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The Housing Recommendation System Uses Multi-Criteria Decision-Making Methods

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ABSTRACT

Economic and population growth, increasing urbanization, changing habits, new welfare requirements, and lower interest rates have led to increased demand for housing in cities. However, housing conditions in many cities are slightly alarming, while housing is a primary need for the community. Selecting housing for low-income people (LIP) that meets the criteria required by LIP is not an easy task. Because most of the decisions people made did not utilize detailed information. Therefore, a recommendation system for LIP is required. This study aims to develop the housing selection recommendation system for LIP that best suits their wishes. This study integrated two multi-criteria decision-making (MCDM) methods: the Best Worst (BW) method, which has fewer pairwise comparisons compared to other MCDM methods for selecting criteria and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method for determining housing recommendations for LIP according to their wishes. Based on the analysis results, ten criteria dominate the housing selection for LIP sequentially: Location, Land Size, Down Payment, Public Facilities, Price, Booking Fee, Home Design, House Specifications, House Quality, and Home Ownership Credit. Furthermore, the sensitivity analysis results showed that the robustness score of this approach was high. The model could recommend housing for LIP that best suits their wishes.

Keywords: BW; Housing; MCDM; Recommendation System; TOPSIS

INTRODUCTION

One of the primary needs that affect the economic, social, and several other crucial aspects of life is the house. Along with economic and population growth, increasing urbanization, changing habits, and lower interest rates have led to increased demand for urban housing in Indonesia, especially for low-income people (LIP). However, due to the limited purchasing power of the people, the Government of Indonesia provides housing financing assistance for LIP (Indonesia, 2021). This housing finance assistance policy has also received global attention over the last few decades as a way to address the increasing population, urbanization, and poverty (Wu, Luo, & Peng, 2020).

One effort to assist the LIP in selecting housing according to the desired criteria is to provide a recommendation system for selecting housing locations. Selecting housing according to some people is a simple and easy problem, however, this turns out to be complicated when faced with many choices of housing locations where each housing has advantages and disadvantages. For example, the number of housing for LIP in Palembang city reaches hundreds of locations (Indonesia, 2022).

Most selection problems are the number of criteria that are associated with which creates uncertainty which can make the final decision difficult and unrealistic (Gustriansyah, Ermatita, Rini, & Malik, 2020a). One determinant of the success of the recommendation system is the selection of criteria required by the recommendation system (Sadjadi & Karimi, 2018). This study used the BW approach to select the criteria based on feedback from decision-makers. The BW approach has fewer pairwise comparisons when compared to other multi-criteria decision-making methods (Sadjadi & Karimi, 2018). The BW method has been applied in many cases such as assessment (Salimi, 2017), selection (Gustriansyah, Ermatita, Rini, & Malik, 2020b), investment (Askarifar, Motaffef, & Aazaami, 2018), classification and evaluation (Abadi, Sahebi, Arab, Alavi, & Karachi, 2018; Salimi & Rezaei, 2018), key success factors (Ghaffari, Arab, Nafari, & Manteghi, 2017), innovation and strategy-making (Khanmohammadi, Zandieh, & Tayebi, 2019), and group decision-making problems (Maharani, Ridwanto, Hatta, Khairina, & Ibrahim, 2021).

Meanwhile, the TOPSIS is utilized to select the most recommended LIP housing according to the LIP criteria. Because the TOPSIS approach is straightforward, understandable, computationally efficient, and can be used to assess the relative performance of several decision alternatives (Aulawi, Riansyah, & Kurniawati, 2020). The integration of the two approaches is expected to produce housing recommendations that are more optimal, easy to implement, and

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in line with public expectations.

There were twenty-one studies relevant to housing selection in the last five years. The data was retrieved from Scopus and Google Scholar using the publish or perish (PoP) software. Seven studies used SAW, three studies applied AHP, two other studies used TOPSIS, and the remaining nine studies used FSAW or SMART or MAUT or MOORA or PROMETHEE or ELECTRE or ARA or HDM or FTOPSIS/FVIKOR/ FWASPAS/FMMOORA. However, all studies were not evaluated except (Kizielewicz & Bączkiewicz, 2021).

Furthermore, several case studies used the BW-TOPSIS approach, such as supplier selection (Javad, Darvishi, & Javad, 2020), service selection (Youssef, 2020), evaluation (Chen, Ming, Zhou, & Chang, 2020) and assessment (Gupta & Barua, 2017). However, no studies have applied the BW-TOPSIS approach to the LIP housing recommendation system. In addition, this research is also expected to expand knowledge about the factors that influence people's decisions to select LIP housing. It can also be input for developers when developing LIP housing, and it can even be a marketing strategy to increase sales of LIP houses.

