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Decision Support System for Subsidized Housing Selection Based on Best-Worst Method and Simple Additive Weighting

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ABSTRACT

The increase in population and urbanization in Indonesia has led to a large demand for housing supply in cities, but the increase has not been matched by an increase in population welfare, so the Government offers subsidies for household loans to Indonesian citizens through household loan credit (KPR). The selection of subsidized housing that meets the criteria desired by the people is not a simple problem because of the many choices of subsidized housing with relatively similar prices and limited information that is owned by the general public. Therefore, this research will fulfill the wishes of the people through the development of a decision support system (DSS) for the selection of subsidized housing that uses the Best-Worst Method (BWM) and the Simple Additive Weighting (SAW) approaches. The results of testing in this study have provided adecision support system for subsidized housing that is most following the wishes of the person. This decision supportsystem also makes it easier for the person to select subsidized housing so that low-income persons can avoid making mistakes in choosing the subsidized housing they must pay within the next 15-20 years.

Key words: BWM, Decision-making, DSS, SAW.

1. INTRODUCTION

Housing is a primary need that affects social, economic, and several other important aspects of life. Lately, the demand for housing in big cities has increased, following the economic, population, and urbanization growth in Indonesia. However, housing conditions in many cities are quite alarming, so that the Government of Indonesia has initiated the provision of subsidized proper housing to assist the lower middle-class population.

The next effort is to provide a decision support system[1], [2] that can assist people to select subsidized housing that fits their criteria.

For some people, selecting to the house is a simple and easy matter, however this become complicated when faced with many housing choices where each housing must have advantages and disadvantages.

The more criteria and choices that must be considered in the selection process, the final decision-making on a choice becomes more difficult and unrealistic because most selection problems are related to uncertainty [3]. Therefore, one way that can facilitate the selection of criteria and final decision making is by implementing a decision support system [4].

This research will apply the Best-Worst Method (BWM) [5] which involves feedback from experts in determining the weight of each criterion and the Simple Additive Weighting (SAW) method [6] to determine a decision support system for the subsidized housing that best fit the criteria desired by the public.

Based on data obtained from Scopus in the past 5 years; there are 339 articles/chapters that use the BWM approach, 24 articles/chapters that discuss the decision support system that uses BWM, and only 3 articles that implement BWM and SAW namely the selection of web service [7], the selection of wagons [8], and the search models [9], and no research was found that implemented the BWM and SAW approaches in a decision support system for the subsidized housing. The combination of these two approaches is expected to obtain the results of a decision support system for the subsidized housing that is more optimal, easily implemented, and in line with the public expectations.

2. MATERIAL AND METHODS

2.1 Research Approach

This study would collect feedback from ten experts with long experience in affordable housing marketing.

The results of the feedback from the experts that were first validated are all the criteria that influence the purchase of subsidized housing [10]. The results of this feedback will be the source of data to obtain the second feedback results using the Best-Worst Method [11]. Then, the priority weight which is the output of BWM will be processed with the value of each criterion chosen by a person using SAW to get the most subsidized housing ranking that is most appropriate to the value of the criteria chosen by that person.

The research approach is carried out through five phases as illustrated in Figure 1.

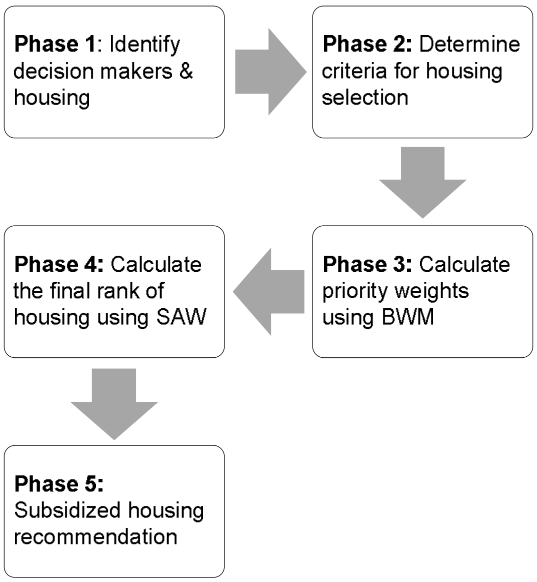

Figure1: The overall phases of research approach

The decision support system for the subsidized housing will be designed using UML [12] and become a subsidized housing recommendation tool [13], [14].

