 2004). Additionally, a semi-structure procedure that simply identifies key questions, but is not limited to a set structure, retains a degree of flexibility. So, from previous investigations (i.e. observations, literature and own knowledge) the researcher should have a general idea about the research population, overall practices in the industry and the main problem areas to facilitate drawing up an interview template to support and provide an approximate direction or enforce a particular interview flow. This support material, in addition to crucial questions that need to be covered, can include possible probes that encourage participants to elaborate on their response (King, 2004; Eriksson & Kovalainen, 2008).

Besides providing some guidance, this format allows the researcher to offer more question explanation when required and inquire about other topics that emerge during the interview proceedings, increasing the accuracy level (Mills & Reed, 2003). Simultaneously, an interview style accepting partially spontaneous questioning, provides the interviewee with great flexibility in respect of their answers and creates a more relaxed atmosphere (Bachiochi & Weiner, 2002). However, despite having a guideline to follow, the researcher must acknowledge that not one session is identical and the template only attempts to avoid

missing central points. In fact, formulating and choosing interview questions during the actual interviews always has the potential for investigator bias as it permits to adapt to different backgrounds and personalities (Barriball & While, 1994; Thurmond, 2001).

Finally, as briefly mentioned in the previous section, in situations where there are intermediaries between the DMs and the product or service provider (seller), these should also be studied. Therefore, if applicable, a separate, tailored interview schedule should be developed to obtain the intermediaries' view on the situation, whilst also including questions that can be used to directly compare answers from these intermediaries to the actual DMs.

Having provided a description of the interview style that ought to be adopted in this second data collection step, it is now time to highlight the particular contribution to structuring the MCDM problem, the sample requirements and corresponding data analysis methods.

6.3.1.2.1 Objective

The interviews have three main objectives:

- gaining a deeper understanding of the study population (discovering DMs' characteristics)
- gathering substantial information on the decision problem to help design a valid quantitative data collection instrument (questionnaire)
- creating a complete list of evaluation criteria that carry some degree of decision power

Evidently, all three add to the final goal of structuring the MCDM problem, but the latter provides the first indication on the number of criteria that could potentially be involved in the decision process. At this point, it is valuable to actually include all variables, no matter how small their impact may be, since the list undergoes additional examination and modifications proceeding further through the framework. Obtaining a comprehensive list is achieved by inquiring about expectations and past experiences with the decision making situation. By recalling alternatives that have been reviewed previously, more criteria can emerge, considering an interactive relationship where alternatives and criteria can generate each other (Corner, et al., 2001).

6.3.1.2.2 Sample Size

With regards to the sample size, it is suggested that interviews should be conducted until diminishing value is perceived by adding another informant (Francisa, et al., 2010; Suter, 2012). That is to say, if no new criteria emerge or DM characteristics are repeatedly coming up, data saturation has been reached and should consequently terminate the interviewing process. So, depending on the research problem, the number of interviews that need to be conducted varies (McLafferty, 2004).

6.3.1.2.3 Analysis

Adopting the sequential exploratory strategy for this framework, it is crucial to conduct data analysis prior to moving on to the next data collection stage. Thus, all interviews need to be transcribed to conduct a thematic and content analysis. Herein, both analysis techniques are employed as they aim to discover different characteristics. The thematic analysis best interprets the results, whilst a content analysis is fundamental to pinpoint the variables appreciated by the DMs in the decision problem context. The latter essentially creates the criteria list and counts the occurrences of individual criteria, potentially providing an initial indication of criteria importance. Noteworthy here, the content analysis was already adopted in research studies for precisely this reason, to yield relevant assessment variables (Adair, et al., 1996).

6.3.1.3 Focus Group

As suggested by Saaty and Shih (2009), involving a group of experts in problem formulation is a good practice to ensure completeness and logicality. As a result, an important stage to be included in the problem-structuring framework consists in a discussion session (focus group) with industry experts. Here, experts refer either to individuals that have addressed the decision problem multiple times themselves and accumulated substantial experience and knowledge on the matter, or professionals, specialists and potentially academics that have long been in contact with the target population and got a clear understanding of their behaviour and thought processes.

6.3.1.3.1 Objective

The focus group includes various tasks to achieve five objectives:

- reviewing and validating interview findings
- revising the list of evaluation criteria
- defining criteria and finding an appropriate measure
- structuring the criteria into a hierarchy that follows the DMs' thought process
- discussing whether any connection exists among criteria (dependencies and/or correlations)

Starting with the first objective, the experts should be able to first verify the interpretation and then reflect on the interview findings to promote a thorough discussion. Using multiple participants here aims to avoid biases that may be created when including the perspective of a single DM (Maier & Stix, 2013). Once the experts familiarised themselves with the situation, the full list of evaluation criteria is presented. Here, revising the list has the objective of eliminating variables that are inadequate and may damage the analysis. For instance, synonyms of others already included in the list or attributes that encompass measurability constraints may be removed. The latter also incorporates ambiguous criteria that have a very subjective stance or are accompanied with different interpretations across different decision stakeholders (Keeney & Gregory, 2005; Kim, et al., 2005). On the other hand, based on justification from the experts, renaming or adding to the list of criteria may

be considered. It has been acknowledged that particularly brainstorming exercises are very powerful in identifying relevant decision criteria (Maier & Stix, 2013). Next is the provision of conceptual descriptions, including the unit of measurement (Kaklauskas, et al., 2007). This essentially refers to eliciting short statements that clarify the meaning of all remaining criteria and defining the respective measures. The researcher may also participate in this process having reviewed existing literature and having questioned decision stakeholders. This may further reduce the list if no consistent measure can be agreed upon or the assessment is too subjective.

Then, with the final set of criteria, the experts form a coherent hierarchical structure. This involves grouping criteria into adequate categories. It is anticipated that categories also emerge during this process when trying to cluster criteria. To facilitate this process, authors like Maier and Stix (2013) suggested using card sorting procedures in situations with a high number of relevant criteria. Ultimately, a hierarchy with the performance assessment at the top that is derived from a set of categories with sub-categories and so on until reaching the lowest measurable level of criteria. Belton and Stewart (2010) emphasised the benefit of graphical representations in problem structuring. Equally, Ball et al., (1994, p. 71) advised that “structuring any problem hierarchically is an efficient and intuitive way of dealing with complexity”. Establishing a widely acceptable hierarchical structure is only attainable in a joint effort. It is the confrontation with other experts and their explanations and thoughts on the task that should eventually lead to a common result/solution that best portrays the logical thought process (Morgen, 1996). In other words, individual interviews would most certainly generate very unique hierarchies, which have no value when aiming to define the problem for the target population as a whole. As a result, the group discussion session is seen as the single data collection method that can achieve the set goals, i.e. data cleansing, identifying criteria measures and, as outlined above, organising them into a hierarchy. To conclude the discussion, it must be established whether the decision problem consists of dependent and/or correlated criteria. Hence, if previously hinted in the interviews, relationships among evaluation criteria should be discussed. Alternatively, brainstorming between the experts can shed light on potential connections.

6.3.1.3.2 Sample Size

Within literature it was confirmed that a single focus group might suffice if it directly achieves the set goals (McLafferty, 2004). Accordingly, to encourage greater interaction and in-depth discussion, a small group size is suggested, which also enhances the control of the researcher over the discussion flow and topics (Morgen, 1996). Also, with caution to not interfere or prevent interaction between session participants, the researcher can engage in the discussion if he/she has a competent knowledge base.

6.3.2 Post-Qualitative Phase

From the extensive data collection in the first part of the problem-structuring framework, there are two unrelated paths, which both require this acquired information. On the one

hand, the insights from the interviews and the criteria structure (hierarchy) from the focus group allow the construction of a quantitative data collection instrument. On the other hand, the final list of criteria now specifies the information that is required to construct a dataset. Therefore, sections 6.3.3 and 6.3.4 should be viewed separately, both attending different problem structuring objectives.

6.3.3 Quantitative Phase

The quantitative data collection phase herein refers to the construction of a questionnaire and distribution to a large audience.

6.3.3.1 Questionnaire

The open-end answers from the interviews, which were summarised by means of the thematic analysis, allow the formulation of valid closed-end answers for a survey. Then, for the criteria preference extracting section, the hierarchical structure developed in the focus group dictates the presentation of criteria groups to the respondents.

The distribution of the questionnaire also plays a role in achieving the set goals discussed hereafter (section 6.3.3.1.1). The recommended distribution channel is the Internet. An online survey software platform can enable fast and efficient distribution to the target audience with minimal resources and time requirements (Cole, 2005), whilst greatly facilitating the development of the questionnaire. Also, in situations where a question is not applicable to the individual, it allows tailoring the questionnaire to some degree with an interactive design, for instance by hiding irrelevant questions (Cole, 2005). Caution must only be taken when the decision problem investigates a population with limited access or with reluctance to use the Internet.

6.3.3.1.1 Objective

The questionnaire was incorporated into the problem-structuring framework for three reasons:

- generalising the qualitative findings
- obtaining criteria preference information of prospective DMs
- discovering DMs' expectations for decision support models

First, it is necessary to increase generalisation power of the qualitative findings. With the completion of a large number of standardised questionnaires, statistical analysis can draw conclusions from the study sample to the target population. Second, preference information can be obtained, possibly allowing to identify key differences between groups of survey participants that differ on some demographic characteristics. Here, the previous constructed hierarchy should be used as the input for structuring and formulating the preference eliciting questions (Ball & Srinivasan, 1994). Depending on the DM's cognition and the decision problem, a suitable weight eliciting method should be selected, such as direct scoring or pairwise comparison (Guitouni & Martel, 1998; Ishizaka & Labib, 2011). Also, the survey

aims to clarify current issues with the decision making process and expectations set for practical/useful decision support models. Ultimately, if the goal is to go beyond matching or developing a decision model by actually attempting to introduce a computer interface for the DM(s), the expectations should be incorporated in the DSS to promote high adoption rate.

6.3.3.1.2 Sample Size

In general, online surveys have the potential to reach a large population (Cole, 2005). Often, researchers cannot precisely determine or even estimate the actual population size, making it extremely difficult to calculate the appropriate sample size (Bartlett, et al., 2001). Therefore, it is challenging to provide accurate recommendations as to the survey sampling. Generally, informed judgments need to be made, including any budgetary constraints (i.e. time, money, personal, etc.) to avoid the costs outweighing the benefits of adding an extra informant (Hill, 1998). In turn, it is well known that the greater the sample size, the better the statistical power. There are a number of approaches to determine the sample size, for instance by specifying the allowed error, along with the confidence required (Hill, 1998). An indication of appropriate sample size is also provided by Krejcie and Morgan, who introduced a table with sample sizes for finite populations (Hill, 1998). As expected, sample size increases at a diminishing rate when the population grows.

6.3.3.1.3 Questionnaire Analysis

Firstly, the data should be summarised using descriptive statistics. This allows drawing preliminary conclusions and supporting qualitative findings. Where the latter is an important objective of the quantitative study, to later select or build an MCDM support model on accurate information. Then, cross tabulations can further examine the dataset and interrelationships by creating the joint frequency distribution and computing the chi-square statistic.

6.3.4 Dataset

The foundations of any decision analysis are the alternatives to be evaluated in order to achieve the DM's objectives (Keeney & Gregory, 2005). Generating the dataset with existing decision options is crucial to both build and, subsequently, test a decision support model. Essentially, the focus group in the qualitative section of the problem-structuring framework provides the basis for collecting the required information on different alternatives. Put differently, the specified bottom level criteria are used to enquire information on a finite set of alternatives to construct the dataset.

6.3.4.1 Data banks

In situations where alternatives are openly available, providing all relevant information, the researcher can simply use the medium to prepare the dataset as required. Yet, frequently information on alternatives' criteria values is limited, missing or vague, which demands an active collection process. It is proposed that first data banks can be used to a degree,

obtaining all information on the chosen alternatives that are widely accessible. In short, data can simply be drawn from secondary sources.

6.3.4.2 Discussion Sessions

As already mentioned, data banks are often incomplete or insufficient and do not reflect the criteria initially specified by the focus group. Hence, once drawing data from the option above is exhausted, the researcher can arrange discussion sessions or interviews with those who hold the missing data, for instance intermediaries, sellers, experts, among others. They can then fill in the missing gaps.

6.3.5 Rating Exercise

Next, taking participants from the survey and using the created dataset, the final task to gather all data required for building, training and testing a decision support model is to rate decision options. In other words, each alternative included in the dataset must have an associated output. Essentially, approaching individuals who participated in the survey is crucial due to their preference information. They should then be asked to give performance scores of individual decision options. This stage in the problem-structuring framework is only required as we are assuming that decision outcomes of the high-involvement goods are subjective. Hence, there is not a single right answer, but rather individuals perceive criteria importance differently and derive unique outcomes when combining the evidence.

6.3.5.1 Objective

The list of alternatives, along with corresponding outcomes, has the potential to analyse relationships between variables. Thus, if possible dependencies and/or correlations were highlighted during the interviews or the focus group, the dataset can be used to assess relationships in more detail. This is helpful when choosing, adjusting or building an MCDM support model as such conditions should be incorporated to produce more accurate results.

6.3.5.2 Sample Size

The alternatives should be presented to the assessors one by one, each with the complete information on the criteria values, and possibly some photos. To reduce time and avoid frustration, a small group of alternatives should suffice for the purpose of building the decision support model. A guideline may be to take 10% of the survey participants to assess 25 to 50 alternatives, depending on the number of evaluation criteria. Evidently, a larger number of criteria would require more time to provide a robust performance score; hence less alternatives should be included in the rating exercise.

To conclude, whilst this last stage of rating decision options most certainly involves a lot of effort and time, it essentially allows the development of a very accurate decision tool.

6.4 Discussion

For the purpose of disecting high-involvement product or service selection problems, the sequential exploratory strategy was most valid in serving as the foundation for the framework; however, it should be noted that a different combination of methods to those presented in the previous sections was available to the researcher. Case surveys for instance received considerable consideration. As a result, this research approach was regarded inappropriate in situations where limited literature exists, i.e. not enough published cases are available to quantify the results and conduct statistical analysis. And the collection of a large enough dataset to conduct and then compare a number of cases statistically is often not feasible, in terms of time and resources available. Focus groups were also contemplated as a possible substitute for the in-depth interviews in the qualitative phase. This approach seemed inappropriate at that point to achieve the set goals. In more detail, focus groups were removed from further consideration, since it was believed people would follow social norms when answering questions, not expressing their true feelings and fearing their anonymity being compromised. Particularly, the last point would play a large role in discussing sensitive topics such as income, religion and political views, to name a few.

Alternatively, the sequence of the research design could have been changed to conduct a large scale survey in the first stage, followed by a qualitative approach to adress specific findings in more depth and breath (Creswell & Clark, 2010). Yet, it was ruled difficult to include all relevant questions and closed-end answers in a quantiative data collection instrument without first obtaining some insight through in-depth converstations. This holds particularly true in situations where limited information is available on the investigated issue. This brief discussion section does not present the complete list of methods considered, yet emphasises the most obvious alternatives. For a thorough understanding of the data collection and analysis approaches reviewed, along with corresponding advantages and disadvantages, Chapter 5 offers a detailed picutre.

Overall, the developed framework repeatedly encourages reflection on previous findings, and discussion on the individual elements, to constantly increase the analyst's understanding of the problem under investigation. Contemplating MCDM literature, in combination with existing empirical research with various data collection and analysis methods, ensured a focused framework design. Therefore, it is anticipated that these guidelines have potential in assisting researchers understanding and defining an MCDM problem in the said context. Accordingly, application is believed to be adequate for defining MCDM problems that assess high-involvement products or services offered to the population for consumption. These decisions are generally less frequent purchases, more complex, require more time and effort for research and are often associated with a significant investment. Examples include, but are not limited to, selection decisions of an automobile, boat, bicycle, house, furniture, computer, watch, phone, life insurance and holiday packages. In contrast, DMs facing one-off decisions, such as government policy making, may not benefit from adopting the framework to define the decision space. Also,

due to the obvious high resource demand when following the proposed structure, the procedure may only apply to researchers who have the means to conducting such an extensive study to best tailor a decision support model for a high-involvement product selection problem.

6.5 Summary

The thus far limited literature on MCDM problem-structuring techniques prompted the investigation in this area. A resulting detailed research plan with the potential to facilitate the identification of problem characteristics emerged. Particularly, applying the framework in structuring a specific decision problem can clearly determine the necessary input data to identify, adjust or build an MCDM model that can subsequently be trained and tested. In support of this, Guitouni and Martel (1998) argue that pinpointing the quality and quantity of availability information in the decision environment dictates the final selection of the support mechanism. To conclude, this general framework might not be applicable in every situation, but, as illustrated later, has proven to be a very powerful and useful tool in the field of real estate selection.

7 Research Context

Setting the scene, this chapter provides a deeper understanding of the research site. The focus is on location characteristics and the property market.

7.1 Introduction

To allow the development of an MCDM real estate selection tool, it was essential to select a research site to gather key information. Majorca, being considered a prime luxury real estate market within Europe, was chosen for this purpose. The next sections describe and justify the choice and the research focus within this space.

7.2 Research Location

For the empirical research, Majorca was identified to be an ideal real estate market for data collection due to its well defined geographical space. Vague boundaries can make the investigation unnecessarily challenging. Additionally, its reputation as a favourable location for holiday, and/or secondary residencies, ensures the continuous demand and supply of houses on the island. Equally important, to obtain a substantial amount of data, it was crucial to select a site where the study units would be willing to co-operate. In this context, the researcher spent a considerable time living in Majorca, increasing the prior knowledge about individual areas and gaining access to the prospective study populations, owing to an existing network. These reasons greatly influenced the selection. Next, the island itself is described in more detail.

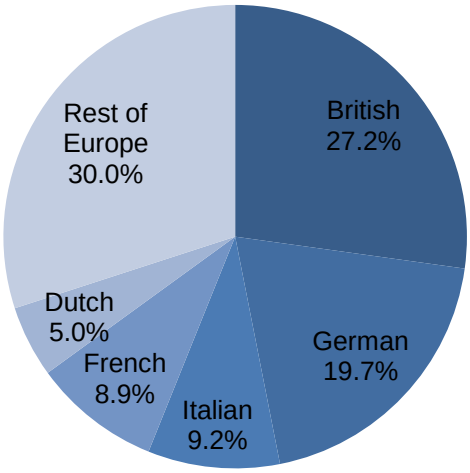
7.2.1 Island Characteristics

Majorca is located in the Mediterranean Sea and is the largest of the Balearic Islands in Spain (illustrated in the map below), with an area of 3640 square kilometres rounded by 555 kilometres of coastline (IslasBaleares, 2015).

Figure 11, Map of Spain

There is one airport close to the capital, Palma, connecting it to the rest of Europe. Essentially, the booming real estate industry in Majorca is a direct consequence of its excellent aviation network with all main European cities (AjuntamentPalma, 2012). This continuously boosts passenger arrivals at the airport, Son San Juan, reporting a total influx of 19.9 million between January and September 2015 (representing a 2.07% increase over the same period in 2014) (Aena, 2015a). Particularly for the Europeans, who represented 61.4% of the arrivals in the first semester of 2015 (excluding Spanish nationals) (Aena, 2015b), the island has long been a dream destination to buy holiday or secondary homes. The pie chart below (Figure 12) presents a good picture of the dominant nationalities visiting Majorca.

Figure 12, European Nationalities visiting Majorca (January-June 2015)

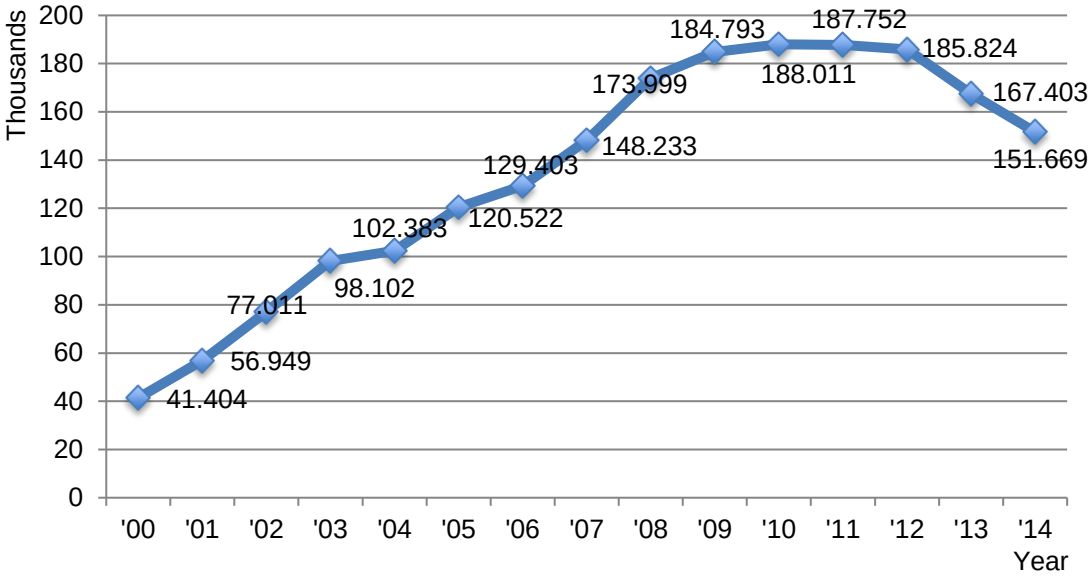


Source: Aena (2015b)

Characteristics that attract many Europeans to Majorca, apart from the favourable climate, include the geography of the island with all its facets, the 44 marinas (BalearicEstates, 2010), countless beaches around the island and its 20 golf courses (SimplyMallorcaGolf, 2014). Given these points, coupled with low language barriers and good infrastructure, this destination provides a relaxing atmosphere for vacationers.

Evidence reveals that Majorca welcomes a large foreign base throughout the year, which is also strongly represented among the island's population. Whilst the Spanish population increased by a moderate 11.18% since 2000 (up to 2014), the foreign portion represented on the island grew by 266.32% (from 41,404 in 2000 to 151,669 in 2014) (Ibestat, 2015). Notably, in 2010 a total of 188.011 foreigners were registered residents in Majorca (representing a 354.09% increase from 2000). This development of the foreign population over the last 15 years is displayed in Figure 13 and, regardless of the decline in international citizens since 2010, the presence of this segment is still impressive.

Figure 13, Number of Foreign Residents in Majorca from 2000-2014



Source: Ibestat (2015)

Another source specified that in 2014, 18.3% of Majorca's population was represented by foreigners (Dixon, 2014). Hence, a differentiation between two property sectors may be adequate, one comprising the Spanish nationals and the other being the property market lead by oversea buyers (Westwood, 2015).

7.3 Real Estate Market

Comparing Majorca's property market to the rest of the country, it is often viewed as a micro market, independent to the rest of Spain (Westwood, 2015). Even during the 2008 turbulent economic environment, a lot of the luxury estates in Majorca's prime areas, like Son Vida, generally held their value, whilst any price decrease was still moderate compared to the situation in mainland Spain, where prices slumped dramatically (BalearicEstates, 2010; OnlyMallorca, 2012). This phenomenon can largely be explained by looking at the foreign buyer base of British, German, Scandinavian and Swiss nationals (Redwood, 2014; Westwood, 2015; Engel&Völker, 2015b). Herein, if one of these countries experiences difficulties, impacting the nationals' ability or willingness to purchase a luxury house in Majorca, there are generally others that fill the created gap (Dost, 2012). However, this also indicates that Majorca's real estate market condition is predominantly driven by the economic situation of the highly represented nations. More recently, despite the remaining dominance of the four nationalities, an increasing number of French and Russians are purchasing properties in Majorca (Engel&Völker, 2015b). In this context, Russian buyers actually increased by 109% from 2008 to 2013 and now account for 8.12% of all oversea purchasers (Westwood, 2015). Diversifying the target buyers slightly can further stabilise real estate demand. In turn, the constant inquiry generated by this consume segment influences the supply. The president of the Balearic Association of Development emphasised that almost all development projects are concentrated on trends dictated by the

foreign buyer segment (Novi, 2016). Due to the high value associated with such properties, the market nearly exclusively attracts foreigners with the necessary funds. Respectively, in spite of the nationality, the luxury-homebuyers are generally successful business professionals, who want to safely invest their money, but also enjoy the benefits of a place in the sun (Arenas, 2014; Engel&Völker, 2015b). More precisely, it is frequently wealthy individuals, who have visited Majorca over the years on a regular basis and decided at one point to acquire their own residency.

With regards to the market performance at the time of the study, although Majorca was less affected than other holiday destinations by the economic difficulties across European countries, in 2015 the market indicated a turnaround from slightly less prosperous previous years. Here, the General Council of Notaries reported a 16.5% increase in sales volume on the island, along with a property price surge of 4.8% in 2015 (Struecklin, 2016). Another source indicated that Engel&Völker actually experienced a 27% sales increase at the start of 2015, compared to the same period in 2014, and high end properties in top destinations attained a 10% price increase on average (PropertyWire, 2015). For the future, demand is predicted to asselerate further attributed to terror fears in other vacation hotspots (McVeigh, 2016). Put differently, many individuals avoid areas at risk of terror attacks and simultaneously are reluctant to visit resorts in Tunesia, Tukey or Egypt due to past events (Ram & Powley, 2016). Estimations hint a substantial increase (up to a third) in visitors to the Spanish island over the summer month 2016 (Harley, 2016).

7.3.1 Regions

There are properties offered across the entire island, yet it is worth differentiating the individual regions. First, the capital and its surroundings are very densely populated, with the majority of properties being apartments or townhouses. This region in particular received a lot of attention recently, being voted the ‘best place to live in the world’ (Davies, 2015). Consequently, this, together with the above mentioned reasons, is expected to stimulate demand even more in the immediate future. Meanwhile, the South West area is often viewed as a prime location for property buyers, with the most luxury estates found here. In the South West, foreigners account for 40% of all sales (PropertyWire, 2015). When reviewing the developments of the property market in these two regions (i.e. the capital Palma and the South West), they both recorded sales and price increases of 27% and 10-15% respectively, whilst the West experienced stable conditions compared to last year (PropertyWire, 2015). The Central region of Majorca offers a very different atmosphere to the coastline, with beautiful mountains and countryside. A lot of prospective homebuyers opt for the middle of the island due to less tourism, but also for the better value for money. In this context, square meter prices in 2014 ranged from 900 to 5,800 Euros per square meter, a contrast to the price range in the South West of 2,500 to 27,000 Euros per square meter (Engel&Völker, 2015b). This price difference is mainly associated to the shortage of available space close to the coastline to build new properties (OnlyMallorca, 2012).

Additionally, any estate with sea view records large mark-ups, with sea view houses in the South West costing up to 46% more and in the North West even averaging 53% extra (PortaMallorquina, 2015). Based on these facts it can be assumed that the North West has increased in popularity, offering some beautiful fincas on the coastline with steep cliffs (Redwood, 2014). Finally, North East properties are generally less desirable and few luxury houses are sold in this region. Generally, the properties on the market here are offered at a price below 500,000 Euros (PropertyWire, 2015). A potential reason for the low demand may be the distance to the airport and Palma city centre.

7.3.2 Comparable Locations

Despite conducting the research project at this unique location, the resulting model can potentially be applied in similar regions with alike characteristics. For instance, the South of France may provide comparable conditions, with a high number of foreigners and comfortable climate. Also, Engel&Völker, who are operating in 36 countries around the world, suggested in their 2014 market report that Ibiza, Menorca, Costa Esmeralda, Cap Ferrat and Miami Beach have booming real estate markets, particularly targeting high-net-worth individuals who want to acquire a dream holiday or secondary home (Engel&Völker, 2015b). In more detail, Engel&Völker computed the average price of a five bedroom sea view villa in these hot spots, where prices ranged from 15 million Euros in Cap Ferrat to 2.5 million Euros in Menorca (Majorca approx. five million Euros) (Engel&Völker, 2015b). Nevertheless, it is expected that the MCDM model must undergo some modifications to account for any differences and, in turn, derive fully satisfying results in alternative settings.

7.3.3 Real Estate Agencies

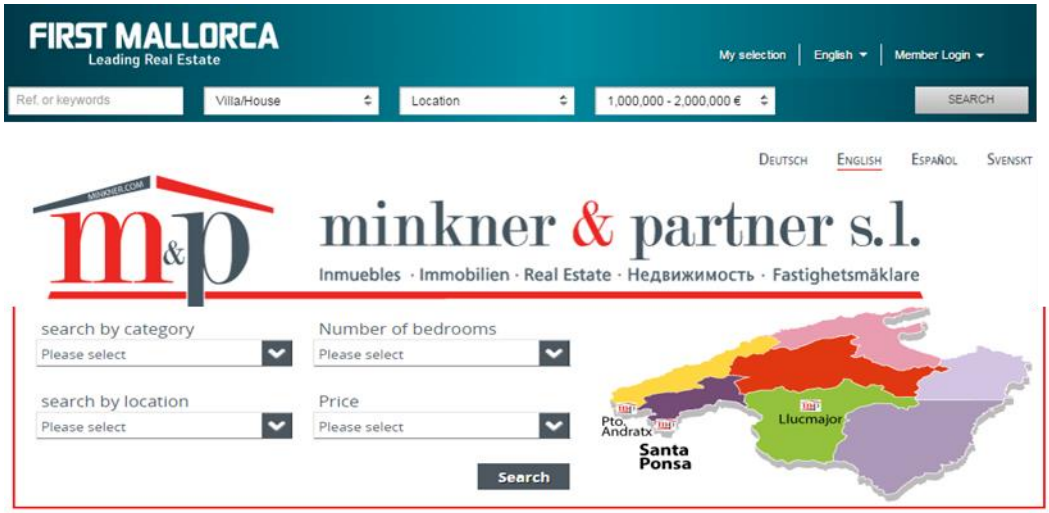
In many locations, real estate buyers and sellers are linked through intermediaries, like agents. Hence, the real estate agents are believed to play a vital part in this research, not only to obtain their perspective on the decision making process, but more importantly for the access to the target population, i.e. foreign luxury real estate buyers. There are hundreds of real estate offices in Majorca from which to choose (ImmobilienMallorca24, 2013). Generally, the nationalities they attract vary, with some offices predominantly representing German buyers, some a mixture of British and German and others focusing on the growing Russian clientele. For instance, almost half of all clients from Engel&Völker are reported to originate from Germany, Switzerland or Austria (Engel&Völker, 2015b), whilst FirstMallorca has a near even split of German speaking (38%) to British nationals (32%) (FirstMallorca, 2015b).

On another note, the most prominent real estate brokers such as Engel&Völker, Minkner, FirstMallorca, Kensigton, to name a few, offer a vast variety of luxury estates. At the time of the research, Engel&Völker held 948 real estates with a listing price of above one million Euros in their portfolio, whilst Minkner, FirstMallorca and Kensington also accounted for around 550 properties on offer (514, 544 and 563 respectively) (Engel&Völker, 2015a; Minkner, 2015; FirstMallorca, 2015a; Kensington, 2015). Even smaller property boutiques

like Sotheby, Kuhn&Partner or FinestProperties still demonstrated a substantial portfolio, accounting for 298, 353 and 357 items respectively (FinestProperties, 2015; Kühn&Partner, 2015; Sotheby, 2015). Although, it has been estimated that about 4,000 properties are actually on the market (PortaMallorquina, 2015), these obviously include all price segments and property types. Hence, actual luxury housing supply is a number significantly below this figure. Competition among agencies is fierce and exclusive rights for properties are rarely obtained. Put differently, the large luxury real estate portfolios held by many agencies reflects the trend that sellers generally market their property through multiple sources. This in theory means that homebuyers should only need to commission one agency, since properties are offered by competing agencies as well. In practice however, it is commonly known that potential buyers engage with a number of agencies. This phenomenon may be the result of different property descriptions provided by the various intermediaries (Bünger, 2015). Besides the limited and contradictory housing descriptions, particularly concerning and frustrating for the homebuyers are dissimilar property prices across real estate brokers for one and the same estate, illustrated by an example in Appendix B.

Next, practically all agencies on Majorca have an online presence. The capabilities of these existing decision aiding or alternative identification tools are very limited. They generally only consider a low number of relevant criteria for the filtering process. Two real estate website examples are illustrated below.

Figure 14, Real Estate Websites' Filtering Tools



Source: FirstMallorca (2015a)

Also, whilst there are Multiple Listing Services available in UK or Germany (as discussed in section 2.5.2), Majorca does not provide such platforms. That is to say, homebuyers have no unified platform they can use to search, review and compare alternatives. Accordingly, they must first know where to search, and then get comfortable with the different websites, i.e. search tools. Complicating the situation, property descriptions, both online as well as the agents' knowledge, are very basic, making it extremely hard to eliminate options from the

choice set prior to examining houses in person. Even if homebuyers have a precise idea of their future real estate, it is difficult to compare the various options and create a short list. Consequently, the process duration of finding the most suitable buying opportunity increases substantially if multiple agencies are hired and numerous viewings conducted. In the case of luxury items, which are not immediate necessities, homebuyers often reduce the search intensity if they have no pressure in finding a suitable property in a certain timeframe (Zheng, et al., 2006).

7.3.4 Homebuyers

As previously highlighted, Majorca attracted many overseas nationalities over decades and real estate supply on the island has greatly been adapted to the needs of this particular buying segment. An astonishing growth was recorded over the last six years, showing that foreign ownership on the island has more than doubled (Nicholas, 2014). Mostly, the houses purchased by Europeans are holiday or secondary residencies. These luxury goods are relatively illiquid and capital-intensive, generally limiting the buyers to high-net-worth individuals. Therefore, to set a research focus, this project looks at the foreign real estate buyer segment that wants to acquire a holiday or secondary home in Majorca. Individuals who act foremost as investors are excluded from the study, since they often consider a very different set of property characteristics than personal use buyers. This argument builds upon the literature findings that indicated investors generally put more weight on the location and are increasingly willing to do major renovation work if the site is right (Arenas, 2014), suggesting the property itself is not a major decision input.

7.3.5 Real Estate Type

The focus in the previous section, emphasising the target audience being foreigners who wish to purchase their very own place in the sun, needed to be further narrowed down to conduct a meaningful study. Since the estate type and price bracket definitely has an impact on the evaluation criteria that are being considered, it was necessary to clearly define these in light of this project.

Considering that Majorca is a prime luxury real estate market within Europe and foreigners often aspirate to purchase a large finca in the countryside or a sea-line property, the corresponding prices generally lie above one million Euros. Whilst in 2014 the average price for a 5-bedroom property in Majorca was 1,627,000 Euros (Dixon, 2014), the subsequent pilot study (in the next chapter) also emphasises that luxury houses in Majorca are generally offered at above the said amount. Such high-end properties evidently have a lot of different features to be considered and the high capital intensity may increase the homebuyers' requirements and expectations. Hence, an MCDM problem, with a large number of criteria, is defined and addressed in this research.

7.4 Summary

Initially, this chapter provided a brief description of the research location, its main features and the real estate market. Whilst the location selection was hugely based on the researcher's access to experts, agents and the homebuyers, it also provided favourable conditions for a focused research. Towards the end, the research focus was defined, clarifying that the remainders of this thesis relate to foreign homebuyers with the intention to obtain a luxury holiday or secondary home offered at a price above one million Euros.

8 Pilot Study

Prior to following the proposed MCDM problem-structuring framework to define the real estate selection process, a pilot study was conducted to enhance the researcher's knowledge of the phenomenon.

8.1 Introduction

A small pilot study with five real estate brokers from different agencies across Majorca was conducted to get a first impression of the decision problem and the target audience, i.e. luxury real estate buyers. At the same time, a pilot study seemed appropriate to initiate the fieldwork and offer inputs for the more focused data collection phases to come. This stage used semi-structured interviews to discuss a number of topics relating to the property selection process.

8.2 Data Collection and Findings

Five agents were recruited from five distinct agencies. The intention was to include diverse offices in terms of size. Respectively, two agents originated from the two market leading agencies in Majorca, two additional participants were employed by medium-size brokers and the fifth individual worked at a small real estate boutique. The agencies were all located in the South West region of the island, implying that their main business was also within the said area.

The recruiting consisted in approaching the agents via telephone. This initial contact had two purposes. First, the research project and the corresponding aims were explained to raise interest in the investigation. Second, the co-operation of the agents was stressed in order to reach the set research objectives. Having described the pilot study as an informal conversation, all five agents agreed to participate.

Prior to the interview sessions, the researcher briefly outlined the topics that should be discussed during the interviews. In no specific order, the agents should comment on:

- client profile and key differences between clients
- stakeholders involved in the decision making process
- number of criteria considered and constraints used to assess a property
- the most important assessment criteria
- approximate number of viewings with a single client
- percentage of successful sales and reasons for failed business
- existence of decision aids and the perceived demand for decision support models

This list of topics merely provided some guidance and did not imply other areas could not be discussed.

At the time of interviewing the agents, the researcher opened the discussion by asking to define a luxury property. Although it was previously not included in the initial list of topics, it was thought important to agree on a definition in terms of acquisition cost. All five agents estimated the minimum budget to purchase a luxury villa/house in Majorca to be around 1.0-1.5 million Euros. In this context, they already noted that the price is very dependent on location, view and property size.

With regards to the client profile and in accordance to the national statistical data records (see section 7.3), the pilot study participants emphasised the high proportion of German and British customers. Further, they claimed that between the two groups no major differences can be observed in respect to their prior constraints and demands. It was also mentioned that more recently there has been an increase in Swedish customers acquiring equity in Majorca. Then, on a related subject, respondents stressed, whilst there are no significant differences between nationalities, there are noticeable distinctions between genders. Precisely, when dealing with a couple, agents perceive a higher influence of the female party during the decision making process. Besides the partner acting as a key stakeholder in the decision making process, three out of five participants also suggested friends and property appraisers are often consulted, whilst one agent included lawyers in this context. As anticipated, the majority (four out of five) strongly believes that they too have an impact on the DMs and correspondingly on the final choice.

In relation to requirements, i.e. the number of attributes that are acknowledged by the clients and, consequently, their relevance in the decision, ranged from three to ten. This stressed the expected use of a very small number of criteria during the selection process, and possibly the ignorance or unawareness of some relevant criteria. In other words, homebuyers frequently neglect factors that can potentially boost the post-purchase satisfaction upon reflection.

Next, when agents were asked to define the most important criteria, all five agreed that location and price are always taken into consideration followed by view. The property size may also play a key role. Here, most people set a limit on the price, a constraint on the location(s) of interest and a threshold requirement is defined for the number of bedrooms. These filtering criteria are frequently used on the agencies' webpages and help narrow down the list of potential alternatives at the first meeting between agent and client. Concerning is however that it is the agent's task to select nine to 15 properties from this list of alternatives, which may still contain more than 100 properties. Often the real estate broker has only briefly met the client, yet has to make a selection based on the first impression. As a matter of fact, in many cases it is unlikely the agent has seen all the houses in the database, possibly leading him/her towards prioritising properties he/she is familiar with and can provide more information, even if this might ignore the client's true preferences. Kethley et al., (2002) also noted that a mismatch between property characteristics and DM preferences does not hinder relators to include an alternative in the final short list. By not actively

considering the buyers tastes, the search process is little different from random (Anglin, 1997). This may lead to frustrated clients and can cause confusion with regards to the desire to buy.

As noted in the previous chapter, it is widely known that luxury-homebuyers are not loyal to one agency, but rather hire multiple brokers to try to help them identify the most suitable property. The pilot study participants supported this phenomenon and pointed towards tough competition among the real estate agencies. Herein, if each agent shows the client between nine and 15 properties, an information overload is created. In more general terms, any realtor not prioritising clients' preferences when selecting houses, combined with the low number of criteria actually being acknowledged during a property purchase are probable reasons for the reported high number of unsuccessful sales and extensive searching periods. Brokers foremost assumed other reasons for incomplete business, including no access to financing or money shortage, fierce completion and confusions on the buyers' side.

Finally, another discovery was that once a short list of potential properties is derived, no guidance is available to assist in the comparison of alternatives, requiring the client to rely and trust their intuition or consult the agent. Hence, offering support in the process can potentially achieve a higher satisfaction level upon acquisition. A complete summary of the pilot study findings is available in Appendix C.

8.3 Summary

This small-scale pilot study clarified that real estate selection is indeed an MCDM problem. It further provided the research with a rationale to particularly look at defining a meaningful list of decision criteria. The evidence also suggests directing some efforts towards identifying any false perspectives real estate agents might have accumulated over the years regarding their clients, which may have led to this multi-agency trend in the industry sector. Overall, the pilot study supplemented the researcher's knowledge and literature findings to efficiently start the problem structuring process.

9 Data Collection

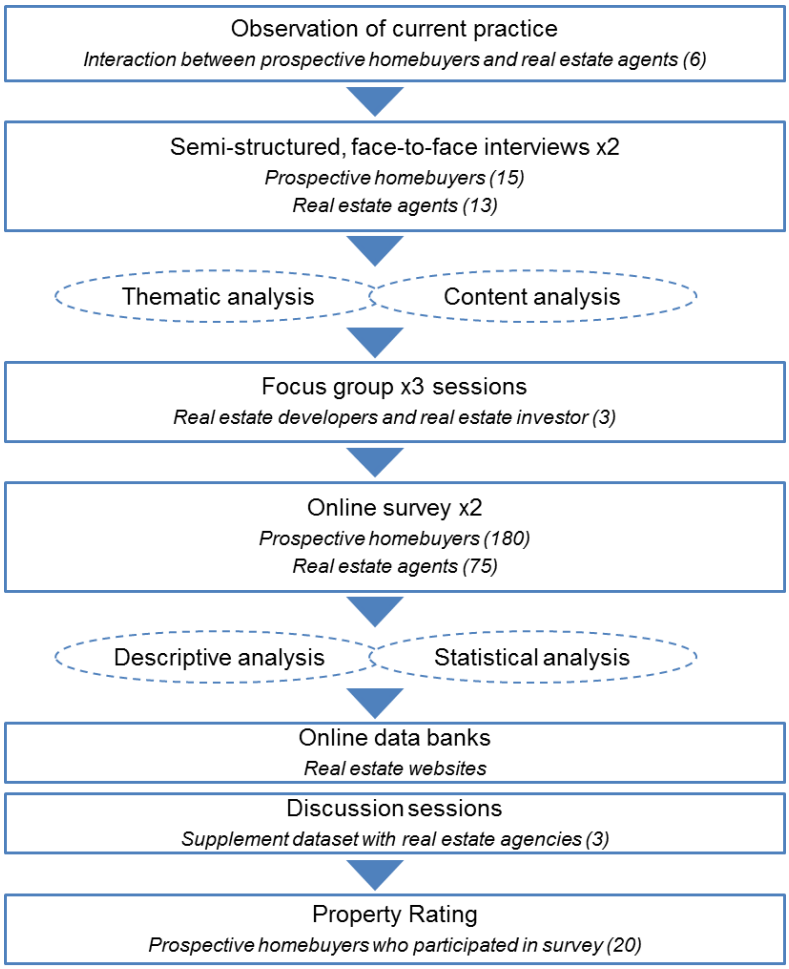
This chapter follows the developed problem-structuring framework to understand and define the real estate selection problem.