LITERATURE REVIEW

Best-Worst Method

The MCDM is one of the most well-known decision-making methods utilized in various fields. There are several MCDM methods for determining criteria weights and ranking such as AHP (Mardison, Ramadhanu, Rani, & Enggari, 2021), DEMATEL (Chen et al., 2020), FAHP (Gustriansyah, Sensuse, & Ramadhan, 2015), TOPSIS (Youssef, 2020), ANP (Abdel-Baset, Chang, Gamal, & Smarandache, 2019), FTOPSIS (Aulawi et al., 2020), VIKOR (Abdel-Baset et al., 2019), SAW (Mardison et al., 2021), GRA (Chen et al., 2020), ELECTRE (Akcan & Güldeş, 2019). BW is one of the MCDM methods that can generate criteria weights by using pairwise comparisons based on the most dominant (best) criterion over other criteria and all other criteria over the least dominant (worst) criterion (Liang, Brunelli, & Rezaei, 2020).

The BW method steps utilized to calculate the criteria weights are as follows (Sadjadi & Karimi, 2018):

Step 1. *Determine the decision criteria.* Experts identify l criteria ($q_1, q_2, \ldots, q_l$) that significantly affect decision making.

Step 2. *Deciding the best and worst criteria.* The experts only choose the most dominant (best) criterion and the least dominant (worst) criterion from the criteria that have been obtained in Step 1 based on their experience. Where q_B represents the best criterion and q_W represents the worst criterion.

Step 3. *Define the preference score for the best criterion over all other criteria*. Determining the preference rating using numbers 1 to 9 (1: equally dominant, 9: extremely more dominant). This step produces the Best-to-Others (B2O) vector, $a_B = (a_{B1}, a_{B2}, \ldots, a_{Bl})^T$, where $a_{BB} = 1$ and a_{Bj} is the rating of the best criterion B over any other criteria j (j=1,2, …, l). All experts' consensus involved in decision making is taken as the final preference score.

Step 4. *Define the preference score for all other criteria over the worst criterion*. Similar to the third step, determining the preference rating using numbers 1 to 9. This step produces the Other-to-Worst (O2W) vector, $a_w = (a_{1w}, a_{2w}, \ldots, a_{lw})^T$, where $a_{ww} = 1$ and a_{jw} is the dominance of each criterion j over the worst criterion W. Furthermore, all experts' consensus is taken for the final preference score.

Step 5. *Define the optimal weights for each criterion.* It aims to calculate the weights of all criteria so that the maximum absolute difference for all j of the set $\{|w_B - a_{Bj}\, w_j|, |w_j - a_{jw}\, w_w|\}$ can be minimized. This set can be defined in the min-max optimalization, as in (1).

$$\text{minimize} \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \qquad (1)$$

Furthermore, it can be defined in a linear programming model as in (2).

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$$\begin{aligned} & \text{minimize } \xi \\ & \text{subject to:} \\ & \left|\frac{w_B}{w_j} - a_{Bj}\right| \le \xi^* \\ & \left|\frac{w_j}{w_w} - a_{jw}\right| \le \xi^* \\ & \text{where } \sum w_j = 1 \text{ and } w_j \ge 0 \\ & j = 1,2,\dots,l \end{aligned} \quad (2)$$

The optimal weight criteria w_j^* and ξ^* can be obtained by solving (2). The next step is to determine the consistency ratio of the pairwise comparison vector. The consistency ratio (*RK*) is a critical variable to assess the consistency of pairwise comparison vectors. The *RK* was determined using (3)(Gustriansyah et al., 2020b).

$$RK = \frac{\xi^*}{IK} \quad (3)$$

Where *IK* is the consistency index or the maximum ξ value for each a_{BW} as presented in Table 1, and ξ^* is the solution of (2). The *RK* value is between 0 and 1. The closer the *RK* value is to 0, the higher the vector consistency. Otherwise, the closer the *RK* value is to 1, the lower the vector consistency. Based on (3), *RK* is equivalent to ξ^*. Therefore, the smaller ξ^*, the smaller the *RK*, or the higher the vector consistency.

Table 1
IK Values

a_{bw}	1	2	3	4	5	6	7	8	9
IK	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

TOPSIS Method

Technique for order preference by similarity to ideal solution (TOPSIS) is one of the MCDM methods to obtain the optimal alternative (Hildayanti et al., 2018). The basic concept of the TOPSIS method is to determine the optimal alternative that has the farthest distance from the negative ideal solution and the nearest distance from the positive ideal solution (Youssef, 2020).

The more criteria and decision alternatives involved in the decision-making process, the more difficult it is to decide on a problem. Especially if the decision making of an issue involves several decision-makers. The TOPSIS method can be utilized for multi-criteria decision-making issues because it can rank decision alternatives, is computationally efficient, and has a simple concept (Aulawi et al., 2020).

