



NEIGHBORHOOD SELECTION FOR A NEWCOMER VIA A NOVEL BWM-BASED REVISED MAIRCA INTEGRATED MODEL: A CASE FROM THE COQUIMBO-LA SERENA CONURBATION, CHILE

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Abstract. Nowadays, cities are developing differently according to their needs, limitations and certain strategic plans. Moreover, conurbation areas will be more common in so many countries like Chile when there are two or more cities developing one next to another, leaning on each other. In this atmosphere, typical residents live in a region or a neighborhood based on certain criteria, so they know how and where they are going to live. From another point of view, a newcomer is usually faced with a city full of contrasts which make things completely and surprisingly complicated. In order to illustrate this, a real case was selected based on the research field, qualitative and quantitative (real) data. The Coquimbo-La Serena conurbation and its regions as “*Comuna (in Chile)*” is a really suitable case to show the complexity of the study. In order to face the challenge, a new hybrid Multiple-Attribute Decision-Making (MADM) method is introduced based on the Best-Worst Method (BWM) and Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA). The five best different neighborhoods as *Comunas* of the conurbation were analyzed based on the two main scenarios: having a private car or using only public transportation. To obtain more reliable results, a sensitivity analysis was made so as to determine the behavior of the proposed model against weight changes. Besides, the final results were compared with the other MADM methods, for example: Multi-Attributive Border Approximation Area Comparison (MABAC), Visekriterijumsko Kompromisno Rangiranje (VIKOR) and COmbinative DIstance-based ASsessment (CODAS).

Keywords: neighborhood, locating, newcomer, evaluation, MADM, BWM, MAIRCA.

Introduction

Mobility is considered to be a natural part of the human lifecycle. According to Li and Tu (2011), mobility is one of the main reasons for changes in the arrangement and character of a settlement. Mobility studies have emerged due to the dissatisfaction with the original location caused by the lifecycle changes. Furthermore, preliminary studies on this subject matter were carried out by Rossi (1955) and Brown and Moore (1970). Mobility is divided into inter-urban mobility and intra-urban mobility. Inter-urban mobility is a long-distance movement usually done for job-related reasons, whereas intra-urban mobility is a short-distance movement associated with non-job-related

causes. Intra-urban movers are more likely to consider non-economic factors (Li & Tu, 2011).

The neighborhood is crucial for a household deciding to move to another place in terms of the quality of life. Expectations regarding the neighborhood include both physical and social characteristics. A clean, calm and secure neighborhood is always preferred. The neighborhoods whose natural appearance is beautiful, where the air is clean, with respectful and safe social environments have positive effects on neighborhood decisions. Furthermore, the important features of the neighborhood are linked to the accessibility of services and facilities as well. Various services offered by a city and the accessibility of public

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facilities/public relations/social relations/work and the workplace can be considered in this context. Moreover, easy access to public transportation and the main roads, and closeness to sports, education and health facilities/cultural and recreational local services/shopping places/relatives and friends are among the most prominent behaviors in selecting a neighborhood.

It is not astonishing that a number of studies have sought to understand how people make their neighborhood decisions. Previous studies suggested that one's satisfaction with the neighborhood mostly depends on a good locality (Ioannides & Kan, 1996; Earnhart, 2002; Wang & Li, 2004; Jabareen, 2005; Kauko, 2007; Opoku & Abdul-Muhmin, 2010), whereas recent studies have shown that social, cultural, environmental, and economic factors also play crucial roles in the neighborhood preferences (Głuszak, 2015; Lux et al., 2018; Mulliner, Malys, & Maliene, 2016; Gluszak & Marona, 2017; Hanafi, Mazree, Umar, & Ahmad, 2018). In the literature, however, there are merely a few studies on the selection of the most suitable neighborhood (Głuszak, 2015; Gluszak & Marona, 2017; Zavadskas, Cavallaro, Podvezko, Ubarte, & Kaklauskas, 2017; Ren, Folmer, & van der Vlist, 2018). Furthermore, the models considered are often not easy for researchers to understand. Therefore, this study contributes to this literature by suggesting a useful, simple, and efficient decision-making tool. The proposed multi-attribute decision-making (MADM) framework is suitable for both determining the weights of evaluation factors and selecting the best settlement among others.

A neighborhood decision is a very complex and challenging process to select from taking into consideration many quantitative and/or qualitative criteria and the contradictory characteristics of alternative neighborhoods. This problem, which requires many criteria and many alternatives, is actually considered as a MADM problem. Therefore, this problem seeks the best solution or alternative, which creates a trade-off between qualitative and quantitative criteria (Ecer, 2018). In the past decades, many MADM methods have been introduced to more accurately evaluate criteria and alternatives (Ecer, 2015; Hashemkhani Zolfani, Zavadskas, Khazaelpour, & Cavallaro, 2018; Nikolić, Milovančević, Petković, Jocić, & Savić, 2018). In recent years, various MADM methods, like the complex proportional assessment (COPRAS), the weighted sum model (WSM), the integrated determination of objective criteria weights (IDOCRIW), the weighted product model (WPM), the Analytical Hierarchy Process (AHP), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), the entropy method, the criterion impact LOSs (CILOS), Simple Additive Weighting (SAW), Evaluation based on Distance from Average Solution (EDAS), and the fuzzy-sets-based MCDA methods (Viteikienė & Zavadskas, 2007; Mulliner, Smallbone, & Maliene, 2013; Nuuter, Lill, & Tupenaite, 2015; Said, Majid, & Nozin, 2016; Cetinkaya, Özceylan, Erbaş, & Kabak, 2016; Mulliner et al., 2016; Zavadskas et al., 2017; Ciavarella, Carbone, & Vinogradov, 2018; Drakaki, Gören, & Tzionas, 2018; Tianlin, Jianzhong,

Fang, & Renjian, 2019) have been applied in order to analyze settlement places.

Hybrid models can also be utilized in order to solve such a difficult problem. The BWM method is a relatively new MADM method proposed by Rezaei (2015). It is based on the pairwise comparison principle and is considered as an improved form of the AHP method. Although the BWM is a new method, it has attracted great attention of researchers (Chitsaz & Azarnivand, 2016; Rezaei, Hemmes, & Tavasszy, 2017; Ren, Liang, & Chan, 2017; Badri Ahmadi, Kusi-Sarpong, & Rezaei, 2017; Rezaei, van Roekel, & Tavasszy, 2018; van de Kaa, Janssen, & Rezaei, 2018; Nawaz et al., 2018; Husain et al., 2018; Salimi & Rezaei, 2018; Stanujkić, & Karabašević, 2018). The Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA) method proposed by Pamučar, Vasin, and Lukovac (2014) is one of the latest MADM methods and is based on the principle of the gap between ideal and empirical priorities. If we examine the literature on MAIRCA, we can see that very few studies have been conducted (Gigović, Pamučar, Bajić, & Miličević, 2016; Pamučar, Mihajlović, Obradović, & Atanasković, 2017; Badi & Ballem, 2018; Chatterjee, Pamucar, & Zavadskas, 2018; Mamak Ekinci & Can, 2018). Eventually, the goal of current study is to assess the neighborhood alternatives through an integrated BWM-MAIRCA methodology in order to get more robust outcomes. In light of the background, it is thought that the following will contribute to the relevant literature and fill the gap in the literature, too.

- To combine MADM methods. To achieve this, the BWM and the revised MAIRCA methods are integrated.
- To assess 5 neighborhoods in Chile. To do so, criteria are ranked by the BWM and potential neighborhoods are ranked through the revised MAIRCA method.
- To highlight the most suitable neighborhood for a newcomer.
- To illustrate the effectiveness and usefulness of the proposed-suggested framework.

Therefore, in light of the background, the main innovation and contribution of the current study is that it proposes a BWM-based decision-making tool for assessing settlement places, taking various criteria into consideration.