9.1 Introduction

Most real estate decision problems are naturally ill-defined and there is a great challenge of identifying and transforming the decision components to allow further decision processing steps (Argiolas, et al., 2010). Besides, the very complex process of acquiring such capital-intensive assets implies dealing with high-involvement goods (Daly, et al., 2003; Ratchatakulpat, et al., 2009). For these reasons, the identified process steps, in Figure 10, were expected to dissect and clearly structure the problem, with a focus on extracting the information required for the decision support model development. Following the proposed framework, the hereafter presented fieldwork also serves as a form of empirical validation.

Prior to attending separate data collection stages, Figure 15 graphically illustrates the sequence of actions (identical to Figure 10), along with suitable target samples (and size).

Figure 15, Data Collection and Analysis Sequence



Here, the information that the researcher anticipated to obtain include:

- clear understanding of current decision making practices in terms of the identification of alternatives and interactions with intermediaries
- DM(s) characteristics, decision stakeholders and external influences
- a complete list of relevant evaluation criteria
- a hierarchical structure of all criteria that is in accordance with the DMs' thought process, and hereby increases transparency
- evaluation criteria measures, i.e. qualitative evaluation grades and appropriate quantitative scoring units (for instance distance in minutes or kilometres)
- indication of interdependencies among criteria
- DM(s) preference information, i.e. criteria weights
- expectations of users for a decision support mechanism
- list of alternative decision options

9.2 Qualitative Phase

The main objectives of the qualitative research phase were to profile real estate buyers, identify possible false assumptions agents hold when assessing a client, create a list of evaluation criteria, organise these in a rational way and discover whether there are interdependencies among criteria. In more detail, this qualitative research phase was split into three stages. First, 15 interactions between real estate agents and prospective buyers were observed. Here, the primary objective was to uncover the process of selecting a number of alternative properties for the client. Second, in-depth qualitative data was collected during semi-structured interviews. Third, three discussion sessions with experts finalised the qualitative fieldwork. Having a combination of multiple qualitative methods intended to complement the other processes by increasing data richness and breath. Meanwhile, the sequential strategy also repeatedly supported the next research step.

9.2.1 Observations

Initially, the goal was to capture interaction behaviour between agent and prospective buyer. Thus, this research phase focused on the visual data, i.e. the process of presenting requirements, stating constraints and creating a short list of alternatives. The nine largest agencies were contacted to participate in this first stage. As a result, a total of six agents invited the researcher to each observe three client meetings. Since the agents' most frequent tasks range from meeting new clients, going on viewings and registering new properties to their portfolio, the researcher was contacted over a period of two weeks, as to the convenience of the realtor.

Prior to each meeting, the clients were informed about the researcher's intention to observe and take notes about the interaction and behaviour. Once approval of prospective homebuyers was obtained, the conversation with the agent started as usual. Despite the first contact between the two parties usually being via email or telephone at an earlier time, it

seemed that the alternative selection was solely based on the discussion at the brokers' office. Herein, the agent started off with casual conversation, whilst simultaneously trying to identify the purpose of buying a property, the price limit and preferred locations. Then, he/she typically asked a very broad question, such as what are the must-haves of your future house? In this context, some additional questions typically arose in respect to parking, children or sport facilities in close distance. It was observed that the higher the clients budget, the more time the agent spent analysing the requirements, as well as engaging in more small talk to develop some kind of relationship with the other party. Often, the real estate sales associate particularly engaged with the female, which seemed predictable since the pilot study revealed the agents' assumption that women have a leading role in a property purchase decision.

Moreover, after the initial dialog that included questions to unravel requirements, constraints and preferences, the broker presented the client with five to ten potential properties. Accordingly, the homebuyer reviewed the suggestions and often detected features that were undesirable or missing. This triggered another search through the database and resulted, in most cases, in a final list of houses that would be viewed during the next meeting(s). A preferred date was subsequently discussed, and the agent agreed to get back to the client once the viewing appointments were confirmed with the property owners. Towards the end of the appointment, the agent engaged in more yet relationship building conversation, rather than trying to further classify the clients' preferences.

Once the prospective homebuyers left the office, the agent was asked to give a brief feedback whether the participants behaved normally, or whether it was believed that the researcher's presence influenced responses. With the agents assuring typical behaviour, the observational process provided the researcher with invaluable insight into the phenomenon under investigation and helped, along with the literature review, pilot study and researcher's knowledge, to draw up an interviewing strategy.

9.2.2 Interviews

The semi-structured interviews are at the heart of the qualitative research phase, requiring a detailed description of the layout, sample and data collection process.

9.2.2.1 Interview Design

Supported by existing literature and previous investigations, the researcher created two relevant interview protocols, each purposely tailored and designed to address either the prospective homebuyers or the real estate agents.

9.2.2.1.1 Real Estate Buyers

Assuming that most luxury holiday or secondary homebuyers have in the past bought and owned real estate, the objective of the interview was to obtain insight of previous experience

and, more importantly, on their expectations regarding the current search process. Thus, the interview was designed to cover five main categories.

To set the scene, interviewees initially received a concise briefing on the research topic and the objectives. Subsequently, to be able to create a profile of the luxury-homebuyer in Majorca, questions about the participants' background were asked. This concentrated on the interviewee's marital status, nationality, current employment status, children and familiarity with Majorca. Once a comfortable environment was created and initial dialog occurred, the attendee was asked to provide some insight into a past real estate purchase process. Herein, focus was directed towards the search experience, the buying motive and duration, including the number of houses viewed, the DMs and their involvement and lastly their satisfaction with that purchase.

During this second part, some evaluation criteria emerged that helped the DM assess alternatives. The next two sections in the interview were dedicated to the present situation. Hence, first individuals were asked to state their motive, the people involved in the decision and how long they had been thinking about buying a property in Majorca. Also, the motives for using a real estate broker were investigated, as well as the reasons for choosing a particular agency. In the penultimate block, attention was directed towards the selection of property alternatives, any constraints, requirements and criteria preferences. In this context, possible relationships (dependencies or correlations) between property criteria were discussed. For instance, a common connection was drawn between a property's view and the offered sales price. To finalise the interviews, a summarising question about the island was asked, such as why Majorca was chosen for the holiday or secondary home. This last information would potentially provide the researcher with an idea of similar locations to extend the research.

9.2.2.1.2 Real Estate Agents

The interview guide for the real estate brokers was significantly shorter and focused on their perspectives on the customer base. Nevertheless, similar to the homebuyers' interviews, agents were initially asked to provide background information such as nationality, time employed as a real estate sales associate and time worked in Majorca. Then, the main body of the interview concentrated on the agency, their clients and the real estate selection process. More precisely, the researcher tried to uncover some general information on the agency's property portfolio, comprising the predominant price segments and most represented areas in Majorca. Further, some questions addressing the agent's knowledge and experience with clients were asked, specifically whom they believed the main DMs to be and the perceived familiarity of those customers with the market. Another key point stressed the number of houses realtors choose to show a client and whether a specific strategy is followed. Finally, this section ended by investigating the brokers' thoughts on why people often take a long time to decide, or even fail to buy. The third and penultimate section of the interview centred around the housing criteria that were believed to be acknowledged in a

purchase. In this respect, agents were also asked whether they stick exactly to the clients' brief, or whether they also consider showing houses, which for instance are above the set price limit. Finally, the last set of questions aimed to classify the Majorquin real estate market and identify features that attract such an international clientele.

Overall, the development of an interview guide that outlined key areas of interest was essential to sufficiently standardise the data for comparability during data analysis (Barriball & While, 1994). The interview schedules were discussed with two experienced real estate agents and a real estate expert to assure the relevance of certain points and avoid missing important topics. In fact, finalising the sequence of possible questions was also an important task in order to portray a logical flow throughout the interview that mirrored respondents' experiences (Barriball & While, 1994). This validation phase resulted in only minor changes to the protocol. Noteworthy, to account for the high number of German and British customers on the island, the interviewees were given the opportunity to be questioned in the language with which they were most comfortable.

9.2.2.2 Sampling

With respect to the sample, Majorca has hundreds of real estate agencies with multiple offices across the island (ImmobilienMallorca24, 2013). The real estate brokers represented a vital part of this research, not only to obtain their perspective on the decision making process and identify possible disagreements between them and the DM(s), but more importantly for the access to the target population. Intermediaries that stand between seller and buyer are often seen as the best medium to approach the research population (Ratchatakulpat, et al., 2009). For this reason, established real estate agencies were first approached for data collection. The intention here was to include all major agencies. They were asked to provide a list of their branches on the island that were available for data collection. All agencies included their main office, making it plausible to use those, particularly as they simultaneously received most business and had a larger number of agents. Then, a sample was randomly chosen from the people working in each office. On average, an office employed 11 realtors, some of which were newly hired and others that were with the particular agency for over 15 years.

In respect to recruiting prospective homebuyers to participate in the research, it was the broker's judgment and assessment in deciding whether to approach a particular client. Hitherto, they were given a brief description of the sample selection criteria that individuals needed to meet to be valuable informants. Respectively, all candidates should have set a budget above one million Euros for the purchase and the intention should be to live in the property. Once the intermediary determined a potential informant, he/she asked the client for consent prior to inviting the researcher in for questioning. Since a large proportion of the high-net-worth individuals who buy luxury homes are very keen on their privacy, it took, as anticipated, some time to get a sufficient number of individuals to agree to take part in the research study.

Typically, the sample size depends on the number of interviews required to reach data saturation, referring to the diminishing value of adding another informant to the study (Francisa, et al., 2010; Suter, 2012). Yet, it was rather difficult to identify the point in time data saturation was achieved and was therefore primarily determined based on obtaining a comprehensive picture of the situation and discovering no new information from further respondents. Also, since sample size in qualitative research always depends on the method used, the population studied and the depth of individual responses (Sandelowski, 1995), it was decided that data collection ended once 15 in-depth interviews were completed, bearing in mind that supplementary interviews were subsequently conducted with the real estate brokers. By contrast, the access to agents was comparably easy. These interviews were conducted at the convenience of the agent. On the whole, interviews being time consuming and the access to participants requiring substantial resources, the combined sample size (broker and buyer interviews) for this research project was perceived to be reasonable, not too small to support statements, nor too large to extremely increase time and effort analysing and investigating individual interviewees (Sandelowski, 1995). In fact, a detailed examination of adequate sample size by Guest et al. (2006) showed that six comprehensive interviews might even be sufficient in deriving meaningful themes and valuable interpretations.

9.2.2.3 Data Collection

With the interview schedules in place, the research proceeded by first questioning the prospective homebuyers, followed by the real estate agents. Interviews with the clients were ideally conducted after their first meeting with the agent. Hence, the research sites for data collection consisted in the agencies' offices that volunteered to support the research project. The purpose was to further deepen the understanding of property selection within the luxury segment by deriving a comprehensive list of relevant evaluation criteria, any relationship between them, as well as reasons for choosing Majorca. With regards to relevant decision factors, it is important to emphasise again that these are expected to deviate in situations where the purpose is to find an investment opportunity in contrast to the current investigation of residential properties (Ratchatakulpat, et al., 2009). Arguably, investment assets have a considerable lower number of criteria that need to be included in an evaluation process, as well as very different weighting scores.

All semi-structured interviews were recorded and, in some instances, field notes were taken. Audio taping this stage was crucial to later perform precise data analysis (Barriball & While, 1994). The researcher tried to include all bullet points from the guide developed previously and added some extra questions in situations where the respondent provided very brief answers. The 15 interviews lasted approximately 19 minutes.

With respect to the real estate brokers, the objective was to interview the individuals who had previously arranged the contact to a prospective buyer. Thus, after the successful completion of the client interview sessions, the researcher approached the brokers. Similarly

to the above data collection process, interviews were tape recorded to avoid losing any information. A total of 13 interviews were conducted, with an average duration of 22 minutes.

9.2.2.4 Findings

Although the subsequent chapter is entirely devoted to data analysis, the sequential exploratory research methodology requires data analysis of the first data collection phase prior to starting the next phase. Respectively, in this section some of the key findings are presented from the interview analysis used to support the construction of the quantitative data collection instrument. Hence, as emphasised previously, all 28 interviews were transcribed and analysed. A summary of the main findings is provided below, whilst the complete analysis is presented in Chapter 10.

9.2.2.4.1 Homebuyers

The age of male respondents ranged from 35 to 75 years (with 57% in their 50th or 60th), whereas the age of the female contestants was between 32 and 70 (with 58% in their 50th). Additionally, 81% of the respondents were German and 87% had children. With respect to the homebuyers' employment status, 73% were self-employed, 20% retired and the remaining 7% were employed. All participants were familiar with the island and had thought about a property purchase in Majorca for a long time prior to taking any actions. The investigation also established that 60% of respondents did not own a property in Majorca at the time of the interview.

Turning to previous house purchases, not every participant was familiar with real estate brokers, but clearly the majority did contract an agency during a previous transaction. Past experience indicated the duration of finding a suitable property varied substantially from one to 18 months. However, all candidates agreed buying a house involves the partner, often with equal decision power, and in some cases advice from children, lawyers, architects or property appraisers are considered. This contradicts the pilot study findings, as well as the research by Levy and Lee (2004), which concluded that the wife in high socio-economic status families takes on a key role throughout a number of different stages of the decision process. On a related note, all interviewees concurred that real estate agents have a very low influence on the final decision, if any. They believe, agents simply arrange the access to properties, only influencing the buyer slightly through the alternative assortment. Particularly in Majorca, the property search process raised some interesting points. The evidence suggests the use of an agency on the island is primarily triggered by the limited access to real estate. Besides, it is widely known and accepted that most properties on the market are being distributed through various channels, yet individuals typically commission multiple brokerage firms simultaneously.

Next, the fourth interview section identified 157 criteria, whereas, in order of frequency view, style, location, number of bedrooms, constructed area, pool, price, quality and distance to

Palma were highlighted by more than 50% of the respondents. Also, the homebuyers emphasised a number of 31 possible criteria relationships, for instance proximity to sea and repair costs or touristic area with crime rate. On the next topic, 22 reasons were provided to justify a purchase in Majorca. Strikingly, the key attractor to the island is its central location and accessibility, with an airport connected to all major European cities. Other features valued by international clients included the infrastructure, medical care facilities, restaurants and weather conditions.

9.2.2.4.2 Real Estate Agents

Analysing the agent interviews, 92% of the respondents were German (78% male) and on average between 42-53 years old. In relation to their job, the 13 brokers worked on average 14 years in the industry, whilst being approximately seven years with their current employer. Besides, the majority of respondents lived relatively long on the island, with an average of 11 years. These results must be interpreted with caution. Neither the job length, nor the time spent in Majorca, are representative, since the majority of interviewees were senior real estate executives.

Now, contrasting the answers of the two study groups, brokers suppose women play a leading role in the property purchase decision, whilst the clients' perspective is that a couple generally reaches a decision jointly. Also interesting, and contradictory to the previous findings, agents' believe that they, as consultants, have a major influence on their clients. For this reason, they implied that high-net-worth individuals actually use their service for consultancy purposes.

Continuing, the real estate agents also generated an extensive list of 131 variables that they believed to be important, or which were persistently mentioned by their customer base. The most striking criterion for a luxurious holiday home was said to be the view, followed by the property's location. Other features suggested by more than half of the sample included pool, price, style, number of bedrooms, constructed area, proximity to sea and furniture. In relation to criteria connections, 25 potential links were established, such as plot size and distance to the neighbour or constructed area with acquisition price. The last section focused on industry performance during the past years, particularly considering the economic recession in Spain. Overall, 54% stated that the real estate market was stable throughout the previous five years, with minor fluctuations. And surprisingly, 15% experienced growing demand over the last five years; of which two brokers stressed that property demand in Majorca during an economic downturn will always have a superior performance than in other locations. Addressing the economic situation in the customers' countries, agents saw a low influence on luxury housing demand. Above all, reasons mentioned for this relative stable market situation were the island's infrastructure and comfortable weather all year around. Other positive island features repeatedly cited included high living standard, multifaceted surroundings and multiple international schools.

The interview data was organised in a summarised format in Microsoft Excel. Combining the information gathered from the two study groups, a total of 214 different criteria were identified. Thereby, across the two groups, only 74 criteria were overlapping, i.e. mentioned by both parties. To validate the data analysis, the summarised findings were presented to three agents that participated in the interviews. They were asked during a focus group session to provide feedback and verify that the data interpretation and analysis had resulted in valid conclusions (Maxwell, 2005). This process aimed at increase the degree of construct validity (Creswell, 2003). As a result, the validation stage supported the interview results.

9.2.3 Focus Group

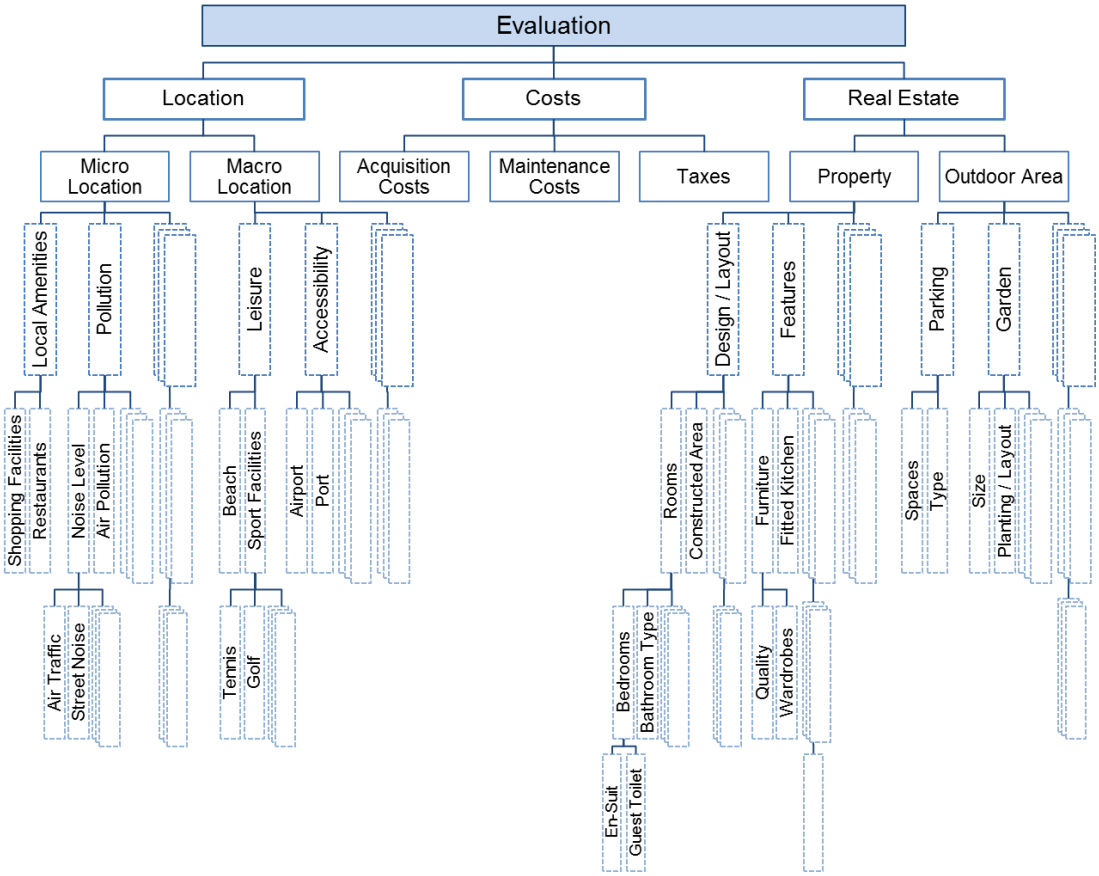
Independently, a discussion session was arranged with three real estate experts to review and discuss the interview findings. The researcher's personal contacts provided the access to these professionals, including one property investor and two developers. It is worth highlighting the three experts have extensive experience in purchasing real estate in Majorca, particularly accounting for multiple acquisitions for own use.

A key aim was to finalise a list of criteria. Including an unnecessary large number of criteria in an analysis may not be feasible; hence, it is important to ensure only relevant factors are considered (Dodgson, et al., 2009). For the current case, this meant eliminating variables shared the same meaning, but were originally classified differently. At the same time, relevance and wording was discussed. Ratchatakulpat et al. (2009) proceeded similarly, using a panel to review the variables they believed to be relevant with the intention to delete irrelevant items and possibly add neglected ones. After thorough examination, the previously identified criteria were condensed from 214 to 144. Respectively, 58 synonym criteria were deleted, 41 attributes were considered too subjective, or hard to measure by the experts, 10 were renamed, whilst 29 criteria, not yet included in the property evaluation list, were added. Whilst this clearly is a large list of factors that should always be included initially, Saaty (1990) suggested less important components can always be dropped retrospectively to best portray individual DMs.

Another task attended during a second meeting was grouping or categorising these criteria into a logical, hierarchical structure. This was relatively time consuming and some controversial points arose. In this context it is worth acknowledging that in large decision problems "there is arguably no unambiguous correct structure or grouping of criteria" (Dodgson, et al., 2009, p. 34). Nevertheless, the three experts ended up agreeing on one single framework, which would be used for this research project. Without their knowledge, the experts acted in accordance to existing publications, where for instance the capital requirements, associated to acquisition price, maintenance costs and taxes were clustered under the heading 'costs' (Daly, et al., 2003). Overall, 141 criteria were first allocated to one of three upper level categories, i.e. location, real estate or costs. This process was repeated until all variables were appropriately categorised, creating a meaningful and valid representation of the criteria, with a total of six ranks and 106 bottom level criteria. A

simplified version of this hierarchy is demonstrated in Figure 16 below, whilst a full version of the developed real estate assessment framework can be found in Appendix D.

Figure 16, Example of Hierarchical Structure



In the third and final session, the experts were asked to review the researcher's pre-defined criteria measures, foremost attending controversial variables that can be measured in various ways. For example, all criteria that involved distance measures. Herein, it was debated whether to measure distances in kilometres (meters) or in time travelled. In some situations, it may also be more appropriate to measure distance in qualitative terms, such as walking distance, short drive or long drive. Ultimately, to stay consistent, it was agreed to measure distances in kilometres (meters) or minutes. In the end, 106 variables took on a qualitative nature and 38 were classified as quantitative. Afterwards, the real estate professionals reviewed and supported the remaining data analysis findings from the interviews, hereby finalising the qualitative data collection and validation stage.

9.3 Quantitative Phase

With the successful completion of the first research phase, the next concentrated on validating and generalising some of these qualitative findings (increase external validity), as well as identifying criteria relevance. Although substantial data was previously collected, which had multiple objectives, the interpreted, categorised and summarised interview data together with the expert sessions also supported the construction of the online survey required in the quantitative research phase to achieve the next set of objectives. Qualtrics

survey software was used to assist the development stage. Qualtrics, is a research platform that enables straightforward and flexible questionnaire design and systematic data collection with their incorporated distribution tool (Qualtrics, 2015). The distribution channel was chosen for various reasons. First, the fact that most people interested in buying a property search foremost the real estate webpages for suitable alternatives, plus the access to the Internet is assumed to be granted to almost everyone in the research population (Cole, 2005). Hence, distributing a questionnaire via email or through the brokers appeared to be most convenient for the prospective respondents. Second, the online version allowed the candidates to easily switch to the desired language. Third, a number of questions were irrelevant in some cases; therefore, the system was programmed to show only those questions that were relevant in that specific situation and accordingly appeared depending on previous answers (Roberts, 2007). Another advantage is that completed surveys were saved on the research platform and could be downloaded in form of an Excel sheet for data cleaning and analysis.

9.3.1 Survey Design

Similar to the interview data collection process, two distinctive surveys were produced to gather data from homebuyers, as well as real estate agencies. By including both, different perspectives are obtained, resulting in a type of data source triangulation (Thurmond, 2001). In relation to this, comparisons between these two study groups can be made and potential gaps identified or generalised.

9.3.1.1 Homebuyers

The surveys targeted at prospective homebuyers initially introduced the research study and assured anonymity and confidentiality of data. Subsequently, the first 41 questions closely followed the interview structure with the intention to generalise some of the qualitative findings. Here, a maximum of 12 questions were formulated to obtain some demographic information about each individual. Predominantly multiple choice and dropdown lists were used in this section. Then, nine questions appeared if people specified they already own any real estate or had previously commissioned a real estate agency. This subsection intended to identify past experiences with property search and selection, using a mixture of multiple choice, dropdown lists, gap analysis, rank order and text entry questions. Gap analysis in this case focused on identifying customer satisfaction with broker performances and the text entry box allowed respondents to provide additional information on positive or negative experiences. The next block of questions concerned the current property selection problem. Again multiple choice type questions were used in the majority of cases, with either single or multiple answer options. However, a matrix table seemed suitable when investigating informants' view on real estate webpages and on different viewing strategies employed by brokers. This finalised the survey section that was primarily included to profile the homebuyers in Majorca and enhance the generalisability power of the interview data.

The remaining survey sections intended to extend the dataset. To reiterate, the quantitative method had two objectives, being able to generalise initial findings, as well as expanding the information. Concentrating now on the latter, emphasis was given to the criteria determined by the real estate experts. In this context, the hierarchical structure dictated the question content and sequence to efficiently determine the level of importance of individual attributes. Respectively, respondents were asked to compare a set of criteria that were organised on the same hierarchical rank and fed into the same upper criterion. This was done by scoring each on a scale from zero to 100, zero indicating no influence in the property evaluation process and 100 denoting high relevance. Note that participants were not required to provide scores totalling to 100 across competing criteria, since the researcher was interested in obtaining absolute weights. A total of 39 criteria groups were assessed in this part of the survey. Next, criteria connections that were raised during the interviews were examined by allowing survey participants to decide whether they agree, disagree or neither agree, nor disagree with a particular relationship statement. Essentially, 33 correlations and/or dependencies were established and presented to the audience. The last section addressed likely problems arising during the selection process, and whether people would appreciate more structure in the form of some guidance. Herein, a maximum of eight questions were shown to the survey attendee. However, anticipated was that the three text entry boxes, which only appeared if the respondent could not find an appropriate answer among the multiple choices, would not be displayed in the majority of cases.

In summary, the client survey addressed six sections with a variety of question types. To ensure the majority of targeted candidates could participate, English and German survey versions were offered. The full questionnaire is available in Appendix E.

9.3.1.2 Real Estate Agents

The real estate agent questionnaire was comparably shorter (see Appendix F) It started by briefly introducing the research, yet the majority were expected to already have a fairly good idea, since they were asked to approach and recruit their clients to participate. Next, they were asked to provide some profiling information and to comment on their property portfolio. These two sections occupied seven questions, including multiple choice, dropdown lists, a heat map and a slider. The heat map intended to identify the five areas that dominated the agency's portfolio, whereas the slider should highlight the number of luxury properties administered by the agent's office. Furthermore, a different section with 12 questions concentrated on the client base, i.e. the typical characteristics of the DMs. Naturally, since realtors have the trust of their clients and are not likely to discuss individual client cases, the questions were held relatively broad and focused more on the aggregate level of client behaviour and characteristics. This means, of interest was the distribution of nationalities and if agents observed differences between these. This had the objective of possibly identifying different groups within the target population. Additionally, brokers were asked to profile their clients in respect to average age, typical marital and employment status, their most likely educational background, children and familiarity with Majorca. These

assumptions could ultimately be compared and verified with the actual client base that had attended the online survey. Then, within this section, three questions focused on who the DMs are (i.e. individuals, couples, families or others) and the influence of other parties. Again, this particular point had the intention to generalise previous findings from both the pilot study and the interviews that emphasised agents' believe of women having more influence in this capital-intensive purchase decision. The following section focused on the real estate selection process itself. A number of questions that were asked in the client survey were repeated here to compare responses. The penultimate question block focused on Majorca's real estate market performance and the reasons for continuously attracting a large base of international, high-net-worth individuals to the island. Eventually, the survey was finalised by investigating whether agents believed buyers face some difficulties during the property search or selection, and whether they think a decision support tool would be valued in this industry.

In sum, the realtors were invited to answer 33 questions, divided into six different sections. The focal point of these surveys was to compare answers to client responses and identify differences. Note, although all real estate agents in Majorca were expected to have a proficient knowledge of the English language, the survey was also provided to them in English and German.

9.3.2 Survey Pilot Test

It was important to field test the survey prior to distribution in order to establish content validity of the data collection instrument and identify potential wording inconsistencies or formatting errors (Creswell, 2003). Correspondingly, five individuals from the researcher's personal contacts, who were currently, or had previously been searching for a real estate in Majorca, and therefore fit the sample profile, were asked to read the survey questions carefully, whilst making notes in case of confusion. They were also requested to time themselves once they had started the survey. This last task gave the researcher an idea on the approximate time scale required to answer all questions, which would be important when approaching and recruiting potential survey participants.

Once the five individuals had completed the survey, they had a few comments in respect to question wordings and suggested some simplifications. The proposals were implemented, allowing to finalise the survey. In terms of duration, the average time spent by the participants was 40 minutes. Furthermore, since the agent survey had fewer questions, yet a large proportion similar or identical to the client survey, no pilot test was conducted in this case. The final version of both questionnaires can be found in Appendix E and Appendix F.

9.3.3 Sampling

Recalling the sample scheme of the qualitative data collection, for this second phase a parallel relationship can be expressed, because sample members were drawn from the same population (Onwuegbuzie & Collins, 2007). First, all real estate agencies that had an

online presence and offered luxury houses for sale were contacted via email. After a thorough search on Google, a total of 79 agencies were believed to represent the full population, with maybe neglecting a few if they were hard to find on the Internet. However, since the study is limited to luxury properties, which are most certainly distributed through real estate webpages, the number of ignored service providers is believed to be minimal. Continuing the selection of study members, it was decided to include all 79 brokerage firms to obtain as many responses as possible and potentially have access to a larger client base.

With respect to the homebuyers, no definite number can be assigned to the size of the population. Therefore, over a time frame of ten weeks, the brokers were asked to pass on the survey link to all clients that decided to search for a property in Majorca and had a budget above one million Euros. Alternatively, after providing the client with a letter soliciting their co-operation by explaining the research objectives and highlighting the potential benefit of participating, i.e. deep insight into the decision components and process, they were asked to provide the agent with their contact details that were later passed on to the researcher. This sampling approach seemed most effective and efficient in the current research project. Also, as described before, various empirical studies adopted a similar approach in accessing the research population (Park, 1982).

9.3.4 Data Collection

To establish the first contact with the study subjects, 79 real estate offices received an introduction to the research project via email and were asked to contribute by approaching their clients to participate as well as asking their colleagues to complete a short, anonymous online survey. In the original email, the agent found two links, one for their clients and one for them and their colleagues. They were also notified that the surveys would be active for a period of ten weeks. In respect to the completion of surveys, the research platform Qualtrics kept track of started and completed questionnaires, allowing the researcher to keep track of the number of responses. Consequently, the agencies that had not opened the link after eight weeks were sent a reminder email.

Concerning the client survey, agents were told they could provide the survey to their customers directly at their office, forward the link to them or take their contact details so the researcher could get in touch with them directly at a later date. These three options were provided to convince participation and potentially increase the response rate. Moreover, agents should emphasise the anonymity to the high-net-worth individuals, potentially persuading them to share their information. The aim was to get a minimum of 150 participants.

9.4 Real Estate Dataset

In order to develop and test a decision support model, it was necessary to collect data on a number of alternative properties, i.e. create a dataset in accordance to the identified criteria.

9.4.1 Data banks

Initially, the researcher chose properties offered on a number of real estate websites. Here, 41 properties were selected that predominantly covered locations in the South West, South and island middle, which was in accordance with previous findings of desired island locations. Also the price range almost reflected the profile of the 180 survey responses, where 89% had a price limit between one and 2.5 million Euros. Accordingly, whilst property prices in the dataset ranged from 1.2 to 3.9 million Euros, 80% of the properties were offered at below 2.5 million Euros. Next, to simplify data collection and acquire all data points, a template in Excel with all bottom level criteria was constructed. To clarify, 106 criteria in the hierarchy structure were not further broken down, i.e. representing the measurable property attributes. Each property then had to be defined on these variables.

9.4.2 Discussion Session

Whilst some of the information was recorded directly from the real estate websites, the majority of information was obtained in co-operation with three agencies that filled the missing gaps. Noteworthy, agents were presented with identified measures from the focus group sessions (and corresponding definitions). This helped to define alternatives' performances on qualitative variables in light of the accepted evaluation grades and specified the correct quantitative measurement unit.

9.5 Rating Exercise

By means of the full dataset, buyers were able to evaluate the 41 properties. Correspondingly, 20 individuals who had previously taken the survey, and agreed to be contacted at a future point in time for additional data collection, were approached for the rating exercise. The benefit of using survey participant for this task was the availability of their demographic data, search profile and weight structure for all evaluation criteria.

The researcher reached the 20 individuals via telephone or email to first explain the exercise. Accordingly, they were informed that they should review 41 properties, one by one, and assign an appropriate score between zero to 100 for each alternative, based on their personal perception and preferences. Once the task was understood, the participants received the Excel sheet with the property information in addition to multiple pictures of each real estate. The photos were intended to avoid inspecting the properties in person and to obtain an idea of the external and internal property-scape (Ratchatakulpat, et al., 2009). The researcher slowly talked the participant through each case until arriving at the property performance score. As a result, the sample provided a total of 820 scores. This represented the basis for constructing the MCDM model and studying criteria relationships.

9.6 Summary

This chapter followed the problem-structuring framework developed to understand and define MCDM problems of high-involvement products or services. It helped to gather the

right data to understand the problem, whilst at the same time extracted all relevant information needed to build a decision support model. Foremost, the chapter underlined that the research design had multiple, interlinked stages, necessary to increase internal validity, collect an appropriate amount of data to answer the various research questions and, most importantly, to structure the MCDM problem at hand. The next chapter emphasises the data analysis processes of the datasets generated above. Above all, it is worth reiterating that analysis of separately obtained records always occurred immediately after and before initiating the next stage.

10 Data Analysis

This part of the thesis discusses the data analysis processes.

10.1 Introduction

The analysis presented in this chapter excludes the data collected through the pilot study and the observations, since these results were already presented and do not require further illustration. Consequently, the main focus is on interpreting the interviews and focus group sessions, dissecting the questionnaires, describing the property dataset, as well as summarising the rating exercise.

10.2 Qualitative Analysis

A brief summary of the interview findings was provided in the previous chapter, because insight was required to proceed with the subsequent data collection phase. Nevertheless, a more detailed explanation of the data and, in particular, the analysis process, needs to be explored.

10.2.1 Homebuyer Interviews

The duration of the interviews ranged from 12 to 35 minutes, with an average of 19 minutes. After finalising the data collection, the interviews were transcribed in the original language (mainly German). This enabled the thematic and content analysis of the text.

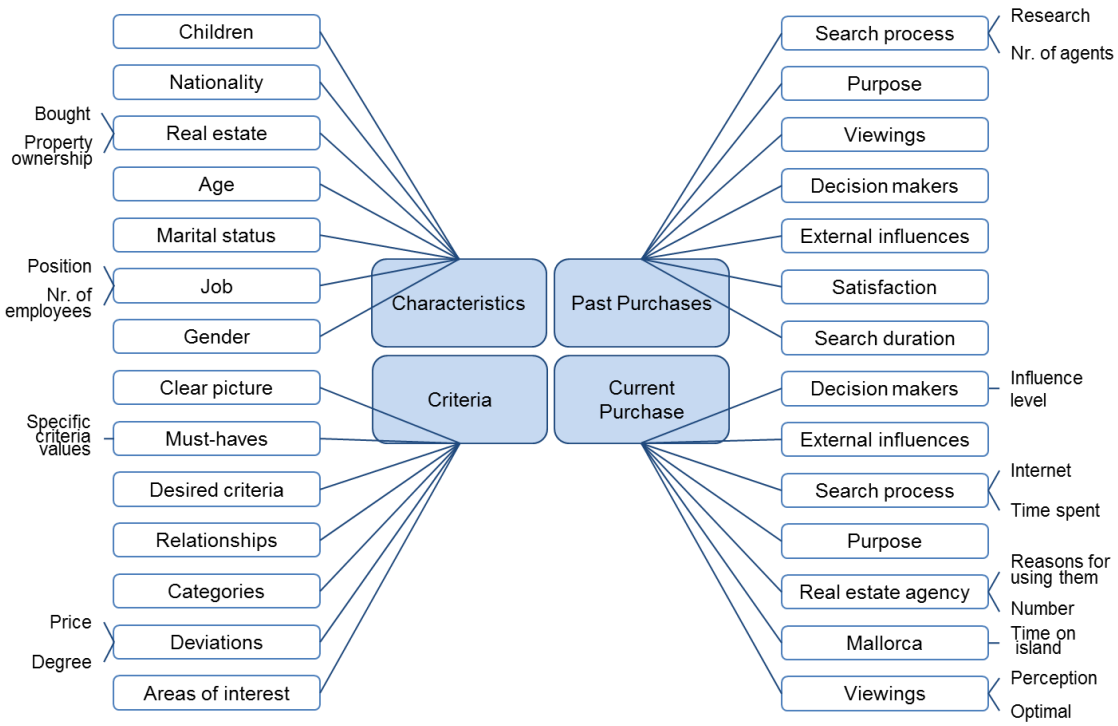
10.2.1.1 Thematic Analysis

Choosing to first conduct a thematic analysis had the objective to obtain a deeper understanding of the research phenomenon and, in particular, answer most of research question two (What is the luxury-homebuyer's decision making process when selecting a property in Majorca?, including the various sub-questions available in section 4.2.2). This data analysis technique is a focused and time efficient way to obtain the key messages of the interview dataset, since no line-by-line analysis is required.

With respect to the analysis procedure, prior to conducting the interviews, a coding template was created based on the researcher's expectations on the repetition of certain codes. Herein, combining the researcher's industry knowledge and existing research studies on decision making and real estate, a number of themes were identified that were expected to occur. Yet, the initial template was kept relatively broad and only concentrated on aspects intended to be examined with pre-determined questions. The basic coding diagram is available in Appendix G. Thematic analysis being a very flexible data analysis technique, allowed the alteration and adaption of pre-defined labels. Respectively, the researcher kept an open mind for new or different themes arising during the interviewing stage. This clearly emphasises the previously mentioned point that data collection and analysis are inseparable in qualitative research. Principally, during the process and after repeatedly examining the

transcribed data to connect data elements, the template was adapted to derive the final coding framework below (Figure 17). The structure chosen presents a form of hierarchical coding, with broad themes at the upper level (positioned at the centre of the figure) and sub-categories forming lower levels, narrowing the themes down to more specific ones.

Figure 17, Coding Scheme



The above coding scheme was generated to index the text and establish a thematic framework of the main ideas (Gibbs, 2007). More importantly, it was believed to be a suitable representation of the themes found in the dataset. Key facts were extracted from the transcribed text and respectively organised in a summarised format in light of the coding scheme. In the current study, Excel served as the best tool to arrange this data into a coherent way. In this way, the fundamental objectives were met, which consisted in reducing the large dataset and establishing a meaningful structure to best understand, interpret and write up the findings (Winchester, 1999; Crabtree & Miller, 1999; Leech & Onwuegbuzie, 2009). Additionally, focus was directed towards identifying underlying themes across interviews (Creswell & Clark, 2010). A thematic analysis example of one an interview is demonstrated in Appendix H.

Based on the thematic analysis, the 15 homebuyer interviews were summarised and conclusions were drawn. With respect to the first index category, i.e. interviewees' characteristics, 11 out of the 15 interviews were conducted with a couple, adding up to a total of 14 male and 12 female respondents. The age of the luxury-homebuyer sample ranged from 32 to approximately 75. Associated with the study group's age, 87% had children, of which 54% were over 18 years old. Also of interest was the high proportion of German buyers among the sample, representing 77%, whilst other nationalities included

English, Czech, Peruvian, Swiss and French. Despite the fact that Germans are extremely present in Majorca (Redwood, 2014), this figure may be an incorrect representation of the luxury-homebuyer population. Perhaps an explanation can be attributed to an increased willingness of the German clients to participate in the research study. Furthermore, the occupation of luxury-homebuyers was investigated, revealing a self-employment rate of 73% and 20% retired clients. Along these lines, it would have been inappropriate to ask about the annual income, hence the number of employees was questioned to provide an indication of the size of the company. Herein, the employee number ranged from zero to 1300. It was also discovered that 40% already owned a property on the island, whilst 13 out of the 15 respondents were very familiar with Majorca, having lived or commuted there during earlier years. Finally, all, excluding one, had experience with house purchases in various locations.

Following the evidence above, the next category focused on previous purchase decisions. First, participants were asked to describe their last property search process. Here, whilst 60% engaged with a real estate broker, initial own research was also mentioned eight times. Related to this and in contrast to the practice in Majorca where multiple agencies are used, the norm in other locations seems to be different, where usually only one brokerage firm is contracted. The number of viewed houses varied substantially across the participants, ranging from one to more than 20 (29% viewed more than 20). In the same way, the duration of the entire process also differed across buyers from one month up to 18 months. Next, the stakeholders involved were examined. The evidence here appears to contradict the general belief held by real estate agents. Indeed, 80% of the informants reported reaching the final decision in a joint effort with their partners, or even with family members. Other sources consulted during the decision making process included friends, architects, lawyers and property appraisers, whereas 60% implied not being influenced by external parties. Overall, past acquisitions discussed during the interviews were reviewed regardless of the purchase purpose. The section foremost served to get an idea of the level of experience, coupled with the intention to retrieve relevant criteria by recalling past actions.

The following part investigated the current decision profile. Herein, similar sub-codes to the past purchase category were identified. To start with, the predominant purpose of purchasing a luxury real estate in Majorca was to own a holiday (47%) or secondary (27%) home to increase the time spent on the island. However, 27% of the study sample stated their intention to permanently move to Majorca at some point in the future. There were also different reasons for choosing the island over other locations. For instance, the accessibility from all major cities within Europe (87%), the pleasant climate (33%) and its infrastructure (60%), including medical care, restaurants and shopping facilities, were repeatedly mentioned.

Reflecting upon comments related to decision stakeholders, 12 interviewees agreed that a final purchasing decision would be reached together. Worth noting in this context, the individuals who specified the equal involvement represented the 12 interviews conducted

with a couple. Additionally, eight respondents explicitly mentioned they would include external sources, mainly friends. Interestingly, only two DMs believed their real estate agent might, to some degree, have an influence, yet this is generally reduced to the assortment of properties that is presented to the individual. Continuing this topic, from the obtained responses (11), it was clear that 45% already contracted multiple agencies to help find an appropriate real estate, whereas 55% just started the search and engaged with only one agency so far. When asking the sample about the key reasons for engaging with the intermediaries in Majorca, 33% noted the access to properties as the prime motivator. On the other hand, 27% valued the agents' market and legal knowledge and 13% their large property portfolios. Nonetheless, all but one did Internet research prior to contacting an agent. This period of initially deciding to buy a property, before taking major actions to pursue this 'dream', has been identified to be relatively long. Whilst some individuals played with the thought of buying a house in Majorca for six months, others contemplated this idea for years. Therefore, it can be suggested that people acknowledge the capital obligation of purchasing a luxury holiday home in Majorca and intensively analyse the decision, often resulting in precise expectations for the future home.