The steps of the TOPSIS method are as follows (Hildayanti et al., 2018):

Step 1. *Determine the decision criteria.*
Make an alternative decision matrix A (a_{ij}) on each criterion, then normalized to a matrix B (b_{ij}) using (4).

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{k} a_{ij}^2}} \quad (4)$$

Where a_{ij} = decision matrix, b_{ij} = normalized matrix, $i=1, 2, \dots, k$, and $j=1, 2, \dots, l$.

Step 2. *Determine the weighted normalized decision matrix (Y_{ij}) using (5).*

$$Y_{ij} = w_j * b_{ij} \quad (5)$$

Where w_j is the weight of the j^{th} criterion.

Step 3. *Determine the positive and negative ideal solutions (X_j) using (6) and (7).*

$$X_j^+ = \{(\text{maks } Y_{ij} \mid j \in J^-), (\min Y_{ij} \mid j \in J^+), i=1,2,3,\dots k\} = \{Y_1^+, Y_2^+, \dots, Y_l^+\} \quad (6)$$

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$$X_j^- = \{(\min Y_{ij} \mid j \in J^-), (\text{maks } Y_{ij} \mid j \in J^+), i=1,2,3,...k\} = \{Y_1^-, Y_2^-,..., Y_l^-\} \quad (7)$$

Where $J^+ = \{j=1,2,3, ..., l$ and j are positive criteria$\}$ and $J^- = \{j=1,2,3, ..., l$ and j are negative criteria$\}$.
Step 4. *Calculate the distance between each alternative i with a positive and a negative ideal solution using (8) and (9).*

$$D_i^+ = \sqrt{\sum_{j=1}^{l}(Y_{ij} - Y_j^+)^2}\ ; i = 1,2,3,..., k \quad (8)$$

$$D_i^- = \sqrt{\sum_{j=1}^{l}(Y_{ij} - Y_j^-)^2}; i = 1,2,3,..., k \quad (9)$$

Step 5. *Calculate the value of the closeness coefficient (Cc) which is the preference value for each alternative using (10).*

$$Cc_i^+ = \frac{D_i^-}{D_i^+ + D_i^-}\ ; 0 \le Cci^+ \le 1 \text{ and } i = 1, 2, 3, ..., k \quad (10)$$

Step 6. *Sorting the value of closeness coefficient.*

METHOD

The general research phases are shown in Fig. 1.

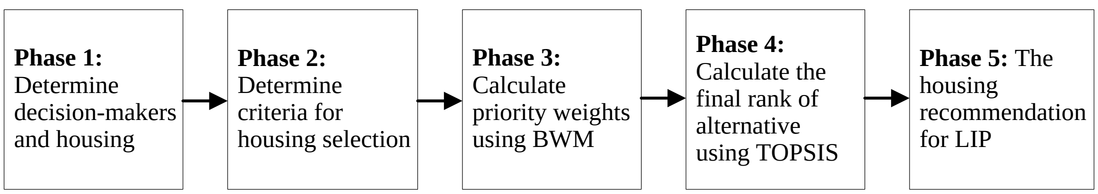

Fig. 1 Research design

This research collects the opinions of ten experts who have experience marketing houses for LIP. The first questionnaire is a questionnaire that collects criteria that influence the selection (purchase) of housing for LIP (Taherdoost & Brard, 2019). Furthermore, the collected criteria will become the second questionnaire (the initial step of the BW) after being validated by a minimum of six experts (Javad et al., 2020). The BW outputs were the optimal criteria weights. They were utilized (by TOPSIS) to rank the housing for the LIP that best suits them. Finally, the housing recommendation system for LIP was evaluated using sensitivity analysis (Baharin, Rashidi, & Mahad, 2021).

RESULT

Weight determination using the BW approach

Criteria are determined based on opinions obtained from marketers of housing for LIP who have long experience. The literature review, first questionnaire, and interview are the first step in selecting criteria for this research. There are twenty-two criteria identified. However, only ten criteria are validated by a minimum of six experts. The ten criteria are Q_1: Location, Q_2: Public Facilities, Q_3: Land Size, Q_4: Down-Payment, Q_5: Price, Q_6: Home Design, Q_7: Booking Fee, Q_8: House Quality, Q_9: House Specifications, and Q_{10}: Home Ownership Credit. These ten criteria will be assessed for the level of preference at a later step.

The best criterion was the criterion chosen by each expert as the most influential criterion in the housing selection for LIP. The worst criterion was the criterion that least influenced the housing selection based on the preferences of each expert. Feedback was gathered from a short questionnaire, and the results were as shown in Tables 2 and 3. Ten experts were requested to state their priorities. Expert consensus will be used to resolve the preferences rating.

Experts state the priority value for the best criterion over all other criteria using the numbers 1 to 9. Table 2 shows the feedback results in the B2O matrix.