The advantages of the BWM and MAIRCA methods are unified in this approach (Rezaei, 2015; Pamučar et al., 2014). In this study, the authors have chosen the BWM method in order to calculate the weight coefficients of the criteria due to the following advantages (Rezaei, 2015): (1) a less number of pairwise comparisons; (2) the weight coefficients calculated using the BWM are more reliable; (3) BWM outputs are always consistent; (4) when making comparisons in criteria pairs, the BWM only uses integer values. Correspondingly, the authors chose to apply the MAIRCA method due to its many endorsed advantages (Pamučar et al., 2014): (1) the stability of the solution in relation to the all types of changes; (2) a well-structured analytical framework for ranking alternatives; (3) the

number of steps remains the same regardless of the number of criteria; (4) it is suitable in those cases which there are a large number of alternatives and criteria; (5) it provides objective ranks depending on the predefined dominance threshold.

The rest of this paper is prearranged as follows: Section 1 reviews certain related literature on the criteria and methods for making a settlement decision. Section 2 briefly introduces certain basic concepts related to the BWM and the revised MAIRCA method. Section 3 provides a case study concerning an example of settlement selection. Section 4 presents the main scenarios considered in this study, demonstrates the results of the proposed methodology and covers both the comparison and the sensitivity analysis in order to show the applicability, validity, and stability of the suggested framework. Finally, discussion and conclusion will be presented.

1. Literature survey

In the literature, studies in the field of neighborhood decisions can be said to be usually carried out in terms of mobility decisions/behaviors, residence mobility, housing mobility, location decisions, and housing affordability. In this work, the presented literature survey is divided into two sections. First, the criteria used in the evaluation of neighborhood options are reviewed. Second, the various methods applied in order to solve neighborhood selection problems are highlighted.

1.1. Criteria used for decision making about neighborhoods

Ahmad (1992) found that ethnic factors were powerful in determining location selection and had an important influence on the subsequent mobility of migrant households as well. Dökmeci and Berköz (2000) observed that young people gave importance to closeness to the workplace, closeness to their relatives, cleanliness, the social environment, and facilities when choosing their living place. Bailey, Blake, and Cooke (2004) qualitatively analyzed the effects of proximity to the family, reciprocity within family networks, caring for children and parents on mobility behavior. In another study, Chiang and Hsu (2005) found that those who had migrated from Taiwan to Australia paid attention to the following factors: the income level, housing costs, children's education, the distance to the workplace and shopping centers, and proximity to their friends and other Taiwanese. The findings also indicated the fact that location selection was closely related to income and the housing budget, proximity to good schools and shopping centers, and information obtained from friends or previous migrants.

Viteikienė and Zavadskas (2007) investigated the most sustainable residential area in Vilnius according to 22 criteria: a safe, extensive supply of trade services; an extensive supply of recreation; noise; the distance to the city center, school, kindergarten, polyclinics, drugstore or workplace;

clean air; a nice environment; a good transport service to (from the city center or workplace); a well-attended environment; no drug addicts; good facilities for sports; cultural institutions; no alcohol addicts in sight/dereelicts in sight; the nice architecture of buildings; and well-attended parks. Niedomysl (2008) used several factors, such as health, natural beauty, transportation, natural resources, the sea, education, shopping opportunities, local tax rates, sports, culture and entertainment facilities, and fairs. As per the results, the most notable factors in neighborhood selection were social factors, occupational factors, housing, facilities, and transportation. Safety concerns, moving to an extended family house, proximity to jobs, eviction, marital reasons, separation/divorce/death of the spouse, the wish to own a house, an increase in the size of the family, and an affordable rent were taken as the evaluation criteria in Ardayfio-Schandorf's (2012) study. In their study, Mulliner et al. (2013) took into consideration the availability of social and private rented accommodation, the availability of affordable home ownership products, safety, access to employment opportunities/public transport services/good quality schools/shops/health services/child care/leisure facilities/open green public space, and the presence of environmental problems as the sustainable housing affordability criteria.

Nuuter et al. (2015) considered general economics, the housing stock, housing affordability, population and social conditions, housing quality, and environmental quality factors. Haybatollahi, Czepkiewicz, Laatikainen, and Kytä (2015) used the distance to work, the distance to the school, the distance to grocery stores, the distance to shopping centers, the distance to the errand-running environment, the distance to sports and the outdoor activity environment, the distance to the leisure time environment, density, the destination accessibility, and green areas as the evaluation criteria in their analysis. Mulliner et al. (2016) tracked the availability of rented accommodation/low cost homeownership products, crime, access to employment/public transport/good quality schools/shopping facilities/health services/child care/leisure/open green public space, and the presence of environmental problems as the key drivers for determining the most right settlement.

Cetinkaya et al. (2016) took into account acreage, proximity to the water source, the distance to the forest, the distance to windy areas, the elevation, the slope, the flood risk, the landslide risk, the earthquake risk, the distance to conflict zones, the availability of drainage, proximity to the roadway, proximity to the railway, proximity to airports, proximity to seaports, public land, proximity to the local population, proximity to poverty density, the distance to tourist attractions as the evaluation factors for determining a suitable settlement. Said et al. (2016) highlighted a large number of criteria, such as topography, closeness to the commercial area, hospitals, the post office, entertainment, transportation, education, workplace, density, the view, traffic congestion, security, environmental quality, the availability of waste management, and the

availability of child care as the factors for choosing the best neighborhood.

Recently, Zavadskas et al. (2017) addressed housing prices, crime rates, the population density, the density of single-family and two-family houses, the density of the blocks of flats, the number of jobs/educational institutions/seats in kindergartens/healthcare institutions/recreational facilities, air pollution, noise, the distance to the city center, and green spaces as the evaluation factors. Drakaki et al. (2018) considered the camp settlement size, drainage, water availability, sanitation, the distance from major towns, the distance from protected areas, the distance from tourist attractions, the accessibility of health institutions, the accessibility of the roadway, the availability of electricity, and the accessibility of educational institutions utilized as the evaluation criteria in their study. Finally, Tianlin et al. (2019) addressed the density of the population, the area of land, the gross regional domestic product (GRDP), and the density of the highway as the key factors for making neighborhood decisions.

1.2. Methods used for making a neighborhood decision

A neighborhood decision has become a significant and meaningful issue. For example, Ahmad (1992) and Niedomysl (2008) used a linear regression analysis. Dökmeci and Berköz (2000) and Ardayfio-Schandorf (2012) applied a descriptive analysis. Bailey et al. (2004) and Chiang and Hsu (2005) employed a qualitative data analysis. Viteikienė and Zavadskas (2007), Mulliner et al. (2013), Nuuter et al. (2015), and Said et al. (2016) used the COPRAS method. Mulliner et al. (2016) compared 6 different MADM methods, including the WSM, the WPM, the revised AHP, TOPSIS, and COPRAS. Zavadskas et al. (2017) integrated the entropy, CILOS, IDOCRIW, TOPSIS, SAW, COPRAS, and EDAS methods. Tianlin et al. (2019) proposed an entropy-based geometry methodology. Cetin-

kaya et al. (2016) suggested the FAHP and TOPSIS for ranking alternative neighborhoods, while Drakaki et al. (2018) integrated the FAHP and the fuzzy axiomatic design approach. Haybatollahi et al. (2015) applied SoftGIS. An overview of the methods applied to neighborhood problems is given in Table 1.

According to Table 1, we can see that the integrated MADM models have mostly been preferred in dealing with neighborhood problems. However, the number of these studies is quite inadequate. Hence, it could be useful if two MADM methods were integrated in order to make a better decision. This not only contributes to the literature on settlement selection, but also helps to make a better decision.

