# MULTI-CRITERIA DECISION MAKING FOR REAL ESTATE SELECTION – A PROBLEM STRUCTURING FRAMEWORK AND REAL ESTATE DECISION MODEL

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## ABSTRACT

The real estate selection process is a typical Multi-Criteria Decision Making (MCDM) problem. This paper presents the methodology adopted to identify relevant decision problem parameters for luxury real estate selection in Majorca. The fieldwork was translated into a generic MCDM problem structuring process and a modified Evidential Reasoning (ER) approach was used for decision analysis.

## INTRODUCTION

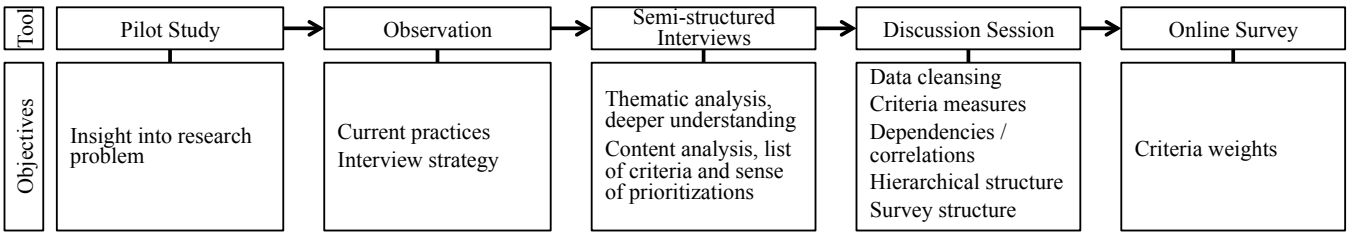
At present, a homebuyer's selection decision is greatly reliant on intuition and is frequently simplified using rules of thumb to deal with high complexity. This complexity results from a large number of correlated and dependent criteria, and is further intensified by scarcity of available information. Accordingly, to provide a robust analysis of alternatives, the research first investigates current practices to enhance problem understanding, proposes a generic MCDM problem structuring process to contribute to limited literature in this area [1] and employs a modified ER approach to model the decision problem.

## FIELDWORK AND GENERIC MCDM PROBLEM STRUCTURING FRAMEWORK

Data for this study was collected in Majorca due to its well-defined geographical space. A multi-stage mixed methods approach was designed with each collection method having a unique purpose to capture certain data and support subsequent phases. A pilot study with five estate agents provided a first impression of the problem and target audience, i.e. luxury homebuyers. Then, observations helped capture interactions between these two stakeholders, offering invaluable insights into current practices. Subsequently, 28 semi-structured interviews highlighted 214 non-repeating criteria. A discussion session with three property experts reduced this number to 144 relevant but potentially dependent and correlated factors, whilst also specifying associated measures and organising remaining criteria into a hierarchy. In the final stage, 255 online surveys provided more representative data and elicited weight distributions.
From the study, valuable data collection and analysis procedures emerged. Figure 1 presents a generic MCDM problem structuring process that can be followed to define a decision problem and subsequently choose an adequate decision-making model, adjust one or develop a tailored method.

**FIGURE 1**

**MCDM Problem Structuring Framework**



## EVIDENTIAL REASONING RULE

The ER rule, based on the Dempster-Shafer evidence theory, is a general probabilistic reasoning process facilitating the combination of multiple independent pieces of evidence, whilst acknowledging evidence weight and reliability [3] and forming a prior-free inference process [2].

First, a frame of discernment ($\Theta$) is defined of mutually exclusive and collectively exhaustive propositions$\{\theta_1, \dots, \theta_N\}$ [2]. Basic probabilities are assigned to any subset of propositions, profiling each piece of evidence by a belief distribution (BD) on the power set of $\Theta$ [3]. The power set of the frame of discernment $P(\Theta)$ entails $2^N$ subsets of $\Theta$ [3].

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

where $\emptyset$ represents the empty set. A piece of evidence $e_j$ profiled using a BD is defined by:

$$e_j = \left\{\left(\theta, p_{\theta,j}\right), \forall\theta \subseteq \Theta, \sum_{\theta\subseteq\Theta} p_{\theta,j} = 1\right\} \quad (2)$$

where $p_{\theta,j}$ is the degree of belief to which $e_j$ supports proposition $\theta$, being any element of $P(\Theta)$ except $\emptyset$ [3] [2]. Following the section above, there are three key elements that are used when combining multiple pieces of evidence, the BD, weight and reliability [3] [2]. First, to attain the reasoning process in the ER rule, a weighted BD with reliability needs to be computed [3]:

$$m_j = \left\{\left(\theta, \tilde{m}_{\theta,j}\right), \forall\theta \subseteq \Theta; \left(P(\Theta), \tilde{m}_{P(\Theta),j}\right)\right\} \quad (3)$$

where $\tilde{m}_{\theta,j}$ is the degree of support for proposition $\theta$ from $e_j$ with reliability $r_j$ and weight $w_j$:

$$\tilde{m}_{\theta,j} = \begin{cases} 0 & \theta = \emptyset \\ c_{rw,j} m_{\theta,j} & \theta \subseteq \Theta, \theta \neq \emptyset \\ c_{rw,j}(1 - r_j) & \theta = P(\Theta) \end{cases} \quad (4)$$

A normalisation factor $c_{rw,j}$is used to ensure $\sum_{\theta\subseteq\Theta} \tilde{m}_{\theta,j} + \tilde{m}_{P(\Theta),j} = 1$, where $c_{rw,j} = 1/(1 + w_j - r_j)$. $m_{\theta,j}$ is the probability of proposition $\theta$ multiplied by the weight ($p_{\theta,j} w_j$). Note, only if pieces of evidence are acquired from different information sources, $w_j$ is not equivalent to $r_j$, i.e. $w_j \neq r_j$.

Given the weighted BD with reliability, combined support for proposition $\theta$ using two pieces of evidence $e_i$ and $e_j$ can be computed using the ER rule [3]:

$$p_{\theta,e(2)} = \begin{cases} 0 & \theta = \emptyset \\ \frac{\hat{m}_{\theta,e(2)}}{\sum_{D\subseteq\Theta} \hat{m}_{D,e(2)}} & \theta \subseteq \Theta, \theta \neq \emptyset \end{cases} \quad (5)$$

$$\hat{m}_{\theta,e(2)} = \left[(1 - w_j) m_{\Theta,i} + (1 - w_i) m_{\Theta,j}\right] + \left[m_{\Theta,i} m_{\Theta,j}\right] \quad (6)$$

The first part of equation (6) symbolises the bounded sum of individual support on proposition $\theta$ from evidence $e_i$ and $e_j$, whilst $\left[m_{\Theta,i} m_{\Theta,j}\right]$ represents the orthogonal sum of collective support from both pieces measuring the level of all intersected support on proposition $\theta$ [3] [2].

A modified version of the ER rule capable of handling dependencies amongst evaluation criteria was applied to the identified real estate selection problem.

## REFERENCES


[1] Franco, A.L. & Motibeller, G. Problem Structuring for Multi-Criteria Decision Analysis Interventions. *Wiley Encyclopedia of Operations Research and Management Science*, 2009, 1-15.

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[3] Yang, J.B. & Xu, D.L. Evidential Reasoning Rule for Evidence Combination. *Artificial Intelligence*, 2013, *205*, 1-29.