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Table 2
All B2O Values from The Experts

Experts	Best Criterion	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_8	Q_9	Q_{10}
1	Q_1	1	3	2	2	4	7	5	6	8	9
2	Q_1	1	5	2	2	5	7	8	9	2	4
3	Q_1	1	2	3	4	5	6	9	7	8	7
4	Q_1	1	5	3	3	2	6	4	7	8	9
5	Q_1	1	5	2	2	4	6	3	8	7	8
6	Q_1	1	3	2	3	5	7	4	6	8	9
7	Q_1	1	2	2	3	5	8	4	6	7	9
8	Q_1	1	3	4	3	2	6	5	9	8	7
9	Q_1	1	2	3	5	4	5	6	8	7	9
10	Q_1	1	4	2	3	5	6	5	8	9	7

The fourth step is identical to the third. However, the experts were requested to state the priority values for all other criteria over the worst criterion. Values are still expressed with the numbers 1 to 9. Table 3 shows the feedback results in the O2W matrix.

Table 3
All O2W Values from The Experts

Experts	Worst Criterion	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_8	Q_9	Q_{10}
1	Q_{10}	9	7	8	8	6	3	5	4	2	1
2	Q_8	9	8	6	7	5	2	3	1	4	2
3	Q_7	9	8	7	6	5	4	1	3	2	3
4	Q_{10}	9	4	7	7	8	6	5	3	2	1
5	Q_8	9	4	8	8	5	6	7	1	3	2
6	Q_{10}	9	7	8	7	5	3	6	4	2	1
7	Q_{10}	9	8	8	7	4	2	6	5	3	1
8	Q_8	9	7	6	7	8	5	4	1	2	3
9	Q_{10}	9	8	7	6	4	5	4	2	3	1
10	Q_9	9	3	8	7	6	5	4	2	1	3

Optimal weights were determined using the BW linear model, as in (2). The priority weights for each criterion from each expert produce an average weight matrix that be seen in Table 4. It shows that the average value of ξ^* is close to zero (0.3857). It means that the value of *RK* is also getting closer to zero based on (3). These results indicated that pairwise comparisons have high consistency.

Table 4
The Priority Weights of Each Expert

Criteria (Q)	The priority weights of each expert										Average
	1	2	3	4	5	6	7	8	9	10	
1	0.2315	0.2167	0.2635	0.2454	0.2278	0.2454	0.2315	0.2454	0.2578	0.2578	0.2423
2	0.1135	0.0637	0.1937	0.0722	0.0683	0.1203	0.1702	0.1203	0.1895	0.0948	0.1207
3	0.1702	0.1593	0.1292	0.1203	0.1709	0.1804	0.1702	0.0902	0.1264	0.1895	0.1507
4	0.1702	0.1593	0.0969	0.1203	0.1709	0.1203	0.1135	0.1203	0.0758	0.1264	0.1274
5	0.0851	0.0637	0.0775	0.1804	0.0854	0.0722	0.0681	0.1804	0.0948	0.0758	0.0983
6	0.0486	0.0455	0.0646	0.0601	0.0570	0.0516	0.0425	0.0601	0.0758	0.0632	0.0569
7	0.0681	0.0398	0.0155	0.0902	0.1139	0.0902	0.0851	0.0722	0.0632	0.0758	0.0714

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Criteria (Q)	The priority weights of each expert										Average
	1	2	3	4	5	6	7	8	9	10	
8	0.0567	0.0127	0.0554	0.0516	0.0142	0.0601	0.0567	0.0144	0.0474	0.0474	0.0417
9	0.0425	0.1593	0.0484	0.0451	0.0488	0.0451	0.0486	0.0451	0.0542	0.0152	0.0552
10	0.0136	0.0797	0.0554	0.0144	0.0427	0.0144	0.0136	0.0516	0.0152	0.0542	0.0355
ξ*	0.3392	0.5471	0.3369	0.3724	0.4548	0.3311	0.3819	0.3499	0.3571	0.3871	0.3857

Therefore, the average weight of each criterion can be used in the calculation. This value indicates the priority of the criteria. Table 4 shows the prioritization of criteria in housing selection in order, namely Location (Q_1), Land Size (Q_3), Down-Payment (Q_4), Public Facilities (Q_2), Price (Q_5), Booking Fee (Q_7), Home Design (Q_6), House Specifications (Q_9), House Quality (Q_8), and Home Ownership Credit (Q_{10}).

Determination of housing recommendations for LIP using the TOPSIS method

Testing the housing recommendation system was applied to ten housing for LIP as a case study. The community as a prospective consumer (decision-maker) is requested to complete a questionnaire with a scale of 0-4 for each criterion in each housing as in Table 5. The scoring matrix (b_{ij}) from Table 5 is normalized using (4) so that the results can be seen in Table 6.