As can be seen from the literature survey – to the authors’ best knowledge – there is no study dealing with the neighborhood selection for a newcomer with the BWM-MAIRCA framework. Zavadskas et al. (2017) conducted a research which is closest to ours. They aimed to select healthy and safe neighborhoods through the framework of the sustainable development principles. Put it differently, the proposed approach is rather complex, complicated, and difficult for researchers and decision-makers to apply. After reviewing the literature, it was determined that the BWM-based MAIRCA approach was appropriate for this field. Thus, we focused on determining the most suitable neighborhood. To do so, this paper will not only search the importance of evaluation criteria, but it will also offer a proper neighborhood for a newcomer by taking into account the importance of criteria weights through a sensitivity analysis.

2. Methodology

A new hybrid MADM model will be introduced here for the first time in order to apply the new updated MADM methods, taking the best advantages of them. The BWM is a new method which can be said to be an updated ver-

Table 1. The summary of the methods employed in making a neighborhood decision

Category	Method	Literature
MADM model	COPRAS	Viteikienė and Zavadskas (2007), Mulliner et al. (2013), Nuuter et al. (2015), Said et al. (2016)
Integrated MADM model	WSM, WPM, The revised AHP, TOPSIS, COPRAS	Mulliner et al. (2016)
	Entropy, Criterion Impact LOSs (CILOS), Integrated Determination of Objective Criteria Weights (IDOCRIW), TOPSIS, SAW, COPRAS, and EDAS	Zavadskas et al. (2017)
	Entropy based geometry method	Tianlin et al. (2019)
Fuzzy MADM model	FAHP and TOPSIS	Cetinkaya et al. (2016)
	FAHP and fuzzy axiomatic design approach	Drakaki et al. (2018)
Other models	SoftGIS	Haybatollahi et al. (2015)
	Descriptive analysis	Dökmeci and Berköz (2000), Ardayfio-Schandorf (2012)
	Qualitative data analysis	Bailey et al. (2004), Chiang and Hsu (2005)
	Linear regression model	Ahmad (1992), Niedomysl (2008)

sion of the AHP. So, it can be considered as an appropriate method for weighting criteria in comparison to the AHP method, which is based on pairwise comparisons. MAIRCA is one of the latest MADM methods, which is a suitable method for evaluating alternatives and for the final ranking. This new method can be considered as an updated version of some perspectives, especially the WASPAS method (Zavadskas, Turskis, Antucheviciene, & Zakarevicius, 2012). Eventually, the BWM-MAIRCA seems to be a suitable hybrid MADM perspective as a model which can increase the accuracy level of decision-making faced with real-world challenges and problems. In this paper, a novel MCDM approach is presented by introducing the hybrid BWM-MAIRCA model, Figure 1.

Phase 1 takes into account the evaluation of the criteria by using the BWM. After applying the BWM, the MAIRCA method is used for the assessment of the alternatives. The last part of the proposed MCDM model is employed to analyze the data obtained in the previous phase. This phase deals with validation of the suggested evaluation model.

2.1. Best-Worst Method (BWM)

A settlement choice is a complex and challenging decision, which may include multiple and conflicting purposes. Potential movers collect information about many criteria or characteristics of the settlement, which are then evaluated

and weighted before a decision is made (Baláz, Williams, & Fifeková, 2016). To accomplish this, there are many MADM methods which have successfully been used in various topics related to the decision-making problems.

The BWM is a new MADM method which can be considered as a new approach to weighting criteria based on the updated perspective of pairwise comparisons (Rezaei, 2015, 2016). Generally, the MADM methods can be divided into the two main parts: the first category is those related to weighting criteria, and the second one are those related to alternatives evaluation and ranking. Although the basic concept of the BWM is the same as that of the AHP method, this method only works when weighting criteria is concerned, whereas the same is not suitable for ranking alternatives. The AHP (Saaty, 1980), ANP (Saaty, 1996), SWARA (Keršulienė, Zavadskas, & Turskis, 2010), FARE (Ginevičius, 2011), SMART (Gupta & Barua, 2016), Extended SWARA (Hashemkhani Zolfani, Yazdani, & Zavadskas, 2018), the Full Consistency Method (FUCOM) (Pamučar, Stević, & Sremac, 2018a) are other and common MADM methods for weighting criteria although the AHP, the ANP and FARE are capable of evaluating alternatives as well. Yadav, Mangla, Luthra, and Jakhar (2018) mentioned that, in comparison with the other methods such as the AHP, the ANP, FARE and SMART, the BWM was more consistent. The main difference between the BWM method and the other methods based on pairwise

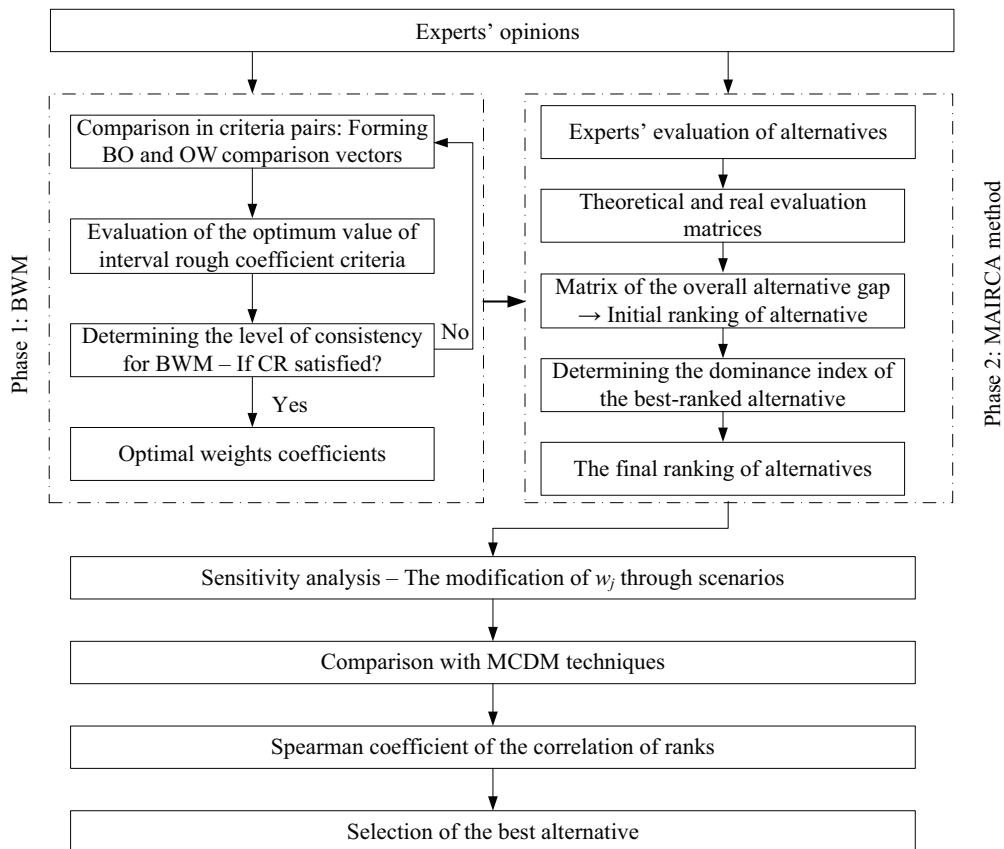


Figure 1. The framework of the proposed model

comparisons is its main structure based on the most significant and the least significant criteria (Salimi & Rezaei, 2016; Popović, Kuzmanović, & Savić, 2018). The algorithm of the method is presented as follows (Rezaei, 2015, 2016):

Algorithm: BWM

Input: Expert pairwise comparison of criteria
Output: Optimal values of the weight coefficients of criteria /sub-criteria

Step 1: The identification of the selected criteria as a set of the criteria related to the topic. The set of the criteria can be evaluated as $C_1, C_2, C_3, C_4, \dots, C_p$.