Carrying on with the desired property characteristics, the last coding category related to the evaluation criteria. Initially, it was discovered that a South West location is extremely popular, with 11 respondents exclusively searching in this area. The remaining four were more interested in the area around Palma and the island middle. Subsequently, interviewees were asked to highlight some 'must-have' criteria for a property to be of interest. Surprisingly, the lists were often relatively large (up to 15) in comparison to existing real estate studies suggesting there are only around five crucial requirements that need to be met (sections 2.3 and 2.5.2). Accordingly, characteristics mentioned multiple times in order of frequency count (starting at 13 down to four times) were location, number of bedrooms, constructed area, sea view, distance to Palma, plot size, garage, construction quality, distance to airport, view, noise level and price. With respect to the acquisition costs, practically all interviewees specified a price limit between 1.5 and 2.5 million Euros. In addition to this, only two couples noted they would not be willing to exceeding their set limit. This financial leeway observed may be the result of the particular item investigated. In more detail, in spite of providing a desirable investment limit, the individuals who buy a luxury real estate to serve as a holiday home are generally prepared and, more importantly, are able to pay a percentage over the specified limit to acquire the most suitable property. The maximum deviation buyers would regard as acceptable receives more attention during a later data collection stage.

Moving on to desirable features that have some influence on a purchasing decision, reoccurring criteria included sea view, guest apartment, kitchen size, house orientation and proximity to sea. More detail on the 'must haves' and desirable property characteristics is part of the content analysis. Less data was collected on the last two coding groups, namely criteria relationships and categories. Merely 31 potential linkages between variables were

highlighted. For instance, the plot size often influences the level of privacy, whilst a closer proximity to the sea increases the property price. Surely, the interviews did not reveal all probable relationships, but the answers certainly supported the premonition of criteria interdependencies in a real estate selection process. Hence, this needs to be acknowledged when building an appropriate decision support model. Ultimately, with respect to labels that describe a group of criteria, the interviewees defined general categories such as location, outdoor area, interior, costs and property features, among others.

10.2.1.2 Content Analysis

In a second analysis phase, all interviews were reviewed to count the number of criteria. Interviews were analysed one by one to create a list of real estate evaluation criteria. Proceeding with the next interview, if a criterion reoccurred, it was noted in the Excel sheet. Ultimately, this allowed identifying criteria that receive more, or less, attention from homebuyers.

Basically, the homebuyers identified a total of 157 different criteria, with view, style, location, number of bedrooms, constructed area, pool and price being mentioned by almost every candidate. Other criteria that seemed to be on the homebuyers mind during past and current purchase decisions included the construction quality, distance to Palma, maintenance costs, noise level, plot size, covered terraces, distance to the airport, distance to the neighbour, garage, garden, privacy level, proximity to sea, renovation work, distance to schools and storage rooms. However, the counting was done on the original wording of the interviewees, implying that most likely criteria sharing the same meaning were included. Respectively, the created list was carefully inspected by experts in the subsequent focus group sessions.

10.2.2 Agent Interviews

A total of 13 agents were interviewed. Two agents who originally agreed to participate were neglecting due to absence and holiday leave. The conducted interviews took between 13 and 29 minutes, with an average duration of 22 minutes.

10.2.2.1 Thematic Analysis

Again, initially a thematic analysis was conducted to transform the transcribed interviews into a coherent, reduced format. Notably, interviewing a distinct stakeholder group, it was necessary to adapt the coding scheme accordingly. Whilst the demographics and criteria category were also relevant in this case, other general themes, such as search/buying process, customer group and property portfolio, were added to code the agents' interviews. The adapted coding scheme can be found in the Appendix I.

Using the relevant coding scheme, the 13 agent interviews were analysed. Three categories, i.e. characteristics, agency portfolio and customer base, focused on the interviewee, his/her employer and the clientele. During the other two remaining categories

(search/buying process and evaluation criteria) the agents had to assess their clients and, particularly, what they believed their clients value most.

To begin with, the 13 interviewees came from 11 different real estate agencies. From the participants, 77% were male consultants and 92% were German. Furthermore, the age bracket ranged from 27 to approximately 65 years. Whilst at least 38% of the individuals switched from an unrelated previous career to real estate, the average period worked as a realtor was 14 years, ranging from 0.3 to 20 years. Relating to this, the sample lived and worked in Majorca between four and 25 years, with an average time of 11 years. Focusing now on the agencies' portfolios, it became apparent that business activity is highest in the South West regions of Majorca, which mirrors the previously discovered preferences of international luxury-homebuyers. Nonetheless, the participating agencies have branches all over the island and practically cover all locations. At the time of the interviews, portfolio sizes of the smaller property boutiques accounted for 300 to 500 properties on sale, whilst internationally renowned offices, like Engel&Völker and Minkner, offered up to 2500 real estates on the island (without restricting the price bracket). Generally they market properties starting as low as 120,000 Euros, up to record high 50 million Euros.

Profiling the agencies' customer group was another objective. Nine out of the 11 different agencies reported a predominant German customer base. Often Swiss and Austrian citizens were also seen as a strong buyer group alongside the German clients. Two agencies seemed to attract mainly Russians. Other noticeable nationalities included British and Scandinavians. These patterns may however be influenced by national economic performance and exchange rate fluctuations at the time of the study. When comparing these nationalities and their decision behaviours, agents highlighted that in general British use more external sources, such as property appraisers than any other nationality. Also, Germans appear to be relatively quick in their decision, Swedish are often willing to pay higher square meter prices and Russians seem to be loyal to one single agency. There is an inconsistency with this argument, considering agents' responses during the pilot study. Under these circumstances, this topic should be incorporated in the quantitative data collection protocol. Lastly, it was suggested that the clientele interested in luxury houses in Majorca often own mid-sized companies or are successful entrepreneurs who are in very comfortable financial positions.

Continuing to assess the search and buying process, most realtors (85%) believed clients' prevailing purpose of acquiring real estate in Majorca is to own a holiday home. This dream is generally pursued by a couple or family, who pose as the main decision drivers. Nonetheless, as indicated previously, 11 agents thought the female party has the most influence on a purchasing decision. This suggests that agents attending clients under this assumption will most certainly give more attention to women. On a related subject, mixed views were recorded across the sample in respect to using external sources in the decision making process. Some believed friends, architects, lawyers and property appraisers are

commonly consulted towards the end of a process, whilst others experienced only occasional interaction with third parties. Furthermore, the real estate sales associate being a source of information, it was investigated how these individuals feel about their influence on homebuyers. Here, seven believed they certainly do have an impact, whilst five stated it varies across clients and one thought the influence is minimal. Additionally, all interviewees acknowledged that their clients engage with multiple agencies at the same time, despite the majority of real estate portfolios covering the same properties. Recalling the results from the homebuyer interviews, it was emphasised agents are predominantly contacted to obtain access to the properties. Agents on the other hand did not see this as their fundamental purpose. They believed people use their service primarily to take advantage of their market knowledge, overcome language barriers and to save time.

Regarding the viewing procedures, the real estate intermediaries often pursue different strategies. Maybe, one mentioned recurrently consists in showing the property believed to best fit the client's requirements at the end. This however may increase frustration among homebuyers who believe the agent has not listened to their brief and are basically wasting their time. This issue is particularly concerning since an agent shows their client up to 16 properties. Or rather showing, the 'best' property after viewing five to 16 different alternatives arguably reduces the intended effect pursued by agents. Again, considering that homebuyers engage with multiple agencies, information overload can easily discourage and scare people into rethinking buying a property in the first place.

Next, agents were also asked about possible evaluation criteria relevant from their client's perspectives. The common 'must-have' criteria cited again and again concern the price, location, view (preferably sea view), number of bedrooms, constructed area, garage, proximity to sea and style. Here, despite price seemingly being a critical attribute in the decision, many real estate brokers nonetheless think their clients would pay around 20 to 30% on top of their set price limit, and sometimes even more. Yet another assumption that potentially leads to misunderstandings and irrelevant viewings. In fact, it is astonishing that 56% of the realtors (five out of nine who provided this information), admitted to overlook their clients brief when selecting properties to be viewed, whilst the remaining 44% said they try to 'mostly' stick to the requirements. On a different note, agents also provided a list of desirable features often requested by their clients. As a result, characteristics considered to have some influence on the DMs include pool, furniture, maintenance costs, neighbourhood, renovation costs, style, constructed area, proximity to sea and year of construction, among others. In a subsequent question, possible relationships between various criteria were addressed. For instance, greater proximity to the sea may damage the building facade, the size of the garden is predicted to have an influence on the maintenance costs and the year of construction can indicate the construction quality. When asked to provide category names in order to group identified evaluation criteria under one heading, outdoor area and interior was frequently mentioned.

10.2.2.2 Content Analysis

Equal to the content analysis presented in the homebuyer section, the criteria cited during the agent interviews were counted. In total, the real estate brokers expect 131 criteria to be relevant from a buyers' perspective. This, in combination with the 157 variables from the homebuyers, derived a total of 214 non-repeating criteria (see Appendix J).

10.2.3 Comparison of Stakeholder Interviews

The findings of the qualitative data analysis were already presented in the preceding paragraphs. To supplement the above findings, the reduced and summarised datasets enabled the comparison between the two stakeholder groups. In particular, the assumptions or believes the real estate sales associates hold when interacting with their clients provided valuable insights into the decision making process. The most striking finding to emerge from this was that the interviewed homebuyers strongly believed a property purchase decision is reached together as a couple with equal contribution, whereas the agents assumed the women have more influence in the entire process. Therefore, it can be suggested that real estate agents, who predominantly communicate with the female client, rather than with the two DMs, may provide less valuable consultation and find it harder to convince a couple to purchase a real estate.

Another prejudice held by many brokers relates to the involvement and level of influence they exert. Consequently, in this job position the majority claimed having a close tie with their clients, allowing them to influence the decision. In reality however, homebuyers were very keen on not being influenced from an agent, particularly in Majorca, where the reputation of the profession is relatively bad. One interviewee regarded the brokers on the island as "salesman". In the current research location, the predominant reason for engaging with an agency was to gain access to the properties. Supported by statements such as "I just see them as being a link between my requirements and what's out there". From the researcher's experience, together with the interview findings, it appears that properties for sale in Majorca are not freely available on the Internet. On the contrary, real estate agents thought their consultation and market knowledge is the driving force of attracting clients. It is believed that the discovery of these discrepancies is fundamental to improve the real estate selection process.

10.3 Focus Group

As a next step, a focus group was arranged with three industry professionals. Here, two property developers and one investor, who were familiar with the property selection process in Majorca, agreed to participate in brainstorming sessions. The objectives were to verify the interview findings, combine similar criteria, change the wording or eliminate irrelevant as well as hard to measure variables from the list, create a hierarchical structure and discuss possible measures. Due to the various objectives and the high time required to address

each thoroughly, the experts preferred to discuss individual issues during separate sessions. Therefore, three appointments over a two week period were arranged.

First, the total list of 214 criteria was assessed. The process consisted of looking at individual variables and relating them to a real estate purchase decision from the perspective of a homebuyer. This lengthy procedure allowed the elimination of 99 criteria, of which 58 were believed to be similar to other variables and 41 rendered hard to measure or too subjective. Additionally, ten evaluation criteria were renamed and 29 added. As a result, the experts agreed on a final list of 144 criteria (see Appendix K). These were related to existing literature, and 90 criteria (63%) found support across different real estate journals (see Appendix L). This first meeting was conclude after two hours.

During the second meeting, a hierarchical structure needed to be developed to increase transparency and understanding of the various contributors. This task was a non-trivial part of the focus group and required extensive attention. Various structures were proposed and to arrive at the final hierarchy, a heated debate was observed. Nevertheless, in the end the goal of agreeing on a single representation was achieved. Describing the whole process in more detail, the division into three main categories was relatively obvious from the start. Herein, the experts believed a property was viewed to have various components that can be allocated to location, costs or the real estate itself. These three categories formed the upper hierarchy level.

Regarding the location group, the experts believed a location was determined by its micro and macro location. This was further broken down using 28 and 14 variables for micro and macro location respectively. Then, three sub-criteria were allocated to the cost category, i.e. acquisition costs, taxes and maintenance costs. Here, no further break down was needed. With respect to the real estate itself, this category was divided into the property, or interior, and the outdoor area. The former consisted of 59 sub-criteria, arranged on hierarchy levels three to six. The outdoor area on the other hand was associated with 26 variables, of which 19 represented measurable bottom level criteria. The above description of the criteria structure of three level-one, seven level-two, 23 level-three, 59 level-four, 46 level-five and 6 level-six criteria is demonstrated in the hierarchy figure in Appendix D. Overall, this structure can certainly be recognised as being adequate for the current decision problem, since “an acceptable structure is simply one that reflects a clear, logical and shared point of view about how the many criteria that may be relevant to an multi-criteria analysis assessment can be brought together into coherent groups, each of which addresses a single component of the overall problem” (Dodgson, et al., 2009, p. 34). The second session was considerably longer, accounting for 3.5 hours of the experts’ time.

After determining an appropriate structure to represent the luxury property evaluation problem, measures were identified in a third session. All variables that were made up of lower level criteria did not require any specific measure, since they were assessed using the

performance of those basic attributes. In other words, categories such as location or costs were simply qualitative variables, and received an evaluation score based on the aggregate performance of the respective bottom level criteria. The defined measures and criteria descriptions of the 106 bottom level criteria are outlined in Appendix M, whereas the grades created for the qualitative factors are presented in Appendix N. As a next step, the experts were asked to identify likely relationships between variables. The discussion produced a list of agreed connections that were later introduced and covered in the online survey to obtain a collective view. Some of these included:

- larger plot means more privacy
- larger house (constructed area) means more bedrooms
- more bedrooms means more en-suite bathrooms
- a newer house means higher quality
- closer proximity to sea means smaller plot size
- larger plot means bigger terraces
- touristic area means higher crime rate
- etc.

Again verifying the assumption of dependencies and correlations among pieces of evidence. All relationship statements can be found in Appendix E. This last meeting also approximated two hours of brainstorming.

10.4 Quantitative Analysis

After multiple qualitative research phases, it was crucial to obtain more representative data through a quantitative data collection instrument. In other words, the standardised survey instrument provided the researcher with a large dataset, which was statistically analysed using SPSS to draw conclusions and generalise the interview findings. The data was obtained during a ten-week period, where a total of 180 homebuyer and 75 agent questionnaires were completed. This section presents the data in a summarised format, detects patterns and investigates relationships, which in turn are compared to previous findings from the qualitative analysis.

10.4.1 Homebuyer Surveys

With regards to the homebuyer surveys, the researcher received 142 client contact details from the agencies. A connection was established with 102 via email or telephone, of which 82 took part in the study (response rate 58%). The remaining 98 surveys were completed either directly at the real estate boutiques, or through the link initially distributed to the agencies. In the end, of the potential 271 respondents, 25 questionnaires remained incomplete and 66 declined to participate, resulting in an overall response rate of 66%. Once the survey was taken off-line, the results were downloaded from the user account in a coded and text format. The coded data was then introduced in SPSS to conduct a comprehensive analysis. In fact, since the survey was organised into various section, the analysis also addressed the different sections separately.

10.4.1.1 Profiling Luxury-Homebuyers

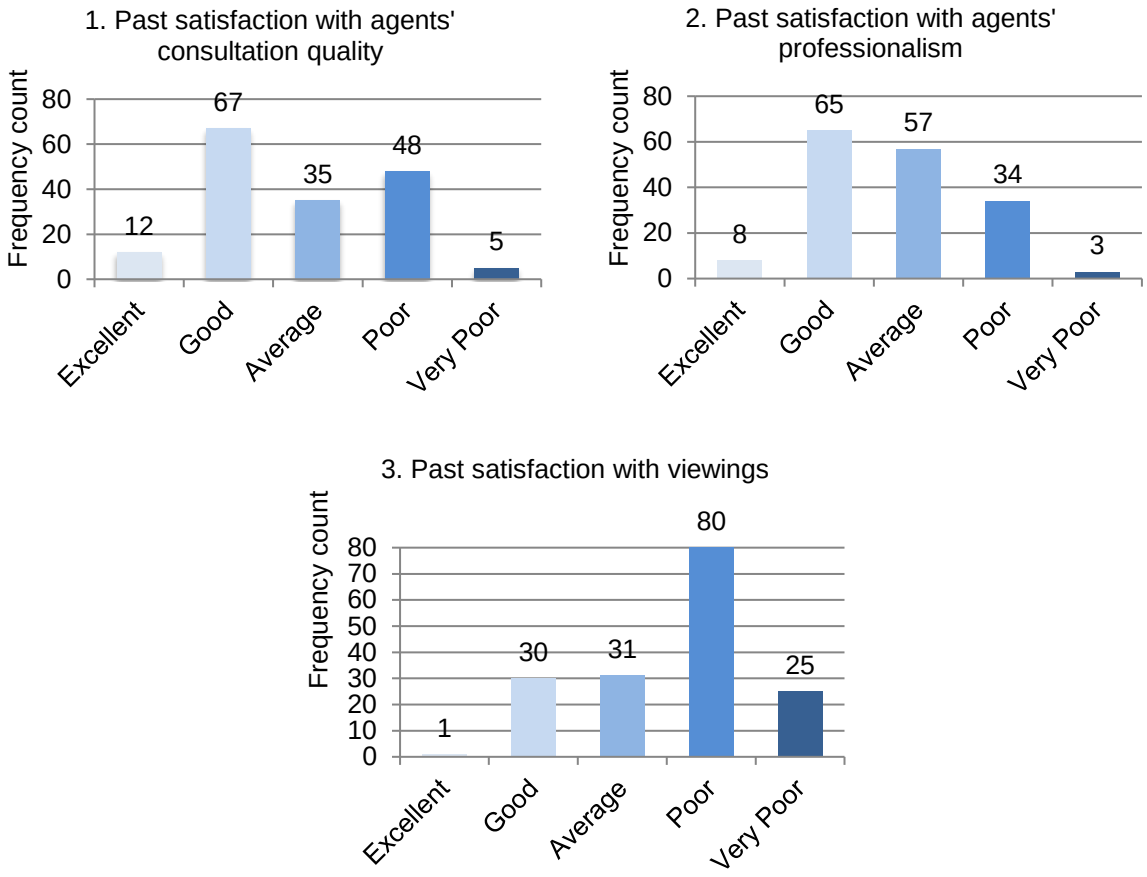
To begin with, the intention was to construct a profile of the luxury real estate buyer in Majorca. Whilst the characteristics were also recorded during the interviews, the generalisation power of 15 interview candidates was too low to make reliable inferences. Nonetheless, in the analysis section, when presenting the findings from the survey, comparisons are made to the interview findings when applicable. This may also be seen as a form of validation. First, the data indicated that practically all luxury real estate buyers in Majorca are married or are in a domestic partnership. Additionally, the most common age to engage in these capital-intensive decisions seems to be between 46 and 55 years (representing 42% of the survey sample). However, either side of this age bracket, namely 36 to 45 and 56 to 65, also represent a fair share of the luxury-homebuyers, 20% and 22% respectively. A comparable pattern was observed in the interviews.

Furthermore, it is safe to say that most individuals interested in buying a property for more than one million Euros, which is generally associated with a reasonable size, have children. In this context, 91% of the survey and 87% of the interview sample had children, of which a large share was older than 16. Next, looking at the nationalities, 77% were German and 8% British, with the remaining 11 nationalities representing an insignificant share. Despite Germans being among the dominant buying groups, the 77% is believed to be an inaccurate representation of the Majorquin real estate market. As previously indicated, this recorded phenomenon may be the result of greater interest in the research, the influence of the real estate agents by intentionally recruiting this group, or a possible seasonal impact. Regarding the profession of the high-net-worth individuals, 61% (110 out of 180) were self-employed and 8% retired. Whilst the self-employed percentage seems relatively small, it is assumed that 22% of the respondents represented care keepers or ‘housewives’ of their self-employed partners.

10.4.1.2 Past Purchasing Experience

In addition to the above characteristics, the study participants past experience was investigated. It was anticipated that individuals or couples who seek buying a luxury house as a holiday or secondary residence are highly likely to have purchased a property in the past. As it turned out from the dataset, all participants had acquired at least one real estate. Hence, they have some idea about the process and build on past experiences. In this context, it is worth noting that 61% of the survey sample did not own a real estate in Majorca and the decision making process on the island may be fundamentally different to other locations. Similarly, previous interactions with real estate intermediaries (167 out of 180) might be distinctive to agents in the Majorquin market. Regardless, respondents provided information on past acquisitions and feedback about collaborations with real estate agencies (displayed in Figure 18).

Figure 18, Feedback of Interaction with Real Estate Agents



Overall, reviewing the poor feedback from the third graph, DMs also provided reasons for the negative rating. Here, 93 out of 167 respondents (56%) felt that too many houses were shown, and 63 (38%) stated the estates viewed did not meet their requirements. Another unsettling observation of 48 (29%) participants was that the agents had very poor knowledge about individual properties (referring to the first graph). To complete this section, and to identify which decision process step needs particular attention, the target audience was asked to tick the activity that requires most time during real estate selection. Here, whilst two refrained from commenting, 71 out of 178 responses (40%) believed the viewing of properties is the most time consuming task, followed by the search process, which includes accessing the Internet and meeting with real estate agents. Therefore, it is desirable to make these activities more efficient.

10.4.1.3 Current Decision Making Process

Having discussed the typical characteristics of luxury-homebuyers and general past experiences, the current, or upcoming, buying decision was reviewed. First of all, 83% of the survey sample was exclusively searching for a holiday or secondary homes, whilst the remaining 17% was interesting in finding a property that may serve as a permanent residency in the future. When excluding the latter, 62% are spending between four and seven weeks annually in Majorca. Considering next the involved DMs for the upcoming selection process, six potential stakeholders were identified. Foremost, the role of the survey participants' partners was examined. Previously (section 10.2.1.1), it was highlighted that

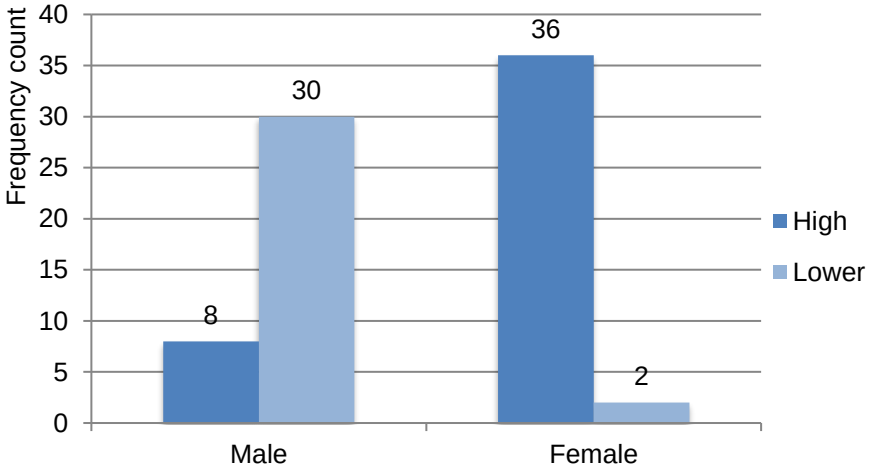
principally the decision making process is attended jointly, often with same influence levels. The survey data depicts a similar pattern, with 103 out of 180 answers (57%) agreeing to an equal involvement. Despite the general perception of equal influence, authors like Park (1982) suggest that influence level differs across criteria. For instance, the wife may insist on a large kitchen, whilst the husband is indifferent towards this characteristic. In contrast, the husband potentially emphasised the need for a double garage, whereas the wife is not concerned with this decision element. Overall, a joint decision between spouses may more accurately be viewed as a conflict-avoiding, muddling-through process, yet with the potential of reaching an efficient selection together (Park, 1982). Returning to the survey findings, interestingly, an imbalanced involvement usually meant the male dominating the decision making process (Table 2), which strongly contradicts the assumptions of real estate agents (sections 10.2.2.1 and 10.4.2).

Table 2, Cross Tabulation Gender/Decision Influence Level

Frequency count	Male	Female	Total
High/more influence	8	36	44
Equal influence	55	48	103
Low/less influence	30	2	32
No involvement	1	0	1
Total	94	86	180

Describing the table above, only eight male informants believed their wife has more decision power, whereas 36 (42%) of all women claimed their partner actually has more influence. On the other hand, 30 men were convinced taking the lead role and only two women assumed they are in charge. Figure 19 illustrates the responses of those who expressed varying influence levels. A tendency of male homebuyers allocating a lower influence level to their partners was observed, in conjunction with the female contestants feeling their partners have more contribution in the process.

Figure 19, Gender Effect on Decision Influence



The chi-squared test in SPSS was used to enrich the above descriptive analysis and find significant statistical differences between male and female contestants according to the

decision influence of their partners. The results in Table 3 check if the findings in the figure above happened by chance.

Table 3, Chi-Squared Test for Effect of Gender on Decision Influence

	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	42.318[a]	1	.000
Likelihood ratio	48.671	1	.000
Linear-by-linear association	41.761	1	.000
N of valid cases	76		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.00

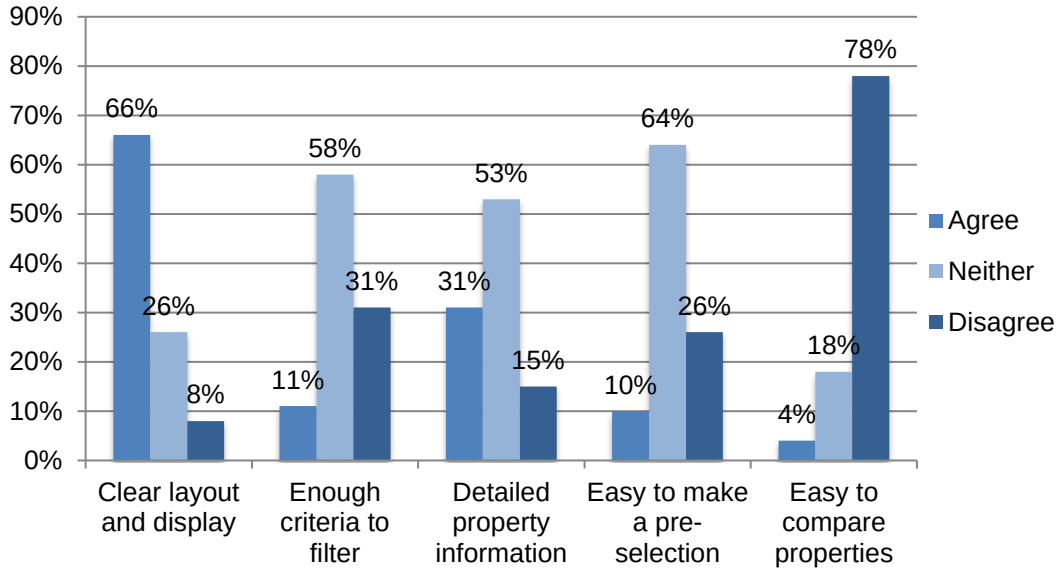
The chi-square statistic $x^2 = 42.318$ with one degree of freedom, $p = .000$, confirms that the difference between the categories is statistically significant. Therefore, there is a relation between gender and influence level. The observed pattern is strengthened when considering the occupation status. Table 4 shows exclusively those 76 individuals who stated an uneven decision involvement. From the evidence it can be assumed if the male individual is self-employed, there is a higher likelihood he believes his partner has less influence. Also, in cases where the female is neither employed, nor self-employed (represented by 39 in the whole sample), 27 (i.e. 69% of the 39) believed their partner is the driving force behind the purchase. This represents 31% of all women.

Table 4, Cross Tabulation Gender/Occupation/Influence Level

Frequency count	Male				Female				
	Employed	Self-employed	Retired	Other	Employed	Self-employed	Retired	Other	Total
More influence	2	5	1	0	3	6	0	27	44
Less influence	0	28	2	0	0	2	0	0	32

Supplementing the above analysis, five additional influence sources were reviewed. Noticeable was the expected involvement of real estate experts and/or children, emphasised by 60% and 58% of the DMs respectively. Yet, architects, lawyers or property appraisers recorded only limited or low impact (71%), as did children (80%). Other external sources, friends, agents and relatives, were consulted in 24%, 22% and 12% of the cases correspondingly. Whilst their opinions are generally taken into account, the impact on the outcome is minimal. Next, researching the typical timeframe between recognising the need or desire to purchase a property and actually interacting with an agency, it was discovered 80% of the sample took between four and 11 months. Generally, during this period, prospective buyers conduct independent Internet search. Consequently, in the survey sample a total of 156 were able to provide feedback regarding online real estate search tools in Majorca. Results are demonstrated in Figure 20 below.

Figure 20, Feedback on Online Real Estate Search Tools



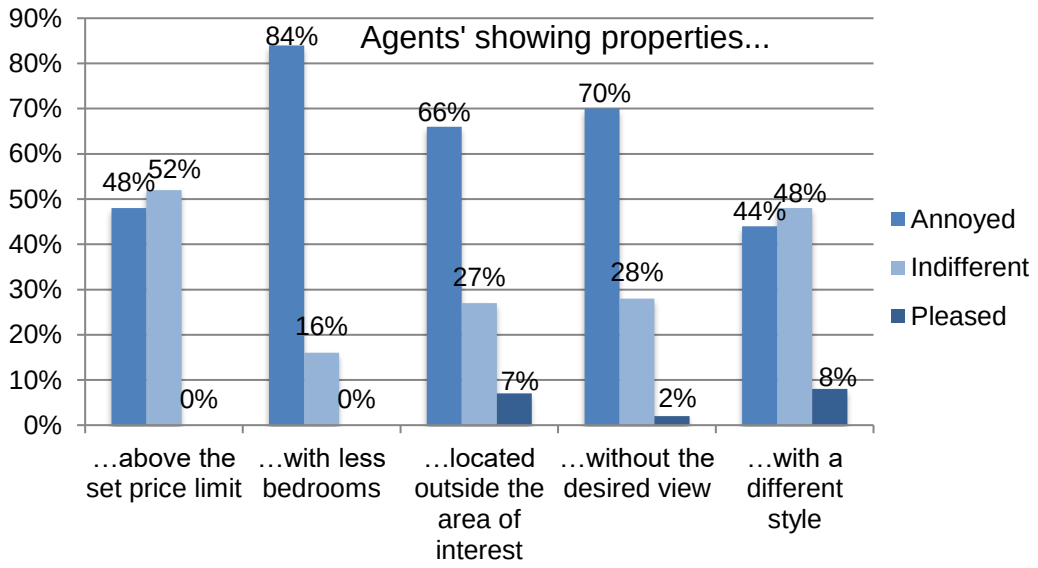
Strikingly, homebuyers found it extremely hard to compare properties on the different websites, often making an appropriate pre-selection either difficult or impossible. The findings also suggest that more filtering options could be put in place to improve online search activities. From the evidence it may be implied that individuals search the web primarily to get a feel for the market, rather than to identify a final set of alternative properties to be viewed. Furthermore, even in the very few cases where a pre-selection is made, an agent would be needed to access the properties. Hence, all but three survey participants stated the access to properties being one of the key reasons for using a real estate intermediary. Validating the respective findings from the qualitative phase, another reason mentioned 82 times is the large portfolios offered by the real estate boutiques in Majorca. Only about a quarter of the sample actually sees the consultation service as an additional driver. Based on this data, it was expected that customer loyalty to a single agency is low. As a matter of fact, 81% confirmed using two or three agents, whilst 15% even engaged with four or more. Considering the use of multiple agencies, obviously the number of viewings increases. This assumption was also confirmed in Table 5 below. Noteworthy, to estimate the number of probable viewings, attention was exclusively on the individuals who reported they were in the process of viewing properties (102 out of 180; 57%) in addition to those who had already completed this stage and proceeded to deliberating to make a decision (34; 19%). Excluding participants who were at the start of viewing alternative options seemed appropriate, since they were going to view a lot more in their upcoming property search, and therefore were not yet able to provide final viewing numbers.

Table 5, Cross Tabulation Nr. of Agencies/Nr. of Viewings

Frequency count	Nr. of viewings														
Nr. of agencies	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36	37-39	40-45	45<	Total
1	1	1	0	2	0	0	0	0	1	0	0	0	0	0	5
2	1	0	4	4	5	4	7	10	5	2	3	0	3	1	49
3	1	0	2	2	4	8	6	6	9	4	6	6	3	3	60
4≤	0	0	0	2	0	0	1	2	3	2	2	3	6	1	22
Total	3	1	6	10	9	12	14	18	18	8	11	9	12	5	136

First of all, it can be noted that 26% of the 136 respondents already viewed between 25 and 30 properties, whilst 33% personally reviewed more than 30. Clearly, after seeing such a large number of alternatives, homebuyers most certainly experience confusion and frustration. In some cases, they might even be unsure about their initial requirements when confronted with several variations and criteria combinations. Additionally, whilst 7% viewed less than 13 houses, 75% of the respondents above were still in the viewing process and more viewings may be added. Overall, the table provides an indication and highlights a serious issue in the real estate decision making process. In relation to the number of viewings, it was discovered that there are certain requirements that are intentionally not met by the real estate intermediary. For instance, taking a look at the agent survey, in 72% of the cases agents show houses above the client's set price limit, with the remaining 18% also sometimes arrange such viewings in section 10.4.2. Such practice is often not appreciated by the homebuyer, and may also help explain the disloyal behaviour and high switching tendency to competitors. Figure 21 provides some insight into the homebuyers' feelings regarding deviations from their requirements. Note, this topic is further investigated in relation with the agents' responses (section 10.4.2).

Figure 21, Homebuyers' Perception on Agents' Viewing Strategies



Providing more detail on the price limit, the sample provided their price bracket for the intended purchase. This was also required to later produce a dataset of alternatives with comparable acquisition costs. Ultimately, the predominant purchase price for luxury homes in Majorca ranged from 1.5 to 1.99 million Euros, emphasised by 93 out of the 180 informants (52%). Additionally, a fair amount of people were allocated either side of this group, with 26% wanting to spend between one and 1.49 million Euros and 11% willing to go up to 2.49 million Euros. In this context, although 48% claimed they would be annoyed with an agent if he/she deliberately offered a property over the set price limit (Figure 21 above), 76% were actually willing to spend a little more for their dream home. This phenomenon may suggest that frustration mainly arises when the realtor simply arranges viewings without getting the consent from the clients and not efficiently communicating they could get closer to their requirements by slightly increasing the limit. Yet, it must be acknowledged that there are also clients who would definitely not purchase a real estate above their limit. In the same context, roughly every other client would potentially be willing to spend up to 10% extra. Now, prior to discussing different criteria categories in more detail, the survey dataset showed that most prospective homebuyers (146 out of 180; 81%) had a fairly good idea of what they want, including an exact list of 'must have' criteria and some desirable property features. When asked to tick all factors that must fully meet requirements, construction quality (mentioned by 150 respondents; 83%), number of bedrooms (147; 82%), location and pool (126; 70%), price (122; 68%), view (120; 67%) and heating (114; 63%) were among the criteria seriously considered in the purchasing decision. In turn, indicating these should potentially be used during a pre-screening process to narrow down the list of suitable alternatives prior to an in-depth analysis.

10.4.1.4 Criteria Weights

Another important survey block examined the importance of the previously defined evaluation criteria. Herein, the hierarchical structure designed by the real estate experts was used to compare variables in groups. The task of the survey candidate then was to allocate a number between zero and 100 to each criterion. This allowed identifying criteria weights and highlight factors with minimal impact. However, concentrating first on the three top level criteria groups, namely real estate, location and costs, descriptive statistics were computed to provide indications about the research sample. Since all remaining 141 criteria were allocated to one of these, it was expected that all three categories were highly weighted by the survey participants. The results are shown in Table 6.

Table 6, Descriptive Analysis of Top Level Criteria

Criteria Name	Min.	Max.	Mean	Median	Std. Deviation	Variance
Real Estate	30	100	88.17	91	13.702	187.749
Location	15	100	81.39	85	17.862	319.033
Costs	34	100	84.47	89.5	14.750	217.569

Next, the criteria feeding into these three upper level categories needed to be examined. Although a full descriptive analysis with central tendency measures is available in Appendix O, some key findings are presented in the following paragraphs.

10.4.1.4.1 Costs

In relation to the cost category, if a person set a price limit over 2.5 million Euros, the mean weight of costs dropped to 68.36. Meanwhile, individuals who stated they would not exceed their price limit (44 out of 180), 75% of them weighted the cost criterion 90 or above. Next, as described previously, the costs category is evaluated using three lower level variables (acquisition costs, maintenance costs and taxes). Here, the leading mean score was 90.84 for maintenance costs. The standard deviation of 14.7 also indicated that the responses for this criterion were fairly concentrated around the mean. Resembling the maintenance cost weight, the acquisition costs also received a relatively high mean score of 86.3.

10.4.1.4.2 Location

Reviewing the location cluster, it was discovered that in situations where the property was also viewed as an investment vehicle, location was given a value between 75 and 100. In addition, micro location factors on average seemed to be more relevant to the luxury-homebuyers than macro variables, obtaining mean scores of 76.9 and 63.12 respectively. Given this evidence, the most striking characteristics contributing to the micro location were view, pollution, security and neighbourhood with mean values of 80.48, 77.74, 70.27 and 70.09 respectively. Also important, with a high consensus across the sample and a standard deviation of 16.5 around the mean of 91.32, was the electricity grid connection in the supply system category. Similarly, street noise received a high score from most participants. Among the less significant factors in micro location were the residential complex criterion, which had a low mean and standard deviation, and public transport, with a mean of 23.25. In macro location, accessibility sub-criteria, such as distance to medical facilities, educational institutions and ports, received relatively low averages. On top, the standard deviation of these variables portrays a large variation around the mean, indicating that people either find the proximity to a particular place relevant, or not. For instance, the distance to international schools obviously was only applicable in specific cases. Here, individuals who at some point intend to move to Majorca and have children aged below 16 appeared to rate this factor high, with a mean of 81.84, compared to the mean of 23.98 from all respondents). Moreover, the wish to be located close to pubs and clubs is mostly trivial, with a mean of 38.57. On the other hand, having a beach nearby could potentially improve a property's performance score. Mostly in the cases where a holiday residency is desired, the beach criterion received a score of 70 or more (61 out of 109; 56%), with 27% even allocating a score above 90. Also, despite sport facilities obtaining a mean and median of 52.7 and 53 respectively, the standard deviation shows that in both directions there are scores far from the mean.

10.4.1.4.3 Real Estate

Next, the real estate criterion was divided into the property itself and the outdoor area. Across the sample, these two subsections on hierarchy level-two received similar evaluations, with minimums of 44 and 30 respectively, high mean and median values, plus a low standard deviation score. Comparing the interior with the exterior, weight distributions appeared different depending on the purchasing purpose. Table 7 highlights the property itself receiving more attention from secondary or permanent homebuyers. Meanwhile, the outside is often valued higher than the outdoor when purchasing a holiday home. Yet, equal weighting also occurred frequently.

Table 7, Cross Tabulation Purchase Purpose/Real Estate Weight

Frequency count		Property	Outdoor area	Equal weight
Holiday home	Count	8	56	45
	% weight	15%	84%	76%
Secondary or future permanent residency	Count	46	11	14
	% weight	75%	16%	14%
Total		54	67	59

Focusing first on the property, out of the six sub-criteria or –categories, property quality, technical facilities and layout seemed to be important to all respondents, producing all high means with low standard deviations. Providing more detail on the layout, only three out of the seven associated criteria appeared to contribute to the category's performance, i.e. rooms, room sizes and constructed area. Herein, the highest mean weights in rooms and room sizes concentrated on the number and sizes of bedrooms and bathrooms. Regarding the number of bedrooms in particular, all 32 survey participants with two or three children gave a score of 70 or above. Next, number of stories scored a low mean, yet with a high standard deviation. One may suggest that the age of the homebuyer plays some role in the evaluation of this criterion. It was discovered that 89% (17 out of 19) of 26 to 35 year old individuals felt no need to assign a weight higher than 50. Furthermore, as expected, the desire to have a dressing room differed across genders, with 44% of all female candidates taking this into account, whilst only 0.6% of the men acknowledge it in the selection process. Similarly, a preference for a separate office space was expressed depending on the respondent's occupation. Here, the mean weight for office considering all individuals that were self-employed (i.e. 110 from the sample) was 50.48, whilst 55% provided a score of 50 or above. Contrary to this, considering the remaining sample of retired, employed or jobless (70 out of 180) revealed a mean of 19.33 for this criterion. Also noteworthy, heating was the most significant criterion in the technical installations category, demonstrating a mean of 86.19 and a median of 99.5. In more detail, it is very likely (90%) that if a homebuyer intends to resign in the property permanently at some time in the future, a score above 80 was given. Finally, across hierarchy levels four and five connected to property feature, overall low mean scores were achieved, whilst any mean value above 50 was accompanied by a high standard deviation, implying mixed results with high dispersion around the mean.

To complete the preference analysis, the variables associated to the outdoor area need to be reviewed. First, the six criteria directly connected to this main category had mean scores between 47.81 and 84.66. The former value was computed for autonomous water and electricity supply systems, yet it simultaneously recorded a standard deviation of 33.03 with scores scattered around the mean. Contrary, the highest mean score was obtained for seating areas, accompanied by a moderate standard deviation of 22.12. The terraces and balconies accounted for the most important sub-criteria in this category. Moreover, the BBQ area as another sub-criterion resulted in a high standard deviation, potentially due to different opinions across genders. Here, 41% of all male participants found the thought of a BBQ area appealing, scoring the variable 80 or above, whereas only 23% of the 86 female respondents felt the same way.

In the subsequent survey section, the target audience was asked to verify the previously identified criteria relationships. The aim was to get an initial indication of dependencies and/or correlations between pieces of evidence. Consequently, the majority confirmed 13 out of 15 relationships. The remaining two, i.e. larger constructed area implies more bedrooms and increased proximity to the sea infers more sea view, most participants (44% and 42% respectively) neither agreed, nor disagreed with the statements. A second question asked whether a link between a set of variables was assumed. Here, all 18 factor confrontations appeared to be connected in some way. The exact answer distributions to this survey section are available in Appendix P.