Table 5
The Score of Each Criterion for Each Housing

Criteria (Q)	Score for each housing (S)									
	1	2	3	4	5	6	7	8	9	10
1	4	3	0	4	3	3	3	4	3	4
2	4	4	2	4	2	4	3	4	4	3
3	0	4	4	4	2	4	2	4	4	4
4	3	4	0	3	3	4	3	3	4	3
5	4	4	0	4	0	4	0	4	3	4
6	0	4	0	3	3	4	3	3	4	3
7	2	4	0	2	3	4	3	2	4	2
8	3	4	4	4	4	4	4	4	4	4
9	2	2	2	2	2	2	2	2	2	2
10	4	4	0	2	2	4	2	2	4	2

Table 6
Matrix Value Analysis for Each Housing (B_{ij})

Criteria (Q)	The normalized value for each housing (S)									
	1	2	3	4	5	6	7	8	9	10
1	0.3831	0.2873	0.0000	0.3831	0.2873	0.2873	0.2873	0.3831	0.2873	0.3831
2	0.3621	0.3621	0.1811	0.3621	0.1811	0.3621	0.2716	0.3621	0.3621	0.2716
3	0.0000	0.3651	0.3651	0.3651	0.1826	0.3651	0.1826	0.3651	0.3651	0.3651
4	0.2970	0.3961	0.0000	0.2970	0.2970	0.3961	0.2970	0.2970	0.3961	0.2970
5	0.3904	0.3904	0.0000	0.3904	0.0000	0.3904	0.0000	0.3904	0.2928	0.3904
6	0.0000	0.4148	0.0000	0.3111	0.3111	0.4148	0.3111	0.3111	0.4148	0.3111
7	0.2209	0.4417	0.0000	0.2209	0.3313	0.4417	0.3313	0.2209	0.4417	0.2209
8	0.2425	0.3234	0.3234	0.3234	0.3234	0.3234	0.3234	0.3234	0.3234	0.3234
9	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162
10	0.4364	0.4364	0.0000	0.2182	0.2182	0.4364	0.2182	0.2182	0.4364	0.2182

The weighted normalized decision matrix (Y_{ij}) is obtained using (5), where each value from Table 6 is multiplied

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by the average weight of each criterion from Table 4 (BW output) as presented in Table 7.

Table 7
The Weighted Normalized Decision Matrix (Y_{ij})

Criteria (Q)	The weighted normalized for each housing (S)									
	1	2	3	4	5	6	7	8	9	10
1	0.0928	0.0696	0.0000	0.0928	0.0696	0.0696	0.0696	0.0928	0.0696	0.0928
2	0.0437	0.0437	0.0218	0.0437	0.0218	0.0437	0.0328	0.0437	0.0437	0.0328
3	0.0000	0.0550	0.0550	0.0550	0.0275	0.0550	0.0275	0.0550	0.0550	0.0550
4	0.0378	0.0504	0.0000	0.0378	0.0378	0.0504	0.0378	0.0378	0.0504	0.0378
5	0.0384	0.0384	0.0000	0.0384	0.0000	0.0384	0.0000	0.0384	0.0288	0.0384
6	0.0000	0.0236	0.0000	0.0177	0.0177	0.0236	0.0177	0.0177	0.0236	0.0177
7	0.0158	0.0315	0.0000	0.0158	0.0237	0.0315	0.0237	0.0158	0.0315	0.0158
8	0.0101	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135	0.0135
9	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175
10	0.0155	0.0155	0.0000	0.0077	0.0077	0.0155	0.0077	0.0077	0.0155	0.0077

Table 8 presents the positive and negative ideal solutions calculated using (6) and (7). Furthermore, Table 9 shows the Euclidean distance for each alternative housing for LIP established using (8) and (9).

Table 8
The Positive and Negative Ideal Solutions (X_i)

	Criteria (Q)									
	1	2	3	4	5	6	7	8	9	10
Xi^+	0.0928	0.0437	0.0550	0.0504	0.0384	0.0236	0.0315	0.0135	0.0175	0.0155
Xi^-	0.0000	0.0218	0.0000	0.0000	0.0000	0.0000	0.0000	0.0101	0.0175	0.0000

Table 9
The Distance of The Positive and Negative Ideal Solutions (D_i)

	The housing (S)									
	1	2	3	4	5	6	7	8	9	10
Di^+	0.0633	0.0232	0.1221	0.0224	0.0597	0.0232	0.0566	0.0224	0.0251	0.0249
Di^-	0.1117	0.1190	0.0551	0.1251	0.0893	0.1190	0.0900	0.1251	0.1163	0.1237

Finally, using (10) can be obtained the closeness coefficient (Cc) and the housing ranting for LIP as shown in Fig. 2. The test results show that S_4, S_8, S_2, S_6, S_{10} and S_9 housings are recommended based on prospective consumer who is sampled in this case study. The S_4 and S_8 housings are the most recommended housing. Meanwhile, S_1, S_5, and S_7 housings are less recommended. In addition, the third housing (S_3) is not recommended.