Step 2: Finding the best and the worst criteria. As is mentioned above, it should be done by experts and the involved decision-makers.

Step 3: The creation of a matrix of the preference of the best criterion over all the other criteria (BO vector) by applying numbers between 1 and 9:

$$A_b = (a_{1b}, a_{2b}, a_{3b}, \dots, a_{pb})$$

Step 4: The creation of a matrix of the preference of the worst criterion over all the other criteria (OW vector) by applying numbers between 1 and 9.

$$A_w = (a_{1w}, a_{2w}, a_{3w}, \dots, a_{pw})$$

Step 5: Generating the relative importance of the criteria through calculating the final and optimal weights for the criteria. The weights will show the same as : $w_1, w_2, w_3, \dots, w_n$.

$$\min \xi$$

s.t.

$$\left| \frac{w_b}{w_j} - a_{bj} \right| \leq \xi, \forall j$$

$$\left| \frac{w_j}{w_w} - a_{wj} \right| \leq \xi, \forall j$$

$$\sum_{j=1}^n w_j = 1$$

$$w_j \geq 0 \quad \forall j$$

Step 6: The same as with the AHP, there is a consistency index shown in Table 2. The consistency ratio should be calculated as follows:

$$\text{Consistency} = \frac{\xi}{\text{Consistency index}}$$

Table 2. The consistency index table for the BWM method

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

The BWM method has been applied in a large number of new studies and different research fields; generally, the main scope of the applications as per different fields includes: the supply chain management (SCM) (Rezaei, Wang, & Tavasszy, 2015); water resource management (Chitsaz & Azarnivand, 2016); complex bundling configurations (Rezaei et al., 2017); urban sewage sludge (Ren et al., 2017); social responsibility (Badri Ahmadi et al., 2017); logistic performance (Rezaei et al., 2018); standard dominance (van de Kaa et al., 2018); the cloud service (Nawaz et al., 2018); R&D performance (Salimi & Rezaei, 2018).

2.2. Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA)

The MAIRCA method is based on the definition of the gap between ideal and empirical ratings (Pamučar, Božanić, Lukovac, & Komazec, 2018b). To solve a decision problem by applying the MAIRCA method after determining alternatives and related criteria the following steps are validated.

Provided that the criterion $A_{D,1-j} < I_D$ is satisfied, then the rank of the alternative compared to the best-ranked alternative will be corrected, and then treated as

Algorithm: MAIRCA method

Input: Optimal values of the weight coefficients and initial decision-making matrix
Output: The final rank of the alternatives

Step 1: The determination of the initial decision-making matrix (X).
Step 2: Defining preferences for the choice of alternatives P_{A_i} .

$$P_{A_i} = \frac{1}{m}; \sum_{i=1}^m P_{A_i} = 1, i = 1, 2, \dots, m$$

Step 3: The calculation of the elements of the theoretical ratings matrix (T_p). The elements of the T_p are calculated as a product of preferences for the selection of the alternatives P_{A_i} and w_j .

$$T_p = P_{A_i} \begin{bmatrix} t_{p1} & t_{p2} & \dots & t_{pn} \end{bmatrix} = P_{A_i} \begin{bmatrix} P_{A_i} \cdot w_1 & P_{A_i} \cdot w_2 & \dots & P_{A_i} \cdot w_n \end{bmatrix}$$

Step 4: Defining the elements of the real ratings matrix (T_r). The elements of T_p are multiplied by the elements of the normalized initial decision-making matrix.
Step 5: The calculation of the total gap matrix (G). The elements of the G matrix are obtained as a gap between the theoretical and real ratings.
Step 6: The calculation of the final values of the criteria functions (Q_j) by alternatives. The values of the criteria functions are obtained by summing up the gap by alternatives
Step 7: Defining the dominance index ($A_{D,1-j}$) of the best-ranked alternative and the final rank of the alternatives. The dominance index of the best-ranked alternative defines its advantage in relation to the other alternatives

$$A_{D,1-j} = \left| \frac{|Q_j| - |Q_1|}{|Q_1|} \right|, j = 2, 3, \dots, m$$

Once the dominance index is determined, the dominance threshold I_D is determined by applying

$$I_D = \frac{m-1}{m^2} \quad \text{where } m \text{ denotes the number of the alternatives}$$

If $A_{D,1-j}$ is greater than or equal to I_D , the obtained rank will be retained Else
 If $A_{D,1-j}$ is smaller than I_D , Then the first ranked alternative has not enough advantage

$$R_{final,j} = \begin{cases} A_{D,1-j} \geq I_D & \Rightarrow R_{final,j} = R_{initial,j} \\ A_{D,1-j} < I_D & \Rightarrow R_{final,j} = R_{initial,1} \end{cases}$$

the best-ranked alternative, and it will be assigned the value “1” (Badi & Ballem, 2018). In this manner, it is emphasized that the best-ranked alternative is characterized by a smaller advantage than the one specified in I_D .

When the literature is examined, it is noteworthy that the MAIRCA method is still in its development period and is gradually being used in different fields. For instance, Gigović et al. (2016) combined the geographic information system (GIS) and multi-criteria decision-making approaches in the problem of the location selection for ammunition depots. To do this, the priority weights of the criteria were determined by DEMATEL-ANP. The sequence of alternative regions was performed by MAIRCA. Pamučar et al. (2017) applied DEMATEL-ANP in order to find criteria weights by using interval rough numbers in order to model uncertainty in decision-making processes. Furthermore, MAIRCA was used to evaluate the alternatives. The proposed method was used in the public tender procedure by the Government in the process of the selection of willing firms. The results obtained from the proposed method were also compared with the results of the fuzzy versions of the TOPSIS, VIKOR, MABAC, TODIM, ELECTRE I and DEMATEL-ANP methods. Badi and Ballem (2018) have also integrated the BWM-MAIRCA methods by using rough numbers. They used the proposed approach in the supplier selection process. As a result, the cost, the quality and the profile of a firm were determined as the three most important criteria. Chattarjee et al. (2018) used the DEMATEL-ANP-MAIRCA integrated model in the green supply chain management process. When the criterion weights were changed, the difference in the alternative rankings was determined by using Spearman’s Rank Correlation Coefficient. Finally,

Mamak Ekinci and Can (2018) suggested the CRITIC-MAIRCA integrated model in their study. The proposed method was used to determine the operators' integrated ergonomic risk levels by evaluating the two different factors that affect the ergonomic risk level.

3. Case study

The coastal La Serena-Coquimbo conurbation lies around the Elqui River basin outlet located at the southern edge of the Atacama Desert, Chile. This conurbation is the main urban area of Chile's Region IV (Región de Coquimbo, La Serena (The Capital)), and based on the 2012 national record the population counted 413,716 inhabitants. All the regional population was 707,654 (Salinas, Gironás, & Pinto, 2016). The climate of the region is arid, but there is a short, wet season in the winter, lasting for about three months. The average annual temperature in the region is about 13.5 °C. The average highest and minimum temperatures of the region are between 21 °C and 7 °C (Squeo et al., 2006).

Coquimbo and La Serena are two cities really close to one another, but with different backgrounds and histories. Even today, the lifestyles of these cities and the people are totally different, but the cities are too close to each other. Nowadays, it has become a common thing to work somewhere in the region and live in quite another part of the region. Recently, La Serena-Coquimbo conurbation has been mentioned in the literature and in the country. Although there are two municipalities with different regulations, yet there are some mutual developing plans for the conurbation. Eventually, different characteristics of the regions in the conurbation have become the main challenge for this study to do an investigation of the region and the conurbation.