10.4.1.4.4 Decision Process Difficulties

To complete the homebuyers' survey analysis, the last section addressed current difficulties experienced during the real estate selection process and desired improvements. The major issue noted by 73% of participants (132 out of 180) relates to the time requirement to find the ideal real estate. As a result, a significant proportion of the research sample (79%) seeks a shortened property search process and specifically a reduced number of viewings. Additionally, 112 respondents stated they were unaware of several criteria introduced in the previous exercise. They indicated that, in general, too few factors are being acknowledged. Therefore, 143 homebuyers would appreciate some guidance or a comprehensive list of criteria influencing a real estate selection decision. Relating to the last point, 108 respondents stressed the need for more information on location criteria. This emphasises the currently limited attention directed towards properties' surroundings. Another problem identified was the misunderstandings between buyers and agents (mentioned by 51% of the research sample), again causing frustration and time delays. Higher satisfaction with the final decision and more transparency of the process was desired by 54% and 49% respectively. In accordance with those reasons, the entire research sample would welcome a decision tool helping to manage current problems and addressing the proposed improvements.

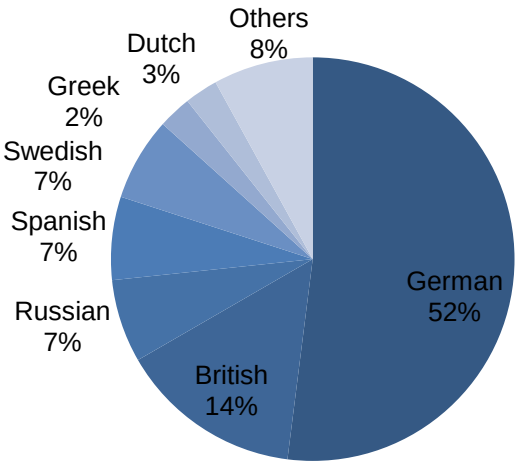
10.4.2 Agent Surveys

Considering the survey designed specifically for the real estate agents, 48 out of 79 agencies contributed to the research project in two ways. First, it was these 48 agencies that provided the access to the target population. Second, since they were asked to distribute the link within their offices, a total of 75 completed surveys from 48 agencies were obtained, investigating the agents' perspective on the real estate selection process. Overall, the response rate can be derived from the 48 agencies that actively supported this research and completed 75 surveys, the 31 offices that did not participate and five questionnaires that were left incomplete. Hence, from the total of 111 possible responses, a response rate of 68% was achieved.

10.4.2.1.1 Profiling Real Estate Agents

First, it was important to define the real estate agent sample. The results may portray a good representation of the population, bearing in mind the entire population (all 79 agencies) was contacted to take part in this research. The collected data indicated a more or less equal gender split in the real estate profession (53% male and 47% female). Additionally, whilst 88% of the respondents were between 26 and 55 years of age, a large proportion (35%) were aged 46 to 55. With regards to the nationalities, Figure 22 below emphasises the high number of German realtors, potentially due to the large amount of German customers.

Figure 22, Real Estate Agents' Nationalities



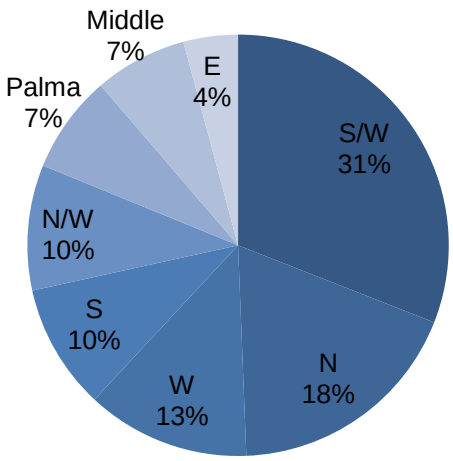
Next, since interviewees and survey respondents repeatedly pointed out that agents in Majorca appear to be underqualified, the highest degree or level of schooling was documented. In this context, 30 individuals out of 73 responses noted they had previously conducted an apprenticeship, 20% graduated from high school, 24% completed their bachelor's degree and nine realtors obtained a master. However, these qualifications may have been unrelated to real estate or the agent profession. Consequently, the experience in the market was examined. Interestingly, 25% of the sample had more than 10 years of experience as an agent and another 35% worked for a real estate broker between five and

seven years. On the contrary, only 13% were relatively new to the profession, noting three years of experience or less.

10.4.2.1.2 Agencies' Portfolios

Discussing the agencies' portfolios, only 49 records were acknowledged, one questionnaire from every participating agency. As expected, there were huge differences between portfolio sizes. Respectively, whilst an internationally renowned agency like Engel&Völker offer up to 1,000 luxury houses around the island, other smaller boutiques manage a limited amount of real estate in specific areas. Providing no valuable indication, the mean portfolio size was 314. Additionally, the South West region, which is intensively targeted by foreigners, generally dominates the agencies' portfolio. Figure 23 provides more detail on the regions of the luxury houses up for sale. Evident from the survey data, the North and West of Majorca also seemed popular island spots.

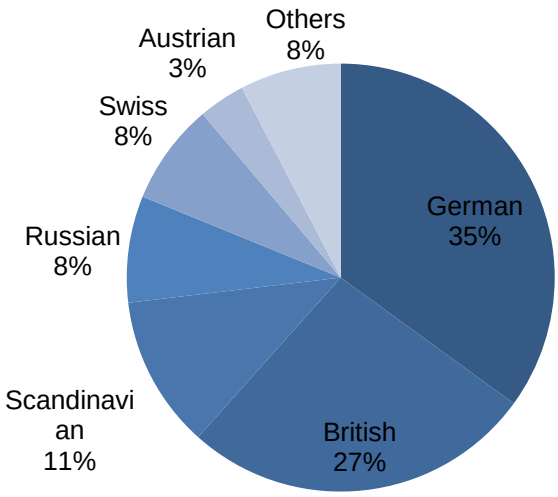
Figure 23, Dominant Areas in Agencies' Portfolios



10.4.2.1.3 Client Base

Despite having provided a descriptive analysis of the 180 homebuyers in respect to their characteristics, it was of interest whether agents correctly assessed their clientele. Hence, in relation to examining the customer group, the agents were asked to estimate the percentage of different nationalities among their clients. Since the perception of client base is a more subjective judgement, than recording portfolio figures, all 75 respondents were acknowledged. Figure 24 indicates a large proportion of German clients, followed by British. Scandinavians are also very keen homebuyers in Majorca, whereas the Russian and Swiss customers have somewhat declined lately, yet still represent approximately 8% overall. Worth reiterating, this figure is consistent with the market report by Westwood (2015), which also suggests Russians account for 8.12% of all oversea purchasers.

Figure 24, Homebuyers' Nationalities

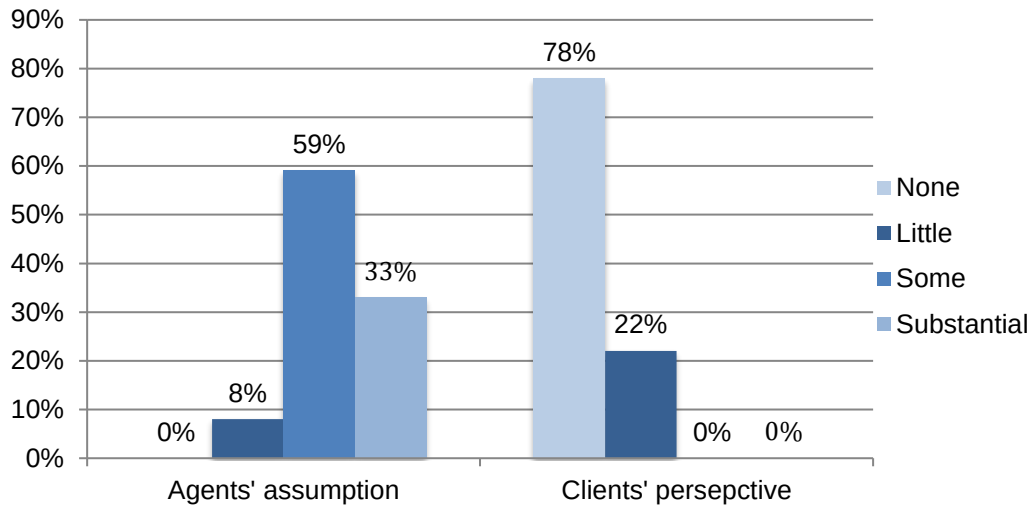


The information represented here is obviously a summary of all 75 records, yet it was observed that most agencies specialised their service towards one or two nationalities. This latter behaviour may be a consequence of major differences across nationalities, noted by 73% of the agent sample. In more detail, many of the real estate intermediaries believed that British customers often use external sources, such as architects or lawyers, whilst Germans generally try to negotiate prices. Additionally, Swiss and German buyers are often more cautious and conduct some computations with respect to the prospective purchase. These findings were in accordance with the interviews conducted with 13 agents.

Regarding the clients' age, the predominant age group was believed to be 46 to 55. This was also concluded during data analysis of the homebuyers' surveys. Similarly, the brokers commonly agreed that all their customers are married or in a domestic relationship and 79% of the agents were sure that their clients usually have children, again confirmed by the homebuyers' answers. Additionally, 64% of the sample expected the clients' education level to go no further than high-school, whilst the predominant employment status was self-employed. In terms of real estate purchases, the majority of agents (88%) knows, or suspects, that their clients already own a property. Then, the purpose for buying a house in Majorca was primarily considered to be for holidays (69 out of 75) and/or as a secondary home (44 out of 75), estimations comparable to the actual results of the homebuyer sample. Overall, with respect to the homebuyers' characteristics, the real estate sales associates in Majorca had a fairly good idea who they are dealing with. This appears to have a connection with the level of experience reported by the agent sample, i.e. 87% actively pursuing the career for more than three years. Nonetheless, this may not eliminate misunderstandings and poorly delivered service. For instance, although the perceived DMs are 95% of the time couples, 80% of the agent sample assumed women have greater decision power. Obviously, this may lead to excessively and wrongly targeting the female client. In this context, it must be emphasised again that in the homebuyers' dataset only eight out of 93 men believed their wife has more decision influence, whilst another 30 thought they occupy

the dominant role. Similarly, the assumption of agents' own influence on a house purchase was very inaccurate when compared to the homebuyers' opinions. Figure 25 clearly demonstrates the opposing viewpoints.

Figure 25, Agents' Influence on the Decision vs. Clients' Perspective



Along these lines, homebuyers predominantly (98%) apprehend the service delivered by agents as providing access to available properties, rather than offering valuable advice. Even though 59% of the brokers acknowledged their large property portfolios, 92% assumed their main role to be consulting and guiding the DMs. In relation to this, practically all intermediaries were well aware that their clients use multiple agencies simultaneously; implying prospective buyers go on a large number of viewings. Evidence shows that the average number of viewings conducted by a realtor with a single client per day was 4.39, with a minimum of 2 and a maximum of eight. This, in combination with 41% of agents meeting clients approximately three times and 33% even four times over a three month period, clearly confirms the hypothesis of a large number of viewings. In fact, if people engage with three agencies (as 41% of homebuyers do), they are expected to assess around 40 properties in person. Under these circumstances, it can be assumed DMs are very likely to view a single house twice with different agencies. This in turn emphasises the significance of having accurate property figures and keeping the information up to date (previously addressed in section 7.3.3).

10.4.2.1.4 Criteria Weights

With regards to the evaluation criteria, 56% of agents felt their clients generally have defined some 'must-haves', yet are unsure about other desirable features. By contrast, 39% stated DMs are frequently indecisive. In comparison to the homebuyer survey, 49% were certain about their 'must-haves', whilst 32% had a very detailed list of requirements, including desirable criteria. Furthermore, it was discovered that agents assume the location (rather than the real estate itself or the costs) to be the most important aspect of a luxury home in Majorca. They provided an average score of 87.72 out of 100 to location (with a minimum score of 40), whilst the real estate and costs only received a mean of 77 and 66.33

respectively. Reviewing the buyers' evaluations, here the real estate is ranked first, followed by costs and then location, with the latter factor reporting the largest range and a minimum score of 15. Next, Table 8 gives an overview of the criteria that must meet the buyers' expectations (the right column) in comparison to the realtors' perceptions (on the left). Here, it becomes apparent that the construction quality, cited by 83% of prospective buyers, was only acknowledged by 48% of the agent sample. Considering the frequency counts on the left, these are consistent with the agents' emphasis on location, with view occupying the pole position. Similarly, the homebuyers' first three factors are part of the real estate category.

Table 8, Agents' and Homebuyers' Perspectives on Top Requirements

Rank	Agents (75)	Frequency count	Homebuyers (180)	Frequency count
1	View	71	Quality	150
2	Nr. of bedrooms	68	Nr. of bedrooms	147
3	Price	67	Pool	126
4	Locality/region	65	Locality/region	126
5	Pool	51	Price	122
6	Style	49	View	120
7	Quality	36	Heating	114

Although 89% of agents acknowledged price to be among the top requirements, 49% still thought their clients are willing to spend 21 to 30% over their price limit, and 37% suggested a 11 to 20% deviation is acceptable. However, 49% of homebuyers would actually only consider a property that exceeds the price limit by a maximum of 10%, whilst 24% do not wish to go beyond their set budget. Also, as previously indicated in Figure 21, the buyers were generally annoyed if agents did not listen to their specific requests, yet it appears the sales associates still choose properties from their portfolio either based on false assumptions or simply ignoring certain client demands. Respectively, 72% of agents confessed always including houses above a client's price limit and 53% typically arrange viewings of properties that deviated from the desired style. Surprising was also the high percentage of brokers (80%) suggesting houses outside the client's area of interest, with very contrasting views to the expected.

10.4.2.1.5 Island Characteristics

Besides describing the property portfolios in Majorca and profiling homebuyers, the island's features were studied to find similar areas around the globe that would be worth considering for generalising research findings. Thus, the entire sample believed the easy access and climate are to a large extend causing the high demand for holiday and/or secondary homes. Also, the existing infrastructure is an advantage and low language barriers further promote the island.

10.4.2.1.6 Decision Process Difficulties

Finally, agents were asked to highlight potential difficulties their clients may encounter during the search and selection process. Whilst 28% of the sample did not observe any problems in

the past, 36 individuals (48%) merely emphasised the buyers' indecisiveness in respect to requirements and the instability of preferences. Evidently, these observations are considerably conflicting with the homebuyers' responses, who generally see the real estate selection process as highly time consuming, acknowledging limited criteria and having restricted information on properties' surroundings. Opinions are even further apart with regards to support mechanisms that could help identify a buyer's most suitable purchase opportunity. Here, 81% of realtors believed their clients would not be interested or willing to employ such decision tools, whilst the entire sample of 180 prospective buyers would be pleased to receive some guidance for improving the process.

10.5 Real Estate Dataset

The real estate dataset includes information on 106 bottom level criteria for 41 properties. Figure 26 provides a snapshot (49%) of the houses used for this research project.

Figure 26, Property Dataset

Briefly describing the dataset, the predominant area of interest was the South West, South and island middle, of which 18 different towns were selected. In this context, the mean distance to Palma and the airport were 21.6 and 22.4 minutes respectively. Asking prices ranged from 1.21 to 3.9 million Euros, with a median of 1,990,000.00 Euros. Hence, in accordance to the budgets defined by the 180 homebuyers, 80% of the dataset represented houses offered at below 2.5 million Euros.

With respect to property characteristics, the constructed area ranged from 207 to 935 square meters, providing a mean and median space of 415 and 405 square meters respectively. The plot size also varied substantially from 795 to 31,000 square meters. It was further observed that the majority of alternatives had four bedrooms (resulting in a mean of 4.49 and median of four). In addition, 39% accommodated a private guest area. The remaining characteristics of the dataset are outlined in Appendix Q.

10.6 Real Estate Rating Outcomes

As a result of using a subset of the survey sample, the preference information of the 20 individuals participating in the property rating exercise is explored. Then, the 820 property performance scores are described. Here, each of the 41 properties received 20 different ratings in accordance to individual perceptions, producing a performance distribution of each alternative.

10.6.1 Criteria Relevance

Based on the criteria weight assignment in the surveys, it was possible to identify less relevant factors. To provide more insight into the sample subset, the information previously provided by the 20 homebuyers was analysed. The results of a descriptive analysis are outlined in Appendix R. Nevertheless, coming back to criteria relevance, variables that generally scored a low value among the 20 homebuyers, as well as the 180 survey respondents, may indicate less important criteria that can potentially be excluded in the MCDM model. Similarly, the 41 properties in the dataset may not differ on some criteria, rendering these irrelevant for the assessment. For instance, the descriptive analysis of the dataset concluded that none of the alternatives was located in a residential complex. In combination with the dataset, this criterion also received a relatively low weight across the 20 and 180 homebuyers. Here, a mean of 17, median of 12.5 and a maximum of 54 were observed for the 20 participants who had rated the 41 properties, and similar results were obtained from the 180 survey respondents, i.e. mean of 17.5, median of 12.5 and maximum of 59. Hence, it was plausible to remove this factor from further consideration. Also, whilst no property from the dataset had a steam room, walk-in fridge or other extras, at the same time their mean, median and maximum values were extremely low. Other factors that were ignored in the model building process due to low relevance, along with unknown or inconsistent measures, included other rooms (in the room category) and other seating areas (in the outdoor category). These two variables accounted for a mean of 15.2 and 16.3, as well as a median of 1.5 and 3.6 respectively. Next, despite a relatively high relevance (mean 43, median 30, range 100), measuring the locality criterion or, in other words, quantifying all possible values seemed irrational. Yet, this criterion may be used as a preliminary filtering exercise before conducting the MCDM analysis if people feel very strongly about a specific town. Furthermore, collecting data on the 41 properties, moisture/humidity and insulation data was not available, making the inclusion of these variables unnecessary.

After adjusting the dataset in accordance to the above discussion, a total of 97 bottom level criteria remained relevant for the property evaluation model. Although there were still a number of variables in the remaining list that had low mean values in conjunction with a low median, none of these were excluded from the model as they seemed to be relevant for a few individuals (supported by the maximum scores in Table 9). For instance, if a DM would attach significant importance to the distance to educational institutions, excluding this variable would most likely influence results for this individual. At this stage,Table 9 presents the criteria that in most cases have little impact on the final alternative ranking.

Table 9, Descriptive Analysis of Low Relevance Criteria

	Weight characteristics of 20 participants for property rating exercise			Weight characteristics of 180 survey participants			Excluded variables
Criteria label	Max.	Mean	Median	Max.	Mean	Median	
Locality	100	43.3	30	100	58.7	68.5	X
Residential complex	54	17	12.5	59	17.5	12.5	X
Distance to police	100	32.2	26.5	100	34.2	31	
Public transport	72	16.9	5	100	23.3	15	
Educational instit.	100	31.7	9.5	100	24	8.5	
Distance to pubs	65	24.2	16.5	100	38.6	39	
Disabled friendly	45	5.7	0	100	22.7	6.5	
Alarm system	100	32.1	18	100	44.1	39.5	
Elevator	54	10.2	0	100	20.9	8.5	
Nr. of livingrooms	29	10.1	10	60	11.1	8.5	
Gym	60	18.8	13	100	20	12	
Other rooms	25	3.6	0	26	2.7	0	X
Cellar	50	16.5	13	90	21.8	15	
Spa facilities	86	28.9	20	100	31.4	26	
Wine cellar	50	15.7	11.5	100	21.6	14.5	
Home cinema	70	18	12	100	16.8	6	
Walk-in fridge	31	6.6	0	90	7.2	0	X
Generator	100	35.4	27	100	30.4	14	
Rooftop terrace	100	31.6	25.5	100	31.9	22.5	
Nr. of terraces	100	33.5	22	100	35	30.5	
Other seating areas	100	15.2	1.5	100	16.3	3.6	X
Patio	90	28.7	21.5	100	28.5	18	

10.6.2 Property Ratings

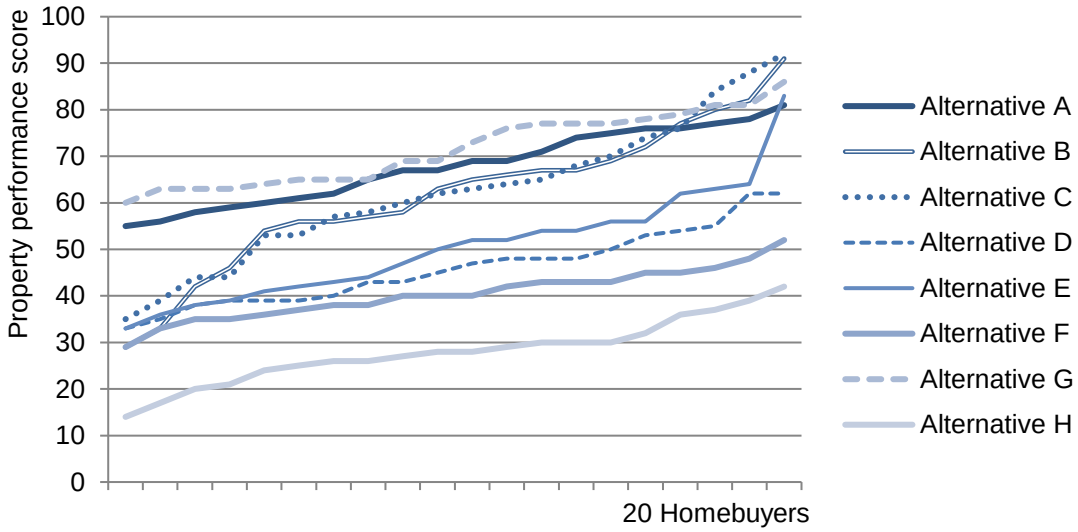
The homebuyers reviewed the properties within the dataset. After considering each individual alternative separately, acknowledging the estate's location, property features and associated costs, a score between zero and 100 was provided. For the 20 respondents, the minimum and maximum scores, as well as the mean ratings are summarised in Table 10.

Table 10, Descriptive Analysis of Property Ratings

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Min.	14	37	21	26	29	28	24	25	24	20	25	27	26	27	30	39	28	39	32	17
Max.	74	84	86	87	97	94	77	95	86	74	87	94	91	92	96	83	90	86	84	85
Mean	54	60	64	54	65	67	55	52	61	52	62	71	66	61	69	62	66	67	62	58

From the table it can be observed that the mean ranged from 52 to 71. Besides, the lowest and highest score provided across all respondents was 14 and 97 respectively. Now, having obtained 20 different performance scores for every real estate, the variations in the subjective outcomes is illustrated by an example below (Figure 27).

Figure 27, Property Performance of Eight Alternatives



The eight properties illustrated reveal major performance score deviations across individuals. For instance, one DM did not regard alternative C as a good fit to his/her requirements, providing a score of 35. Contrary to this, another candidate reviewed the same alternative and derived a significant higher rating, i.e. 92. In another case, according to a maximum score of 42, it appears that the sample as a whole felt alternative H had limited desirable features.

10.7 Summary

This chapter attended the data gathered during the multiple data collection stages with appropriate data analyses. First, qualitative findings were summarised and outcomes from the focus group were discussed. Next, the surveys were separately analysed, yet simultaneously establishing links to the interview findings and making comparisons between buyer and agent datasets. In particular, the contrasting opinions that emerged between the two stakeholder groups provided the base to answer parts of research question two. Whilst the comparison served a specific purpose, the data collection and analysis process produced key inputs for all research questions and established the requirements of an MCDM method.

11 Model

Chapter 11 presents support models for real estate selection using a modified Evidential Reasoning rule.

11.1 Introduction

Previously, a novel problem structuring process was presented for high-involvement product decisions concentrating heavily on identifying and extracting input variables to find or build a suitable support mechanism. After applying this to the real estate selection situation, it was discovered that the multitude of criteria affecting the property performance hinders individuals to make an informed choice. Most DMs resort back onto their intuition, overweighing key factors, whilst neglecting others. Consequently, the ER rule (introduced in Chapter 3, section 3.5.2) was identified as a powerful method in consistently aggregating property criteria, whilst at the same time coping with various problem specifications. Ultimately, a modified version of the evidence combination algorithm has the potential to estimate a property's overall performance. This chapter attends two tasks. First, the data discretisation process is presented to facilitate the modelling process in the second step.

11.2 Data Discretisation

Whilst there are various statistical discretisation methods available, in the current case, the discretisation was derived in co-operation with three experts, who previously identified suitable criteria measures in the qualitative data collection phase. This process was not included in the problem-structuring framework as it can sometimes be avoided by simply using statistical methods to determine the number and size of intervals. In other words, experts directly determining adequate intervals is not required for all MCDM problems, but was most appropriate in the real estate situation due to varying bin sizes across intervals.

Therefore, with the availability of the dataset and 820 property ratings of the 20 study participants, the experts brainstormed to obtain the most valid categorisations of the 38 quantitative (continuous and discrete) bottom level criteria and the overall outcome (see Appendix S).

First, they decided that the decision analysis outcome would best be represented in form of four unequal groups. In the ER framework, these constitute the propositions θ_1, θ_2, θ_3 and θ_4. Since the 20 individuals previously provided a score for each property between zero and 100, the experts agreed upon the following intervals:

- 'Very good match' would be any property rated 85 or above.
- 'Good match' constitutes alternatives with a score between 68 and 84.
- 'Average/alright match' represents all properties with ratings of 50 to 67.
- 'Bad/poor match' were those alternatives with scores below 49.

It was argued real estate that yields a score above 85, to a large degree meets the key demands of the homebuyer and potentially exceeds expectations on some features. Hence, these properties should definitely be viewed in person and carefully considered. Obviously, only a small portion of properties falls within this group, justifying the creation of the second group offering feasible alternatives. These can be taken into account if, on the one hand, an individual sets too high standards that existing properties within the data bank only approximate the requirements or, on the other hand, the supply simply doesn't meet the homebuyers expectations. Next, whilst the experts thought average matches should not be the aim for any luxury-homebuyer as it is not a necessity, they believed a separation to the properties barely meeting any of the client's requirements (i.e. 'poor match') needed to be made. In this context, these assessment grades (θ) were also acceptable for all criteria that stood between the overall performance and any bottom level criteria. Hence, an alternative can be characterised by a very good location, a very good cost rating and poor real estate performance, derived from corresponding lower level attributes. Then, depending on the weights given to the three upper level criteria, the overall performance belief distribution can be determined.

In contrast to the discretisation above, the bottom level criteria all received specific attention, defining varying numbers of intervals and unique bin-width. For instance, distance to the nearest port was divided into four categories. The first, most preferred option was any distance up to ten minutes. Group two and three ranged from 11 to 20 and 21 to 30 minutes respectively, whilst the distance was perceived way too far with a drive over 31 minutes. Constructed living area, as another example, received three distinct intervals (i.e. 500<; 251-500; 250≥ square meters). Here, it was assumed that homebuyers would not greatly differentiate between a house of 550 square meters and one of 800 square meters. Another case can be demonstrated with the variable bedroom size. This was divided into three unequal bins, where bin one pinpointed bedrooms larger than 35 square meters, bin two contained everything between 20 to 35 square meters, and less than 20 square meters was allocated into bin three. The reasoning behind this grouping was that any master bedroom with lower than 20 square meters is small, whilst any value above 35 square meters is considered superior. Accordingly, the experts agreed there is no major perceived difference between a master bedroom of 36 or 50 square meters.

After the discussion with the experts, the researcher believed it would be good practice to validate the discretisation with actual homebuyers. Here, as briefly discussed in the next section, the meaning of the 98 variables was inspected (38 quantitative and 59 qualitative bottom level variables, plus the outcome categories). Finally, the purpose behind discretising the data into discrete intervals was to facilitate the modelling process and enhance transparency for the analyst and/or DM.

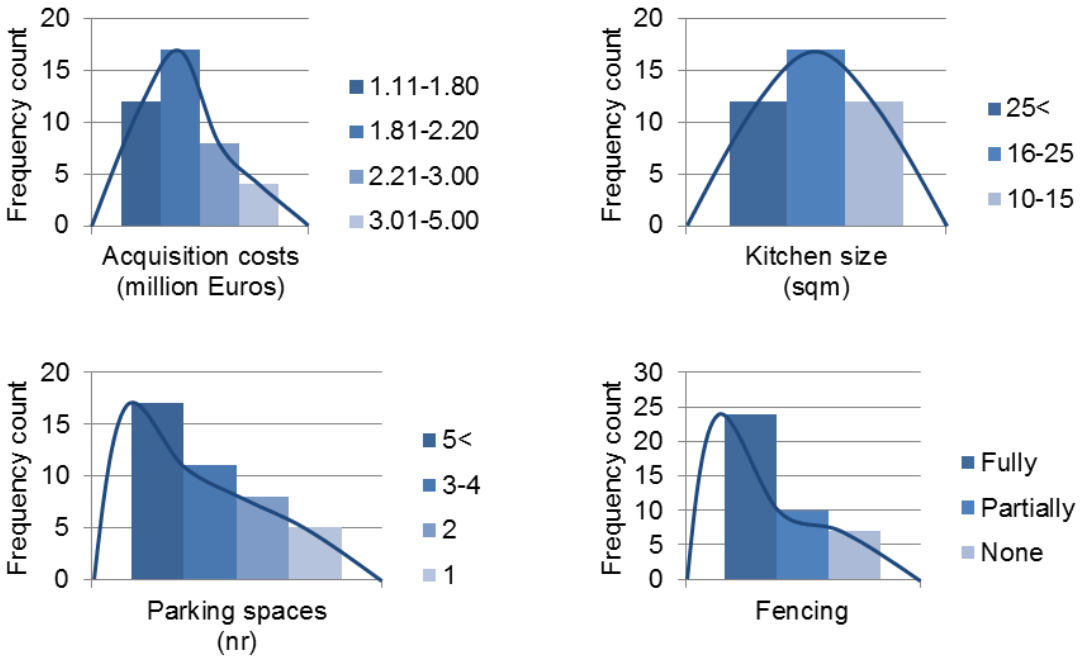
11.2.1 Meaningful Intervals

To validate the intervals, a quick review of the final bin-widths was done with potential homebuyers from the survey, who agreed to be contacted again at any time for further questions. This process however was relatively short and informal, requiring no further data analysis. A total of ten candidates understood the logic behind the varying interval sizes and largely agreed with the proposed discretisation of the continuous and discrete data. Hence, the 38 quantitative basic attributes, with their respective discretisation, are illustrated in Appendix S. Whilst the grades for the qualitative criteria were previously identified in the earlier discussion sessions (section 10.3), the ten homebuyers also quickly reviewed the categorisations chosen for the 59 qualitative criteria. This also included agreeing on the logical order of the criteria categories from generally the best to the worst. This led to no further changes to the criteria descriptions presented in Appendix N.

11.2.2 Criteria Frequency Distributions

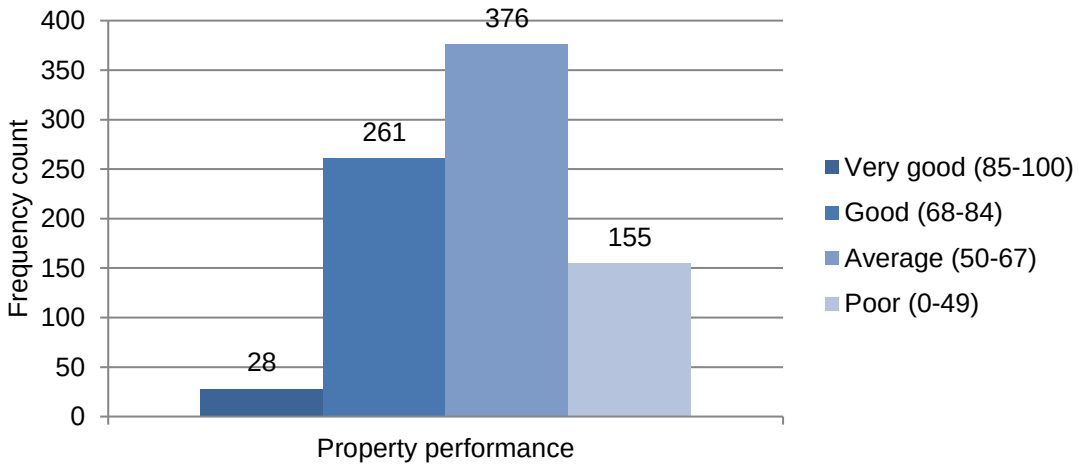
From the proposed discretisation, couples with the constructed dataset, graphs were developed to show the frequency distribution of the property criteria. Due to the high number of variables, only a few were selected to illustrate the overall idea and show the diversity of the dataset. First, considering the histograms in Figure 28, the acquisition cost variable was discretised into four unequal bins. From the illustration and the respective mean (2.11 million Euros), median (1.99 million Euros) and mode (1.99 million Euros), the dataset approximates a normal distribution. Likewise, when reviewing the data on kitchen size, the mean of 22.05 and median of 20 square meters are both within bin two. With the provided discretisation, the data on kitchen size is perfectly symmetrical, i.e. follows a normal distribution. A different situation can be observed with parking spaces and fencing. Both frequency distributions indicate the data is skewed to the right.

Figure 28, Criteria Frequency Distributions



Now, when reviewing the property performance ratings, the researcher had a restricted number of individuals who offered their participation in additional data collection phases. Here, the 20 homebuyers from the survey who provided property ratings obviously had different expectations in terms of number of bedrooms, view, locality and/or budget, among other key requirements. Since the properties were not pre-screened using such 'must-have' variables, it was expected that the majority of scores indicated an average match (θ_3) between prospective homebuyer and property. Herein, the descriptive analysis provided a mean of 61, a median of 63 and mode of 65. However, as illustrated in Figure 29, a significant amount also resulted in a good performance $(\theta_2 = 0.32)$, and 19% suggested a poor (θ_4) match.

Figure 29, Outcome Frequency Distribution



11.3 Real Estate ER Model

Prior to presenting the different MATLAB models, the steps involved in combining two pieces of evidence, and then adding a third piece of evidence $(e_1 \oplus e_2 \oplus e_3)$, are illustrated in an example. For this purpose, the three criteria privacy level, fencing and plot size defining the upper criterion plot boarder were chosen. The three variables (two qualitative and one quantitative) were previously organised into logical categories as follows:

- privacy level (e_1): high, medium, low
- fencing (e_2): fully, partially, none
- plot size (e_3): 2500<,1501-2500, 1001-1500, 701-1000, ≤700 square meters

First, the frequency distributions for the first two pieces of evidence need to be constructed for each of the identified intervals relative to the observed performance outcome (i.e. very good, good, average or poor). In other words, the analyst reviews the dataset and sorts the occurrences of the four outcomes into the variable's intervals. As a result, frequency tables for privacy level (Table 11) and fencing (Table 12) are as follows:

Table 11, Property Performance Frequency Distribution of Privacy Level

e_1 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
High	**16**	131	163	70	380
Medium	5	86	139	30	260
Low	7	44	74	55	180
Total	**28**	261	376	155	820

Table 12, Property Performance Frequency Distribution of Fencing

e_2 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
Fully	17	174	224	65	480
Partially	5	47	78	70	200
None	6	40	74	20	140
Total	28	261	376	155	820

As a next step, using the frequency information above, likelihoods for the variables' intervals can be computed. The likelihoods are obtained by dividing the frequency in one cell by the total of that column. For instance referring to the highlighted numbers in Table 11, the likelihood refers to the probability that the privacy level is high, given that the property performance is very good, i.e. $16/28 = 0.571$. Doing the calculations for all frequencies in Table 11 and Table 12, the likelihoods are generated:

Table 13, Likelihoods of Privacy Level

e_1 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
High	**0.571**	0.502	0.434	0.452	**1.958**
Medium	0.179	0.330	0.370	0.194	1.071
Low	0.250	0.169	0.197	0.355	0.970
Total	1	1	1	1	

Table 14, Likelihoods of Fencing

e_2 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
Fully	0.607	0.667	0.596	0.419	2.289
Partially	0.179	0.180	0.207	0.452	1.018
None	0.214	0.153	0.197	0.129	0.693
Total	1	1	1	1	

Prior to aggregating the two pieces of evidence, the normalised likelihoods (or basic probabilities) now need to be identified. Basically, by dividing the cell with the sum of that particular piece of evidence interval, the analyst can provide the normalised likelihood that a property yields one of the four outcomes, given that the property has a high privacy level, i.e. very good: $0.571/1.958 = 0.292$; good: $0.502/1.958 = 0.256$; average:$0.434/1.958 = 0.221$; poor: $0.452/1.958 = 0.231$. Therefore, the normalised likelihoods for the four outcome

possibilities in relation to the privacy level and fencing are presented in Table 15 and Table 16 below.

Table 15, Normalised Likelihoods of Privacy Level

e_1 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
High	**0.292**	**0.256**	**0.221**	**0.231**	1
Medium	0.167	0.308	0.345	0.181	1
Low	0.258	0.174	0.203	0.366	1

Table 16, Normalised Likelihoods of Fencing

e_2 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
Fully	0.265	0.291	0.260	0.183	1
Partially	0.175	0.177	0.204	0.444	1
None	0.309	0.221	0.284	0.186	1

Note the normalised likelihoods directly constitute the BDs. For instance, the BD for a property associated to a high privacy level indicates that 29.2% ($\beta_{1,1} = 0.292$ and $\sum_{\theta \subseteq \Theta} \beta_{\theta,1} = 1$) of the time the property performance is very good, and there is a 25.6% ($\beta_{2,1} = 0.256$), 22.1% ($\beta_{3,1} = 0.221$) or 23.1% ($\beta_{4,1} = 0.231$) chance of the alternative to yield a good, average or poor outcome respectively. The BDs, considering pieces of evidence individually, are represented in Figure 30 and Figure 31.

Figure 30, BD of Property with High Privacy Level

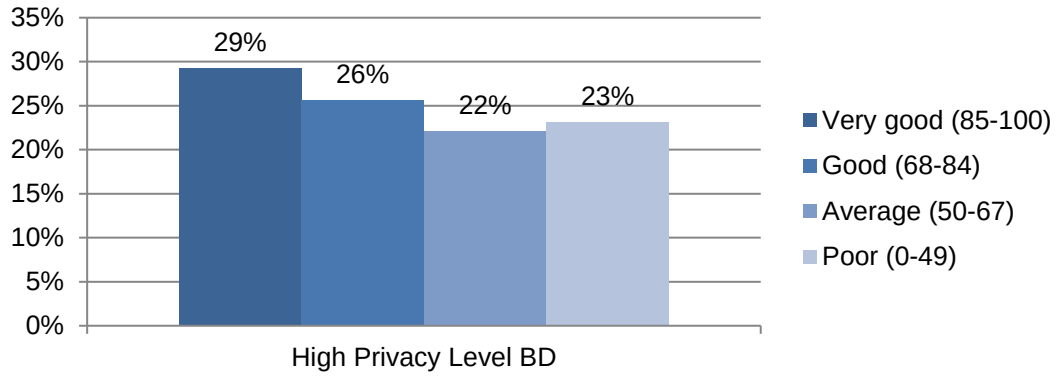
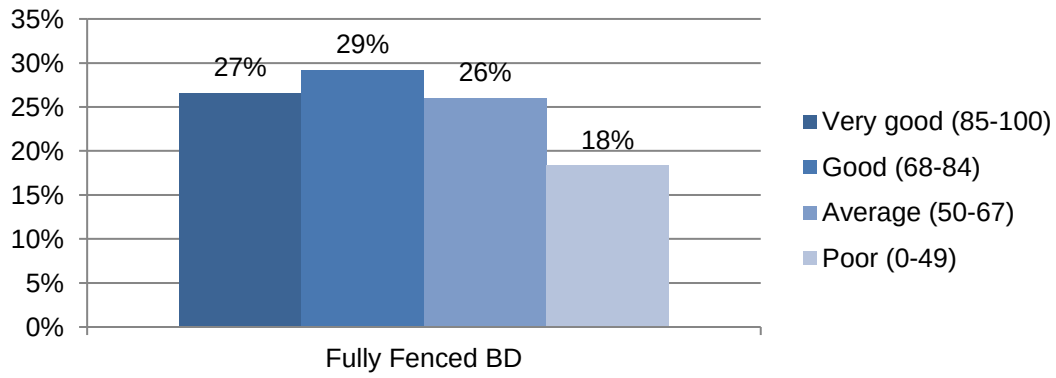


Figure 31, BD of Property with a Fence



These preliminary calculations provide the basis for the aggregation procedure. Then, the ER rule is used to combine the two pieces of evidence. Herein, it estimates the performance of a real estate by looking at its specific characteristics and aggregating the BDs.

Now, as emphasised in the literature chapter, the ER rule takes into account the BD, reliability and weight to measure the degree of support for a proposition (property performance outcome) from a piece of evidence. Hence, it is important to define the weight (w_i) and reliability (r_i). To illustrate the aggregation process, the average weight of the variables is taken, provided from the 20 individuals who rated the properties (available in Appendix R). For the current case, the mean weight for privacy level (w_1) and fencing (w_2) was 0.9 and 0.67 respectively. More recently Yang et al. (2015) proposed a modification to the ER rule by adding the alpha-index to the computation. This alpha-index accounts for interdependencies and correlations between variables. However, whilst the next section introduces the various ER optimisation models, including the modification of the alpha-index using the dataset to accurately account for the criteria inherent characteristics, for this example, alpha was set to one, i.e. $\alpha = 1$. That is to say, for simplicity, complete independence between all input variables is assumed.

To continue the example, particular property cases need to be determined. Assuming:

- Property one (a_1) has a high privacy level and is completely surrounded by a fence.
- Property two (a_2) also has a high privacy level but has only partial fencing.
- Property three (a_3) has a low privacy level and no fence.

This allows the computation of the weighted belief degree $m_{\theta,i} = w_i \beta_{\theta,i}$ for the individual properties:

Table 17, Privacy Level Weighted BD

Alternatives	Outcome – Property performance				$P(\Theta)$
	Very good	Good	Average	Poor	
a_1	**0.263**	0.231	0.199	0.208	0.100
a_2	0.263	0.231	0.199	0.208	0.100
a_3	0.232	0.156	0.183	0.329	0.100

Table 18, Fencing Weighted BD

Alternatives	Outcome – Property performance				$P(\Theta)$
	Very good	Good	Average	Poor	
a_1	0.178	0.195	0.174	0.123	0.330
a_2	0.118	0.119	0.137	0.297	0.330
a_3	0.207	0.148	0.190	0.125	0.330

For instance, to obtain 0.263 for a_1 on proposition θ_1, the previously calculated normalised likelihood was multiplied by the weight of evidence e_1, i.e. $0.292 * 0.9 = 0.263$. This was repeated for the entire table. The unassigned degree of belief due to weight is presented by the power set $P(\Theta)$, i.e. $1 - w_i$. Similarly, for evidence e_2, the normalised likelihoods were multiplied by the respective weight $w_2 = 0.67$.

Next, the WBDR is computed for the two pieces of evidence, requiring the reliability values of e_1 and e_2. For now and for simplicity, a reliability of 0.7 is assumed for both pieces of evidence, i.e. $r_1 = 0.7$ and $r_2 = 0.7$. This means that the unreliability of e_1 is represented by $1 - r_1$, allowing other pieces of evidence that are combined with e_1 to play a role in providing stronger support for, or against propositions. In this case, $\widetilde{m}_{P(\Theta),1} = 1 - r_1 = 0.3$.