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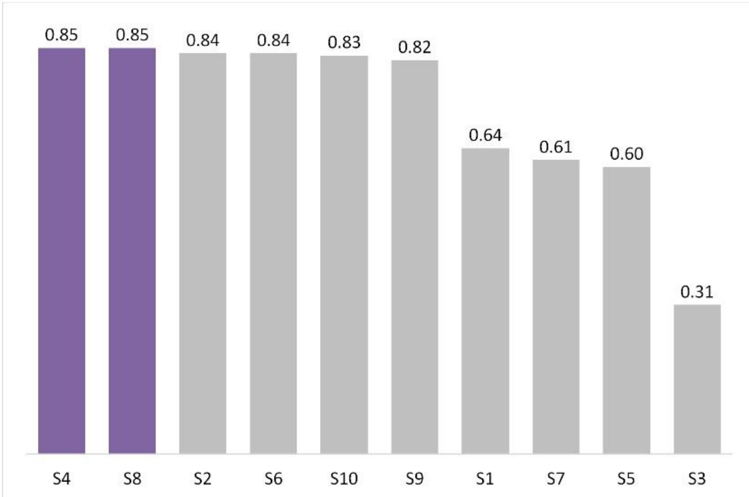

Fig. 2 Closeness coefficient (Cc) and the housing rating for LIP.

Sensitivity analysis

The consistency of housing ratings in this study was evaluated by sensitivity analysis. It aims to measure the robustness of the alternative ratings generated by the BW-TOPSIS model when the input weight data is modified. For this purpose, ten different scenarios were designed by changing the weight of each criterion from the TOPSIS to zero (Baharin et al., 2021). The consistency of the model is low if the rantings of the alternatives differ very when the weighting scenarios are applied. Details of the sensitivity analysis results for the ten scenarios are shown in Table 10.

Table 10
The Sensitivity Analysis Results

The housing (S)	The closeness coefficient (Cc) values for each criterion (Q) are dropped									
	1	2	3	4	5	6	7	8	9	10
1	0.4958	0.6340	0.7815	0.6291	0.6239	0.6556	0.6436	0.6388	0.6385	0.6363
2	1.0000	0.8345	0.8198	0.8229	0.8292	0.8341	0.8318	0.8368	0.8369	0.8357
3	0.4101	0.3145	0.0269	0.3315	0.3223	0.3151	0.3185	0.3106	0.3110	0.3128
4	0.7892	0.8461	0.8337	0.8655	0.8416	0.8514	0.8863	0.8480	0.8481	0.8558
5	0.5044	0.6166	0.6160	0.5811	0.6615	0.5958	0.5928	0.5993	0.5995	0.6006
6	1.0000	0.8345	0.8198	0.8229	0.8292	0.8341	0.8318	0.8368	0.8369	0.8357
7	0.5248	0.6166	0.6340	0.5967	0.6839	0.6105	0.6077	0.6137	0.6139	0.6152
8	0.7892	0.8461	0.8337	0.8655	0.8416	0.8514	0.8863	0.8480	0.8481	0.8558
9	0.9066	0.8198	0.8032	0.8067	0.8292	0.8193	0.8168	0.8224	0.8224	0.8211
10	0.7663	0.8461	0.8163	0.8455	0.8250	0.8348	0.8640	0.8322	0.8322	0.8389

Figure 3 demonstrates a graphical representation of the sensitivity analysis results. The findings indicated that alternative S_4 has a robustness score of 90% (in scenarios 2-10) in the first rating. Similar to alternative S_8 in the second rating with a robustness score of 90% (in scenarios 2-10). Although, it seems that for each scenario, there are alternative rankings that change. However, the overall rankings for all alternatives did not change. Therefore, it can be validated that alternatives S_4 and S_8 are the most recommended housing than others. Meanwhile, alternative S_3 is the least recommended housing.

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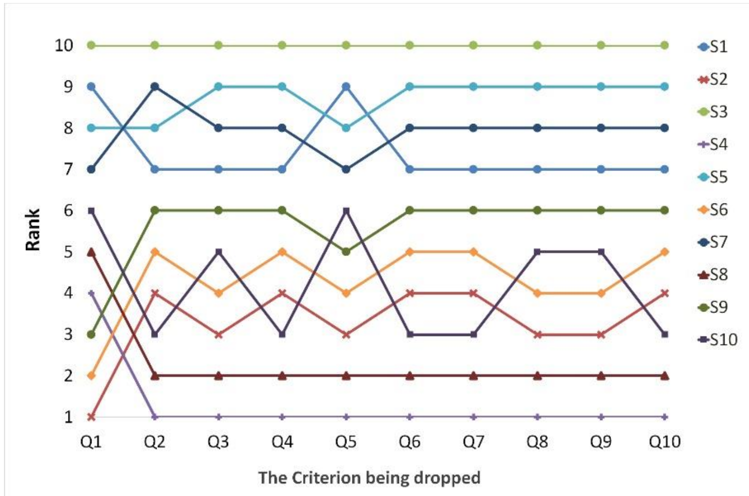

Fig. 3 The diagram of sensitivity analysis

DISCUSSIONS

This study integrates the BW and TOPSIS methods to recommend housing according to the wishes of LIP. Based on the analysis results, ten criteria dominate in housing selection sequentially, namely Location, Land Size, Down-Payment, Public Facilities, Price, Booking Fee, Home Design, House Specifications, House Quality, and Home Ownership Credit.