Comuna is a local name in the management of the different regions of the cities in Chile, and it has its characteristics. Probably the best definitions for the *comuna* would be: *Comuna* is a form of the social and economic organization based on collective ownership and the elimination of traditional family values, and a group of the people who live in an economic community, which may sometimes be on a sexual basis, with the rules of coexistence outside the organized society. In order to touch on the best picture of the definitions, metropolitan Santiago can be the best example. *Comunas* differ from one another in architecture, the management systems and the lifestyles. Even a tourist can feel these big differences from one *comuna* to another. The alternatives have been selected based on *comunas* of the region.

The first alternative (A₁) – The Coastal Region of La Serena

This region is characterized by a magnificent view of the ocean and of Downtown Coquimbo during the day. This place is famous for its amazing sunrises and sunsets. During the summer, thousands of tourists usually arrive in the region and the largest number of them prefer to accommodate themselves in this location. The Faro Monumental, as a light house, has made this area more special. Somehow, the best nightlife location of the region is exactly inside this

area. Renting houses and apartments in this region is really a common thing to do, but the biggest problem related to this is that owners will rent their places mostly for 10 months because they can always rent them 3 more times during January and February. This region is exposed to a danger of a tsunami and the last tsunami happened in 2015, when 10 people were killed (Akkoc & Alexander, 2015). So, this place is really special, but in terms of natural hazards it is not really safe. There is actually a suitable system in this region for risky situations, too, meaning that after severe earthquakes you have at least 5 to 15 minutes to find a safe place on higher floors and run downtown, which is undoubtedly safer. This region is characterized by a new building style and it is also a tourist area.

The second alternative (A₂) – Downtown Coquimbo

Downtown Coquimbo is located on the top of a high hill and has a really beautiful view from the distance generally; and the atmosphere of the region is not modern and it is common to see a lot of colorful houses. There are almost no high-rise buildings and it is common to see houses; there are almost no really big apartments throughout the region, either. The selected location is just a small area of the region. The recently constructed Vivo Coquimbo Mall opened its doors one year ago. Somehow, that could make a big change in the face of the region. This region has a good view of the coastal area of La Serena and, generally speaking, lies in the north of the area. The area is located closely to the city bus station from where one can travel to other cities, so it can be the area's yet another advantage. The general culture of the downtown area is also different, and, in comparison with all the other regions, it is not modern. Safety is the main problem of the region. During the night, it can be dangerous, especially for a newcomer. The area is almost risky if faced with a tsunami, for which reason the people need to move to higher areas of the hill. The general atmosphere in the downtown area can be interesting for some people because that part of the city is really old-fashioned and the region is quite cheap for one to stay.

The third alternative (A₃) – Coquimbo Herradura (Coastal Region)

Herradura means a "horseshoe" and is located in the center of the coastal part of the bay. The place has a really good view and a good beach. It is safe and, because of the bay, a tsunami may not pose a severe danger, which implies that generally the whole area is safe. Only the owners of the apartments really close to the coastal area should be careful. There is the same challenge here as in the coastal areas of La Serena and it is usually possible to rent a house or an apartment for a period of 10 months because this region is a tourist area as well. Although the place is really charming, it is a bit far away from the nightlife and common entertainments. The general atmosphere of the area is quite modern and the population here does not believe they live in the same city as the people living downtown because the common general cultures in these two areas are totally different.



Figure 2. The location Universidad Católica del Norte

The fourth alternative (A_4) – Downtown La Serena

This can be yet another common area for a newcomer to live in. The same as Downtown Coquimbo, this area is old-fashioned and is not modern. The architecture is of a really better quality in comparison with Downtown Coquimbo, and may remind people of the general atmosphere found in European countries. It is a tourist area and you can find so many shops and entertainments there. Safety is a good point about the downtown area – it is almost safe if faced with a danger of a tsunami, but it lacks a view of the ocean. It can be reached in several ways. The airport for the whole of the region is closer to Downtown La Serena, which can be yet another advantage of the area. When the bus station is in question, there is no big difference because both La Serena and Coquimbo have it. The general atmosphere inside the area is modern and there is better access to different schools and universities and the best shopping centers are closer to the area in comparison with the other areas.

The fifth alternative (A_5) – Penuelas (Top Hills) in Coquimbo

This area has an almost good view of, but is far away from the ocean. There is a possibility of having some good views, which depends on the exact location. The region is sufficiently far away from the coastal area to be safer in terms of facing a tsunami and is generally greener and almost closer to the village atmosphere. The area is safe and it is a common thing to see houses, not apartments, around. The area is located between Coquimbo and La Serena, and both main regions are possible to access, but the area itself is special to some extent. It has certain advantages and disadvantages characteristic of the other areas, and is suitable

for those looking for a quieter place, safe and far away from the city life style, while simultaneously being really close to those other areas and having available services.

4. Application of the hybrid BWM-MAIRCA model

According to increase the impact of the research, an ordinary daily-life case was selected. The idea was to use real data as much as possible; therefore, locations should be clearer as much as possible. The real case is about someone working at Universidad Católica del Norte, Coquimbo Campus, Larrondo 1281. Figure 2 shows the exact location of the university in Coquimbo, which is not far away from Downtown Coquimbo.

Decision-making is planned to be performed based on this location and this situation – a new professor as a newcomer and a real case were selected. According to reality and in order to consider all the situations, the two main scenarios are considered.

4.1. Application of the Best-Worst method

Due to the analysis of the available literature and the experts' opinions (ten other professors had been interviewed), nine criteria for Scenario 1 (public transportation) and eight criteria for Scenario 2 (having a private car) were used, Table 3. In the first phase of the hybrid BWM-MAIRCA model, the BWM was used to determine the weight coefficients of the criteria in both scenarios. The application of the BWM is presented through the next four steps.

Step 1. Identifying the selected criteria. *The evaluation criteria for the first scenario* – Public transportation

in this conurbation works based on small buses and the shared taxi on defined routes. There are two bus routes covering both cities. Route 1 covers both city centers and Route 2 covers the city center of La Serena and the region not far away from the city center of Coquimbo, but was originally designed to cover the road to Universidad Catolica del Norte in Coquimbo. The most important bus lines are these two, although there are some other routes covering the other regions.

The evaluation criteria for the second scenario – The distance between these two cities in this conurbation is less than 15 kilometers around all the important regions of the conurbation. Although the toll, the tariff and payments are common in Chile, yet there are no costs that may justify having a car with the aim of improving comfortable living. The best common way to buy basic necessities is going to big retail markets such as Leiden, Santa Isabel, and Jumbo. Preparing the basic needs from these retail stores without a private car will be harder and, in some cases, impossible. So, having a private car can be an advantage itself.

Step 2. Defining the best and the worst criteria. Based on a field research and a mini-conference, a pairwise comparison of the BWM method was carried out. The new professor lived in two buildings and in two locations so as to check the general lifestyle in the regions. As a newcomer, the new professor visited some other houses and apartments in the regions and in the locations. Ten

other professors were interviewed by the new professor and at a mini-conference, the final decision based on the field research, the interviews and sharing ideas was made. The selected specialists as the experts pointed and selected the best (*B*) and the worst (*W*) criteria by consensus.

Steps 3 and 4. Defining the BO – OW vectors. According to this, the experts defined the BO vectors, where the advantage of the *B* criterion over the other criteria from the defined set of criteria was measured for both scenarios (both Scenario 1 and Scenario 2), Table 4.

After defining the BO vector, the experts have defined the OW vectors, where the advantage of the remaining criteria over the *W* criterion was defined for both scenarios (both Scenario 1 and Scenario 2), Table 5.

Step 5. The calculation of the optimal values of the weight coefficients for the criteria. A nonlinearly constrained optimization problem was formed using the BO and OW vectors (Tables 4 and 5). The model was used for calculation of the optimal values of the weight coefficients, Table 6.