The scores presented in Table 19 are derived by $(1 - r_2)m_{\theta,1}$, and those in Table 20 follow $(1 - r_1)m_{\theta,2}$. For the first cell this essentially consists in $(1 - 0.7) * 0.263 = 0.079$.

Table 19, Privacy Level WBDR

Alternatives	Outcome – Property performance			
	Very good	Good	Average	Poor
$\boldsymbol{a_1}$	**0.079**	0.069	0.060	0.062
$\boldsymbol{a_2}$	0.079	0.069	0.060	0.062
$\boldsymbol{a_3}$	0.070	0.047	0.055	0.099

Table 20, Fencing WBDR

Alternatives	Outcome – Property performance			
	Very good	Good	Average	Poor
$\boldsymbol{a_1}$	0.053	0.059	0.052	0.037
$\boldsymbol{a_2}$	0.035	0.036	0.041	0.089
$\boldsymbol{a_3}$	0.062	0.044	0.057	0.037

Recalling the modified ER rule presented in the literature (section 3.5.2.3.5), the equation for aggregating interdependent and correlated pieces of evidence is given by:

$$\widehat{m}_{\theta,e(2)} = \left[(1 - r_2)m_{\theta,1} + (1 - r_1)m_{\theta,2}\right] + \sum_{B \cap C = \theta} m_{B,1}m_{C,2} * \alpha \quad \forall \theta \subseteq \Theta$$

First, the bounded sum of the evidence individual support $\left[(1 - r_2)m_{\theta,1} + (1 - r_1)m_{\theta,2}\right]$ is generated by simply combing Table 19 and Table 20. Or, following the equation for a_1 and proposition θ_1, the bounded sum of individual support is computed by $[(1 - 0.7)0.263 + (1 - 0.7)0.178] = 0.132$.

Table 21, Bounded Sum of Individual Support of Privacy Level and Fencing

Alternatives	Outcome – Property performance			
	Very good	Good	Average	Poor
$\boldsymbol{a_1}$	**0.132**	0.128	0.112	0.099
$\boldsymbol{a_2}$	0.114	0.105	0.101	0.151
$\boldsymbol{a_3}$	0.132	0.091	0.112	0.136

Second, the orthogonal sum of the collective support, measuring the level of all intersected support on proposition θ_n, is attended $(\sum_{B \cap C = \theta} m_{B,1}m_{C,2})$. This simply requires the multiplication of the weighted BD of e_1 and e_2. Again for the first cell in the following table

this constitutes $0.263 * 0.178 = 0.047$. Note, adding the alpha value of one to this equation would not change the results.

Table 22, Orthogonal Sum of the Collective Support of Privacy Level and Fencing

Alternatives	Outcome – Property performance			
	Very good	Good	Average	Poor
a_1	**0.047**	0.045	0.035	0.025
a_2	0.031	0.027	0.027	0.062
a_3	0.048	0.023	0.035	0.041

In turn, the full aggregation of the two pieces of evidence is derived adding the bounded sum of individual support to the orthogonal sum of the collective support (for example $0.132 + 0.047 = 0.179$):

Table 23, Combined Degree of Belief of Privacy Level and Fencing

Alternatives	Outcome – Property performance				$\widetilde{m}_{P(\Theta)}$
	Very good	Good	Average	Poor	
a_1	**0.179**	0.173	0.147	0.125	0.090
a_2	0.145	0.132	0.128	0.213	0.090
a_3	0.180	0.114	0.147	0.177	0.090

Considering the two pieces of evidence, unassigned support $\widetilde{m}_{P(\Theta)} = (1 - r_1) * (1 - r_2)$ is redistributed to the power set $P(\Theta)$. This allows a third piece of evidence to play a role in providing stronger support for, or against, propositions.

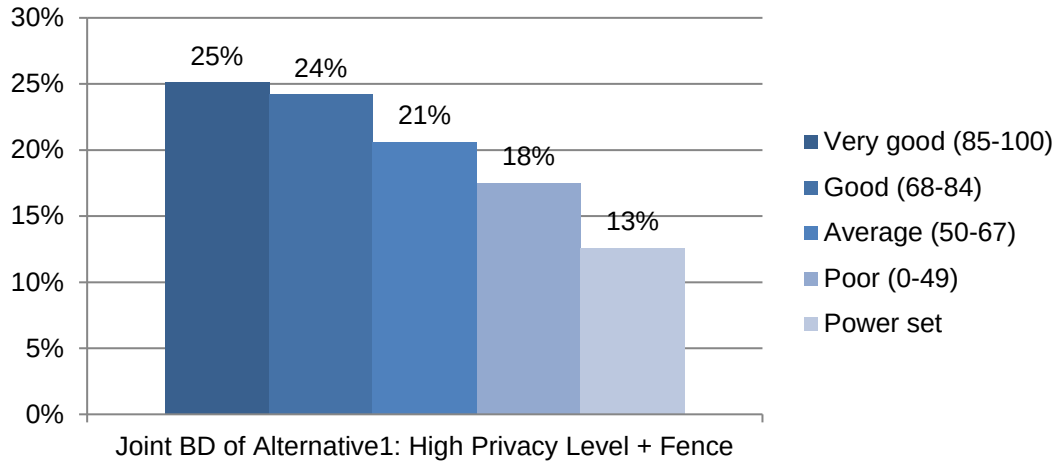
Normalising the belief degrees in Table 23 subsequently offers the BD for each alternative when considering privacy level and fencing jointly:

Table 24, BD considering Privacy Level and Fencing Jointly

Alternatives	Outcome – Property performance				$\widetilde{m}_{P(\Theta)}$
	Very good	Good	Average	Poor	
a_1	**0.251**	0.242	0.206	0.175	0.126
a_2	0.205	0.187	0.181	0.301	0.127
a_3	0.254	0.162	0.207	0.250	0.127

This suggests that a property with a high privacy level and full fencing (i.e. a_1) has a 25.1% (normalised) likelihood of being a very good alternative. For this case the joint BD can be graphically illustrated as follows:

Figure 32, Joint BD of Alternative 1 for Two Pieces of Evidence



Then, to add another piece of evidence, i.e. plot size (e_3), the individual normalised likelihood, weighted BD and WBDR need to be constructed by following the same steps presented from Table 11 to Table 20. To clarify, the normalised likelihoods for e_3 are shown hereafter:

Table 25, Normalised Likelihoods of Plot Size

e_3 intervals	Outcome – Property performance				Total
	Very good	Good	Average	Poor	
2500<	0.264	0.232	0.191	0.312	1
1501-2500	0.321	0.289	0.320	0.070	1
1001-1500	0.276	0.266	0.308	0.150	1
701-1000	0.108	0.266	0.209	0.458	1
≤700	No record	No record	No record	No record	N/A

Now, with $w_3 = 0.66$ taken as the average of the 20 participants, and $r_3 = 0.7$, it is assumed:

- a_1 is characterised by a high privacy level, full fencing and a plot of over 2500 square meters.
- a_2 remains with the high privacy level and partial fencing, adding a plot size between 1001-1500 square meters.
- a_3 has a low level of privacy, no fence and a plot area of 701-1000 square meters.

Adding this third piece of evidence, the calculation can be denoted by:

$$\widehat{m}_{\theta,e(3)} = [(1 - 0.7) * 0.251 + (0.126) * 0.174] + (0.251 * 0.174) * 1$$

This reads, multiplying the normalised combined likelihood of e_1 and e_2 (0.251) by the reliability of e_3 ($r_3 = 0.7$) and adding the multiplication of unassigned support (0.126) with the weighted BD of e_3 $(0.264 * 0.66 = 0.174)$. Then, looking at the orthogonal sum of the collective support, here the normalised combined likelihood of e_1 and e_2 is simply multiplied by the weighted BD of e_3. Finally, the orthogonal sum of the collective support is multiplied by the alpha-index, here denoted by one. This process is repeated for all numbers in the

table to obtain the combined degree of belief (Table 26) and subsequently the belief distribution of the three combined pieces of evidence (Table 27).

Table 26, Combined Degree of Belief of Privacy Level, Fencing and Plot Size

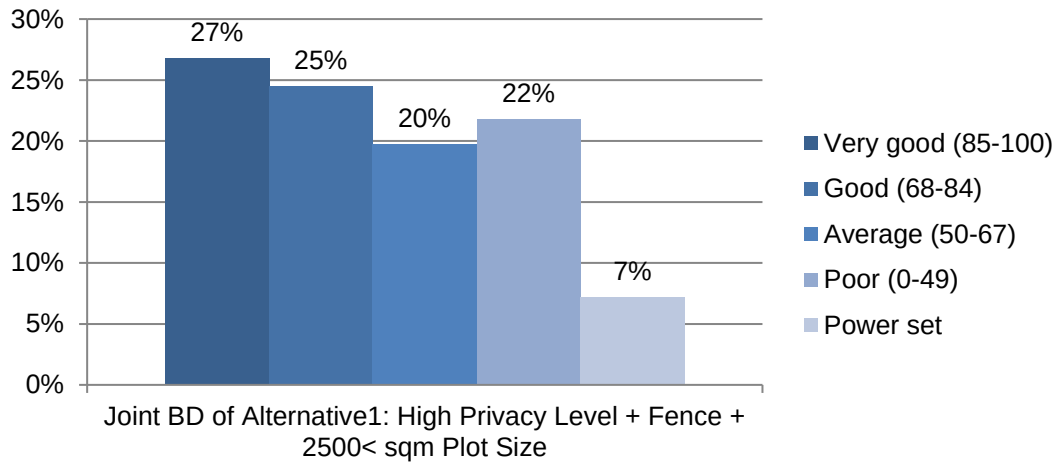
Alternatives	Outcome – Property performance				$\widetilde{m}_{P(\Theta)}$
	Very good	Good	Average	Poor	
a_1	**0.141**	0.129	0.104	0.114	0.038
a_2	0.144	0.138	0.130	0.082	0.038
a_3	0.103	0.092	0.108	0.189	0.038

Table 27, Belief Distribution considering Privacy Level, Fencing and Plot Size Jointly

Alternatives	Outcome – Property performance				$\widetilde{m}_{P(\Theta)}$
	Very good	Good	Average	Poor	
a_1	0.268	0.245	0.197	0.218	0.072
a_2	0.271	0.259	0.244	0.155	0.072
a_3	0.195	0.173	0.204	0.357	0.072

Accounting for the third piece of evidence, the joint BD for a_1 then illustrates the change in likelihood from Figure 32 to Figure 33. As a result, less unassigned support in the new joint BD (i.e. 7%) and stronger support from θ_1 can be observed.

Figure 33, Joint BD of Alternative 1 for Three Pieces of Evidence



This process can be repeated recursively to aggregate all relevant pieces of evidence, until obtaining the final BD of property performance for individual alternatives.

While the above example refers to only three possible combinations (a_1, a_2, a_3) of the three criteria (e_1, e_2, e_3), there are already 45 possible combinations considering the defined intervals (privacy level with three bins, fencing with three bins and plot size with five bins). Evidently, when aggregating the 144 pieces of evidence from the property assessment framework, the extensive computations become unmanageable in traditional spreadsheet applications. Correspondingly, to perform the necessary mathematical operations in the most efficient way, MATLAB was used to develop different aggregation models. In this

context, different aggregation models refer to various scenarios derived from the dataset, as explained in the next section.

11.4 Model Scenarios

The variations of model scenarios are separately discussed, yet the performance of all aggregation models was assessed using three indicators.

First, the Mean Absolute Error (MAE) attends the absolute difference between the predicted $(\hat{x})$ and actual (x) outcome divided by the number of observations (n). Large deviations between actual and observed are punished equally to smaller ones. In short, this measure is more robust to outliners. Mathematically, this can be illustrated by:

$$MAE = \left| \frac{\sum(\hat{x} - x)}{n} \right|$$

The second performance measure was the Mean Square Error (MSE), which focuses on the sum of the square difference between the predicted $(\hat{x})$ and the actual (x) outcome, divided by the number of observations (n):

$$MSE = \frac{\sum(\hat{x} - x)^2}{n}$$

In comparison to MAE, MSE is more sensitive to occasional outliers or large errors, because it squares the errors.

Then, the Mean Accuracy Indicator (MAI) is a proposed indicator that illustrates how accurate the estimations are in comparison to the observed outcomes. Hence, MAI divides the difference between the estimated $(\hat{x})$ and the observed values (x) by the largest possible estimation error (ε). Then, the sum is divided by the number of observations, and then lastly multiplied by 100 to obtain the accuracy percentage of the model.

$$MAI = \left| \frac{\sum(1 - \frac{\hat{x} - x}{\varepsilon})}{n} \right| * 100$$

Explaining the largest possible estimation error, if for instance the model estimates a property to be of very good fit by 100%, yet the DM assigned zero belief degree, the maximum error is one. Hence, for this model, the largest possible estimation error in always one, implying that $MAI = 1 - MAE$. Although MAI can be derived from MAE, DMs are generally more comfortable with an accuracy indicator i.e. find it more intuitive. Hence, whilst it does not provide more insight, MAI simplifies the understanding of the model results and deserves to be included. Overall, these measures are used to contrast estimated property performance BDs to the actual observations in the dataset.

Now, the different model scenarios presented in the following subsections essentially vary in terms of the weights used for $e_i(i = 1, \dots, 144)$, the alpha-index, reliabilities r_i of the pieces of evidence $e_i(i = 1, \dots, 144)$, optimising the model to either minimise MAE or MSE and/or creating sample subsets. Hence, using the identified intervals and respective bin-widths, and always considering L pieces of evidence ($L = 144$), 18 scenarios of the ER rule model were developed.

11.4.1 Scenario 1 – Mean Weight (20)

The first nine models presented herein included the entire dataset to estimate the property performance distribution. The preference information $w_i(i = 1, \dots, 144)$ in the three consecutive models was taken from the 20 prospective homebuyers that provided the property ratings and participated in the previous online survey. Any variations introduced in the scenarios are described in the respective subsections.

11.4.1.1 Scenario 1.1 – Minimise MAE

First, using the complete dataset (820) enabled the training of the alpha-index, accounting for the interdependencies among input variables. Ultimately, this helps to embody the real relationship between pieces of evidence. Then, scenario 1.1 pursued the goal of minimising MAE. Using the mean weights of the 20 homebuyers, which illustrate the superiority of one piece of evidence over another in relation to an upper criterion, the optimisation model was developed to define reliability levels for the 144 input variables. It is very likely the data collection of the alternatives' criteria values, the subjective judgements involved and the subsequent recording affected the quality of information. In turn, although the reliability is an inherent feature of the evidence it is difficult in the real estate assessment to even approximate the true reliabilities of the various pieces of evidence. Hence, as described above, the model changed the reliability scores in order to minimise the overall estimation error. Table 28 highlights the key characteristics of the first aggregation model.

Table 28, Description of ER Model 1.1

Scenario 1.1	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 20

Running the first model with the above specifications, an MAI of 86.9 % was achieved. This expresses the model's accuracy. The MAE and MSE were also derived and are presented in the table below.

Table 29, Performance of ER Model 1.1

Scenario 1.1	Model performance
MAE	0.1310
MSE	0.0384
MAI	86.9%

11.4.1.2 Scenario 1.2 – Minimise MSE

From scenario 1.1 to 1.2 everything remained the same except optimising the reliability to minimise the MSE between the estimated property performance distributions against the real observations. This modification is seen in the objective row of Table 30.

Table 30, Description of ER Model 1.2

Scenario 1.2	ER model description
Dataset	All records (820)
Objective	Minimise MSE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 20

Compared to scenario 1.1 that optimised the model parameters to minimise MAE, this second model, concentrating on reducing MSE, reported almost the same average square error, i.e. showing only a slight improvement of 0.0048.

Table 31, Performance of ER Model 1.2

Scenario 1.2	Model performance
MAE	0.1372
MSE	0.0336
MAI	86.3%

11.4.1.3 Scenario 1.3 – Alpha Equals One

Next, the third model was a replication of scenario 1.1 with one exception. In this regard, scenario 1.3 took a strong assumption that all pieces of evidence e_i $(i = 1, \dots, 144)$ are fully independent $(\alpha = 1)$. Thus, whilst optimising reliabilities again to maximise the performance of the model under the set conditions, the alpha was set to one (Table 32).

Table 32, Description of ER Model 1.3

Scenario 1.3	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	1
Reliability	Optimised
Weights	Mean of 20

The problem with this scenario was that assuming complete independence is not a realistic condition in the current context. The resulting scores of the performance indicators for model 1.3 are shown in Table 33.

Table 33, Performance of ER Model 1.3

Scenario 1.3	Model performance
MAE	0.1708
MSE	0.0493
MAI	82.9%

As expected, the model's performance, in comparison to the previous two, decreased significantly. In this respect, assuming variables are totally independent might derive unrealistic results when pieces of evidence overlap and, to some degree, carry the same information.

11.4.2 Scenario 2 – Mean Weight (180)

The previous examples all considered the weights of the 20 homebuyers, taking the mean score for each criterion. Now, since the researcher obtained preference information $(w_i, i = 1, \dots, 144)$ on the full list of criteria (e_i) from the 180 survey participants, it was worth building and running one model with the mean weight score of those individuals. Model two trained the reliability (r_i) to minimise MAE, whilst accounting for the dependencies from the trained alpha-index (Table 34).

Table 34, Description of ER Model 2

Scenario 2	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 180

Surprisingly, the model performance (Table 35) was not far off from the equivalent model 1.1 that used the weights from the 20 homebuyers who actually completed the dataset with the property performance scores (Table 29).

Table 35, Performance of ER Model 2

Scenario 2	Model performance
MAE	0.1315
MSE	0.0388
MAI	86.9%

11.4.3 Scenario 3 – Weight Optimised

Bearing in mind the relatively stable performance of model 2 in comparison to 1.1, the next two models intended to optimise the weight scores within one standard deviation of the 180 mean weights.

11.4.3.1 Scenario 3.1 – Set Reliability to 0.7

First, scenario 3.1 assumed a fixed reliability level of all pieces of evidence. In other words, it is specified in the model that all inputs are unreliable to $r_i = 0.7$ $(i = 1, \dots, 144)$ (Table 36).

Table 36, Description of ER Model 3.1

Scenario 3.1	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	0.7
Weights	Optimised within 1 st.dev. of 180 mean

Thus, with a set reliability and an adjusted alpha-index, the optimal weights were identified within the given range by optimising the model in light of achieving the lowest possible MAE. For instance, considering the top two hierarchy levels, this optimisation process derived weights (w_i) within the set range as follows:

- level-one: location $w_1 = 0.64$; real estate $w_2 = 0.74$; costs $w_3 = 0.99$
- level-two: macro location $w_{1.1} = 0.38$; micro location $w_{1.2} = 0.56$; property $w_{2.1} = 0.76$; outside area $w_{2.2} = 0.74$; acquisition costs $w_{3.1} = 1.00$; taxes $w_{3.2} = 0.88$; maintenance costs $w_{3.3} = 1.00$

With regards to the three upper level criteria, location and real estate both occupied the lowest value in the set range, in contrast to costs, which resulted in the highest possible weight. As a result of running model 3.1, the model accuracy decreased significantly.

Table 37, Performance of ER Model 3.1

Scenario 3.1	Model performance
MAE	0.2106
MSE	0.0952
MAI	78.9%

It is expected that setting the reliability of all pieces of evidence to 0.7 caused the poor performance. At the same time, this does not represent realistic conditions and may be disregarded as an appropriate scenario to model the real estate decision problem.

11.4.3.2 Scenario 3.2 – Optimise Reliability and Weight

In accordance to the findings above (scenario 3.1), it was worth investigating whether optimising weight as a subsequent step to the optimised reliabilities would enhance the model outcome.

Table 38, Description of ER Model 3.2

Scenario 3.2	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised (first, then weights)
Weights	Optimised within 1 st.dev. of 180 mean

Overall, running the model on the entire dataset, with the alpha-index, the reliabilities were first adjusted to maximise estimation performance. Then, weights were changed in the pre-defined range to further decrease the MAE. For instance, this produced in a first instance the reliabilities:

- level-one: location $r_1 = 1.00$; real estate $r_2 = 0.00$; costs $r_3 = 0.84$
- level-two: macro location $r_{1.1} = 0.67$; micro location $r_{1.2} = 0.01$; property $r_{2.1} = 0.00$; outside area $r_{2.2} = 0.00$; acquisition costs $r_{3.1} = 1.00$; taxes $r_{3.2} = 1.00$; maintenance costs $r_{3.3} = 1.00$

And in a second step, taking the optimised reliabilities into account, the following weights were derived:

- level-one: location $w_1 = 0.81$; real estate $w_2 = 0.74$; costs $w_3 = 0.70$
- level-two: macro location $w_{1.1} = 0.38$; micro location $w_{1.2} = 0.97$; property $w_{2.1} = 1.00$; outside area $w_{2.2} = 0.74$; acquisition costs $w_{3.1} = 0.86$; taxes $w_{3.2} = 0.67$; maintenance costs $w_{3.3} = 0.91$

Table 39, Performance of ER Model 3.2

Scenario 3.2	Model performance
MAE	0.1257
MSE	0.0357
MAI	87.4%

Consequently, from Table 39 there is a visible improvement to the previous scenario that fixed reliability. In other words, estimation accuracy improved significantly after optimising two model parameters, reliabilities and weight (MAI improvement of 8.5%). This model also achieved the best performance in terms of MAE and MAI across all previous models.

11.4.4 Scenario 4 – Individual Weights

Another viable model option involved using the individual weights of the 20 prospective homebuyers on the full dataset of 820 records.

Table 40, Description of ER Model 4

Scenario 4	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	20 individual weights

The weights used in this scenario represent the actual preference profile of individual homebuyers, whilst the alpha-index was again derived from the full dataset and reliabilities were trained to minimise MAE.

Table 41, Performance of ER Model 4

Scenario 4	Model performance
MAE	0.1355
MSE	0.0407
MAI	86.5%

The performance decline observed in the table above to scenarios 1.1, 2 and 3.2, despite the individual weights, can potentially be attributed to using all records (820) for computing BDs. As a matter of fact, evidence aggregation in this case takes into account the scores provided by all 20 homebuyers, rather than just the 41 ratings for each individual.

11.4.5 Scenario 5 – Weight Equals Reliability

In some situations, weight and reliability share the same definition $r_i = w_i$ for $i = 1, \dots, L$. This was previously emphasised in the ER literature, indicating the ER rule reduces to the traditional ER algorithm if no distinction between the two parameters is made (Yang & Xu, 2014; Chen, et al., 2015).

11.4.5.1 Scenario 5.1 – Minimise MAE

Scenario 5.1 first modified the alpha-index in accordance to the available information and then adjusted the reliability of the pieces of evidence to minimise MAE. At this point, when optimising the model, the assumption is reliabilities and weights share the same meaning.

Table 42, Description of ER Model 5.1

Scenario 5.1	ER model description
Dataset	All records (820)
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Equals reliability

With the outlined model features, the optimised reliabilities for the first hierarchy levels were:

- location $r_1 = w_1 = 1.00$
- real estate $r_2 = w_2 = 0.00$
- costs $r_3 = w_3 = 1.00$

These optimised reliabilities/weights indicate the estimation error is minimised when disregarding the evidence relating to real estate, i.e. $r_2 = w_2 = 0.00$. This in turn means the accuracy of the model is greatest when solely considering location and costs. Arguably, this condition is questionable as it was expected that the inclusion of real estate variables do matter in assessing the fit of a property. Therefore, whilst scenario 3.2 reports a slightly higher estimation error, the fact that the real estate weight would only be optimised in the range of $74.46 \leq w_2 \geq 100$ makes it more realistic.

Table 43, Performance of ER Model 5.1

Scenario 5.1	Model performance
MAE	0.1156
MSE	0.0316
MAI	88.4%

Overall, the performance of model 5.1 is slightly better than scenario 3.2, which optimised weights within a set range in a first step and then reliabilities. The lower estimation error in the current case may be explained by not pre-defining a range for optimising the values; hence it had more freedom to find optimal values that would minimise the MAE.

11.4.5.2 Scenario 5.2 – Minimise MSE

This next model reproduced the previous situation with the distinction of minimising MSE.

Table 44, Description of ER Model 5.2

Scenario 5.2	ER model description
Dataset	All records (820)
Objective	Minimise MSE
Alpha	Trained
Reliability	Optimised
Weights	Equals reliability

Table 45, Performance of ER Model 5.2

Scenario 5.2	Model performance
MAE	0.1217
MSE	0.0263
MAI	87.8%

Minimising MSE, the model accuracy decreased marginally in terms of MAI.

11.4.6 Model Comparison (Scenarios 1-5)

A direct comparison of the explained modes is beneficial to identify the best performing ones. Correspondingly, Table 46 summarises the first nine models using the entire dataset. All models considered, scenarios 1.2 and 5.2 experienced only a minor change to the previous construct, and may therefore reduce the number of distinct models to seven.

Table 46, Model Performance Comparison - All Records

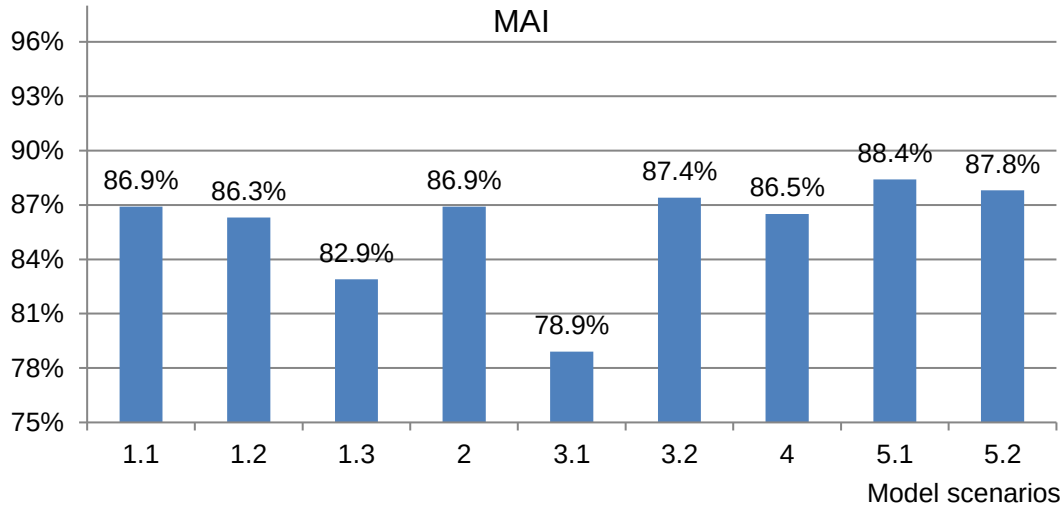
Scenario	1.1	1.2	1.3	2	3.1	3.2	4	5.1	5.2
Dataset	(820)	(820)	(820)	(820)	(820)	(820)	(820)	(820)	(820)
Minimise	MAE	MSE	MAE	MAE	MAE	MAE	MAE	MAE	MSE
Alpha	Trained	Trained	1	Trained	Trained	Trained	Trained	Trained	Trained
Reliability	Opt.	Opt.	Opt.	Opt.	0.7	Opt.	Opt.	Opt.	Opt.
Weights	$\bar{x}$ of 20	$\bar{x}$ of 20	$\bar{x}$ of 20	$\bar{x}$ of 180	Opt.	Opt.	w_i	$w_i = r_i$	$w_i = r_i$
MAE	0.1310	0.1372	0.1708	0.1315	0.2106	0.1257	0.1355	0.1156	0.1217
MSE	0.0384	0.0336	0.0493	0.0388	0.0952	0.0357	0.0407	0.0316	0.0263
MAI	86.9%	86.3%	82.9%	86.9%	78.9%	87.4%	86.5%	88.4%	87.8%

* $\bar{x}$ refers to the mean score; Opt. refers to optimised; w_i refers to individual weights

Reflecting upon the comparison table, scenario 5.1 recorded the highest model estimation accuracy, with an MAI of 88.4%. Nonetheless, it is questionable whether in this particular

case of assessing a property, weight can be set equal to reliability, and the parameters can be optimised with total flexibility between zero and one. A more applicable scenario may be represented by model 3.2, which optimised the weights within a suitable, predefined range. Regardless, the models' efficiencies are graphically illustrated in Figure 34.

Figure 34, Models' Mean Accuracy Indicator - All Records



11.4.7 Scenario 6 – 9 Sample Subsets

Another nine aggregation models were constructed for different sample subsets. Basically, similarities across participants who provided property ratings were discovered and served as the basis to create separate groups. In some cases, and when appropriate, preference data from other individuals within the survey dataset were also considered. The reasoning behind grouping people was to consider the subjective property performance outcomes provided by the homebuyers. More precisely, it was anticipated that buyers sharing some demographic information and/or certain preferences are more likely to have similar views on the performance of properties. Hence, prior to constructing subsets and developing corresponding models, the researcher expected to increase model efficiency, i.e. estimating a more accurate BD for individual properties. The following subsections provide detailed explanations on nine scenarios.

11.4.7.1 Scenario 6

11.4.7.1.1 Selection Criteria

The availability of in-depth information of 180 prospective homebuyers provided different options for filtering and arranging individuals into groups. For the first grouping, the preference scores provided for the highest level of criteria, i.e. real estate, location and costs, were used to differentiate candidates. Twelve individuals assigned a weight score of 100 to the real estate criterion, with five also viewing location and/or costs as equally important. This allowed extracting seven who exclusively considered real estate to be the most crucial factor out of this top category.

Once the seven individuals were identified, further similarities were observed within this sample subset. For instance, they all indicated their moderate to high familiarity with the island, spending more than four weeks there each year. Parallels were also seen on lower level criteria preferences. Looking at location factors, the supply system was identified as the most important variable in the infrastructure category. Real estate being assessed on the interior, i.e. the property itself, and the outside area, the seven candidates provided a weight of 80 or higher to the property criterion. Across the ten sub-criteria defining rooms, the sample subset perceived the number of bedrooms to be either equivalent to another factor or most important. Similarly, in respect to the outside area, the group agreed on the importance of terraces/balconies. In this context, the size appeared to be of high relevance. Other resemblances were observed in the variables quality, electricity grid connection, glazing and bathroom type. Finally, the average weight allocated by the seven individuals across all pieces of evidence ranged from 53 to 68

11.4.7.1.2 Scenario 6.1 – Mean Weight (7)

Scenario 6.1 presents the first model developed on a smaller section of the property dataset. Accordingly, considering a reduced number of candidates from the homebuyer sample who provided the property ratings, only the property scores provided by the seven individuals were relevant. This meant that the alpha-index was trained using the available information of the 287 records. Likewise, in a next step, the reliabilities r_i of the pieces of evidence e_i ($i = 1, \dots, 144$) were modified in light of these records, with the objective to minimise MAE. A summary of the scenario 6.1 ER model is displayed in Table 47.

Table 47, Description of ER Model 6.1

Scenario 6.1	ER model description
Dataset	287 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 7

As expected, running the model with the above specifications provided significantly better results to the previous models that incorporated all 840 records (Table 48).

Table 48, Performance of ER Model 6.1

Scenario 6.1	Model performance
MAE	0.0807
MSE	0.0196
MAI	91.9%

The results obtained from model 6.1 imply a model accuracy of 91.9%. This evidence support the researcher's premonition that grouping comparable DMs can possibly improve the estimation error.

11.4.7.1.3 Scenario 6.2 – Mean Weight (11)

Another group was formed by eliminating two candidates from the group of seven. This was simply the result of having previously communicated with the 20 homebuyers and these five actually stressing the influence a fitted kitchen has on their decision. This was also observed in the dataset, where the two eliminated candidates weighed this factor below 70. A further modification to the previous scenario was the inclusion of preference data from the survey sample. Here, another six individuals from the 160 remaining survey candidates assigned the maximum level of importance to the real estate criterion, whilst location and costs were viewed less relevant in assessing property performance. Consequently, the mean weights for the model were taken from 11 comparable homebuyers.

The ER model description for scenario 6.2 is illustrated in Table 49. Again, further decreasing the number of homebuyers who provided property scores from seven to five, simultaneously reduced the models dataset to 205 records (i.e. $5 * 41$). Hence, α needed to be adjusted in accordance to the available data, whilst subsequently optimising reliabilities to minimise MAE.

Table 49, Description of ER Model 6.2

Scenario 6.2	ER model description
Dataset	205 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 11

To provide an insight into the mean weights of the 11 homebuyers used in this model, the average preference scores for hierarchy levels one and two are as follows:

- leve-one: location $w_1 = 0.58$; real estate $w_2 = 1.00$; costs $w_3 = 0.68$
- level-two: macro location $w_{1.1} = 0.58$; micro location $w_{1.2} = 0.75$; property $w_{2.1} = 0.88$; outside area $w_{2.2} = 0.90$; acquisition costs $w_{3.1} = 0.77$; taxes $w_{3.2} = 0.70$; maintenance costs $w_{3.3} = 0.89$

Table 50, Performance of ER Model 6.2

Scenario 6.2	Model performance
MAE	0.0816
MSE	0.0193
MAI	91.8%

With this dataset, the model performed almost as good as the previous scenario.

11.4.7.1.4 Scenario 6.3 – Mean Weight (41)

Relating back to model 6.1, all seven individuals were again included in this next scenario, with the exception that further preference information was gathered from 34 similar cases within the survey dataset. For that reason, model 6.3 computed and incorporated the mean weights of 41 comparable individuals who all rated real estate the most important factor across the highest hierarchy rank. More precisely, the 41 cases portray a real estate weight of 85 or more, resulting in a mean of $w_2 = 0.97$.

Additional similarities were identified after selecting the 34 similar candidates and included the attention on quality aspects, with levels of importance at 80 or above, as well as relatively high weights for privacy level, outside area, terraces/balconies and technical facilities.

Overall, the resulting model is defined in Table 51. Note, by using the identical dataset to scenario 6.1, the alpha-index should also be the same.

Table 51, Description of ER Model 6.3

Scenario 6.3	ER model description
Dataset	287 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 41

Whilst the real estate received a high level of importance across the DMs, the mean scores for location and costs were significantly lower, representing $w_1 = 0.75$ and $w_3 = 0.77$ respectively. Additionally, on the second level down, the two associated factors to real estate, i.e. property and outside area, both accounted for a mean of 0.93.

Table 52, Performance of ER Model 6.3

Scenario 6.3	Model performance
MAE	0.0827
MSE	0.0202
MAI	91.7%

Adding the preference information of 34 similar cases to the previously identified seven (in scenario 6.1) slightly decreased the model's estimation accuracy (MAI decrease of 0.2%). In this context, the only minor decline in MAI potentially indicates that adding the 34 additional cases may in practice constitute a relatively good grouping.

11.4.7.2 Scenario 7

11.4.7.2.1 Selection Criteria

An alternative approach to establish a legitimate cluster is by using demographic information and common property requirements. In fact, it was believed DMs' age, nationality, home country and number of children are four significant factors that potentially have certain implication on the relevance of some property evaluation criteria. In addition to this, the candidates should all have the same budget for the prospective property purchase and at least three common property characteristics (out of the 19 presented during the survey) that meet a certain standard, from the homebuyers' point of view, in order to regard a real estate acceptable. Respectively, four out of the 20 DMs revealed similar characteristics in the survey data. First, there were six German candidates aged 46 or above, had more than two children and were resident in Germany. On the other hand, there were nine prospective homebuyers with a price limit of 1.5 to 1.99 million Euros. Yet, only five out of the nine also agreed on three important property factors, namely construction quality, price and privacy level. These three essentially represented the 'must-have' criteria that can eliminate alternatives from further consideration if they do not reach a minimum standard. Combining the demographics and the property requirements, four homebuyers emerged as sharing all the features presented above.

During a closer review of the four individuals, other similarities surfaced. For instance, all DMs indicated they would be taking the decision jointly with their partners, where each spouse has the same influence. At the same time, they were relatively experienced in the house purchase process, indicating they had bought more than four real estates in the past. When studying the preference profiles, further connections were drawn. Whilst none of the four assigned a level of importance of 100 to either of the upper level criteria, they did perceive real estate to be equal or more important than location and costs. Then, under the location heading, view received a relatively high score, ranging from 73 to 92. Also, supply system was the most important in the infrastructure category, and distance to motorway in relation to the road network. Crime rate and noise level received weights of 85 or above and 92 or above respectively. The second level down from costs, the maintenance expenses

were regarded as most influential in the decision making process. In respect to the criteria defining the real estate, i.e. outside area and property, both seemed fairly equivalent in terms of weights assigned (outside area ranging from 84 to 94 and property from 81 to 100). Finally, the number of bedrooms played the most crucial role in comparison to the other ten competing criteria on this level and plot boarder obtained a weight score of above 80 from all four candidates.

11.4.7.2.2 Scenario 7.1 – Mean Weight (4)

With the defined sample subset, the resulting model included only the records of those four individuals. In other words, an optimisation model was constructed using 164 records and the mean weights of the four prospective homebuyers. As in the previous cases, first the alphas were trained in light of the dataset and then, with this information, the reliabilities were altered to achieve the lowest error (MAE). The summery of model 7.1 is presented in the table below.

Table 53, Description of ER Model 7.1

Scenario 7.1	ER model description
Dataset	164 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 4

Table 54, Performance of ER Model 7.1

Scenario 7.1	Model performance
MAE	0.0846
MSE	0.0240
MAI	91.5%

Comparing the results to those of the group formed on the basis of weight similarities, the use of demographics and property requirements seems to be slightly less effective (MAI increase of 0.4%) in clustering similar DMs. Nonetheless, the MAE that can be expected using model 7.1 indicated an average 0.08 estimation error, which is still acceptable.

11.4.7.2.3 Scenario 7.2 – Minimise MSE

The above model was duplicated in scenario 7.2 with the objective to minimise MSE (Table 55). Again, as previously explained, this model does not constitute a considerable change to the model construct. Therefore, one may simply gain an insight of the effect on reliability levels when optimising the model to minimise MSE, rather than MAE.

Table 55, Description of ER Model 7.2

Scenario 7.2	ER model description
Dataset	164 records
Objective	Minimise MSE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 4

Continuing the discussion, resulting reliabilities with the above model specifications are:

- location $r_1 = 0.61$
- real estate $r_2 = 0.00$
- costs $r_3 = 0.00$

Revisiting the previous scenario, reliabilities on the first hierarchy level were:

- location $r_1 = 1.00$
- real estate $r_2 = 0.00$
- costs $r_3 = 0.81$

Obviously, in order to minimise the distance from the estimation points to the actual observations, significant variations in reliability levels can be observed. Overall, the previous example (scenario 7.1.) was not concerned with the distance of the error, but rather the absolute error figure. Hence, outliers do not substantially affect the model performance.

Table 56, Performance of ER Model 7.2

Scenario 7.2	Model performance
MAE	0.0932
MSE	0.0199
MAI	90.7%

A minor decrease in model accuracy was observed to the previous model, as experienced in all models that intended to minimise mean squared error.

11.4.7.2.4 Scenario 7.3 – Mean Weight (47)

Similar to scenario 6.3, this time the four earlier identified comparable homebuyers from the sample of 20 were used to find other associated cases within the larger sample of 180 homebuyers. However, instead of exclusively using the demographics, price limit and 'must-have' property standards, which would restrict relevant cases to four additional ones (from the remaining 160), candidates that rated real estate as the most important criterion on the top level made up the new group. As a result, the preference information of a total of 47 survey respondents (including the four from the property rating sample) was obtained to derive the mean weights. Noteworthy, all 47 also insisted on a high quality weight of 80 or above, as well as identified privacy level, outside area, terraces and technical facilities as relatively important factors in the property evaluation process.

Developing the corresponding model, it still only covered the 164 records from the four prospective homebuyers who provided property ratings. Given this point, studying the criteria relationships, α should be equivilant to α in scenario 7.1. Then, incorporating the specifications recorded in Table 57, the model's objective was to minimise MAE.

Table 57, Description of ER Model 7.3

Scenario 7.3	ER model description
Dataset	164 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 47

Table 58, Performance of ER Model 7.3

Scenario 7.3	Model performance
MAE	0.0870
MSE	0.0246
MAI	91.3%

Again, adding the preference information of individuals that did not assess the 41 properties did not have major implication on the model performance.

11.4.7.3 Scenario 8

11.4.7.3.1 Selection Criteria

To recall from the discussion before, the demographic and property requirements selection criteria to create a subset of comparable individuals from the 20 homebuyers did not establish the best group. In comparison, the model acknowledging the individuals who shared similar preference information on key evaluation criteria did a slightly better job. Evidently, another option now consists in grouping individuals on the basis of demographics, property requirements and preference information. First, the sample of 20 was reviewed in terms of their weight assignments. The focus this time was predominantly on the second hierarchical level that assessed location on micro and macro location, costs on taxes, acquisition and maintenance costs, and real estate on the property itself and the outside area. More precisely, there were seven homebuyers who emphasised the importance of macro over micro location and who at the same time all regarded maintenance costs as most important. Then, five regarded the property itself equivalent to the outside area. From the homebuyers' inherent characteristics, 12 originated from German speaking countries and were between 36 and 55 years of age. Seven out of the 12 also already owned a property on the island. Considering the preference information and the demographics together, three individuals met all the selection criteria.

Across the 144 pieces of evidence, this group of homebuyers assigned similar weights (with mean scores of 60, 62 and 63 for the three cases). In addition to this, there were other preference related resemblances as illustrated in Table 59.

Table 59, Preference Similarities Observed across the Three Homebuyers (Scenario 8)

Criterion	Macro location	Pollution	Noise level	Surrounding properties	Quality	Layout	Nr. of stories	Nr. of bedrooms	Guest toilet	Heating	Underfloor heating	Pool	Seating areas	Size of terrace
Weight	94≤	90≤	100	87≤	100	90≤	<10	Most imp.	100	100	100	100	100	Most imp.

11.4.7.3.2 Mean Weight (3)

With the small sample subset of three, the dataset used for model building consisted of 123 records. On that basis, the alpha-index was initially modified to then allow training of the reliabilities with respect to minimising MAE.

Table 60, Description of ER Model 8

Scenario 8	ER model description
Dataset	123 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 3

Table 61, Performance of ER Model 8

Scenario 8	Model performance
MAE	0.0719
MSE	0.0200
MAI	92.8%

Interestingly, Table 61 indicates a more efficient grouping owing to the enhanced model accuracy, reaching 92.8%. Hence, it is worth undertaking further investigations in this direction.