In general, study results show that six out of ten housing are recommended based on prospective consumer choices, namely S_4, S_8, S_2, S_6, S_{10} and S_9, as shown in Fig. 2. S_4 and S_8 are the most recommended housings. In contrast, S_3 is the least recommended housing based on prospective consumer choices. These study results are supported by a sensitivity analysis which produces a high robustness score (90%), as shown in Fig. 3. These show that the recommendation results are acceptable because they have a high consistency value for various scenarios of changes in weight or criteria values.

However, changes in the community's social conditions will create new criteria for housing selection. Regional/provincial differences also affect the determination of criteria and dominance. In addition, the many selection criteria and housing available also make it difficult for LIP to select the best one. Therefore, dynamically dominating selection criteria will enrich research literacy for housing selection. Finally, the results of these studies can assist LIP in choosing housing according to their wishes.

CONCLUSION

Selecting housing that meets the criteria required by the LIP is not easy because most of the decisions they make do not use detailed information. Therefore, the BW-TOPSIS model is proposed to recommend housing for LIP. In the case of this study, the housing recommendations that best suit the wishes of the prospective consumer is the fourth and eighth housing.

This study's results can also be input for housing developers in developing housing for LIP and even as a marketing strategy to increase housing sales. However, this study has limited scenarios for sensitivity analysis and is applied to a limited scope (at the city level). Future research can use more different scenarios in the sensitivity analysis to provide more conclusions about the consistency of the model and its application to a more expansive scope.

REFERENCES

Abadi, F. A., Sahebi, I. G., Arab, A., Alavi, A., & Karachi, H. (2018). Application of best-worst method in evaluation of medical tourism development strategy. *Decision Science Letters*, *7*(1), 77–86. https://doi.org/10.5267/j.dsl.2017.4.002

Abdel-Baset, M., Chang, V., Gamal, A., & Smarandache, F. (2019). An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: A case study in importing field. *Computers in Industry*, *106*, 94–110. https://doi.org/10.1016/j.compind.2018.12.017

* Corresponding author

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Akcan, S., & Güldeş, M. (2019). Integrated Multicriteria Decision-Making Methods to Solve Supplier Selection Problem: A Case Study in a Hospital. *Journal of Healthcare Engineering*, *2019*, 1–10. https://doi.org/10.1155/2019/5614892

Askarifar, K., Motaffef, Z., & Aazaami, S. (2018). An investment development framework in Iran's seashores using TOPSIS and best-worst multi-criteria decision making methods. *Decision Science Letters*, *7*(1), 55–64. https://doi.org/10.5267/j.dsl.2017.4.004

Aulawi, H., Riansyah, A., & Kurniawati, R. (2020). Analysis of the Selection of Shoe Raw Material Suppliers By Fuzzy Topsis Method. *Journal of Engineering Science and Technology*, *15*(6), 3983–3990.

Baharin, N. H., Rashidi, N. F., & Mahad, N. F. (2021). Manager selection using Fuzzy TOPSIS method. *Journal of Physics: Conference Series*, *1988*(1), 1–15. https://doi.org/10.1088/1742-6596/1988/1/012057

Chen, Z., Ming, X., Zhou, T., & Chang, Y. (2020). Sustainable supplier selection for smart supply chain considering internal and external uncertainty: An integrated rough-fuzzy approach. *Applied Soft Computing*, *87*, 106004. https://doi.org/10.1016/j.asoc.2019.106004

Ghaffari, S., Arab, A., Nafari, J., & Manteghi, M. (2017). Investigation and evaluation of key success factors in technological innovation development based on BWM. *Decision Science Letters*, *6*(3), 295–306. https://doi.org/10.5267/j.dsl.2016.12.001

Gupta, H., & Barua, M. K. (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *Journal of Cleaner Production*, *152*, 242–258. https://doi.org/10.1016/j.jclepro.2017.03.125

Gustriansyah, R., Ermatita, Rini, D. P., & Malik, R. F. (2020a). Integration of Decision-Making Method and Data-Mining Method as A Preliminary Study of Novel Sales Forecasting Method. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(4), 5730–5735. https://doi.org/10.30534/ijatcse/2020/227942020