By solving the model (3), the value of ξ^* is obtained for Scenarios 1 and 2, which is $\xi_{S1}^* = 0.4393$ and $\xi_{S2}^* = 0.3353$, respectively. The value of ξ^* is used to determine the consistency ratio, Equation (4), and the values $CR_{S1} = 0.084$ and $CR_{S2} = 0.075$ were obtained. Based on (Rezaei, 2015), the values obtained for the CR were considered as satisfactory.

Table 3. The main criteria for evaluating different neighborhoods based on Scenarios 1 and 2

Criteria		Definitions	Scenario 1	Scenario 2
C ₁	Tsunami danger	Danger of a tsunami after severe earthquakes	✓	✓
C ₂	Distance to entertainment	To shopping malls, the city center and noticeable places	✓	✓
C ₃	General safety	Robbery and other probable things	✓	✓
C ₄	Nightlife	Quality of nightlife (if it exists) and the distance to that	✓	✓
C ₅	Cost of living	Cost of renting an apartment or a house (monthly)	✓	✓
C ₆	View (especially of the ocean)	Based on the general situation in locations	✓	✓
C ₇	Access to public transportation	How many options? (fewer and more accessible)	✓	x
C ₈	Access to shopping retail stores	Access to local branches of big retail stores	✓	✓
C ₉	Distance to the workplace	Based on time (considering the distance and the walking time)	✓	✓

Table 4. The best criterion to the other criteria

Scenario 1									
Best to Others	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉
C ₃	6	3	1	7	9	8	2	5	3
Scenario 2									
Best to Others	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	
C ₃	4	2	1	2	5	3	7	6	

Table 5. The other criteria to the worst criterion (Scenario 1)

Scenario 1		Scenario 2	
Others to the Worst	C ₅	Others to the Worst	C ₇
C ₁	5	C ₁	5
C ₂	7	C ₂	8
C ₃	8	C ₃	8
C ₄	5	C ₄	7
C ₅	1	C ₅	5
C ₆	4	C ₆	6
C ₇	8	C ₇	1
C ₈	6	C ₈	4
C ₉	8		

Table 6. The final results and weights (Scenario 1 and Scenario 2)

Scenario 1 weights		Scenario 2 weights	
C ₁	0.063	C ₁	0.089
C ₂	0.126	C ₂	0.177
C ₃	0.294	C ₃	0.279
C ₄	0.054	C ₄	0.177
C ₅	0.026	C ₅	0.071
C ₆	0.047	C ₆	0.118
C ₇	0.189	C ₇	0.029
C ₈	0.076	C ₈	0.059
C ₉	0.126		

4.2. Application of the MAIRCA method

Some general tips about the decision-making matrix should be explained in more detail, namely as follows:

- There is no tsunami danger for the downtown areas of the La Serena and Penuelas regions. These regions are sufficiently far away from any kind of danger. Herradura is almost safe because it is located in the bay, so there is no special danger for buildings in this region. In the Coquimbo downtown area, there are quite a lot of signs and people know how they should run after a severe earthquake. Although the downtown area is located on a hill, only some small parts of this region are really safe, for which reason people should try to climb as high as mentioned based on the signs. The coastal region of La Serena, which is almost Avenue Del Mar, is in a dangerous situation, and people have 7–20 minutes to run to safe districts, which can be unsafe to do in some cases. There is no hill, so peo-

ple should run as much as they can. Although the last floors of taller buildings are not completely safe, they are still recommended in the case of sever dangers.

- The quality of entertainment is something of importance. This issue is a limitation of this research because people have different ideas and who is he who can describe which places are more quality; generally, the areas closer to La Serena have more attractions.
- The regions were considered as a possibility for one to have a good nightlife. There is still an opportunity for everyone to go to the other regions and look for a better nightlife there.
- The cost of living was considered based on the norm quality, so the average is the basis of decision-making with respect to this.
- Public transportation in this region is based on small buses and shared taxis. Based on these available options, a general perspective was presented.

After the calculation of the criterion weights (w_j), the alternatives were evaluated under the two scenarios (Scenario 1 and Scenario 2), and were selected based on the MAIRCA method.

Steps 1 and 2. Determining the initial decision-making matrix and defining preferences for the choice of alternatives.

Public transportation (Scenario 1) – Table 7 lists the characteristics of the five alternatives for living.

After the calculation of the evaluation criteria (Table 7), the preferences ($P_{Ai} = 1/5 = 0.20$) were defined.

Having a private car (Scenario 2) – After defining the initial decision-making matrix for Scenario 2 (Table 8), the algorithm of the MAIRCA method was applied through Eqs (5)–(7).

Table 7. The initial decision-making matrix for Scenario 1

Alternative	C ₁ (min) qualitative	C ₂ (min) kilometer	C ₃ (max) qualitative	C ₄ (max) qualitative	C ₅ (min) Chilean Peso	C ₆ (max) qualitative	C ₇ (max) qualitative	C ₈ (max) qualitative	C ₉ (min) kilometer
A ₁	7	0.2	8	8	350000	8	5	6	14
A ₂	6	0.5	4	4	250000	5	7	7	3.3
A ₃	3	6	7	3	300000	8	3	5	4
A ₄	1	6.5	7	5	250000	4	7	8	16
A ₅	1	4	7	3	375000	5	7	7	9.3
w _j	0.063	0.126	0.294	0.054	0.026	0.047	0.189	0.076	0.126

Table 8. The initial decision-making matrix for Scenario 2

Alternative	C ₁ (min) qualitative	C ₂ (min) kilometer	C ₃ (max) qualitative	C ₄ (max) qualitative	C ₅ (min) Chilean Peso	C ₆ (max) qualitative	C ₇ (max) qualitative	C ₈ (min) kilometer
A ₁	7	0.2	8	8	350000	8	6	14
A ₂	6	0.5	4	4	250000	5	7	3.3
A ₃	3	6	7	3	300000	8	5	4
A ₄	1	6.5	7	5	250000	4	8	16
A ₅	1	4	7	3	375000	5	7	9.3
w _j	0.089	0.177	0.279	0.177	0.071	0.118	0.029	0.059

Table 9. The real evaluation matrix for Scenario 1

Alternative	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉
A ₁	0.000	0.025	0.059	0.011	0.001	0.009	0.019	0.005	0.004
A ₂	0.002	0.024	0.000	0.002	0.005	0.002	0.038	0.010	0.025
A ₃	0.008	0.002	0.044	0.000	0.003	0.009	0.000	0.000	0.024
A ₄	0.013	0.000	0.044	0.004	0.005	0.000	0.038	0.015	0.000
A ₅	0.013	0.010	0.044	0.000	0.000	0.002	0.038	0.010	0.013

Table 10. The real evaluation matrix for Scenario 2

Alternative	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈
A ₁	0.000	0.035	0.056	0.035	0.003	0.024	0.002	0.002
A ₂	0.003	0.034	0.000	0.007	0.014	0.006	0.004	0.012
A ₃	0.012	0.003	0.042	0.000	0.009	0.024	0.000	0.011
A ₄	0.018	0.000	0.042	0.014	0.014	0.000	0.006	0.000
A ₅	0.018	0.014	0.042	0.000	0.000	0.006	0.004	0.006

After determining the evaluation criteria (Table 8), the preferences were determined as $P_{Ai} = 1/5 = 0.20$.

Steps 3 and 4. The calculation of the elements of the theoretical and the real ratings matrix.

Public transportation (Scenario 1) – The elements of the T_p matrix were multiplied by the normalized elements of the X matrix with the purpose of creating the T_r matrix (Table 9).

Having a private car (Scenario 2) – The same procedure was applied in Scenario 2. The calculation of the T_r (Table 10), is completed when the elements of the T_p were multiplied by the normalized elements of the X (Table 8).

Steps 5 and 6. The calculation of the total gap matrix and final ranking.