11.4.7.4 Scenario 9

11.4.7.4.1 Selection Criteria

Due to the model accuracy improvement in the previous scenario to those using other sample subsets, a final group was created on the same principal with slightly different selection criteria from demographics and relevant criteria. Respectively, the dataset of the 20 DMs was reviewed and nine German nationals with older children were selected (16 years or older). Five of them demonstrated significant knowledge in the current decision making process, recording more than 11 acquisitions, plus spending on average more than eight weeks per year in Majorca. This latter point indicates the primary purpose of a future house on the island (i.e. secondary residency or multiple holidays throughout the year). Then, one additional person is excluded from the new group due to a price limit above two million Euros. During a separate inspection of the preference information, 50% of the prospective homebuyers rated the properties' location as either equivalent to the other two criteria or assigned a higher weight score. Merging the four individuals identified from the demographics selection criteria and the ten from overlapping preferences, three candidates matched across all those features.

Again, once the group was identified, the candidates were assessed in more detail. It emerged that all three attached great importance in terms of core requirements to the number of bedrooms, location, construction quality, privacy level and heating. Additionally, the phenomenon of commissioning multiple agencies was especially noticeable in this group, since three agencies were used to steer the property search. Concerning criteria relevance, preference patterns were observed as illustrated in Table 62.

Table 62, Preference Similarities Observed across the Three Homebuyers (Scenario 9)

Criterion	Maintenance costs	Property	Outside area	Noise level	Air pollution	Smell	Room sizes	Rooms	Nr. of bedrooms	Pool	Spa	Gym	Alarm system
Weight	Most imp.	98≤	94≤	90≤	95≤	92≤	91≤	94≤	97≤	90≤	<19	<10	<12

11.4.7.4.2 Scenario 9.1 – Mean Weight (3)

Accounting for a different dataset to that of scenario 8, 123 records were included. As a result, the alphas needed to be modified. Subsequently, adopting the mean weights from the group of three, the reliability for each piece of evidence was updated to minimise the average absolute estimation errors in the model.

Table 63, Description of ER Model 9.1

Scenario 9.1	ER model description
Dataset	123 records
Objective	Minimise MAE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 3

Table 64, Performance of ER Model 9.1

Scenario 9.1	Model performance
MAE	0.0435
MSE	0.0089
MAI	95.6%

In this scenario, the ER model estimation accuracy significantly improved to previous aggregations. The MAI here expresses that this model is accurate in 95.6% of the cases in estimating the property performance BD.

11.4.7.4.3 Scenario 8.2 – Minimise MSE

A final model was constructed that copied the properties of model 9.1, only changing the optimisation objective. More precisely, alpha was trained to account for interdependencies among pieces of evidence; obtaining the same alpha values than in the scenario above due to the identical dataset. Then, reliabilities were modified to reduce the MSE (Table 65).

Table 65, Description of ER Model 9.2

Scenario 9.2	ER model description
Dataset	123 records
Objective	Minimise MSE
Alpha	Trained
Reliability	Optimised
Weights	Mean of 3

Table 66, Performance of ER Model 9.2

Scenario 9.2	Model performance
MAE	0.0506
MSE	0.0070
MAI	94.9%

Whilst reducing the MSE from the model that concentrated on minimising MAE by 0.0611, the MAI actually reports a slight decrease of 0.7%. Nonetheless, the MSE here indicates a

close fit to the actual data, i.e. the estimations are approximating the observed outcomes. Computing the Root Mean Squared Error (RMSE) $\sqrt{0.007} = 0.0837$, which is arguably easier interpretable than MSE since it takes on the same unit than the data (Hyndman & Koehler, 2006), it implies that the estimation errors vary to 8.37% around the actual outcomes. In other words, the RMSE estimates the standard deviation of the error distribution.

11.4.8 Model Comparison (Scenarios 6-9)

Table 67 offers the model specifications and performance indicator values for the nine models that created sample subsets of the 20 homebuyers, and correspondingly used a reduced dataset for model building and parameter training.

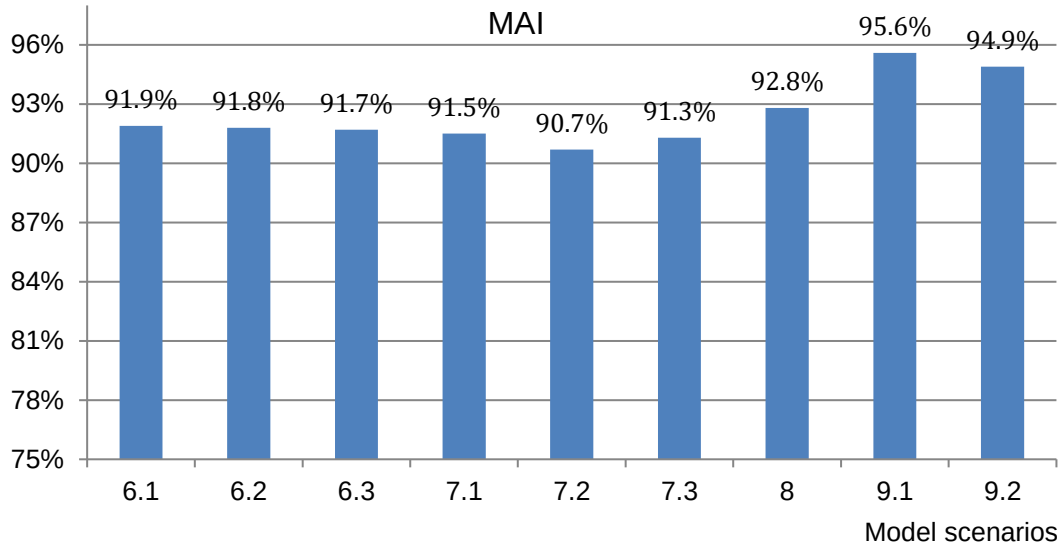
Table 67, Model Performance Comparison - Sample Subsets

Scenario	6.1	6.2	6.3	7.1	7.2	7.3	8	9.1	9.2
Dataset	(287)	(250)	(287)	(164)	(164)	(164)	(123)	(123)	(123)
Minimise	MAE	MAE	MAE	MAE	MSE	MAE	MAE	MAE	MSE
Alpha	Trained	Trained	Trained	Trained	Trained	Trained	Trained	Trained	Trained
Reliability	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.
Weights	$\bar{x}$ of 7	$\bar{x}$ of 11	$\bar{x}$ of 41	$\bar{x}$ of 4	$\bar{x}$ of 4	$\bar{x}$ of 47	$\bar{x}$ of 3	$\bar{x}$ of 3	$\bar{x}$ of 3
MAE	0.0807	0.0816	0.0827	0.0846	0.0932	0.0870	0.0719	0.0435	0.0506
MSE	0.0196	0.0193	0.0202	0.0240	0.0199	0.0246	0.0200	0.0089	0.0070
MAI	91.9%	91.8%	91.7%	91.5%	90.7%	91.3%	92.8%	95.6%	94.9%

* $\bar{x}$ refers to the mean score and Opt. refers to optimised

As previously emphasised, and clearly visible from the comparison table above, scenario 9.1 attains the lowest MAE and simultaneously the highest model accuracy (MAI) (see also Figure 35). Relating Table 67 to Table 46 (scenarios 1-5), it suggests clustering similar DMs into different groups can significantly improve estimations. All models constructed on sample subsets recorded MAI above 90.7% (illustrated in Figure 35), whereas the undifferentiated models, in terms of dataset, attained a maximum MAI of 88.4%.

Figure 35, Models' Mean Accuracy Indicator - Sample Subsets



Nonetheless, having selected clustering criteria ranging from demographic information to preference information, there are definitely other combinations of deriving a meaningful group. Essentially, with a large dataset and clear differentiations between groupings, by understanding which factors to explicitly extract from prospective homebuyers to categorise them in an appropriate group may avoid the time consuming and daunting task of providing exact weight information on 144 criteria. For instance, if an individual would match all characteristics set out in scenario 9 (see section 11.4.7.4.1), it can be assumed that he/she also follows a similar pattern in the missing preference information. These could subsequently be used for estimating the BDs of a set of alternative properties to allow an informed decision making process.

11.5 Model Validation

In relation to the model performance, this section discusses the challenges associated with a validation study. In other words, testing the models' predictive power was problematic and, for a number of reasons, not feasible at this point in time.

The main barrier for the implementation was the dataset size used for training. As a result of restricted access to property records and no existing data bank storing all the required information, increasing the dataset to the point that all criteria combinations are covered to allow adding new alternatives was an impossible task. Alternatively, using the available data would require the researcher to decrease the bin sizes substantially to have records for all values. This would, according to the experts and DMs, not lead to meaningful recommendations. Doing a validation with no changes to the dataset by adding some new real estate cases to predict their overall performances would likely occupy one of the empty bins, for which no likelihoods or alpha is available. Consequently, in the latter case, poor predictive performance is to be anticipated.

Therefore, following the development of the models, the models were presented and explained to some of the DMs. This process included the discussion of realistic model assumptions and achieved estimation errors. Regarding the former, as previously discussed in section 11.4.5 which obtained an optimised reliability/weight of zero for the evidence real estate, to the DMs' understandings, the negligence of real estate in the assessment of a property is rarely supported by experience. Hence, in such situation, to make the model more credible, it was proposed to introduce a lower bound for w_i. Considering the estimation errors, the results were acceptable to the homebuyers. In addition, the DMs also appreciated the structure of the model and its high transparency. They agreed, particularly after talking through the example demonstrated in section 11.3, that the ER rule model increased transparency in the complex decision environment, allowing to better comprehend the process of arriving at a specific solution. Besides, they supported the idea of building separate models for different groups of DMs. Relating this back to the requirements for testing the models, it is not sufficient to have one large dataset, but rather obtain many cases for each sub-group, creating a number of large datasets. The reason for this is, based on the subjective outcomes of the estimation models, higher accuracy was achieved when clustering DMs sharing key characteristics or preferences. Consequently, as observed and discussed previously, large diversions in property ratings between DMs imply that one model does not fit them all. Overall, the prerequisites for a valid model test are classifying a DM to one of the defined groups and the availability of a large dataset, to then allow predicting the likely performance of a property for the individual, by means of a BD. On a final note, it should be acknowledged that the model user is currently limited to the analyst, who may use the obtained knowledge to make recommendations and talk the DMs' through the results.

11.6 Summary

This chapter first attended the important discretisation task necessary to organise the dataset in an appropriate format for model building. Next, to illustrate the ER rule in practice, an example, assuming independent pieces of evidence and reliability of 0.7 was performed. This showed the computational steps to combine two criteria, and subsequently aggregate a third piece of evidence. The last section of this chapter described nine scenarios of 18 different ER models. The various scenarios (except one) used the modified ER rule that accounted for relationships among criteria to aggregate pieces of evidence and derive a final property performance BD. This application research per se is a novelty to existing literature, which up to date only provides a very restricted number of applications of the ER rule without the alpha-index.

12 Discussion and Conclusion

This final chapter pools the results from the research project together by presenting the key outcomes in a condensed and summarised format. To recap, the findings are put into the context of the research questions. Additionally, the research contributions, implications, generalisation power, limitations and future research areas are discussed.

12.1 Introduction

The three main objectives of this research project were presented after a thorough and critical literature review that documented the real estate industry characteristics and subsequently related appropriate MCDM mechanisms. In more detail, it was first implied that a fair portion of MCDM methods can be classified in the prescriptive decision making field. Then, problem elements generally associated with complex MCDM situations were described. Given the identified characteristics, the objective was to find problem structuring guidelines within the literature that assist in extracting required information. Whilst there is an ongoing discussion on problem structuring, authors repeatedly emphasised the need for further research. In fact, existing publications did not reveal any guidance on structuring and dealing with MCDM problems associated to high-involvement product assessments. This literature chapter concluded by providing detailed explanations of a number of MCDM approaches valid in the real estate industry. On the whole, this investigation highlighted some literature gaps or deficits that were put at the heart of this research project. Hence, Chapter 4 emphasised the research focus with purposefully formalised research questions intended to fill gaps and complement existing knowledge. In order to address one of the research questions appropriately, another literature chapter was required, which reviewed different research methodologies. This, in combination with the knowledge of MCDM features, formed the basis for the developed problem-structuring framework in Chapter 6. Next, concentrating on the luxury real estate selection problem, the research site Majorca was introduced, along with insights from a small pilot study. Eventually, data collection in Majorca precisely followed the outlined framework from Chapter 6 to extract all required data for building a decision support model. Once the data was analysed and summarised, the various model scenarios, founded on a modified ER rule, were presented in Chapter 11.

Now, results obtained from the various sections are brought together and discusses in relation to the research objectives. This essentially summarises the research outcomes. Then, a separate section explicitly reviews the key contributions of this inquiry, followed by the resulting research implications, in terms of academic and possible practical consequences in the real estate industry. Additionally, the generalisability of the problem-structuring framework, the comparisons of stakeholders in a real estate purchasing situation and the ER model application is considered. Finally, limitations that arose during the research and upon reflection of the process are presented, along with potential future research avenues.

12.2 Research Questions

In addition to the model results presented in the previous chapter, it is valuable to address the research questions separately and ensure these have been answered throughout the investigation. Hence, the findings are now discussed in relation to the respective research objectives.

12.2.1 Research Question 1

The first research question: **How is an MCDM problem structured?**, resulted in the identification of decision problem elements that need to be known to select, modify or build an appropriate MCDM support mechanism (focus of RQ1.1). Respectively, the literature (section 3.3) pointed towards the following components:

- DM characteristics
- comprehensive list of evaluation criteria
- logical structure of identified criteria
- DM's preference information
- dataset of alternatives
- variable relationships (interdependencies and/or correlations)

These findings, together with the knowledge on diverse data collection and analysis processes provide the first research contribution, the introduction of an MCDM problem-structuring framework (RQ1.2). This framework consists of multiple, interlinked stages, and was carefully designed to be applicable in various high-involvement product decision settings. After applying the framework to the messy problem of real estate selection, it proved to be very useful in shaping the decision environment, extracting required information and providing the necessary inputs for a decision support mechanism. Upon reflection, the various data collection stages evidently require a substantial amount of time, which in many situations is not available. Particularly the qualitative part, known for being resource intensive, has its inherent disadvantages and restrictions, which are simultaneously associated with the proposed framework. These are further discussed in section 12.6. Regardless of several method specific limitations, on the whole, the process served the purpose of clearly structuring the MCDM problem. The adoption of this research plan to structure the real estate decision making problem can ultimately be viewed as an empirical validation, which conjectures a wider application scope.

12.2.2 Research Question 2

The subsequent research focus intended to investigate the decision making process involved in choosing a luxury real estate in Majorca from a pool of alternatives: **What is the luxury-homebuyer's decision making process when selecting a property in Majorca?**

First of all, addressing RQ2.1, various sources claim the engagement of a partner is inevitable in the real estate selection process. Other stakeholders are also occasionally emphasised, but to a significant smaller degree. Distinctive views emerge on the

involvement, and especially the impact real estate agents exert. One interesting finding is 92% of agents believe they actively influence their clients, whereas these mainly see the service providers as a means to an end, so they can access properties (78% and 22% indicated zero and little influence respectively). More on involvement levels (RQ2.2), more than half of the survey answers indicated an equal responsibility in the decisions between spouses, whilst 37% suggested the male DM has more control. This directly relates to another sub-question formalised in this context, i.e. RQ2.3: How is the interaction between homebuyers and agents? An interesting study finding here shows agents generally (80% of the respective survey sample) assume a predominant female contribution. With this in mind, if they mostly target one DM, this might explain the homebuyers' negative impression of the agents' consultancy service (Figure 18). Furthermore, it appears that communications are less effective between homebuyers and the real estate intermediaries, as satisfaction is very low (63%) with viewings. The observed switching behaviour across numerous agencies (81% using two or three agents, whilst 15% engage with four or more) in a way supports the seemingly large room for improvement. Consequently, it is recommended to recognise these obvious discrepancies between the two parties and adapt communication and viewing strategies accordingly.

Another focus of this second research question was to derive a comprehensive list of evaluation criteria relevant in the luxury real estate assessment process (relating to RQ2.4). Here, the interviews served as an initial identifier of all possible criteria (Appendix J), which were then reduced by the real estate experts to the most suitable 144 (Appendix K). Also, attending RQ2.5, in accordance to the DMs' cognitive processes, the variables were structured hierarchically to enhance comprehension and transparency, forming the real estate assessment framework (Appendix D). The interviews and surveys simultaneously support the anticipated relationship between evaluation criteria (RQ2.6). This result encouraged the adoption of the alpha-index in the evidence aggregation models. Finally, as indicated in literature, preference information on property criteria varies substantially across individuals. This was confirmed in the course of this research to answer RQ2.7, yet it might be possible to cluster individuals with similar views and demographics that share a similar preference pattern across most variables (section 11.4.7).

12.2.3 Research Question 3

Next, research question three, **How can the real estate selection problem be modelled to allow transparent and consistent criteria aggregation?**, uses the information gathered, thanks to the problem-structuring framework, in order to model the real estate decision. The modified ER rule offers an effective and transparent aggregation procedure optimal for the current problem. This approach satisfies all requirements identified for the real estate selection problem. For instance, it permits the inclusion of subjective weights, accounts for the different reliabilities in pieces of evidence, acknowledges criteria relationships and produces outcomes by means of BDs. In contrast to MRA discussed in the literature review section, the ER rule is able to aggregate criteria in line with the newly developed property

assessment framework (Appendix D) and certainly overcomes the black box criticised in ANN applications. Another interesting finding from the model results provides support for the hypothesised similar property ratings across homebuyers sharing certain demographic or preferential information. Whilst the model performances enhanced significantly when dividing the dataset into homebuyer groups of similar conditions, these results need to be interpreted with caution. The size of the dataset may somewhat limit the generalisability of using the chosen demographic and/or preference information for clustering homebuyers into specific groups.

12.2.4 Research Question 4

Answering the last research question: **What factors influence the adoption and acceptance rate of a real estate decision support system among homebuyers?**, intends to provide a foundation for the future to develop a computer interface that can be used by prospective homebuyers and support their decision making procedure. Accordingly, from the survey the main requests made by homebuyers are reduced search time (73%), inclusion of more property criteria (62%) in the evaluation process and provision of more information on a property's surroundings (60%). Putting this in the context of a structured decision making approach, the participants agree a DSS should reduce time and the number of viewings, whilst also taking more factors into account when assessing alternatives. The entire sample indicated their willingness to employ such a decision tool that can potentially make recommendations on the suitability of different properties. However, for the success in the industry, any software for this consumer group should be easy-to-use and self-explanatory (i.e. for non-experts) (97%), as well as offer a logical and clear user interface (90%). One final note, the post-model building exchange with DMs suggests the acceptance and support of the ER rule methodology for this particular context.

12.3 Research Contributions

The first research focus directly intended to supplement the existing problem structuring understanding in the MCDM domain. Numerous authors have indicated the considerable effect appropriate structuring, understanding and defining a complex decision problem has on the outcomes (Guitouni & Martel, 1998; Kasanen, et al., 2000; Belton & Stewart, 2002). Simultaneously, suggestions to increase research efforts in this area are eminent across publications. For instance, authors such as Brown and Vari (1992), Corner et al., (2001), Keeney and Gregory (2005), Franco and Montibeller (2009) as well as Maier and Stix (2013) all point towards a literature gap that needs to be filled within the MCDM domain. As a response to this, the research introduced a problem-structuring framework that has the potential to be suitable for a variety of consumer focused decision making problems. In other words, the proposed structure is applicable, but not necessarily limited to, situations where consumers intend to choose a high-involvement product or service from a finite list of alternatives. Correspondingly, the proposed problem-structuring framework can then identify and extract the required information to build a tailored decision support model. In the end,

the framework was validated by means of a successful application to the investigated real estate decision problem.

The above process led to the second contribution. Here, scarce existing behavioural research in the real estate domain, as indicated by Zheng et al. (2006) and Sah (2011), promoted various avenues for further investigations. This part of the research project was dedicated to discover underlying decision behaviour of homebuyers and interactions between real estate agents and clients (Hardin, 1999; Zheng, et al., 2006). Evidently, this insight is a more practical contribution to the Majorquin real estate market and the various stakeholders. However, the data collection also derived a complete list of relevant and measurable real estate evaluation factors and proposed a transparent hierarchical structure in accordance with DMs' thought process. The goal was to address the issue of a missing, accurate set of evaluation variables, as noted by authors such as Kettani, et al. (1998), Gibler and Nelson (2003), Kim et al. (2005), Ratchatakulpat et al. (2009) and Haddad et al. (2011). Additionally, some insight into criteria prioritisations was offered, which has not been done to that extent in the real estate literature. Overall, whilst previous studies focused heavily on a small number of key predictors or property performance indicators, this investigation provided an extensive list of variables that appear to have some degree of influence on a property purchase decision.

Based on the extracted information during the data collection, a viable evaluation model was build that has the potential to recommend actions, allow making an informed choice or to conduct additional analyses in support of the real estate decision making. Whilst currently limited to the specific setting (luxury real estate acquisitions in Majorca), the application study using a modified ER rule inference model is unique in existing literature. Currently, only a very limited number of publications exist demonstrating a practical example of the ER rule (yet, without incorporating the alpha-index) (Yang & Xu, 2014; Zhu, et al., 2015). Hence, the intention was to add a real problem, i.e. the real estate case, and highlight the ER rule's merits, along with its possible superiority to other evidence aggregation mechanisms. Furthermore, publications originating from the real estate domain suggested that MCDM studies with applications in the industry are limited despite their proven abilities to handle and solve complex decision making problems (Kaklauskas, et al., 2007). In support of this, Johnson (2005) argued future work should investigate suitable MCDM methods with the potential to facilitate real estate comparison. Respectively, modelling the real estate selection problem using the ER rule offered an original application and showed the applicability of this method. In sum, this application study is unique in existing literature and provides a practical demonstration of a modified ER rule.

12.4 Research Implications

From the research findings, it is worth briefly reiterating the academic and practical implications.

12.4.1 Academic Implications

From the academic perspective, gaps were filled or literature was supplemented. First, an MCDM problem-structuring framework for decision processes within a specific context outlines the steps that can be followed to define a problem and extract relevant information. This then enables researchers to match or build an adequate decision support mechanism and justify their actions. In sum, the research derived a new framework to structure some highly complex MCDM problems. This outcome essentially responds to the various demands made in literature to further address the problem structuring process as an inherent part of MCDM.

Another implication is felt in the real estate literature, where the reviewed existing studies merely presented a limited number of relevant criteria to assess property alternatives. The provision of an extensive list emphasises the complexity of the real estate evaluation process and might trigger further examinations in this direction. While this research focused on luxury real estate and included a large number of evaluation criteria in the assessment framework, other property types that yield a less extensive list may still follow the proposed hierarchical structure to illustrate the assessment in a transparent fashion.

Finally, this project offers an application study of a modified ER rule, which can benefit the MCDM community and other relevant decision analysis domains. More precisely, the limited number of publications demonstrating a practical case using the ER rule introduced in 2013 demanded more work in this area. This successful method application to a complex real-life problem might now draw further attention to its advantages and possible superiority to other inference processes in specific situations, which in turn could lead to more applications.

12.4.2 Practical Implications

In terms of practical implications, an increased understanding of current practices, inconsistencies between homebuyers and agents and relevant property evaluation criteria has the potential to benefit a number of stakeholders in the real estate industry. First, considering the homebuyers, the findings increase transparency in this complex decision environment. In particular, the establishment of a complete list of relevant factors serves as a form of check-list, reminding individuals to consciously examine more criteria when viewing or comparing properties. Additionally, the detailed hierarchical representation of the real estate selection problem can promote more focused decision making and help articulate preferences (Ball & Srinivasan, 1994). This alone has the potential to increase decision confidence and satisfaction, whist simultaneously reducing the possibility of negative post-purchase surprises. In other words, it attempts to minimise risk and DMs have more grounds on justifying their actions (Kasanen, et al., 2000).

From another perspective, real estate agents can greatly benefit from the comparisons made between them and their clients. Misunderstandings and frustrations can be avoided by adjusting marketing, communication and viewing strategies pursuant to the research

findings. This was also previously suggested by Levy and Lee (2004), implying greater understanding of decision roles and influence levels allows more effective service. Subsequently, with increased satisfaction, a change in the Majorquin real estate industry may be triggered by means of strengthening the loyalty to a single agency. At the same time, commissioning only one agency can increase sales and/or accelerate the search process for DMs, providing an opportunity for positive monetary implications. Respectively, Anglin (1997) provided evidence that an agent who understands and actively considers clients' preferences, is more likely to sell a house after fewer property inspections.

Less investigated stakeholders, such as real estate developers and investors might also benefit by gaining valuable insight into key factors considered in a property assessment process. Real estate developers, for instance, can pay more attention to relevant criteria when planning a new project in order to meet consumers' needs with the supplied properties. Similarly, the investors should consider the highly important criteria when purchasing properties to increase the probability of demand from either tenants or buyers.

12.5 Generalisability of Research Findings

The construction of the problem-structuring framework did not involve data collection as such, but rather relied on literature of MCDM problem characteristics and data collection methodologies. Therefore, it is proposed it can find wide adoption in the described context. More precisely, this guide can be generalised to decision problems that include observable, consumer, high-involvement purchasing activities, such as the real estate selection presented herein. However, the developed framework foremost aims to define a complex MCDM problem in order to match or build a suitable decision support mechanism. As previously highlighted, the multiple data collection stages associated with the proposed framework may reduce practical applicability to researchers who have extensive time and resources available.

In terms of generalising the data obtained from the surveys, as previously mentioned, the distribution of nationalities in the dataset may not be representative of the luxury-homebuyer population in Majorca, yet certainly other characteristics and insights can be related to the studied consumer segment. For instance, the observed marital status of the 180 respondents was clear-cut (99%), assuming such a decision task is generally attended by a couple. Similarly, the evidence (91%) allows speculating that the majority of luxury-homebuyers have children. Furthermore, the individuals within the population are presumably experienced in the property purchase process, with the entire sample having bought real estate at an earlier time. These facts, among many others, may be valuable to real estate agencies to update or enhance their understanding of their clientele in Majorca.

Next, establishing the modified ER inference model on data exclusively collected in Majorca limits the applicability in other regions. It is anticipated that different criteria are relevant in other locations, countries and across cultures. However, as previously highlighted by the

international real estate agency Engel&Völker, there are regions primarily focused on the holiday home or secondary residency segment and, at the same time, almost excessively targeting foreign, high-net-worth individuals. These regions, including Ibiza, Menorca, Costa Esmeralda, Cap Ferrat and South of France, potentially come close to the requirements identified for luxury real estate in Majorca (Engel&Völker, 2015b) and would potentially only require slight adaptations to the model structure. Also evident in this context, some of the 144 criteria used to estimate property performance are clearly not applicable to other real estate types such as apartments or plots. In general, whilst the concept is applicable and realisable in practically all locations and with different types of real estate, the list of criteria and models presented in this research are very specific for the Majorquin market.

12.6 Research Limitations

Complementary to the previous section that already pointed towards the model's generalisability shortcomings, the research did not come without challenges and limitations.

To begin with, one drawback may relate to the equal treatment of prospective buyers who have already viewed properties to those that were in the early stages of the process. Here, further advanced individuals may have different views on criteria relevance as they are said to be emergent. However, this limitation was somewhat mitigated, considering all participants had previously purchased a property and accordingly could not be regarded as totally unexperienced buyers.

Reviewing the qualitative data analysis, as previously highlighted, the interviews were conducted in German and English, creating difficulties with respect to the transcription language. There are no real indications which method is optimal, either direct translation or meaning translation. For this particular case, many typical German sayings made it difficult to use the former option. Yet, whenever possible, the researcher stuck to the original words used by the interviewees. Only occasionally some meaning condensation was applied, which basically extracts meaning from a statement and reproduces a shorter sentence or concept that expresses the essence. Furthermore, it was relatively hard to categorise interview sections into defined codes, many overlapped and it was hard to stay consistent. Here, the researcher made two attempts. First, a coding scheme that was believed to be appropriate was used to allocate sentences. However, this technique was rather problematic and did not seem to arrive at any valuable results. One should always bear in mind that a prior template is tentative, hence subject to change. In the second attempt, the researcher eliminated the idea of a pre-existing index and looked at sections individually. Herein, it was decided what code could be created to fit that information. Helpful was to underline key words within the section to determine the right category. Of course, once initial codes were identified, one had these in mind when continuing to code, trying to match information instead of creating a large number of categories. Moreover, it must be acknowledged that the coding scheme or template is often entirely based on the interpretation of the researcher and allows room for bias. This last point has been noted as one of the main disadvantages

of using qualitative techniques in research studies. To mitigate this issue, the interpretation of the interview data was validated with three real estate agents that participated in the study, whilst also presenting the findings to three industry professionals in the subsequent data collection phase (section 10.3). Adopting this strategy of checking the accuracy and consistency of the final interpretations intended to establish greater validity (Creswell, 2003).

Potentially the most concerning issue arose during dataset construction. More precisely, as a limited number of survey participants agreed to rate individual properties, they often did not share the same indispensable requirements, such as budget, number of bedrooms or preferred view, among others. Therefore, the dataset included 41 properties that were not pre-filtered on key criteria. In other words, the selection was not tailored to the DMs, and the dataset, in some cases, included alternatives that would have been disregarded immediately on the basis of not meeting minimum standards. As a result, and as expected, a fair proportion of the alternatives performed average or poorly across the sample. It is acknowledged that it is more beneficial to construct a model with more relevant alternatives for a group of homebuyers in terms of having the same criteria constraints and potentially share key demographic characteristics and/or preferences. Nonetheless, this condition could not be met in the presented investigation due to limited sample size and restricted access to property information. In relation to this, another limitation describes the availability of housing information, restricting the size of the dataset used for training the ER models. In reality, it is unlikely property owners in the near future would provide more extensive information on their offering. Even if sellers and agents would co-operate and provide more detailed descriptions of individual properties, the objectivity in assessing qualitative variables and, sometimes, the reliability when recording quantitative values might be questionable.

Finally, utility information for criteria value ranges was not enquired. This meant that a linear utility function was assumed for the different intervals, for instance privacy level defined by low, medium and high. Yet, clearly in some situations the distance in terms of utilities between low and medium or medium and high are not perceived equal. For the future this may be investigated in relation to the list of criteria in order to incorporate important distinctions. On the other hand, with the discretisation exercise, the linearity assumption was taken into account so that most appropriate groupings were created from the start.

12.7 Further Research

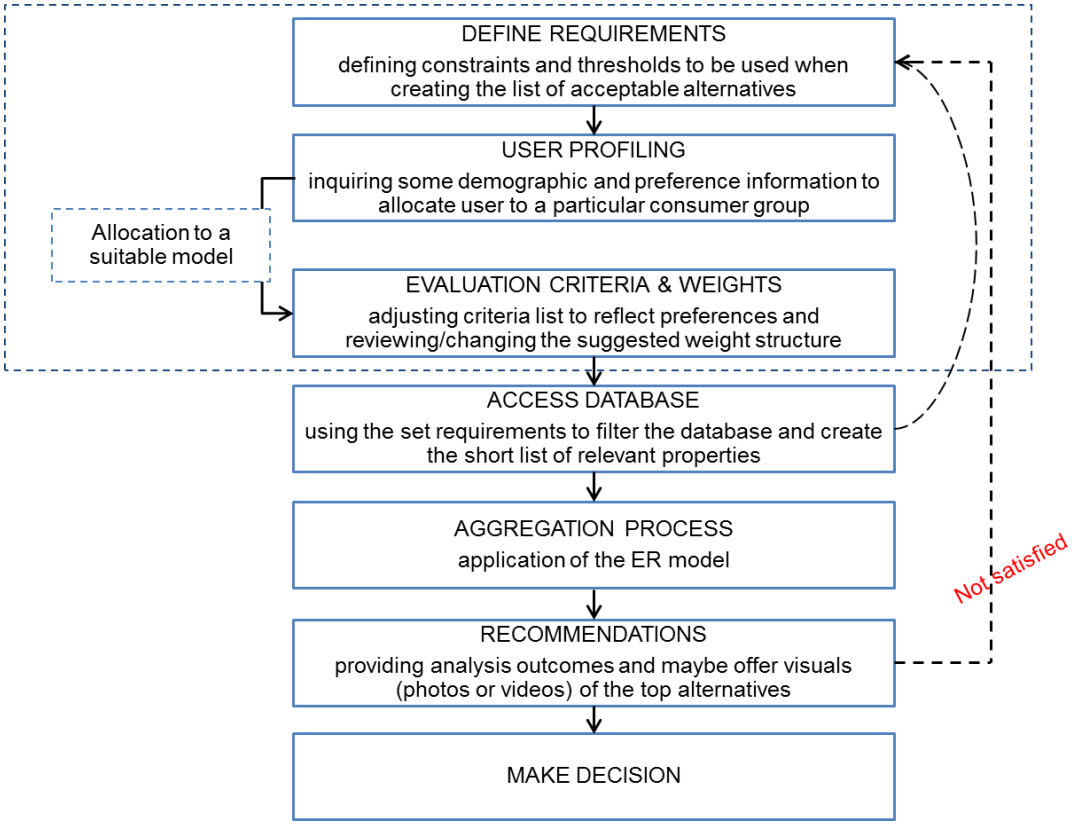
Some suggestions for further research were previously made, yet it is worth emphasising possible areas that deserve more attention.

To strengthen the validity of the MCDM problem-structuring framework, it should be adopted to define a different high-involvement product selection problem. The aim is to show the successful extraction of relevant information in complex multi-criteria decision problems to match or build a suitable support model for the assessment of alternatives.

Alternatively, research could focus on clustering luxury real estate buyers into suitable groups to provide the basis for constructing large datasets for different profiles. With more data, in terms of appropriate consumer clusters and property alternatives, the models presented in this research can be trained on a vast amount of information and subsequently offer the opportunity to make predictions for new customers and new alternatives. Similarly, the research could be replicated in locations sharing similar conditions to Majorca. This could further strengthen the adopted criteria structure.

Finally, whilst this research did not result in a straightforward usable decision support model for homebuyers, there is clearly the potential to develop this in the future. The models presented herein show the applicability of the ER rule in this field and its potential to derive valuable recommendations. Hence, research could be devoted to developing a DSS in accordance with the requirements identified in co-operation with the homebuyers. A potential DSS framework could include the steps in Figure 36.

Figure 36, Possible Real Estate DSS Framework



Briefly explaining the flow chart, first homebuyers should be able to specify key requirements to later create a viable list of alternatives to be analysed in detail. Then, the DM should simply provide some demographic or key criteria preference information to generate the user profile, and if the system offers multiple models, each specifically trained for a particular consumer group, match the generated profile to the most appropriate model. Whilst the system can then simply use the weights that are in accordance to this particular group, the DM should also have the opportunity to make adjustments where necessary.

Filtering an available database of properties in accordance to the requirements provides the basis for the analysis and aggregation of the pieces of evidence. Noteworthy here, there is an ongoing debate about when preference are formed, and whether the process itself influences the perception of DMs' towards previous defined prioritisations (Stewart, 1992). Therefore it is necessary to provide the DM with an option to revise certain specifications again. As a result of the evidence aggregating, the DSS should encourage further data analysis in a specific direction, or provide the DM with a recommendation towards a particular action. In some situations, the DM may not be able to articulate his/her preferences precisely at the start of the process, leading to unsatisfying outcomes. This would require a second review of requirements, evaluation criteria and preference information (Ball & Srinivasan, 1994; Guitouni & Martel, 1998).

Whilst there probably are many more research topics that can be derived from the current research, these appeared to be among the most eminent and interesting opportunities.

Appendices

Appendix A – DS Theory Example

Example taken from Yang and Xu (2013):
Suppose there are two pieces of evidence profiled with the following BDs:

$$e_1 = \{(A, 0.99), (B, 0.01)\} \quad \text{and} \quad e_2 = \{(B, 0.01), (C, 0.99)\}$$

Including the weights:

$$m_1 = \{\big(A, 0.99(1-\gamma)\big), \big(B, 0.01(1-\gamma)\big), (\{A, B, C\}, \gamma)\}$$
$$m_2 = \{\big(B, 0.01(1-\gamma)\big), (C, 0.99(1-\gamma)), (\{A, B, C\}, \gamma)\}$$

Where γ is a small weight such as $\gamma = 0.05$. Using Dempster's rule to aggregate the two pieces of evidence, the following combined BD will result:

$$m = \{(A, 0.4819)(B, 0.0107), (C, 0.4819), (\{A, B, C\}, 0.0256)\}$$

This result shows even if two pieces of evidence are combined that have no ignorance at all will still yield 0.0256 global ignorance allocated to the frame of discernment Θ. In any case where $\gamma > 0$, similar conclusions are drawn. Hence, Dempster's rule will always result in imprecise results where the combined belief degree of $\{A, B, C\}$ will always be positive.

Appendix B – Price Difference across Agencies

Example 1

Source: FirstMallorca (2015a) and Minkner (2015)

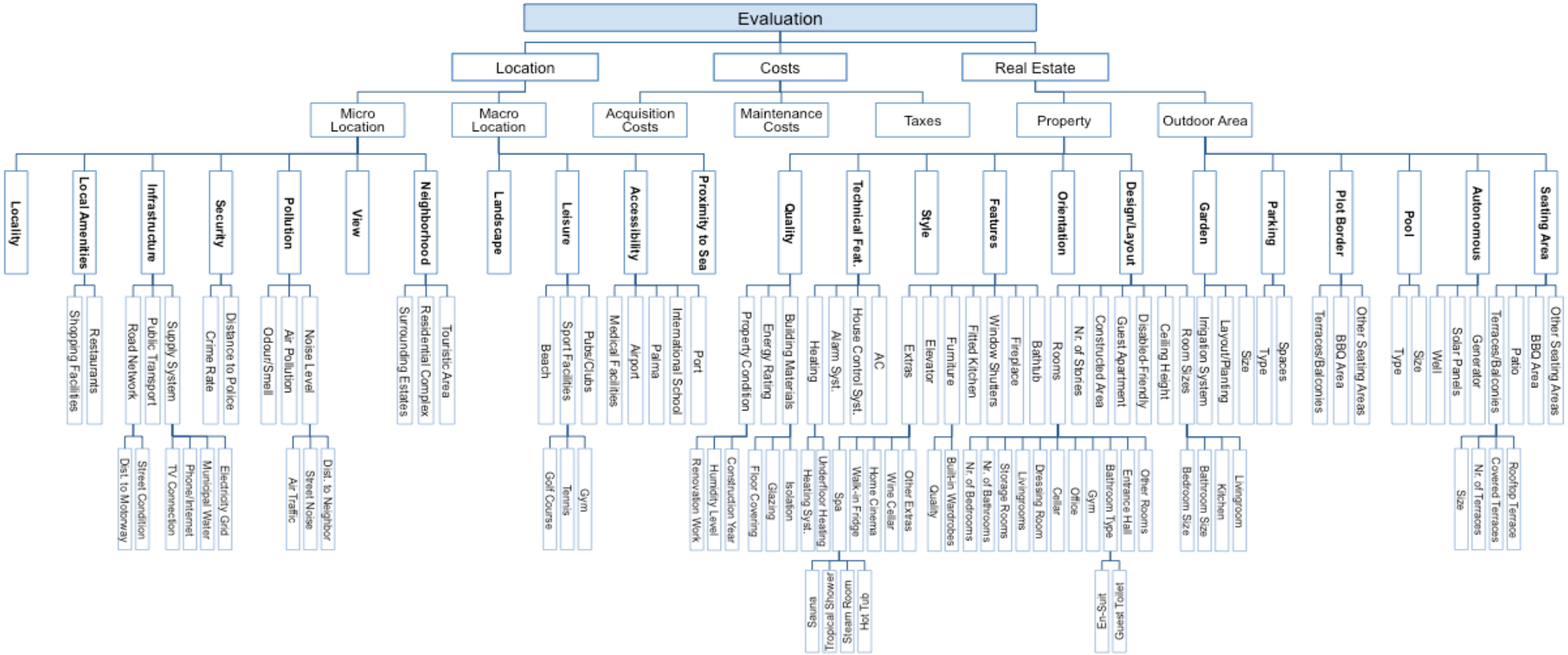
Example 2

Source: Kühn&Partner (2015), Engel&Völker (2015a) and FinestProperties (2015)

Appendix C – Pilot Study Findings

Participant		Agent 1	Agent 2	Agent 3	Agent 4	Agent 5	Summary
Category	Question						
Definition	Luxury property	1.2≤ mil. Euro	1.0≤ mil. Euro	1.2≤ mil. Euro	1.2≤ mil. Euro	1.5≤ mil. Euro	/
Client profile	German	X	X	X	X		80%
	British	X		X	X	X	80%
	Swedish	X		X		X	60%
	National differences	Some	None	Some	None	None	/
Decision makers	Couples	X	X	X	X	X	100%
	Highest influence	Female	Female	Female	Equal	Female	/
	Singles	X				X	40%
Other stakeholders with influence	Friends	X		X	X		100%
	Appraisers		X	X	X		60%
	Lawyers				X		20%
	Agents	X	X	X	X		80%
Criteria	Nr. of relevant criteria	5-7	10	8-9	3-4	5-6	/
	Location	X	X	X	X	X	100%
	Price	X	X	X	X	X	100%
	View	X	X	X		X	80%
	Layout		X				20%
	Size		X	X		X	60%
Constraint criteria	Specific location	X	X	X	X	X	100%
	Price range	X	X	X	X	X	100%
	Nr. of bedrooms	X	X	X	X	X	100%
Selection method	Non-compensatory	X	X	X	X	X	100%
	Agent's experience	X	X	X	X	X	100%
Viewings	Number	9-12	10	12+	10-15	12-15	/
Sales	Transaction rate	25%	25-30%	20-30%	30%	40%	/
Reasons for no purchase	No money	X		X	X		60%
	Confusion			X	X	X	60%
	No suitable property	X	X				40%
	Agency competition	X		X	X	X	80%
Decision aid	No existing aid	X	X	X	X	X	100%
	Demand for aid	Probably	Yes	Yes	Don't know	Probably	/

Appendix D – Property Assessment Framework, Hierarchical Structure



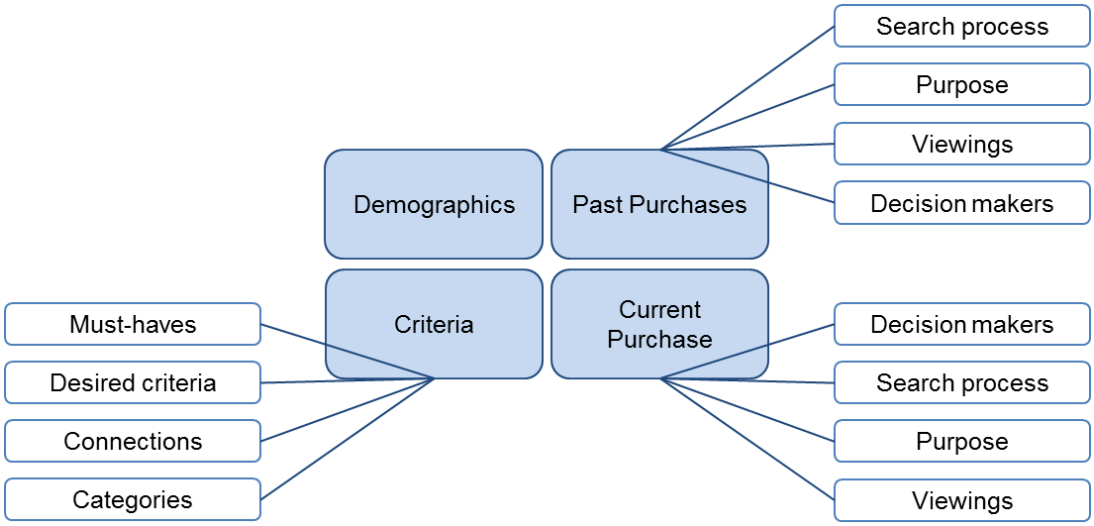
Appendix E – Qualtrics Homebuyer Survey

Available from the author upon request (Dominique.tiesmeier@postgrad.manchester.ac.uk) .