Gustriansyah, R., Ermatita, Rini, D. P., & Malik, R. F. (2020b). The Criteria That Have A Significant Effect on Forecasting the Number of Sales Using the Best-Worst Method. In *2020 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)* (pp. 236–241). Jakarta: IEEE. https://doi.org/10.1109/ICIMCIS51567.2020.9354276

Gustriansyah, R., Sensuse, D. I., & Ramadhan, A. (2015). Decision support system for inventory management in pharmacy using fuzzy analytic hierarchy process and sequential pattern analysis approach. In *2015 3rd International Conference on New Media (CONMEDIA)* (pp. 1–6). IEEE. https://doi.org/10.1109/CONMEDIA.2015.7449153

Hildayanti, S. K., Putra, R. R., Suhandi, N., Sanmorino, A., Antony, F., Heryati, A., … Gustriansyah, R. (2018). Enterprise architecture framework selection for higher education using TOPSIS method. *International Journal of Engineering & Technology*, *7*(4), 5327–5330. https://doi.org/10.14419/ijet.v7i4.16140

Indonesia, K. P. U. dan P. R. Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat, Pub. L. No. 35 (2021). Indonesia: BN 2021 (1492): 24 hlm. Retrieved from https://jdih.pu.go.id/internal/assets/assets/produk/PermenPUPR/2021/12/PermenPUPR35.pdf

Indonesia, K. P. U. dan P. R. (2022). Temukan Lokasi Perumahan Subsidi Berdasarkan Kriteria. Retrieved December 27, 2022, from https://sikumbang.ppdpp.id

Javad, M. O. M., Darvishi, M., & Javad, A. O. M. (2020). Green supplier selection for the steel industry using BWM and fuzzy TOPSIS: A case study of Khouzestan steel company. *Sustainable Futures*, *2*, 100012. https://doi.org/10.1016/j.sftr.2020.100012

Khanmohammadi, E., Zandieh, M., & Tayebi, T. (2019). Drawing a Strategy Canvas Using the Fuzzy Best–Worst Method. *Global Journal of Flexible Systems Management*, *20*(1), 57–75. https://doi.org/10.1007/s40171-018-0202-z

Kizielewicz, B., & Bączkiewicz, A. (2021). Comparison of Fuzzy TOPSIS, Fuzzy VIKOR, Fuzzy WASPAS and Fuzzy MMOORA methods in the housing selection problem. *Procedia Computer Science*, *192*, 4578–4591. https://doi.org/10.1016/j.procs.2021.09.236

Liang, F., Brunelli, M., & Rezaei, J. (2020). Consistency issues in the best worst method: Measurements and thresholds. *Omega*, *96*, 1–11. https://doi.org/10.1016/j.omega.2019.102175

Maharani, S., Ridwanto, H., Hatta, H. R., Khairina, D. M., & Ibrahim, M. R. (2021). Comparison of TOPSIS and MAUT methods for recipient determination home surgery. *IAES International Journal of Artificial Intelligence (IJ-AI)*, *10*(4), 930. https://doi.org/10.11591/ijai.v10.i4.pp930-937

* Corresponding author

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Mardison, M., Ramadhanu, A., Rani, L. N., & Enggari, S. (2021). Hybrid DSS for recommendations of halal culinary tourism West Sumatra. *IAES International Journal of Artificial Intelligence (IJ-AI)*, *10*(2), 273. https://doi.org/10.11591/ijai.v10.i2.pp273-283

Sadjadi, S. J., & Karimi, M. (2018). Best-worst multi-criteria decision-making method: A robust approach. *Decision Science Letters*, *7*(4), 323–340. https://doi.org/10.5267/j.dsl.2018.3.003

Salimi, N. (2017). Quality assessment of scientific outputs using the BWM. *Scientometrics*, *112*(1), 195–213. https://doi.org/10.1007/s11192-017-2284-3

Salimi, N., & Rezaei, J. (2018). Evaluating firms' R&D performance using best worst method. *Evaluation and Program Planning*, *66*, 147–155. https://doi.org/10.1016/j.evalprogplan.2017.10.002

Taherdoost, H., & Brard, A. (2019). Analyzing the Process of Supplier Selection Criteria and Methods. *Procedia Manufacturing*, *32*, 1024–1034. https://doi.org/10.1016/j.promfg.2019.02.317

Wu, Y., Luo, J., & Peng, Y. (2020). An optimization-based framework for housing subsidy policy in China: Theory and practice of housing vouchers. *Land Use Policy*, *94*, 1–8. https://doi.org/10.1016/j.landusepol.2020.104526

Youssef, A. E. (2020). An Integrated MCDM Approach for Cloud Service Selection Based on TOPSIS and BWM. *IEEE Access*, *8*, 71851–71865. https://doi.org/10.1109/ACCESS.2020.2987111

* Corresponding author