Public transportation (Scenario 1) – Here, the elements of the T_p were subtracted from the elements of the T_r in order to obtain the G . According to the values of the G between the T_p and the T_r , the primary assessment of the alternatives was completed, Table 11.

Table 11. The values of the total gaps (Scenario 1)

Alternative	Q _i	Initial rank	A _{D,1-j}	Final rank
A ₁	0.067	1	0.000	1
A ₂	0.091	4	0.222	4
A ₃	0.109	5	0.387	5
A ₄	0.081	3	0.128	1**
A ₅	0.070	2	0.026	1*

It is required for an alternative to have the smallest possible gap, i.e. one with the smallest total gap value (A₁).

Having a private car (Scenario 2) – After determining the total gap between the theoretical and the real evaluations, the initial evaluation of the alternatives was carried out, Table 12.

Table 12. The values of the total gaps (Scenario 2)

Alternative	Q _i	Initial rank	A _{D,1-j}	Final rank
A ₁	0.043	1	0.000	1
A ₂	0.120	5	0.773	5
A ₃	0.100	2	0.570	2
A ₄	0.106	3	0.630	3
A ₅	0.110	4	0.671	4

Step 7. The dominance index and the final rank of the alternatives.

Public transportation (Scenario 1) – In Scenario 1, the dominance threshold is $I_D = 0.160$. Since the DI of the alternative A₁ in relation to the alternatives A₅ and A₄ (initially the second- and the third-ranked alternatives) is smaller than I_D , we conclude that A₅ and A₄ do not have a sufficient advantage in relation to A₁, so the alternatives A₅ and A₄ will be assigned the corrected ranks “1*” and “1**”, respectively. The other values A_{D,1-j} are higher than I_D , so the initial rank is reserved for the other alternatives.

Having a private car (Scenario 2) – In Scenario 2, the dominance threshold is the same as in Scenario 1, i.e. $I_D = 0.160$. Since the DI of the alternative A₁ in relation to the other alternatives is greater than I_D , it is our conclusion that A₁ does have a sufficient merit in relation to the other decision answers. Therefore, the initial rank is reserved for the other alternatives.

4.3. Discussion

The discussion is divided into two main separated parts. The first part is a comparison of the results with those obtained from the other known MADM methods: the VIKOR, CODAS and MABAC methods. The second part covers a sensitivity analysis of the ranks of the alternatives related to changes in the weight coefficients of the criteria.

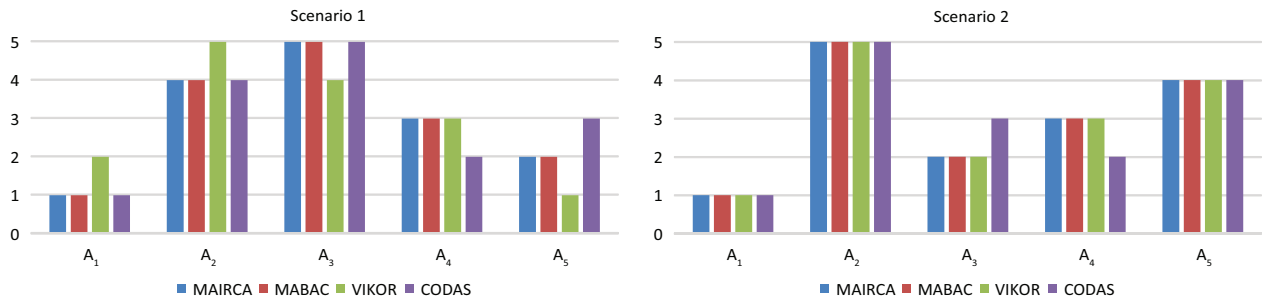


Figure 3. The ranking of the alternatives (Scenarios 1 and 2)

A comparison between the ranks attained from different MADM methods is demonstrated in Figure 3.

The final ranking of the alternatives as locations according to the stated MADM methods illustrates that: (1) for Scenario 1, the alternative A₁ took the highest rank among to all the methods, except the VIKOR method, in which it is the second-ranked (A₅ is the first-ranked); (2) for Scenario 1, the alternative A₅ is also the best-ranked according to the MAIRCA method since the alternative A₁ is not dominant enough, and (3) for Scenario 2, the alternative A₁ is the best-ranked among the all methods.

In this paper, for checking the reliability (Pamučar et al., 2018b), Spearman’s coefficient (r_k) was applied to define the statistical position of the difference results between the obtained results of the hybrid BWM-MAIRCA and the all other mentioned methods, Table 13.

Table 13. The rank correlation of the models

Spearman’s coefficient	MABAC	VIKOR	CODAS	Average value
Scenario 1 (r_k)	1.000	0.800	0.900	0.900
Scenario 2 (r_k)	1.000	1.000	0.900	0.967

The results demonstrate a significant correlation between the ranks of the different MADM methods in both scenarios. The final analysis illustrates the set {A₁, A₅} are dominant (for Scenario 1) and A₁ is dominant for Scenario 2. Based on the presented analysis, it is possible to conclude that the ranking given in Tables 11 and 12 is credible.

This part gives a sensitivity analysis of the ranking of the alternatives to changes in the weight coefficients of the criteria carried out through 12 scenarios (Table 15). The sensitivity analysis is based on Kirkwood’s (1997) and Kahraman’s (2002) recommendations. After identifying the *most important criterion* on the basis of the weights estimated by applying the BWM, the weights sensitivity analysis was performed by varying the weight of the *most important criterion* so as to observe its effect on the ranking performance of the proposed model.

According to Kirkwood (1997) and Kahraman (2002), the weight coefficient of the elasticity (α_c) of the most important criterion (which, for both scenarios, is C₃) is

assumed to be one. For the other criteria, the coefficients of elasticity (α_c) were estimated and are accounted for in Table 14.

Table 14. The weight coefficients of elasticity for changing weights for both scenarios

Criteria	α_c (Scenario 1)	α_c (Scenario 2)
C ₁	0.416	0.124
C ₂	0.178	0.246
C ₃	1.000	1.000
C ₄	0.076	0.246
C ₅	0.037	0.099
C ₆	0.066	0.164
C ₇	0.267	0.040
C ₈	0.107	0.082
C ₉	0.178	

At the next step, the limiting bounds of the weight change (Δx) for C₃ were calculated (Table 15).

Table 15. The limiting bounds of the weight change (Δx) for both scenarios

Criteria set	Δx (Scenario 1)	Δx (Scenario 2)
Set 1	−0.294	−0.279
Set 2	−0.194	−0.179
Set 3	−0.094	−0.1
Set 4	−0.004	−0.029
Set 5	0	0
Set 6	0.1	0.1
Set 7	0.2	0.2
Set 8	0.3	0.3
Set 9	0.4	0.4
Set 10	0.5	0.5
Set 11	0.6	0.6
Set 12	0.7	0.72

For Scenario 1, the limiting bounds of the weight change lie between −0.294 and 0.707. That is indicative of the fact that the weight of C₃ can be increased by the maximum amount of 0.707, and that it can be decreased