Appendix F – Qualtrics Agent Survey

Available from the author upon request (Dominique.tiesmeier@postgrad.manchester.ac.uk) .

Appendix G – Homebuyer Interviews' Coding Template



Appendix H – Thematic Analysis Example

Coding Scheme

Characteristics	Past Purchases	Current Purchase	Criteria
Demographics	Search process	Decision makers	Must-haves
	Purpose	External influences	Desired criteria
	Viewings	Search process	Relationships
	Decision makers	Purpose	Categories
	External influences	Agencies	Deviations
	Satisfaction	Viewings	Areas of interest
	Search duration	Majorca	

First of all, could you provide some background information about yourself?
I am a 50-year-old gentleman; self-employed, professional doctor and I have been working in cosmetic medicine for 20 years.
Are you married?
Married, 3 children.
Nationality?
British.
British. You said you are a doctor, are you, you work in England? Where?
I work in England and I am coming back to Majorca, just open a clinic in Majorca, so I am going to be working both in England and in Majorca.
You said you have 3 children, could you tell me something about them?
Yes, they are a pain in the ass. No. Delete. My oldest daughter is 24, she currently works in London, working for a fashion company. My younger daughter is 22, she recently completed her degree in Marketing and Business and is currently taking a year out and is in Australia and then my son, who is 16 is doing his GCSEs this year.
Alright.

Are you familiar with Majorca?
Yes.
Yes.

Do you permanently life here?
No, currently in London and we have a house here, which we come back to and so I come back every 2 weeks, but we are planning to come back and be based here in Majorca again next year.
Alright.

So you just answered my next question, do you already own a property. Yes you do.
We do.
But do you life in this property?
No, we rent the property out at the moment with a view to selling, and we are looking to downsize, which is one of the things we want to do and so I am currently looking for another property now.
Alright.

How many properties do you currently own in the whole world, and where?
Only the one.
Yes.
Here in Majorca. And we rent a property in the UK.
OK.

Could you tell me roughly how many houses or properties or plots you have bought in your whole live?
In my whole live, starting from when I bought my first flat, I would say, work through my head quickly, 1, 2, 3, 4, 5, 6, 7, this will be my 8th.
OK. Alright.

And regarding the last property you bought, can you describe your previous search experience. In other words, did you leave most of the things to the real estate agent or did you do your own research or how…

In the last property it was primarily, we have with all our properties, we have been quiet sure about what we wanted.
Yes.
So we have given the estate agent our requirements and been pretty rigid on those. Inflexible. We know what we wanted and we asked them to find something of that type.
Yes.

And what was the motive the last time you bought the house?
Last time we bought a house, the main reasons for buying it, one was size, number of bedrooms.
Yes.
And two was location.
But it was for you to live in or for an investment…
To live in.
To live in.
We have always bought to live in, but also with a view that they are an investment as well.
Of course, yes.

Can different stages be identified in the purchasing process? So for example you first, the first step is of course the identification of the need that you want a house, to buy a house and the last is to decide which house you want to buy. In between, what do you think happens?
In between deciding that we want to buy something and finding. I think the most important thing for us is to, firstly for me is that my wife is happy.
Yes.
First and foremost, there is no point if she doesn't like it, I have, we have very definite requirements for my wife. So outside of that then it is possible for me to add my requirements on top of this. So primarily kitchen, bedrooms, bathrooms, and I would say probably size of the local or plot is the least important.
Yes. OK.

And last time, how long did it take, how long did it take for you to decide to buy a property until you found the property?
OK. The house we now own, we built so I am excluding that. I am going to give you 2 extremes if I may.
Yes.
Because the house before that, that we bought, it took me 30 minutes.
Oh, wow.
So it was a case of, I went into an estate agent with my requirements, they happen to have one property, which fitted that. I basically went to have a look at it within 10 minutes, decided that I thought that this would meet my wife's requirements. I picked my wife up from the airport and we drove there on the way to the flat, and I said if you like it, you can have it. And so yes, that was 30 minutes. That was the house in Bendinat.
Oh, yes. OK.
So that one is very different. The one before that took me I would say 4 weeks.
4 weeks, OK. Yes.
Yes.

Did you view multiple houses prior to buying a house? Like with the 30 minutes probably not…
With the 30 minutes, no. With the house before that, probably only 3 or 4 houses, because we were able to, what we tend to do is highlight what we want, highlight the area we want, drive around the area, I mean there are things, about roads that we don't like, so that we can exclude these from the list, because we know that any estate agent will give you everything that fits your price bracket and your requirement in an area.
Yes.
And sometimes outside that area they are trying to convince you to look. So we were quiet explicit so we would be able to go in and say no, no, no, no, yes, no, yes, yes, those 3 or 4.
Yes, that is good.
So we probably view a few because it is a waste of time…
Exactly to view.
…for you, for the estate agent, for the client, for the people who's house it is, everybody, so we are very …

OK, so, but you used real estate agents. So do you believe they have a strategy regarding the sequence of the houses they show you?
Estate agents, some. Yes, not all.
Yes, OK.

And who was involved in your decision making process last time?
The wife.
Yes.
You know. The boss.
Yes.

Did you consult any external sources ***like, I don't know, a lawyer or …***
No.
No.

Is there something that you would do differently now?
I think everybody is different, but whatever we have done, it is, I would do it the same way. It always worked, it works for me because it's, I have a very simple requirement if it fits my wife, then it makes my life easier…
A lot easier.
I can concentrate on my work and it makes it easier. So no.
OK.

So now focusing on the current decision.
Yes.
What is the objective, or motive buying a house here?
One is to return back here for lifestyle. Two I want to downsize, my property at the moment, which we built is really too big for our current requirements, mainly its going to be primarily just my wife and I here and hopefully the kids, when they come and visit or whatever, so the current house is too big. So therefore we have a lot of equity in it and I plan to take the equity out, invest that into another property, but smaller.
Yes.
In the areas that we know and to reinvest the remaining equity either again in property or in my current business.
Yes.

Do you include the requirements of your children ***in the decision?***
We take them into account.
Yes.
They would not be in all honesty, they won't be the highest, what should we say, they shouldn't, they won't be the most important.
Yes.
Firstly the wife, secondly … but equally we would always take their opinions and requirements to a degree. Yes.
OK.
I am not going to buy a one bedroom flat, in other words.
Of course.
There will always be space.
Space, OK.

Why do you use the service of a real estate agent?
I think out of a habit, partly. Two, the process they obviously know the processes in Spanish law etc. a lot. So it is a lot quicker, a lot easier. Two, a lot of the properties you don't know they are on the market.
Yes.
And that is the other thing, whereas in certain places and certain properties you'll see up for sale, a se vende sign whatever, a lot of them and ours in the past haven't had boards, so a lot of the properties you are unaware as to, so having your requirements, you can to a certain degree find out through the internet, looking at websites, but some of the other properties they are kept quiet private.
Yes.

And why did you choose this particular agency?

We have used and looked at agencies in the past, we have had a lot of dealings with various agents, some far more professional than others and this one in particular I've liked their staff, I've liked their professionalism, I've liked their flexibility, when we talk about fees…
Yes.
And the ability to come to a, some kind of an arrangement rather than sticking to a rigid percentage.
Yes, OK.
And sort of those really.
Alright, OK.

Do you believe the real estate agent has some kind of influence on your decision?
Honestly, no.
But do you value the opinion ***of the agent?***
No. To be honest as well, in Majorca there is, I am sure it is different in Germany, a real estate person in the UK is very often qualified, got a qualification, has been in property for 20, 30, 40 years.
Yes.
Whereas here on the island, I see them more as salesman. They are here very short, so really I just see them as being a link between my requirements and what's out there.
Yes.

Do you believe an agent helps you clarify your preferences by asking questions that you might not have thought of?
I think when we first bought a house maybe 20-25 years ago, yes. Now, no. I think we have been through the process a couple of times.
So total beginners would probably…
…more so.
Yes.

How long have you thought about buying a house prior to engaging now with an agent?
Probably, it is again very different here, because the need isn't eminent. Probably we have been thinking about it for the last 6 months to a year.
Yes.
In previous occasions were we decided we wanted to move to an area, much quicker. Maybe a day or two.
Yes, alright.

Have you conducted an Internet search before you came to the agent?
Yes.
Yes.

How serious is your desire to buy?
Committed.
Yes, committed.

So does a clear image exist of the future home***?***
Yes.
Yes.

Do you believe there are too many alternatives currently on the market?
Alternatives what I want?
Houses, yes.
I think the market, Majorca is very different and I think there is an awful lot of properties available. As alternatives to what I want or examples of what I want, I don't think we are quiet specific. It is a price bracket and a size of house that we are looking for is, there are various options but not too many.
Ok.

And what style of home do you have in mind?
I am looking for somewhere between 350-400 square meters.
OK, and Mediterranean or modern?
More modern.

More modern, OK.

Which criteria are used to first create a narrowed down list of alternatives? Like if you go to right move for example or something and click some…
Number of bedrooms, kitchen… I would say number of bedrooms, number of bathrooms, kitchen, pool…
The location as well?
Location, yes. We are quiet, we want one location. Maybe Santa Ponsa, Port Adriano, Nova Santa Ponsa, so yes, we know the area and yes then it is going to be kitchen size, number of bedrooms.
OK.

And may I ask, what is your price limit?
We are looking around about 2 Million.
Alright.

And how much over that amount would you be willing to go, if you find the house that is really appealing to you?
OK, if it is something my wife really wanted, I don't know… we would go to everything, probably we go up to 3 Million, maybe a bit more.
Wow, OK.

So once a list of alternatives exists, with the right price range, with the criteria like the number of bathrooms, whatever you just said, what criteria are now important, which are other must-haves or want-criteria?
Want, sea view would be nice, not for me its not that important, but I think when you looking for, there are two ways looking at this. So I have criteria for what is important to us and then I have criteria which I think would be advantageous when we come to sell, that other people would like.
Exactly, OK.
So those would be my second requirements. Quiet important, but not as important. So those criteria we know, people do like sea view, particularly newcomers to the island. So then sea view, size of plot, southwest facing for the sun, proximity to amenities such as port, shopping, etc., so those and schools.
Yes alright.
Because those are things I think particularly down here then when you are coming are the things that are going to be most important.
Yes.

What is the one thing that you would absolutely not give up, and why?
When searching?
No on your house. In your future house.
In the future house. Its got to be, it would be size of rooms. Got to be big rooms.
Yes, OK.
Can't be doing, can't have small rooms.

And what do you pay most attention to during a house viewing? What you may be not see on an image or a picture?
Feel.
Fell, yes.

What is your favourite room or area in a house?
In a house?
Yes in a house.
I think kitchen and living.
Yes.

From the criteria that you have mentioned, are there any connections between the criteria? So, I give you an example, for example the plot size, if that increases, so does the level of privacy. Is there anything else that you would say has a connection?
For me, outdoor living. Terrace. Outdoor, terrace size. So bigger the plot, better terraces.

Can you also define some overriding categories in which criteria can be grouped as sub-criteria or, how can I say it, may be can you cluster a number of criteria in specific groups? For example, location specific criteria, closeness to amenities you can put in that group or maybe how far it is away from the airport or something like that. Can you name other categories?
Schools, I think I mentioned. I think from a point of view what I want from location categorising, I think as we said earlier, when we look at it from where I want to live, no I think the island is not particularly big, we like being down in the southwest. We like it here. We like, as you said, the proximity to good restaurants, proximity to Palma. It is a balance between being close to Palma but we are not in Palma, we are away from Palma. We are close to the port, but we are not in the port. Those such things, I like to be, should we say, in striking distance of port, Palma, airport, amenities, you know simple things, shopping.
And these are all clustered under the name location?
Location, yes. So my location would be, is that. So from the point of view again for selling, I could add location, but I would add in things like proximity to schools. So, location and privacy.
Are there other categories, for examples costs. You can also have some sub-criteria to that, the price is included, right? Then the maintenance costs maybe renovation costs. So there are different categories where you can put different criteria into those groups. Are there other groups?
For me? No.
OK.

In your opinion, how many properties are optimal to view? Or ideal?
Ideal…optimal… It is difficult. If you are very, I think for me, its been if you are rigid on what your requirements are, then it is fewer. I think if you are more flexible, I think there is no optimal figure. Although I would say I don't like viewing anymore than 2 or 3 at one time.
Yes.
Because I think it, I think you can, how should I say, you can be… not swayed, but your requirements, your needs can be watered down by, if you see a lot of different things in different places, your chance for me, your chance of finding, its like a woman, OK, every woman is different. So if you know what you like in a lady, or if you know what you like in a man, if you start seeing all different things, you can start saying oh I like that about him or I like that about her, and I like that, and then all these finding the ideal thing after that is very hard. So I think for me, once you are very rigid on, I am very, I am quiet element on what we look at before we go. For me most the work is done.
OK.

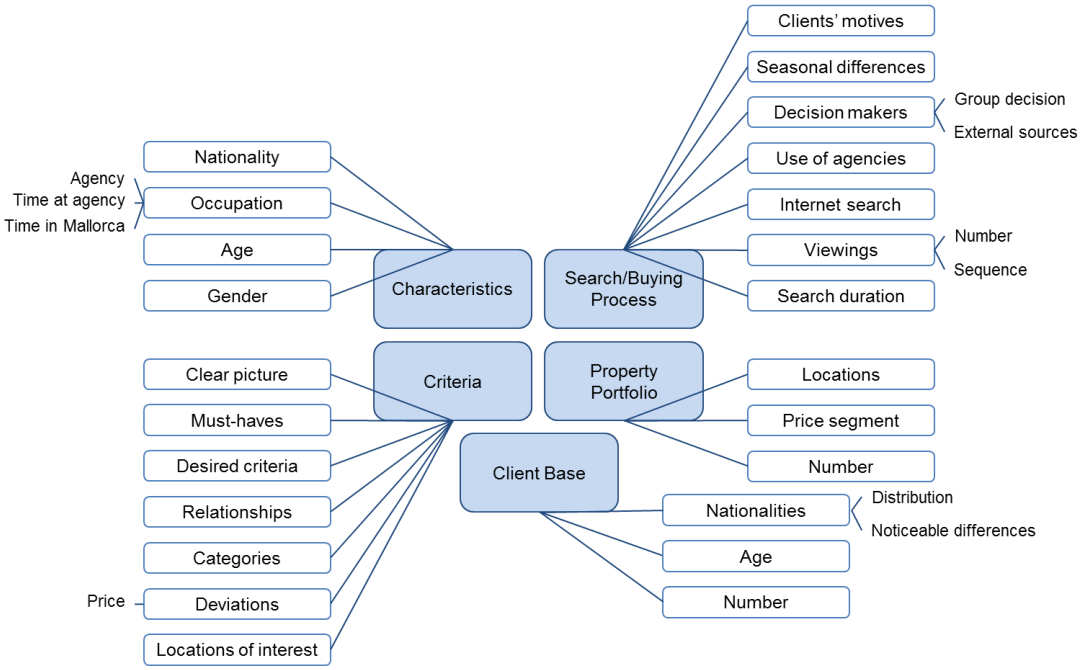
And do you have a specific date in mind? How soon would you like to buy? When is the last possible… because you said you are going to come back before summer or next summer…
Yes, but for me the issue is at the moment because it will be, we will sell the house first. So we dictate that by the house, if the house sold today, I'd buy tomorrow.
OK.
So there wouldn't be a big delay. So for me what dictates that is purely the house is currently rented, if it was sold.
But if you sell the house, and then start looking for a new one to buy, what if it takes quiet a long time to buy? Would you change your requirements?
No.
NO, you just wait and see and wait until you find something.
Yes.

And to finalise the interview, why Majorca and no other place? Why is Majorca special in your opinion?
For me it is not just the climate, it is the outdoor living, it's the proximity, it's the ease of travel to the major cities in Europe for work point of view. It's the quality of life. It is like nowhere else. You know it is not like mainland Spain, its got, it is Spanish, but its not. It has got an island feel, you can get off. I mean it is just different. It is a bit like… it is very difficult to say… you have everything, but it is not… how can I put this… everything is here, but you also need to be away from here. So it feels like home. Again when I said about, what is the first thing when I go into a house, what is the most important thing to me, its feel. I can't describe it, but it is a feeling. And it is the same here, we lived here for 10 years, we went

away, we had 4 different rental houses now back in London, back in the UK, and it doesn't feel right.
Yes.

OK, thank you very much.
That's alright.

Appendix I – Agent Interviews' Coding Scheme



Appendix J – Content Analysis of Evaluation Criteria

Criteria	TOTAL	Criteria	TOTAL	Criteria	TOTAL
AC	6	Garage	9	Price	18
Accessibility	4	Garden	12	Price per square meter	1
Air traffic	2	Generator	1	Price/quality ratio	1
Alarm system	1	Guest apartment	4	Privacy level	11
Any defects	1	Guest toilet	1	Property condition	1
Architecture	1	Gym	4	Property features	4
Atmosphere	1	Heating	7	Property fittings	4
Automated gardening	1	Heating system	4	Protected territory	1
Automated system	1	Home cinema	2	Proximity to sea	13
Balcony	1	Hot tub	1	Ready to move in	4
Bath tub	1	Individuality	2	Rehabilitation work	1
Bathrooms	4	Infrastructure of property	3	Renovating costs	5
BBQ area	2	Infrastructure of the location	5	Renovation work	12
Bedroom	1	Intelligent house control system	1	Repair work	1
Bedroom size	1	Interior	2	Return	1
Budget	3	Internet connection	1	Road distribution	1
Building complex	4	Irrigation system	1	Road traffic	1
Built-in wardrobes	1	Island region	1	Roof condition	1
Ceiling height	1	Isolation	3	Rooftop terrace	1
Cellar	2	Kindergarten	1	Room size	6
Certain roads	3	Kitchen	6	Rooms	1
Changeable construction	2	Kitchen size	2	Rough weather conditions	1
Childproof	1	Lake view	1	Running costs	3
Colours	1	Lawn	1	Rural area	1
Connections	1	Layout	3	Safety issues	1
Constructed area	18	Legal aspects	1	Sanitary facilities	1
Construction condition	1	Leisure activities	4	Sauna	3
Construction materials	3	Lifestyle	2	Schools	8
Construction quality	12	Light level	6	Sea access	1
Construction structure	1	Lighting system	1	Sea view	21
Costs	1	Living space	3	Security system	3
Covered terraces	7	Livingroom	1	Shutters	1
Crime rate	1	Location	22	Site boundary	1
Criteria important for resale	3	Lounge area	1	Solar energy	2
Distance to airport	8	Maintenance costs	10	Spa	2
Distance to beach	3	Maintenance work	3	Steam room	1
Distance to city centre	4	Moisture	5	Storage rooms	6
Distance to friends	2	Mold	4	Street condition	1
Distance to golf course	6	Motion sensors	1	Style	21
Distance to medical care	1	Mountain view	1	Sun exposure	1
Distance to motorway	2	Natural light	1	Supply system	2
Distance to neighbour	9	Neighbourhood	7	Surroundings	4
Distance to Palma	8	No garden	1	Taxes	1
Distance to police station	1	No renovation work	3	Technical features	4
Distance to port	3	Noise level	9	Technological standard	1
Distance to restaurants	7	Not first sea line	2	Terrace size	1
Distance to shopping	5	Not furnished	2	Terraces	10
Distance to sport facilities	5	Not tourist area	1	Tiling	1
Distance to supermarket	3	Nr. of bathrooms	3	Touristic area	1
Distance to tennis course	1	Nr. of bedrooms	19	Transaction costs	3
Distance to work	2	Nr. of stories	2	Transaction timeframe	1
Distances	5	Nr. of windows	1	Trees	2
Doors	1	Odour	1	Tropical shower	1
Double glazing	1	Office	1	TV connection	1
Dressing room	1	One level	3	Type	3
Driveway	1	Open to public	1	Underfloor heating	4
Electrical engineering	1	Open-plan kitchen	2	Unmodifiable	1
Electricity lines	1	Optic	2	Urbanisation	1
En-suit bathrooms	4	Orientation	7	View	16
Energy efficiency	1	Outdoor	3	Vineyard	1
Exclusive location	1	Outdoor design	1	Visibility to plot	3
Façade	3	Panicroom	1	Walk-in closet	1
Feeling	2	Panoramic view	2	Walk-in fridge	1
Fencing	1	Parking	1	Wall covering	1
Financing	4	Patio	1	Water pressure	1
Fireplace	5	Pets	1	Well	2
Fitted kitchen	1	Phone connection	2	Window size	3
Floor	2	Planting	2	Windows	4
Free space	1	Plot size	15	Wine cellar	1
Furnished	7	Pollution level	1	Year of construction	10
Furniture quality	1	Pool	20		
Future asking price	1	Population density	2		

Appendix K – Cleaned Criteria List

	Criteria		Criteria		Criteria		Criteria
	AC	ADDED	Extras		Nr. of stories		Spa
	Accessibility		Façade	ADDED	Nr. of terraces		Steam room
RENAMED	Acquisition costs	RENAMED	Features		Nr. of windows		Storage rooms
ADDED	Air pollution		Feeling		Odour / smell		Street condition
	Air traffic		Fencing		Office	ADDED	Street noise
	Alarm system		Financing		One level		Style
	Any defects		Fireplace		Open to public		Sun exposure
	Architecture		Fitted kitchen		Open-plan kitchen		Supply system
	Atmosphere		Floor covering		Optic		Surrounding Properties
	Automated gardening		Free space		Orientation		Taxes
	Automated system		Furnished	ADDED	Other Extras		Technical facilitis / installations
ADDED	Autonomous supply		Furniture quality	ADDED	Other rooms		Technological standard
	Balcony		Future asking price	ADDED	Other seating areas		Terrace size
	Bath tub		Garage		Outdoor		Terraces / Balconies
	Bathrooms		Garden		Outdoor design		Tiling
ADDED	Bathroom size	ADDED	Garden size		Panicroom		Touristic area
ADDED	Bathroom type		Generator		Panoramic view		Transaction costs
	BBQ area	RENAMED	Glazing		Parking		Transaction timeframe
	Bedrooms		Guest apartment	ADDED	Parking spaces		Trees
	Bedroom size		Guest toilet	RENAMED	Parking type		Tropical shower
	Budget		Gym		Patio		TV connection
	Building/residential complex		Heating		Pets		Type
	Built-in wardrobes		Heating system		Phone connection		Underfloor heating
	Ceiling height		Home cinema		Planting / layout		Unmodifiable
	Cellar		Hot tub	RENAMED	Plot boarder		Urbanisation
	Certain roads		Individuality		Plot size		View
	Changeable construction		Infrastructure of property		Pollution		Vineyard
	Childproof		Infrastructure of the location		Pool		Visibility to plot
	Colours		Intelligent house control system	ADDED	Pool size		Walk-in closet
	Connections		Interior	ADDED	Pool type		Walk-in fridge
	Constructed area		Internet / phone connection		Population density		Wall covering
	Construction condition		Irrigation system		Price		Water pressure
	Construction materials		Island region		Price per square meter		Well
	Construction quality		Isulation		Price/quality ratio		Window size
	Construction structure		Kindergarten		Privacy level		Windows
	Costs		Kitchen	RENAMED	Property		Wine cellar
	Covered terraces		Kitchen size		Property condition		Year of construction/renovation
	Crime rate		Lake view		Property features		
	Criteria important for resale	ADDED	Landscape		Property fittings		
ADDED	Disabled friendly		Lawn		Protected territory		
	Distance to airport		Layout / Design / Structure		Proximity to sea		
	Distance to beach		Legal aspects	ADDED	Public transporta		
	Distance to city centre		Leisure	RENAMED	Quality		
	Distance to friends		Lifestyle		Ready to move in		
	Distance to golf course		Light level	ADDED	Real Estate		
ADDED	Distance to gym		Lighting system		Rehabilitation work		
	Distance to medical care		Living space		Renovating costs		
	Distance to motorway		Livingrooms (nr)		Renovation work		
	Distance to neighbour	ADDED	Livingroom size		Repair work		
	Distance to Palma	ADDED	Local amenities	RENAMED	Restaurants		
ADDED	Distance to pubs/clubs	ADDED	Locality		Return		
	Distance to police station		Location		Road network		
	Distance to port		Lounge area		Road traffic		
	Distance to restaurants	ADDED	Macro Location		Roof condition		
	Distance to shopping		Maintenance costs		Rooftop terrace		
	Distance to sport facilities		Maintenance work		Room size		
	Distance to supermarkets	ADDED	Micro Location		Rooms		
	Distance to tennis course		Moisture / humidity level		Rough weather conditions		
	Distance to work		Mold		Running costs		
	Distances		Motion sensors		Rural area		
	Doors		Mountain view		Safety issues		
	Double glazing	ADDED	Municipal water supply		Sanitary facilities		
	Dressing room		Natural light		Sauna		
	Driveway		Neighbourhood		Schools		
RENAMED	Educational institutions		No garden		Sea access		
	Electrical engineering		No renovation work		Sea view		
	Electricity grid connection		Noise level	ADDED	Seating areas		
ADDED	Elevator		Not first sea line		Security		
	En-suit bathrooms		Not furnished	RENAMED	Shopping facilitites		
	Energy rating		Not tourist area		Shutters		
ADDED	Entrance / hall way		Nr. of bathrooms		Site boundary		
	Exclusivity of location		Nr. of bedrooms		Solar panels		

where the grey cells represent the deleted variables (some of which may have been renamed)

Appendix L – Literature Support of identified Criteria

Criteria	Literature support	Cited terms
AC	(Kim, et al., 2005)	Ventilation
Accessibility	(Pagourtzi, et al., 2003) (Kauko, 2006) (Torres, et al., 2013)	Accessibility
Acquisition costs	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Adair, et al., 1996) (Wolverton, 1997) (Kettani, et al., 1998) (Kethley, et al., 2002) (Daly, et al., 2003) (Mills & Reed, 2003) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Kaklauskas, et al., 2007) (Selim, 2009) (Larraz, 2011) (Haddad, et al., 2011)	Selling price; sale price; house price
Air pollution	(Ball & Srinivasan, 1994) (Limsombunchai, et al., 2004) (Kim, et al., 2005) (Fang & Yan, 2011)	Air pollution; air quality
Air traffic	(Ball & Srinivasan, 1994)	
Airport		
Alarm system	(Branigan & Brugha, 2013)	Alarm system
Autonomous supply system		
Bathroom size		
Bathroom type		
Bathtub		
BBQ area		
Bedroom size		
Built-in wardrobes		
Ceiling height	(Branigan & Brugha, 2013)	Ceiling height
Cellar	(Kettani, et al., 1998) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Larraz, 2011)	Basement
Constructed (living) area	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Adair, et al., 1996) (Kettani, et al., 1998) (Kethley, et al., 2002) (Mills & Reed, 2003) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Kauko, 2006) (Liu, et al., 2006) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Selim, 2009) (Haddad, et al., 2011) (Larraz, 2011) (Branigan & Brugha, 2013) (Torres, et al., 2013)	Constructed area; floor surface; size, house size; gross internal floor area; square footage of home; living area
Construction material	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Daly, et al., 2003)	Construction material; brick construction; condition of walls
Costs	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Mills & Reed, 2003) (Ratchatakulpat, et al., 2009)	Costs; cost of housing; financial characteristics
Covered terraces		
Crime rate	(Johnson, 2005) (Kauko, 2006) (Larraz, 2011) (Mulliner & Maliene, 2012)	Crime rate; robbery or assaults; personal safety
Disabled friendly		
Distance to beach	(Branigan & Brugha, 2013)	Distance to beach
Distance to motorway	(Mills & Reed, 2003) (Theriault, et al., 2003)	Proximity to major roads; travel time to nearest highway entrance
Distance to neighbour	(Ball & Srinivasan, 1994)	Distance to neighbour

Criteria	Literature support	Cited terms
Distance to police station		
Distance to pubs	(Branigan & Brugha, 2013)	Distance to pubs
Dressing room		
Educational institutions	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Mills & Reed, 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Johnson, 2005) (Kauko, 2006) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Fang & Yan, 2011) (Larraz, 2011) (Mulliner & Maliene, 2012) (Branigan & Brugha, 2013)	Educational institutions; nearby schools; school quality; proximity to schools; travel time to nearest school
Electricity grid connection	(Ball & Srinivasan, 1994) (Fang & Yan, 2011)	Electricity system; power supply situation
Elevator	(Selim, 2009) (Larraz, 2011)	Elevator
En-suite bathrooms		
Energy rating	(Mulliner & Maliene, 2012)	Energy rating
Entrance hall	(Adair, et al., 1996) (Haddad, et al., 2011)	Entrance hall; reception
Extras		
Features		
Fencing	(Ball & Srinivasan, 1994) (Kaklauskas, et al., 2007) (Branigan & Brugha, 2013)	Fencing; fence
Fireplace	(Kettani, et al., 1998) (Theriault, et al., 2003) (Pagourtzi, et al., 2003) (Limsombunchai, et al., 2004) (Branigan & Brugha, 2013)	Fireplace
Fitted kitchen	(Adair & McGreal, 1994)	Modern kitchen
Floor covering	(Selim, 2009)	Floor
Furniture	(Daly, et al., 2003) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Haddad, et al., 2011)	Furniture; internal decoration; interior décor
Furniture quality		
Garden	(Limsombunchai, et al., 2004) (Larraz, 2011)	Garden
Garden size	(Lindberg, et al., 1988) (Ball & Srinivasan, 1994) (Branigan & Brugha, 2013)	Garden size; outdoor space; usable space
Generator		
Glazing	(Kim, et al., 2005)	Glazing
Golf course		
Guest apartment		
Guest toilet	(Limsombunchai, et al., 2004) (Selim, 2009)	Toilet
Gym	(Torres, et al., 2013)	Gym
Heating	(Larraz, 2011)	Heating
Heating system	(Adair & McGreal, 1994) (Adair, et al., 1996) (Kaklauskas, et al., 2007) (Selim, 2009)	Heating system
Home cinema		
Hot tub	(Selim, 2009)	Jacuzzi
Infrastructure	(Ball & Srinivasan, 1994)	Quality of infrastructure
Insulation	(Kim, et al., 2005) (Kaklauskas, et al., 2007)	Insulation; thermal insulation
Intelligent house control		
Internet/phone	(Kaklauskas, et al., 2007) (Fang & Yan, 2011)	Internet; communication facility

Criteria	Literature support	Cited terms
Irrigation system		
Kitchen size	(Ball & Srinivasan, 1994)	Kitchen size
Landscape	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Kim, et al., 2005) (Kauko, 2006) (Ratchatakulpat, et al., 2009) (Selim, 2009)	Landscape; open space; density; distance to countryside/downtown; landscaping; locational characteristics
Layout	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Kim, et al., 2005) (Liu, et al., 2006) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Haddad, et al., 2011)	Layout; design; dwelling plan; design and appeal; aesthetics; floorplan
Leisure	(Ball & Srinivasan, 1994) (Mulliner & Maliene, 2012)	Leisure; entertainment
Livingroom size	(Ball & Srinivasan, 1994)	Livingroom size
Local Amenities	(Daly, et al., 2003) (Limsombunchai, et al., 2004) (Johnson, 2005) (Kim, et al., 2005) (Kauko, 2006) (Ratchatakulpat, et al., 2009)	Local amenities
Locality	(Kettani, et al., 1998) (Daly, et al., 2003) (Limsombunchai, et al., 2004) (Kauko, 2006)	Locality; municipality; sector identification; geographical locations
Location	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Adair, et al., 1996) (Daly, et al., 2003) (Mills & Reed, 2003) (Limsombunchai, et al., 2004) (Kim, et al., 2005) (Kauko, 2006) (Liu, et al., 2006) (Ratchatakulpat, et al., 2009) (Haddad, et al., 2011) (Mulliner & Maliene, 2012) (Branigan & Brugha, 2013)	Location; surroundings; site specific details
Macro location	(Mills & Reed, 2003) (Ratchatakulpat, et al., 2009)	General locality; distances
Maintenance costs	(Daly, et al., 2003) (Ratchatakulpat, et al., 2009)	Maintenance costs
Medical facilities (international)	(Johnson, 2005) (Fang & Yan, 2011) (Larraz, 2011) (Mulliner & Maliene, 2012)	Medical facilities; health services
Micro location	(Liu, et al., 2006)	Surrounding conditions
Moisture/humidity level	(Kim, et al., 2005)	Moisture
Municipal water	(Ball & Srinivasan, 1994) (Theriault, et al., 2003) (Selim, 2009) (Fang & Yan, 2011)	Linked to municipal water network; water supply and drainage; plumbing; water system
Neighbourhood	(Lindberg, et al., 1988) (Ball & Srinivasan, 1994) (Daly, et al., 2003) (Pagourtzi, et al., 2003) (Limsombunchai, et al., 2004) (Johnson, 2005) (Kauko, 2006) (Kaklauskas, et al., 2007) (Larraz, 2011) (Torres, et al., 2013)	Neighbourhood
Noise	(Lindberg, et al., 1988) (Ball & Srinivasan, 1994)(Kim, et al., 2005) (Kauko, 2006) (Larraz, 2011)	Noise; interior and exterior noise
Nr of bathrooms	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Adair, et al., 1996) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Ratchatakulpat, et al., 2009) (Larraz, 2011)	Number of bathrooms

Criteria	Literature support	Cited terms
Nr of bedrooms	(Adair & McGreal, 1994) (Adair, et al., 1996) (Limsombunchai, et al., 2004) (Ratchatakulpat, et al., 2009) (Larraz, 2011)	Number of bedrooms
Nr of livingrooms		
Nr of storage rooms		
Nr of terraces		
Number of stories		
Office		
Orientation	(Kim, et al., 2005)	Orientation
Other extras		
Other rooms		
Other seating areas		
Outside area	(Ball & Srinivasan, 1994) (Branigan & Brugha, 2013)	Outdoor description; exterior
Palma (cathedral)	(Lindberg, et al., 1988) (Mills & Reed, 2003)	Proximity to city; distance to downtown
Parking	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Adair, et al., 1996) (Daly, et al., 2003) (Limsombunchai, et al., 2004) (Branigan & Brugha, 2013)	Parking; parking facilities
Parking spaces	(Adair & McGreal, 1994) (Kim, et al., 2005) (Kaklauskas, et al., 2007)	Parking plan; garage spaces; nr of garages
Parking type	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Adair, et al., 1996) (Kettani, et al., 1998) (Daly, et al., 2003) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Ratchatakulpat, et al., 2009) (Selim, 2009) (Larraz, 2011)	Garages; onsite parking; attached shed
Patio area		
Planting/layout	(Ball & Srinivasan, 1994) (Adair, et al., 1996) (Daly, et al., 2003) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Branigan & Brugha, 2013)	Tree coverage; manageable garden; shape of garden; garden aspect; external decoration; lawn
Plot boarder		
Plot size	(Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Adair, et al., 1996) (Wolverton, 1997) (Kethley, et al., 2002) (Daly, et al., 2003) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Kauko, 2006) (Kaklauskas, et al., 2007)	Plot size; lot size
Pollution	(Kauko, 2006) (Kaklauskas, et al., 2007)	Pollution
Pool	(Theriault, et al., 2003) (Selim, 2009) (Larraz, 2011) (Torres, et al., 2013)	Pool; external pool
Pool size		
Pool type		
Port		
Privacy level	(Ball & Srinivasan, 1994) (Adair, et al., 1996) (Daly, et al., 2003) (Branigan & Brugha, 2013)	Privacy level; overlooked
Property	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Pagourtzi, et al., 2003) (Limsombunchai, et al., 2004) (Ratchatakulpat, et al., 2009)	Property; house description; physical attributes of dwelling unit; dwelling unit; interior;

Criteria	Literature support	Cited terms
	(Larraz, 2011) (Torres, et al., 2013)	house characteristics
Property condition	(Lindberg, et al., 1988) (Adair, et al., 1996) (Larraz, 2011) (Branigan & Brugha, 2013)	Property condition; adequate upkeep
Proximity to sea	(Kauko, 2006)	Seashore
Public transport	(Lindberg, et al., 1988) (Mills & Reed, 2003) (Limsombunchai, et al., 2004) (Johnson, 2005) (Kim, et al., 2005) (Kauko, 2006) (Ratchatakulpat, et al., 2009) (Fang & Yan, 2011) (Mulliner & Maliene, 2012) (Branigan & Brugha, 2013)	Public transport; proximity to public transport; transportation facilities; bus stop; distance from railway, bus stop
Quality	(Adair & McGreal, 1994) (Daly, et al., 2003) (Theriault, et al., 2003) (Kauko, 2006) (Liu, et al., 2006) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Mulliner & Maliene, 2012)	Quality; well built; general condition; condition of interior and exterior; construction quality; house quality
Real estate		
Renovation work	(Adair & McGreal, 1994) (Adair, et al., 1996) (Theriault, et al., 2003) (Branigan & Brugha, 2013)	Renovation work; modernisation repair needed; quality foundations
Residential complex		
Restaurants	(Branigan & Brugha, 2013)	
Road network	(Pagourtzi, et al., 2003) (Johnson, 2005) (Fang & Yan, 2011)	Road network; main road distribution; roads and mass transit routes
Rooftop terrace		
Room sizes	(Branigan & Brugha, 2013)	Room sizes
Rooms	(Ball & Srinivasan, 1994) (Kettani, et al., 1998) (Liu, et al., 2006)	Rooms; room count
Sauna	(Selim, 2009)	Sauna
Seating areas		
Security	(Ball & Srinivasan, 1994) (Kim, et al., 2005) (Ratchatakulpat, et al., 2009) (Fang & Yan, 2011) (Mulliner & Maliene, 2012) (Branigan & Brugha, 2013)	Security; safety; safe area; public safety
Shopping facilities	(Lindberg, et al., 1988) (Adair & McGreal, 1994) (Ball & Srinivasan, 1994) (Mills & Reed, 2003) (Theriault, et al., 2003) (Kauko, 2006) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Fang & Yan, 2011) (Haddad, et al., 2011) (Mulliner & Maliene, 2012) (Branigan & Brugha, 2013) (Torres, et al., 2013)	Shopping facilities; distance from commercial network; commercial infrastructure; commercial services; nearby shops; proximity to shops; shops; travel time to nearest local shopping centre
Size of terraces/balconies		
Smell		
Solar panels	(Kim, et al., 2005)	Solar panels
Spa		
Sport facilities		
Steam room		
Street condition	(Torres, et al., 2013)	State of front street
Street noise	(Ball & Srinivasan, 1994) (Adair, et al., 1996) (Ratchatakulpat, et al., 2009)	Street noise; traffic noise; auto traffic
Style	(Ball & Srinivasan, 1994) (Kaklauskas, et al., 2007) (Selim, 2009) (Branigan & Brugha, 2013)	Type of building; architectural design; external decoration; character

Criteria	Literature support	Cited terms
Supply system	(Ball & Srinivasan, 1994)	Systems
Surrounding properties	(Adair & McGreal, 1994) (Adair, et al., 1996) (Kaklauskas, et al., 2007) (Ratchatakulpat, et al., 2009) (Haddad, et al., 2011) (Branigan & Brugha, 2013)	Condition of neighbourhood; recent upgrades to other houses; neighbourhood condition; neighbours standard of living; other buildings; quality of neighbour houses
Taxes	(Pagourtzi, et al., 2003) (Haddad, et al., 2011) (Theriault, et al., 2003)	Taxes; local tax rate
Technical facilities		
Tennis club		
Terraces/Balconies	(Theriault, et al., 2003)	Veranda/balcony
Touristic area		
Tropical shower		
TV connection	(Selim, 2009)	Cable TV
Underfloor heating		
View	(Adair, et al., 1996) (Wolverton, 1997) (Kim, et al., 2005) (Ratchatakulpat, et al., 2009) (Haddad, et al., 2011) (Branigan & Brugha, 2013)	View
Walk-in fridge		
Well		
Window shutters		
Wine cellar		
Year of construction	(Adair & McGreal, 1994) (Adair, et al., 1996) (Kettani, et al., 1998) (Pagourtzi, et al., 2003) (Theriault, et al., 2003) (Limsombunchai, et al., 2004) (Kauko, 2006) (Kaklauskas, et al., 2007) (Selim, 2009) (Larraz, 2011)	Year of construction; age of the structure; age of dwelling; age; age of building

Appendix M – Criteria Measures and Descriptions

Criteria						Type		Unit	Description
1	2	Level 3	Level 4	Level 5	Level 6	Qual. vs. Quant.			
Location	Micro location	*Locality*					*Nominal*	*Categories*	*Area/the locality name where the property is located*
		View					Nominal	Categories	Main view/panorama from the living area
		Proximity to sea					Nominal	Categories	Location from the property in relation to the sea, e.g. 1st line, 2nd line
		Neighbour-hood	Surrounding properties				Nominal	Categories	Building quality of surrounding properties
			Touristic area				Nominal	Categories	Immediate surrounding area, touristic attractions, hotels, etc.
			Residential complex				*Nominal*	*Binary*	*Multiple houses within one complex, usually with fencing*
		Security	Crime rate				Ordinal	3-point scale	Reputation of the area for break ins or other crimes
			Distance to police				Continuous	Minutes	Approx. time needed to get from the station to the property
		Pollution	Noise	Air traffic			Ordinal	3-point scale	Flight path (distance from the ground) and frequency
				Street noise			Ordinal	3-point scale	Distance to busy road and noise level from cars
				Distance to neighbour			Continuous	Meters	Distance from property wall to closest neighbour's house
			Air pollution				Ordinal	3-point scale	Smog levels and frequency
			Smell				Nominal	Categories	Odour and frequency
		Local amenities	Shopping facilities				Ordinal	3-point scale	Supermarkets or convenience stores within 15 min. walk
			Restaurants				Ordinal	3-point scale	Restaurants within 5 min. drive
		Infrastructure	Supply system	Internet/phone			Nominal	Binary	Already existing internet/phone connection
				TV connection			Nominal	Binary	TV reception
				Municipal water			Nominal	Binary	Connection to municipal water supply
				Electricity grid			Nominal	Binary	Connection to municipal electricity supply
			Public transport				Nominal	Binary	Bus stop/tram/train station within 10 min walk
			Road network	Distance to motorway			Continuous	Kilometres	Distance from property to closest slip road

Criteria						Type	Unit	Description
				Street condition		Nominal	Categories	Quality of street pavement
	Macro location	Landscape				Nominal	Categories	Density of population
		Accessibility	Int. medical facilities			Continuous	Minutes	Approx. time needed to get from the property to a doctor
			Airport			Continuous	Minutes	Approx. time needed to get from the property to the airport
			Palma			Continuous	Minutes	Approx. time needed to get from the property to Palma
			Int. education			Continuous	Minutes	Approx. time needed to get from the property to an int. school
			Port			Continuous	Minutes	Approx. time needed to get from the property to nearest port
		Leisure	Sport facilities	Tennis club		Continuous	Minutes	Approx. time needed to get from the property to a tennis club
				Gym		Continuous	Minutes	Approx. time needed to get from the property to nearest gym
				Golf course		Continuous	Minutes	Approx. time needed to get from the property to a golf course
			Distance to pubs			Continuous	Kilometres	Distance from property to nearest pub
			Distance to beach			Continuous	Kilometres	Distance from property to nearest beach
Real estate	Property	Style				Nominal	Categories	Design or construction shape of the property
		Orientation				Nominal	Categories	Compass direction the main living area is facing
		Layout/design	Constructed area			Continuous	Square meters	Gross living area
			Nr of stories			Discrete	Number	Levels within the property
			Disabled friendly			Nominal	Binary	Wheelchair accessible
			Ceiling height			Continuous	Meters	Distance between ceiling and floor
			Guest apartment			Nominal	Categories	Separate area for guests, with separate entrance or within the property
			Room sizes	Bedroom size		Continuous	Square meters	Floor area of master bedroom
				Bathroom size		Continuous	Square meters	Floor area of master bathroom
				Kitchen size		Continuous	Square meters	Floor area of kitchen excluding dining area
				Livingroom size		Continuous	Square meters	Floor area of livingroom
			Rooms	Nr. of bedrooms		Discrete	Number	Number of bedrooms (including any guest bedroom)
				Nr. of bathrooms		Discrete	Number	Number of bathrooms (including guest toiled)
				Nr. of		Discrete	Number	Number of separate livingrooms

Criteria					Type	Unit	Description
		livingrooms					
		Nr of storage rooms			Discrete	Number	Number of rooms to keep things in whilst there are not being used
		Dressing room			Discrete	Number	Number of adjacent rooms to bedroom for changing and storing clothes
		Entrance hall			Nominal	Binary	Room or space immediately inside the main door of the property
		Gym			Nominal	Binary	(Designated) room with equipment for exercising
		Office			Nominal	Binary	Room designated for a place of business
		Cellar			Nominal	Binary	Room under the ground floor of the property
		Bathroom type	En-suite		Discrete	Number	Bathrooms directly connected to a bedroom
			Guest toilet		Nominal	Binary	Lavatory with a sink close to livingroom primarily for guests
		Other rooms			*Nominal*	*Binary*	*Any additional rooms to the ones already mentioned, e.g. dining room*
	Technical facilities	Alarm system			Nominal	Binary	Device that makes a loud noise to warn of danger or an intruder
		Intelligent house control			Nominal	Binary	Computer/IT to control home appliances and features
		AC			Ordinal	3-point scale	System to control ventilation and temperature
		Heating	Heating system		Nominal	Categories	Method used to generate heat
			Underfloor heating		Nominal	Binary	Heating element embedded in the floor
	Quality	Property condition	Renovation work		Ordinal	3-point scale	Need to make changes to the building
			Year of construction		Discrete	Years	Number of years since completion of construction works
			Moisture		*Ordinal*	*3-point scale*	*Humidity level in a room without windows e.g. cellar, bathroom*
		Energy rating			Ordinal	6-point scale	Measure of how much energy supplied is used and how much is wasted
		Construction material	Floor covering		Nominal	Categories	Finish material applied over floor structures to provide a walking surface
			Glazing		Ordinal	3-point scale	Energy efficiency of glazing used for the property e.g. single, double
			Insulation		*Nominal*	*Binary*	*Cover to stop heat, sound or electricity escape or entering*
	Features	Elevator			Nominal	Binary	Device that moves up and down to transport people across stories
		Fireplace			Nominal	Binary	A place for a fire at the base of a chimney
		Fitted kitchen			Nominal	Binary	Kitchen fitted with units and appliances
		Window shutters			Nominal	Categories	Panels (roller blinds) fixed inside or outside a window to close
		Bathtub			Discrete	Number	Plastic, metal or ceramic container to take a bath, usually in the

Criteria						Type	Unit	Description
								bathroom
			Furniture	Quality		Nominal	Categories	Approx. age and value of furniture
				Built-in wardrobes		Nominal	Binary	Wardrobes fitted into the wall during construction
			Extras	Spa	Hot tub	Nominal	Binary	Large tub that can be filled with hot aerated water
					Sauna	Nominal	Binary	Room (usually wooden) that can be heated to a high temperature
					Tropical shower	Nominal	Binary	Large shower head on the ceiling, usually with multiple shower functions
					Steam room	*Nominal*	*Binary*	*Room with high temperature steam with high humidity*
				Wine cellar		Nominal	Binary	Room (usually under the ground floor) with wine storing shelves
				Home cinema		Nominal	Binary	Room with TV, video equipment, speakers and widescreen set
				Walk-in fridge		*Nominal*	*Binary*	*Refrigerated storage room*
				Other extras		*Nominal*	*Binary*	*Any additional extras that have not yet been included*
	Outside Area	Plot boarder	Fencing			Ordinal	3-point scale	Barrier around the property plot
			Plot size			Continuous	Square meters	Measured area (ground plan) of the land where the property is built on
			Privacy level			Ordinal	3-point scale	Degree to which the property is concealed from other people
		Parking	Nr of covered spaces			Discrete	Number	Indoor area for parking, i.e. garage
			Parking spaces			Discrete	Number	Total number of spaces in which a car can be parked on the premises
		Garden	Planting/layout			Nominal	Categories	Garden area design and planting
			Irrigation system			Nominal	Binary	Artificial application of water to maintain the garden healthy
			Garden size			Continuous	Square meters	Outside area excluding terraces and drive-way (generally grassed area)
		Pool	Type			Nominal	Categories	Concrete pool with mosaic tiled interior or plastic pool
			Size			Continuous	Square meters	Approx. length and width of the pool
		Autonomous supply system	Well			Nominal	Binary	Direct access to groundwater with a pump
			Solar panels			Nominal	Binary	Panels to absorb the sun’s rays as a source of energy
			Generator			Nominal	Binary	Dynamo or machine for converting mechanical energy into electricity
		Seating area	Terraces/ balconies	Rooftop terrace		Nominal	Binary	Terrace area on top of a flat roof
				Nr of terraces		Discrete	Number	Separate paved areas connected to the property plus balconies
				Size of terraces		Continuous	Square	Area of paved spaces connected to the property and balconies

Criteria						Type	Unit	Description
					■		meters	
				Covered terraces		Nominal	Binary	Porch covering the paved area that is connected to the property
			BBQ area			Nominal	Binary	Outside area with grill/designated space for BBQ
			Patio			Nominal	Binary	Outdoor area yet within the property, enclosed by walls and doors
			Other seating area			*Nominal*	*Binary*	*Other areas outside not yet mentioned, e.g. paved area around the pool*
Costs	Acquisition costs				■	Continuous	Euros	Price of acquiring the property
	Taxes				■	Continuous	Euros	Monthly sum of money demanded by government levied upon property
	Maintenance costs				■	Continuous	Euros	Monthly expenses to keep property and outdoor area in good condition

* Criteria type with blue square are quantitative

Appendix N – Categorisation of Qualitative Variables

Qualitative bottom level variables categorisations	Bin_1 (best)	Bin_2	Bin_3	Bin_4	Bin_5 (worst)
AC	Fully	Partially	None		
Air pollution	Low	Medium	High		
Air traffic	Never	Occasionally	Frequently		
Alarm system	*Yes*	*No*			
BBQ area	*Yes*	*No*			
Built-in wardrobes	*Yes*	*No*			
Cellar	*Yes*	*No*			
Covered terraces	*Yes*	*No*			
Crime rate	Low	Medium	High		
Disabled friendly	*Yes*	*No*			
Electricity grid connection	*Yes*	*No*			
Elevator	*Yes*	*No*			
Energy rating	A	B	C	D&E	F&G
Entrance hall	*Yes*	*No*			
Fencing	Fully	Partially	None		
Fireplace	*Yes*	*No*			
Fitted kitchen	*Yes*	*No*			
Floor covering	Marble/natural stone	Marble + wood	Wood	Tiles	
Furniture quality	High	Standard	Low	None	
Generator	*Yes*	*No*			
Glazing	Double	Single			
Guest apartment	Yes	Separate area	No		
Guest toilet	*Yes*	*No*			
Gym	*Yes*	*No*			
Heating system	Heatpump	Oil	Gas	Electric/AC	
Home cinema	*Yes*	*No*			
Hot tub	*Yes*	*No*			
Intelligent house control	*Yes*	*No*			
Internet	*Yes*	*No*			
Irrigation system	*Yes*	*No*			
Landscape	Rural	Urban			
Municipal water supply	*Yes*	*No*			
Office	*Yes*	*No*			
Orientation	South	S/W or S/E	West or East	N/W or N/E	N
Patio	*Yes*	*No*			
Planting layout	Lawn + palm trees	Lawn	Palm trees	Trees	
Pool type	Mosaic	Plastic	No pool		
Privacy level	High	Medium	Low		
Proximity to sea	1st line	2nd/3rd line	Within 2km	Within 5km	Far
Public transport	*Yes*	*No*			
Renovation work	None	Some	Major		
Restaurants	A wide variety	One or two	None		
Rooftop terrace	*Yes*	*No*			
Sauna	*Yes*	*No*			
Shopping facilities	High choice	Some	None		
Smell	Neutral	Sometimes unpleasant			
Solar panels	*Yes*	*No*			
Solar panels	*Yes*	*No*			
Street condition	Paved	Paved+holes	Unpaved		

Qualitative bottom level variables categorisations	Bin_1 (best)	Bin_2	Bin_3	Bin_4	Bin_5 (worst)
Street noise	Low	Medium	High		
Style	Majorquin	Mediterranean	Modern		
Surrounding properties	No close neighbours	High and normal-high	Normal	Low	
Touristic area	No	No (but in region yes)	Yes		
Tropical shower	*Yes*	*No*			
TV connection	*Yes*	*No*			
Underfloor heating	*Yes*	*No*			
View	Sea	Partial sea	Distant sea	Countryside	Garden
Well	*Yes*	*No*			
Window shutters	Yes (electric)	Yes (wooden)	None		
Wine cellar	*Yes*	*No*			

Appendix O – Descriptive Analysis of 180 Homebuyers' Criteria Weights

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. deviation	Variance
1	Location	15	100	81.39	85	17.862	319.033
1	Real estate	30	100	88.17	91	13.702	187.749
1	Costs	34	100	84.47	89.5	14.750	217.569
2 (costs)	Acquisition costs	15	100	86.30	91.5	16.341	267.016
2 (costs)	Maintenance costs	29	100	90.84	100	14.704	216.210
2 (costs)	Taxes	0	100	67.45	70	20.842	434.405
2 (location)	Macro location	0	100	63.12	64.5	24.827	616.398
2 (location)	Micro location	15	100	76.90	81	20.477	419.308
3 (macro)	Landscape	0	100	63.07	65.5	25.697	660.331
3 (macro)	Accessibility	4	100	71.97	79	23.787	565.831
3 (macro)	Leisure	0	100	60.19	62	28.886	834.422
4 (access.)	Medical facilities	0	100	49.61	50	34.770	1208.921
4 (access.)	Airport	0	100	57.91	61	28.039	786.198
4 (access.)	Palma	0	100	58.19	60	27.858	776.068
4 (access.)	Educational institutions	0	100	23.98	8.5	32.356	1046.905
4 (access.)	Ports	0	100	46.61	50	31.771	1009.367
4 (leisure)	Beach	0	100	63.24	68.5	28.025	785.401
4 (leisure)	Pubs	0	100	38.57	39	27.713	767.990
4 (leisure)	Sport facilities	0	100	52.72	53	31.540	994.763
3 (micro)	Infrastructure	0	100	57.48	59.5	28.403	806.743
3 (micro)	Security	0	100	70.27	78.5	25.771	664.163
3 (micro)	Local amenities	0	100	62.81	69	24.797	614.895
3 (micro)	View	0	100	80.48	86	21.366	456.486
3 (micro)	Proximity to sea	0	100	66.45	72.5	28.231	797.009
3 (micro)	Locality	0	100	58.74	68.5	31.451	989.188
3 (micro)	Pollution	0	100	77.74	82	23.047	531.163
3 (micro)	Neighbourhood	0	100	70.09	77.5	26.651	710.254
4 (infra.)	Public transport	0	100	23.25	15	26.487	701.541
4 (infra.)	Supply system	0	100	85.97	98	20.876	435.820
4 (infra.)	Road network	0	100	63.85	69.5	24.386	594.653
5 (supply syst)	Electricity grid	9	100	91.32	100	16.494	272.039
5 (supply syst)	Municipal water supply	0	100	87.39	100	21.034	442.418
5 (supply syst)	TV connection	0	100	66.71	73.5	32.919	1083.650
5 (supply syst)	Internet connection	0	100	87.11	100	22.412	502.296
5 (road netw.)	Distance to Motorway	4	100	62.53	64.5	19.881	395.245
5 (road netw.)	Street condition	0	100	50.82	50	25.923	671.994
4 (security)	Crime rate	9	100	79.42	90	23.484	551.508
4 (security)	Distance to police station	0	100	34.37	31	27.158	737.566
4 (pollution)	Noise level	0	100	89.01	98	17.338	300.609
4 (pollution)	Air pollution	0	100	80.83	90	22.805	520.073
4 (pollution)	Smell	0	100	85.06	95.5	21.010	441.421
5 (noise)	Air traffic	0	100	74.17	80	24.721	611.115
5 (noise)	Street noise	0	100	86.81	92	17.221	296.556
5 (noise)	Distance to neighbour	4	100	68.85	71.5	24.318	591.357
4 (local amen.)	Shopping facilities	0	100	63.51	66	25.206	635.324
4 (local amen.)	Restaurants	0	100	60.22	60	25.386	644.442
5 (neighbour.)	Surrounding properties	0	100	73.69	80	22.038	485.668
5 (neighbour.)	Residential complex	0	59	17.49	12.5	18.553	344.229
5 (neighbour.)	No touristic area	0	100	56.84	63.5	34.486	1189.298

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. deviation	Variance
2 (real estate)	Property	44	100	89.91	95	13.993	195.802
2 (real estate)	Outdoor area	30	100	88.73	95	15.121	228.632
3 (property)	Design/layout/structure	17	100	82.57	87	17.695	313.107
3 (property)	Quality	9	100	89.57	95	15.168	230.056
3 (property)	Orientation	9	100	79.90	84	21.014	441.599
3 (property)	Technical facilities	10	100	85.13	90	16.370	267.971
3 (property)	Features	0	100	66.63	70	24.155	583.485
3 (property)	Style	0	100	60.47	66.5	29.008	841.479
4 (design)	Constructed area	23	100	75.34	78.5	17.501	306.283
4 (design)	Room sizes	26	100	79.36	81	16.479	271.560
4 (design)	Rooms	9	100	81.91	87	18.998	360.935
4 (design)	Nr. of stories	0	100	35.24	32	30.334	920.141
4 (design)	Disabled friendly	0	100	22.68	6.5	30.682	941.380
4 (design)	Ceiling height	0	100	43.94	48	27.806	773.197
4 (design)	Guest apartment	0	100	44.64	49	29.128	848.432
5 (room sizes)	Bedroom size	0	100	73.04	79	22.355	499.752
5 (room sizes)	Livingroom size	0	100	79.07	84.5	21.374	456.867
5 (room sizes)	Bathroom size	0	100	66.04	69.5	23.009	529.417
5 (room sizes)	Kitchen size	0	100	63.86	65	21.970	482.690
5 (rooms)	Nr. of bedrooms	17	100	84.62	90	18.166	329.992
5 (rooms)	Nr. of bathrooms	16	100	71.68	74	19.746	389.916
5 (rooms)	Nr. of storage rooms	0	100	36.98	35.5	21.109	445.608
5 (rooms)	Nr. of livingrooms	0	60	11.08	8.5	12.052	145.239
5 (rooms)	Dressing room	0	100	46.12	48.5	28.341	803.203
5 (rooms)	Entrance hall	0	100	45.89	44	27.162	737.749
5 (rooms)	Gym	0	100	19.95	12	22.151	490.651
5 (rooms)	Office	0	100	38.37	29	33.692	1135.139
5 (rooms)	Other rooms	0	100	6.62	0	16.727	279.801
5 (rooms)	Cellar	0	90	21.80	15	22.237	494.463
5 (rooms)	Bathroom type	15	100	66.14	69.5	20.464	418.791
6 (bathroom)	En-suite	0	100	79.64	87	22.095	488.197
6 (bathroom)	Guest toilet	0	100	86.22	95.5	19.933	397.333
4 (quality)	Energy rating	0	100	64.72	71	26.742	715.120
4 (quality)	Building materials	0	100	81.60	86.5	19.551	382.230
4 (quality)	Property condition	12	100	87.94	94	16.856	284.120
5 (building m.)	Floor covering	4	100	63.50	66.5	24.819	615.983
5 (building m.)	Glazing	3	100	78.41	80	20.438	417.718
5 (building m.)	Insulation	11	100	77.18	80	21.305	453.905
5 (property c.)	Renovation work	0	100	76.81	87	26.894	723.286
5 (property c.)	Year of construction	0	100	57.85	62.5	30.742	945.056
5 (property c.)	Humidity level	5	100	75.55	80	22.329	498.606
4 (tech. facil.)	AC	0	100	78.13	85	24.321	591.535
4 (tech. facil.)	Heating	0	100	86.19	99.5	21.245	451.364
4 (tech. facil.)	Intelligent house control	0	100	38.46	38	27.846	775.400
4 (tech. facil.)	Alarm system	0	100	44.06	39.5	34.584	1196.075
5 (heating)	Heating system	15	100	82.17	90	20.839	434.274
5 (heating)	Underfloor heating	0	100	78.38	91	27.959	781.679
4 (features)	Furniture	0	100	62.12	70	33.170	1100.249
4 (features)	Elevator	0	100	20.94	8.5	28.075	788.232
4 (features)	Fireplace	0	100	40.27	40.5	29.117	847.775
4 (features)	Bathtub	0	100	53.43	51.5	30.106	906.380
4 (features)	Window shutters	0	100	40.13	39	31.061	964.775
4 (features)	Fitted kitchen	0	100	79.92	97.5	27.705	767.558
4 (features)	Extras	0	100	28.66	22.5	25.606	655.657

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. deviation	Variance
5 (furniture)	Quality	0	100	60.89	76.5	39.740	1579.257
5 (furniture)	Built-in wardrobes	0	100	66.32	75.5	32.079	1029.091
5 (extras)	Spa	0	100	31.39	26	26.759	716.038
5 (extras)	Wine cellar	0	100	21.64	14.5	22.896	524.232
5 (extras)	Home cinema	0	100	16.83	6	23.940	573.138
5 (extras)	Walk-in fridge	0	90	7.24	0	13.711	188.004
3 (outdoor)	Pool	0	100	82.70	91.5	24.651	607.686
3 (outdoor)	Autonomous system	0	100	47.81	50	33.028	1090.839
3 (outdoor)	Garden	0	100	69.50	76.5	27.597	761.615
3 (outdoor)	Seating areas	0	100	84.66	94	22.117	489.166
3 (outdoor)	Plot border	8	100	77.56	81	21.608	466.919
3 (outdoor)	Parking	3	100	76.25	81	22.353	499.652
4 (pool)	Size	0	100	64.76	66.5	26.196	686.216
4 (pool)	Type	0	100	49.22	50	30.459	927.727
4 (garden)	Planting	0	100	59.17	60	25.599	655.317
4 (garden)	Size	0	100	58.87	61	27.147	736.972
4 (garden)	Irrigation system	0	100	67.91	72	24.673	608.774
4 (seating)	BBQ area	0	100	56.29	59	30.548	933.181
4 (seating)	Patio	0	100	28.53	18	29.159	850.261
4 (seating)	Terraces/balconies	0	100	85.69	93	19.301	372.540
4 (seating)	Other seating areas	0	100	16.32	3.5	24.835	616.787
5 (terraces)	Size	3	100	81.96	87.5	21.136	446.713
5 (terraces)	Number	0	100	35.02	30.5	27.486	755.474
5 (terraces)	Covered terraces	0	100	67.39	74	27.449	753.468
5 (terraces)	Rooftop	0	100	31.86	22.5	29.195	852.370
4 (plot border)	Plot size	0	100	64.22	69	25.674	659.146
4 (plot border)	Fencing	0	100	65.42	71	29.170	850.904
4 (plot border)	Privacy level	14	100	87.83	94.5	17.280	298.598
4 (parking)	Spaces	0	100	60.07	62	29.371	862.648
4 (parking)	Type	0	100	60.02	67.5	33.269	1106.837
4 (auto. syst.)	Solar panels	0	100	50.81	50.5	32.636	1065.137
4 (auto. syst.)	Generator	0	100	30.42	14	33.043	1091.832
4 (auto. syst.)	Well	0	100	45.58	48	34.616	1198.289

Appendix P – Criteria Relationships (Survey Answers)

Enforcing relationship statements	Agree	Neither agree, nor disagree	Disagree
Larger plot means more privacy	64%	28%	8%
Larger house (constructed area) means more bedrooms	41%	44%	15%
Higher nr. of bedrooms means more en-suite bathrooms	48%	37%	14%
A newer house means higher quality	39%	38%	23%
Modern style means more windows and higher light level	78%	16%	7%
Closer proximity to sea means more sea view	34%	42%	24%
Closer proximity to sea means smaller plot size	54%	26%	21%
Touristic area means need for an alarm system	61%	25%	14%
Larger plot means bigger terraces	48%	37%	14%
Touristic area means higher crime rate	61%	25%	14%
Closer proximity to sea means higher price	94%	4%	1%
Larger plot means lower noise level	53%	33%	14%
First line means more repairs on the house	77%	17%	6%
A larger garden means higher maintenance costs	89%	8%	2%
Living in a residential complex means higher security	37%	37%	27%

Connection statements	Yes	Don't know	No
Bedroom size - En-suite bathrooms	71%	18%	11%
Ceiling height - Light level	72%	20%	8%
Cellar - Moisture/humidity level	62%	22%	16%
Constructed area – Price	93%	6%	2%
Crime rate - Alarm system	76%	14%	10%
Disabled-friendly - Nr. of stories	72%	19%	9%
Electricity grid connection - Solar power – Generator	62%	9%	28%
Elevator - Nr. of stories	84%	11%	6%
Municipal water supply – Well	62%	12%	26%
Surrounding properties – Price	90%	5%	5%
Fencing - Privacy level - Visibility to plot	81%	7%	12%
Glazing – Insulation	87%	3%	10%
Guest apartment - Privacy level - Plot size	65%	18%	17%
Intelligent house control system - Year of construction	57%	22%	21%
Nr. of bedrooms - Nr. of bathrooms	84%	12%	3%
Public transport - Road distribution	53%	16%	31%
Renovation work - Year of construction	80%	13%	7%
Style - Year of construction	52%	37%	11%

Appendix Q – Real Estate Dataset Characteristics

Quantitative characteristics	Unit	Mean	Median	Range	Max	Min
Acquisition costs	EUR	2,111,219.5	1,990,000	2,690,000	3,900,000	1,210,000
Airport	min	22.39	22	19	35	16
Bathroom size	sqm	13.88	14	15	24	9
Bathtub	nr	1.37	1	1	2	1
Beach	km	6.31	1.8	22.6	22.9	0.3
Bedroom size	sqm	23.24	23	28	40	12
Ceiling height	m	2.94	2.8	2.5	5	2.5
Constructed area	sqm	414.56	405	728	935	207
Covered parking	nr	2.29	2	10	10	0
Distance to motorway	km	4.84	4.2	18.3	19	0.7
Distance to neighbour	m	97.07	30	1000	1000	0
Distance to police	min	11.02	10 min	20 min	26	6
Distance to pubs	km	2.52	1.9	5.5	6.1	0.6
Dressing rooms	nr	0.71	1	4	4	0
Educational institution	min	11.85	10	36	40	4
En-suite bathrooms	nr	3.46	3	5	6	1
Garden size	sqm	4,183.81	1,099	3,0063	3,0453	390
Golf course	min	11.39	11	26	28	2
Gym	min	9.39	8	15	19	4
Kitchen size	sqm	22.05	20	35	45	10
Livingroom size	sqm	50.20	46	79	100	21
Maintenance costs	EUR	1,817.07	1,800	4,200	5,000	800
Medical facilities	min	12.41	12	26	30	4
Nr. of bathrooms	nr	4.9	5	4	7	3
Nr. of bedrooms	nr	4.49	4	5	7	2
Nr. of livingrooms	nr	1.32	1	3	4	1
Nr. of storage rooms	nr	1.44	1	3	3	0
Nr. of stories	nr	2.39	2	3	5	2
Nr. of terraces	nr	3.15	3	5	6	1
Palma (city)	min	21.56	21	21	35	4
Parking spaces	nr	4.54	4	9	10	1
Plot size	sqm	4,592.07	1,500	3,0205	3,1000	795
Pool size	sqm	40.24	40	85	85	0
Port	min	10.78	9	24	26	2
Size of terraces	sqm	184.49	182	375	420	45
Taxes	EUR	2,770.73	2,600	6,600	8,000	1,400
Tennis club	min	9.29	8	17	19	2
Year of construction	year	2005.71	2008	44	2014	1970

Qualitative characteristics	Categorisation
AC	85% yes; 12% partially; 5% no
Air pollution	80% low; 20% medium
Air traffic	46.3% never; 39% occasionally; 14.6% frequently and noticeable
Alarm system	95% no; 5% yes
BBQ area	54% no; 46% yes
Built-in wardrobes	80% yes; 20% no
Cellar	68% no; 32% yes
Covered terraces	93% yes; 7% no
Crime rate	39% high; 34.1% low; 26.8% medium
Disabled friendly	95% no; 5% yes
Electricity grid	100% yes
Elevator	95% no; 5% yes
Energy rating	76% D or E; 24% F or G
Entrance hall	59% no; 41% yes

Fencing	59% fully; 24% partial; 17% none
Fireplace	76% yes; 24% no
Fitted kitchen	95% yes; 5% no
Floor covering	46% marble/natural stone; 34% tiles; 12% marble with wood; 7% wood
Furniture quality	56% high standard; 20% standard; 12% low; 12% none
Generator	93% no; 7% yes
Glazing	95% double; 5% single
Guest apartment	61% no; 39% yes
Guest toilet	90% yes; 10% no
Gym	73% no; 27% yes
Heating system	46% oil; 27% electric/AC; 22% heatpump; 5% gas
Home cinema	88% no; 12% yes
Hot tub	73% no; 27% yes
House control system	85% no; 15% yes
Internet/Phone	51% no; 49% yes
Irrigation system	85% yes; 15% no
Landscape	68% urban; 32% rural
Locality	20 different locations (mainly covering the South West and island middle)
Municipal water	93% yes; 7% no
Office	66% no; 34% yes
Orientation	46% S/E or S/W; 22% S; 12% W; 12% N/E; 5% 3; 2% N
Other extras	29% yes
Other rooms	73% no; 27% yes
Patio	73% no; 27% yes
Planting/layout	46% lawn; 27% trees; 17% lawn + palm trees; 10% palm trees
Pool type	85% mosaic; 10% plastic; 5% none
Privacy level	46% high; 32% medium; 22% low
Proximity to sea	48.7% within 2km; 34.1% far; 7.3% 1st line; 7.3% 2nd or 3rd line; 2.4% within 5km
Public transport	68% no; 32% yes
Renovation work	71% none; 24% some; 5% major
Residential complex	100% outside a complex
Restaurants	46% a wide variety; 34% one or two; 20% none
Rooftop terrace	71% no; 29% yes
Sauna	78% no; 22% yes
Shopping facilities	80% none; 15% some; 5% high choice
Smell	90% neutral; 10% sometimes unpleasant
Solar panels	81% no; 19% yes
Steam room	100% no
Street condition	51% paved; 39% paved with road holes; 10% unpaved
Street noise	82.9% low; 17.1% medium
Style	37% Mediterranean; 34% modern; 29% Mallorquin
Surrounding properties	56.1% high/normal-high standard; 17.1% low standard; 14.6% no close neighbours or not many; 12.2% normal standard
Touristic area	68.3% not in a touristic town; 31.7% in a touristic town but no touristic area
Touristic area	68.3% not in a touristic town; 31.7% in a touristic town but no touristic area
Tropical shower	59% no; 41% yes
TV connection	73% yes; 27% no
Underfloor heating	68% yes; 32% no
View	26.8% partial sea; 19.5% distant sea; 19.5% countryside; 17% garden; 17% sea
Walk in fridge	100% no
Well	73% no; 27% yes
Window shutters	41% yes; 32% no; 27% yes electric
Wine cellar	83% no; 17% yes

Appendix R– Descriptive Analysis of 20 Homebuyers' Criteria Weights

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. D	Difference to 180 mean Appendix O
1	Location	48	100	80.15	86.5	21.251	-1.24
1	Real estate	50	100	91.55	100	14.873	3.38
1	Costs	50	100	77.75	80	15.774	-6.72
2 (costs)	Acquisition costs	15	100	78.80	85.5	21.020	-7.5
2 (costs)	Maintenance costs	50	100	88.35	96	15.142	-2.49
2 (costs)	Taxes	0	100	60.55	61	23.836	-6.9
2 (location)	Macro location	0	100	67.90	72	24.033	4.78
2 (location)	Micro location	17	100	74.20	84	25.335	-2.7
3 (macro)	Landscape	5	100	60.15	70.5	30.051	-2.92
3 (macro)	Accessibility	38	100	76.55	84.5	21.917	4.58
3 (macro)	Leisure	0	100	52.50	63.5	29.498	-7.69
4 (access.)	Medical facilities	7	100	57.35	67.5	34.722	7.74
4 (access.)	Airport	0	100	55.05	51.5	29.269	-2.86
4 (access.)	Palma	20	100	56.50	55	24.795	-1.69
4 (access.)	Educational institutions	0	100	31.65	9.5	38.898	7.67
4 (access.)	Port	0	96	40.55	45.5	31.821	-6.06
4 (leisure)	Beach	7	95	53.5	50.5	24.154	-9.74
4 (leisure)	Pubs	0	65	24.15	16.5	23.720	-14.42
4 (leisure)	Sport facilities	0	100	48.30	44.5	37.201	-4.42
3 (micro)	Infrastructure	0	100	47.95	50	30.346	-9.53
3 (micro)	Security	29	100	65.25	60.5	23.837	-5.02
3 (micro)	Local amenities	13	100	59.40	55	24.614	-3.41
3 (micro)	View	0	100	73.20	79	25.74	-7.28
3 (micro)	Proximity to sea	0	100	52.95	50	32.66	-13.5
3 (micro)	Locality	30	100	43.25	30	38.09	-15.49
3 (micro)	Pollution	0	100	74.95	81	27.037	-2.79
3 (micro)	Neighbourhood	0	100	65.55	73	31.482	-4.54
4 (infra.)	Public transport	0	72	16.85	5	22.444	-6.4
4 (infra.)	Supply system	0	100	81.45	98	26.415	-4.52
4 (infra.)	Road network	0	100	57.45	55.5	26.670	-6.4
5 (supply syst)	Electricity grid	60	100	91.15	100	12.48	-0.17
5 (supply syst)	Municipal water supply	0	100	83.05	100	29.48	-4.34
5 (supply syst)	TV connection	0	100	54.10	45	38.24	-12.61
5 (supply syst)	Internet connection	15	100	85.55	100	27.08	-1.56
5 (road netw.)	Distance to Motorway	30	100	67.45	70	19.264	4.92
5 (road netw.)	Street condition	0	100	48.70	48	30.398	-2.12
4 (security)	Crime rate	30	100	84.25	90.5	20.15	4.83
4 (security)	Distance to police station	0	100	32.20	26.5	32.07	-2.17
4 (pollution)	Noise level	0	100	86.90	98.5	24.355	-2.11
4 (pollution)	Air pollution	0	100	77.65	90.5	29.12	-3.18
4 (pollution)	Smell	0	100	83.35	97.5	27.66	-1.71
5 (noise)	Air traffic	0	100	69.00	73	30.07	-5.17
5 (noise)	Street noise	0	100	80.35	84	23.47	-6.46
5 (noise)	Distance to neighbour	20	100	67.90	65.5	26.22	-0.95
4 (local amen.)	Shopping facilities	4	100	63.65	65.5	28.23	0.14
4 (local amen.)	Restaurants	13	99	53.15	55	24.22	-7.07
5 (neighbour.)	Surrounding properties	50	100	73.80	72	16.54	0.11
5 (neighbour.)	Residential complex	0	54	17.00	12.5	18.99	-0.49
5 (neighbour.)	No touristic area	0	100	62.25	69	36.38	5.41
2 (real estate)	Property	50	100	89.50	96.5	15.004	-0.41
2 (real estate)	Outdoor area	50	100	88.15	91.5	14.179	-0.58

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. D	Difference to 180 mean Appendix O
3 (property)	Design/layout/structure	17	100	82.20	88	22.745	-0.37
3 (property)	Quality	51	100	93.25	100	12.640	3.68
3 (property)	Orientation	21	100	78.95	88	22.927	-0.95
3 (property)	Technical facilities	50	100	83.70	89.5	17.711	-1.43
3 (property)	Features	0	95	54.25	62	29.279	-12.38
3 (property)	Style	0	100	61.75	62.5	25.233	1.28
4 (design)	Constructed area	25	100	78.60	80.5	18.449	3.26
4 (design)	Room sizes	63	100	83.95	82.5	13.621	4.59
4 (design)	Rooms	32	100	86.65	92	18.167	4.74
4 (design)	Nr. of stories	0	100	38.05	30	35.582	2.81
4 (design)	Disabled friendly	0	45	5.65	0	11.348	-17.03
4 (design)	Ceiling height	0	86	37.60	32	27.961	-6.34
4 (design)	Guest apartment	0	100	47.25	49	33.593	2.61
5 (room sizes)	Bedroom size	18	100	71.60	80	27.048	-1.44
5 (room sizes)	Livingroom size	25	100	73.50	73.5	23.657	-5.57
5 (room sizes)	Bathroom size	6	100	60.90	58.5	27.274	-5.14
5 (room sizes)	Kitchen size	20	100	68.85	68	20.085	4.99
5 (rooms)	Nr. of bedrooms	42	100	84.70	92	18.505	0.08
5 (rooms)	Nr. of bathrooms	34	100	72.40	77.5	21.005	0.72
5 (rooms)	Nr. of storage rooms	0	84	43.60	45	22.246	6.62
5 (rooms)	Nr. of livingrooms	0	29	10.10	10	9.369	-0.98
5 (rooms)	Dressing room	0	100	46.00	43.5	32.138	-0.12
5 (rooms)	Entrance hall	11	100	46.85	46.5	25.705	0.96
5 (rooms)	Gym	0	60	18.80	13	19.218	-1.15
5 (rooms)	Office	0	100	43.10	39.5	37.985	4.73
5 (rooms)	Other rooms	0	25	3.55	0	6.732	-3.07
5 (rooms)	Cellar	0	50	16.50	13	15.028	-5.3
5 (rooms)	Bathroom type	31	94	32.25	57.5	18.450	-33.89
6 (bathroom)	En-suite	10	100	78.95	90	29.971	-0.69
6 (bathroom)	Guest toilet	40	100	89.05	95.5	16.366	2.83
4 (quality)	Energy rating	17	100	63.25	61	29.406	-1.47
4 (quality)	Building materials	40	100	84.25	87.5	17.308	2.65
4 (quality)	Property condition	19	100	84.60	93.5	21.065	-3.34
5 (building m.)	Floor covering	4	100	66.00	68.5	24.811	2.5
5 (building m.)	Glazing	30	100	81.00	84.5	18.206	2.59
5 (building m.)	Insulation	30	100	80.30	81	21.097	3.12
5 (property c.)	Renovation work	8	100	60.05	57.5	33.162	-16.76
5 (property c.)	Year of construction	5	100	49.75	38	35.321	-8.1
5 (property c.)	Humidity level	5	100	75.90	79	23.174	0.35
4 (tech. facil.)	AC	0	100	63.60	74.5	33.633	-14.53
4 (tech. facil.)	Heating	40	100	88.65	100	19.693	2.46
4 (tech. facil.)	Intelligent house control	0	100	37.55	39.5	34.347	-0.91
4 (tech. facil.)	Alarm system	0	100	32.05	18	33.536	-12.01
5 (heating)	Heating system	35	100	87.95	100	19.925	5.78
5 (heating)	Underfloor heating	7	100	76.05	93.5	31.547	-2.33
4 (features)	Furniture	0	100	41.90	38.5	35.597	-20.22
4 (features)	Elevator	0	54	10.15	0	17.676	-10.79
4 (features)	Fireplace	0	96	42.45	40.5	31.775	2.18
4 (features)	Bathtub	0	100	49.05	53	33.835	-4.38
4 (features)	Window shutters	0	100	37.35	32.5	32.613	-2.78
4 (features)	Fitted kitchen	0	100	69.80	78.5	34.786	-10.12
4 (features)	Extras	0	66	16.00	10.5	18.172	-12.66
5 (furniture)	Quality	0	100	43.10	23.5	41.522	-17.79
5 (furniture)	Built-in wardrobes	0	100	54.55	53.5	34.069	-11.77

Hierarchy level & upper criterion	Criteria name	Min.	Max.	Mean	Median	Std. D	Difference to 180 mean Appendix O
5 (extras)	Spa	0	86	28.85	20	27.927	-2.54
5 (extras)	Wine cellar	0	50	15.70	11.5	15.294	-5.94
5 (extras)	Home cinema	0	70	18.00	12	22.131	1.17
5 (extras)	Walk-in fridge	0	31	6.55	0	9.225	-0.69
3 (outdoor)	Pool	19	100	76.50	91	27.556	-6.2
3 (outdoor)	Autonomous system	0	100	49.70	52	34.452	1.89
3 (outdoor)	Garden	0	100	60.10	65.5	27.556	-9.4
3 (outdoor)	Seating areas	50	100	88.15	99	18.088	3.49
3 (outdoor)	Plot border	40	100	80.30	81	18.723	2.74
3 (outdoor)	Parking	50	100	80.20	83.5	18.640	3.95
4 (pool)	Size	23	100	63.25	60	19.804	-1.51
4 (pool)	Type	0	100	49.75	55	31.591	0.53
4 (garden)	Planting	0	100	60.75	66.5	29.001	1.58
4 (garden)	Size	0	100	64.15	69.5	30.275	5.28
4 (garden)	Irrigation system	0	100	68.20	70	26.001	0.29
4 (seating)	BBQ area	0	100	49.65	55.5	29.869	-6.64
4 (seating)	Patio	0	90	28.70	21.5	28.011	0.17
4 (seating)	Terraces/balconies	0	100	86.50	98.5	25.141	0.81
4 (seating)	Other seating areas	0	100	15.2	1.5	27.562	-1.12
5 (terraces)	Size	30	100	77.95	82.5	23.406	-4.01
5 (terraces)	Number	0	100	33.45	22	31.751	-1.57
5 (terraces)	Covered terraces	4	100	70.95	80	27.865	3.56
5 (terraces)	Rooftop	0	100	31.60	25.5	28.863	-0.26
4 (plot border)	Plot size	0	100	66.10	68.5	25.835	1.88
4 (plot border)	Fencing	20	100	67.10	70.5	27.369	1.68
4 (plot border)	Privacy level	60	100	90.10	94.5	11.903	2.27
4 (parking)	Spaces	0	100	67.30	71.5	28.487	7.23
4 (parking)	Type	6	100	67.70	70	32.538	7.68
4 (auto. syst.)	Solar panels	0	100	56.30	63.5	30.406	5.49
4 (auto. syst.)	Generator	0	100	35.35	27	36.487	4.93
4 (auto. syst.)	Well	0	100	56.30	63.5	30.406	10.72

Appendix S – Discretisation of Continuous and Discrete Variables

Quantitative bottom level variables	Unit	Bin_1	Bin_2	Bin_3	Bin_4	Bin_5
Acquisition costs	EUR mil	1.11-1.80	1.81-2.20	2.21-3.00	3.01-5	
Age of house	years	≤3	4-10	11-20	20<	
Airport	min	5-25	26-40	41-60	60<	
Bathroom size	sqm	15<	7-15	2-6		
Bathtub	nr	2<	2	1		
Bedroom size	sqm	35<	20-35	8-19		
Ceiling height	m	3<	2.6-3	2.5		
Constructed area	sqm	500<	251-500	80-250		
Distance to beach	km	≤2	2.1-5	5.1-10	10.1-20	20<
Distance to motorway	km	≤3	3.1-5	5.1-10	10<	
Distance to neighbour	m	30<	21-30	11-20	1-10	0
Distance to police	min	≤10	11-20	21-30	30<	
Distance to pubs	km	≤2	2.1-3	3.1-5	5<	
Dressing room	nr	1<	1	0		
Educational institutions	min	≤10	11-20	20<		
En-suite bathrooms	nr	2<	2	1		
Garden size	sqm	800<	351-800	≤350		
Golf course	min	≤10	11-20	20<		
Gym	min	≤10	11-20	20<		
Inter. medical facilities	min	≤20	21-30	30<		
Kitchen size	sqm	25<	16-25	10-15	5-9	
Livingroom size	sqm	50<	31-50	10-30		
Maintenance costs	EUR	≤500	501-1000	1001-1800	1801-2800	2800<
Nr. of bathrooms	nr	3<	2-3	1		
Nr. of bedrooms	nr	4<	3-4	2		
Nr. of covered parking	nr	4<	3-4	2	1	0
Nr. of livingrooms	nr	1<	1			
Nr. of storage rooms	nr	1<	1	0		
Nr. of stories	nr	1	2	2<		
Nr. of terraces/balconies	nr	3.5<	2-3.5	1-1.5		
Palma	min	≤15	16-30	31-50	50<	
Plot size	sqm	2500<	1501-2500	1001-1500	701-1000	≤700
Pool size	sqm	40<	16-40	4-15	0	
Port	min	≤10	11-20	21-30	30<	
Property performance	score	84<	68-84	50-67	<50	
Taxes	EUR	≤1500	1501-2500	2501-3500	3500<	
Tennis club	min	≤10	11-20	20<		
Terrace/balcony size	sqm	120<	71-120	51-70	15-50	
Total nr. of parking	nr	4<	3-4	2	1	0

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