Table 16. The new criteria weights for Scenario 1 and Scenario 2

Scenario 1												
Criteria	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10	Set 11	Set 12
C ₁	0.089	0.080	0.071	0.063	0.063	0.054	0.045	0.036	0.027	0.018	0.009	0.001
C ₂	0.178	0.160	0.143	0.127	0.126	0.108	0.090	0.072	0.055	0.037	0.019	0.001
C ₃	0.000	0.100	0.200	0.290	0.294	0.394	0.494	0.594	0.694	0.794	0.894	0.994
C ₄	0.076	0.069	0.061	0.054	0.054	0.046	0.039	0.031	0.023	0.016	0.008	0.000
C ₅	0.037	0.033	0.029	0.026	0.026	0.022	0.019	0.015	0.011	0.008	0.004	0.000
C ₆	0.066	0.060	0.053	0.047	0.047	0.040	0.034	0.027	0.020	0.014	0.007	0.000
C ₇	0.267	0.241	0.214	0.190	0.189	0.162	0.135	0.109	0.082	0.055	0.028	0.002
C ₈	0.107	0.097	0.086	0.076	0.076	0.065	0.054	0.044	0.033	0.022	0.011	0.001
C ₉	0.178	0.160	0.143	0.127	0.126	0.108	0.090	0.072	0.055	0.037	0.019	0.001
Scenario 2												
Criteria	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10	Set 11	Set 12
C ₁	0.124	0.111	0.101	0.093	0.089	0.077	0.064	0.052	0.040	0.027	0.015	0.000
C ₂	0.246	0.221	0.202	0.184	0.177	0.153	0.128	0.103	0.079	0.054	0.030	0.000
C ₃	0.000	0.100	0.179	0.250	0.279	0.379	0.479	0.579	0.679	0.779	0.879	0.999
C ₄	0.246	0.221	0.202	0.184	0.177	0.153	0.128	0.103	0.079	0.054	0.030	0.000
C ₅	0.099	0.089	0.081	0.074	0.071	0.061	0.051	0.042	0.032	0.022	0.012	0.000
C ₆	0.164	0.148	0.135	0.123	0.118	0.102	0.085	0.069	0.053	0.036	0.020	0.000
C ₇	0.040	0.036	0.033	0.030	0.029	0.025	0.021	0.017	0.013	0.009	0.005	0.000
C ₈	0.082	0.074	0.067	0.061	0.059	0.051	0.043	0.034	0.026	0.018	0.010	0.000

by the maximum amount of 0.294. For Scenario 2, the limiting bounds of the weight change lie between -0.279 and 0.720 . When $\Delta x = 0$, criteria weights become equal to the original set of weights. After defining these limits, the twelve sets of the new weights are calculated, as shown in Table 16.

According to the presented methodology, the criteria sets were analyzed and the results of the evaluation are presented in Figure 4.

According to Figure 4, the following conclusions can be drawn:

- (1) For Scenario 1, the alternative A_1 retained its 1st rank for the weight interval of $0.290 \leq w_{C_3} \leq 0.9940$.
- (2) For Scenario 1, when the weight of the C_3 criterion is decreased beyond the 0.2 value, A_2 emerges as the best alternative. However, at the lower values of C_3 (i.e. lower than 0.2), the alternative A_1 is always the best alternative. So, the weight stability interval for A_1 is found to be $0.290 \leq w_{C_3} \leq 0.9940$.
- (3) For Scenario 1, changing the weight of the C_3 criterion through 3 sets (Set 1-Set 3) results in the different ranks of the intermediate alternatives. However, these changes are not so drastic, which is confirmed by the values of r_k of the ranks through different sets. By analyzing the results, it is possible to draw a conclusion that there is a high correlation of the ranks,

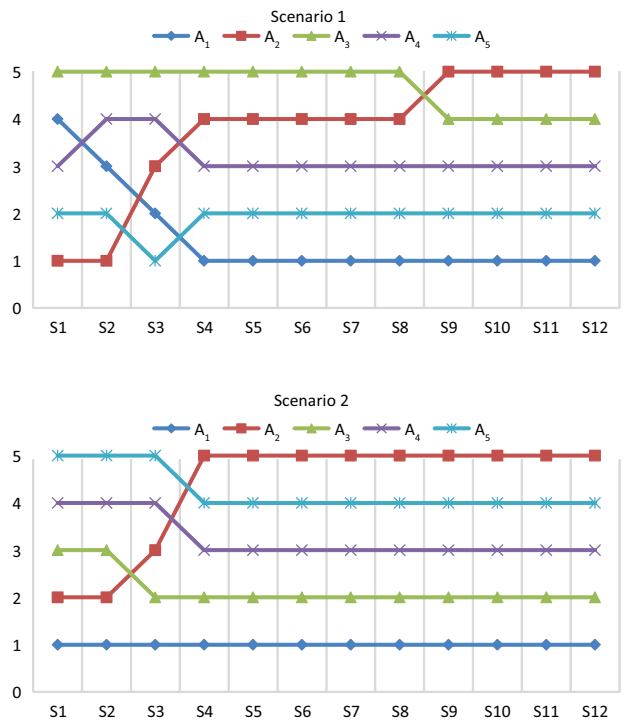


Figure 4. Ranking changes (Scenarios 1 and 2)

since in 10 sets the value of r_k is greater than 0.80, while in nine scenarios, it is greater than 0.9. The mean value of r_k through all the scenarios is 0.817, so, it can be determined that there is a satisfactory closeness of the final ranks.

- (4) For Scenario 2, the alternative A_1 retained its 1st rank for all the values from the weight interval of $0.0 \leq w_{C_3} \leq 0.990$.
- (5) As in Scenario 1, in Scenario 2, changing the weight of the C_3 criterion through 3 sets (Set 1-Set 3) results in the different ranks of the intermediate alternatives. It can be concluded that there is a high correlation of the ranks since, in nine sets, the value of r_k is 1.00. The mean value of r_k through all the scenarios is 0.875, so, we can conclude that the proposed ranking is confirmed and credible.

Conclusions

Generally, cities are managed based on different models, which depends on the policies implemented in particular countries, regions and provinces. It is really important to know the exact challenges of a decision-making problem; therefore, regional information should be really important and vital. This image is also recognizable in the Coquimbo-La Serena conurbation. A different taste of people from different historical backgrounds is understandable, especially so in the downtown area of Coquimbo, and the capitalistic structure of the economy of Downtown Coquimbo cannot be said to be the main driving force. For the reason of the said, there are so many cases of the same kind in this country and this case is an important one.

Nowadays, immigration and mid-term living plans are being developed. Although Chile declined immigration as a human right, they still have immigrants and refugees coming from different countries, such as: Haiti, Venezuela, Colombia, and Peru. The majority of newcomers arrive from these countries and neighborhood selection would be a big challenge for them; the issue of a salary and capital will not be the only issue in this challenge. It seems that even the government needs a program so as to be able to see which regions will have a larger number of newcomers, and they also need to have some plans for managing things. Controlling the population of cities, regions and *comunas* will be a challenge for the government and municipalities to face. In this study, an ordinary case, such as that of someone with the highest job opportunities, was examined. Probably, the planning based on the refugees' situation will be as helpful as some studies; special attention needs to be paid to Haitian and Venezuelan refugees.

The contribution of this study is not only reflected in the case studied in it, but it also reflects in the methodology applied. A new hybrid MADM method based on the BWM-MAIRCA, which was applied for the first time, is presented in the paper. Moreover, the final evaluations and results obtained were compared and matched with the results obtained by applying three other MADM methods

based on VIKOR, CODAS and MABAC, and a sensitivity analysis of the ranks of the alternatives was carried out based on the weight coefficients of the criteria. Meanwhile, due to perfectly consider the things in reality, two scenarios were defined based on two different situations. The scenarios focused on one key point (i.e. transportation). According to the results obtained and the sensitivity results, the new proposed hybrid MADM model can be helpful in different decision-making problems in the future. The VIKOR, CODAS, MABAC and MAIRCA results are only applicable to the specified set of and fixed alternatives.

This study is significant from the two different perspectives: policy-making (the governance perspective), newcomers and immigrants. As a social perspective, the lifestyle and different layers of society are involved. This study can be a suitable pilot study for other social topics related to the lifestyle, ordinary and complicated daily life issues related to the governance, political, economic, and other related aspects. Eventually, other countries such as Germany, Canada, Australia, Turkey and Iran, which have so many immigrants and refugees, can apply this research in some further studies of theirs in their related challenges.

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