2.2 Best-Worst Method

Best-Worst Method (BWM) is one of the newest multi-criteria decision making (MCDM) methods that Rezaei introduced in 2015.

There are several multi-criteria decision-making methods to determine the criteria weights and ratings before BWM such as AHP, ANP, DEMATEL, FAHP, GRA, SAW, TOPSIS, VIKOR, etc.[15]–[21].

However, BWM can determine the criteria and alternative weights by comparing the best criterion with other criteria and all other criteria with the worst criterion for all criteria based on fewer pair comparisons than similar methods[5].

Therefore, BWM will be selected in this study to determine the criteria that dominate the selection of subsidized housing and its weights.

The BWM is made up of five steps that can be used to determine the criteria's weights[4], [5].

Step 1: Collect all decision-making criteria.
Find all the criteria that determine the decision, either through the study of literature or through questionnaires from experts.

Step 2: Specify the best criterion and the worst criterion.
Based on their opinion, the experts are asked to only choose the best criteria (the most dominant) and the worst criteria (the least dominant) among all the criteria identified in Step 1. In this step, the best criteria will be referred to as c_B and the worst criteria will be referred to as c_W.

Step 3: Specify the best criterion for the preference rating against all other criteria.
A number from 1 to 9 (1: equally important, 9: very more important) will be used in the third step to indicate the value of the pairwise comparison preference for the best criterion against other criteria. The "Best-to-Others" matrix can be expressed as a_B, $a_{B}j$ represents the best B criterion against the other criteria where j = 1,2, ..., n and a_{BB} = 1.

Step 4: Specify the preference rating for all other criteria against the worst criterion.
Identical to the third step, a number from 1 to 9 will also be used to indicate the value of the pairwise comparison preference for the worst criterion against the other criteria. The "Others-to-Worst" matrix can be expressed as a_W, aj_W represents the worst criterion against the other criteria where j = 1,2 and a_{ww} = 1.

Step 5: Determine the optimal weights of all the criteria.
Optimal weight is the maximum absolute difference for all j minimized from the set: {| w_B - $a_{Bj}w_j$ |, | w_j - $a_{jw}w_w$ |}, which can be formulated to the min-max model as in (1).

$$\min \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \tag{1}$$

In the linear programming model, (1) can be written as (2):

$$\begin{aligned} & \min \xi \\ & \text{s.t.} \\ & \left| \frac{w_B}{w_j} - a_{Bj} \right| \le \xi^*, \text{ for all j} \\ & \left| \frac{w_j}{w_w} - a_{jw} \right| \le \xi^*, \text{ for all j} \\ & \textstyle\sum_j w_j = 1 \\ & w_j \ge 0, \text{ for all j} \\ & j = 1,2, \ldots, n \end{aligned} \tag{2}$$

The first set of times the value of ξ with wj and the second set of times the value of ξ with ww of (2) is an intersection of 4n-5. By completing (2), the optimal weights of the criteria (w_1^*, w_2^*,…,w_n^*), and ξ * will be obtained.

After the average final weight is obtained, the consistency ratio (CR) which is an important indicator for testing the consistency level of the pairwise ratio will be calculated using (3).

$$CR = \frac{\xi^*}{CI} \quad (3)$$

where CI (consistency index) is the maximum ξvalue for different values of a_{BW} is showed in Table 1, ξ* is the solution of the problem (2), and CR ∈ [0,1]. If the CR value close to 0 indicates that the comparison is more consistent, while the CR value close to 1 indicates that the comparison is less consistent. Equation (3) shows that if the value of ξ * gets smaller then the CR value gets smaller so the comparison is more consistent.

Table 1: Consistency Index (CI) [5]

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

The Best-Worst method will be used in this study to measure the weight of each criterion.

2.3 Simple Additive Weighting Method

Simple Additive Weighting (SAW) is a simple multi-attribute decision method that is based on a weighted average and is also the oldest [22]. The SAW method was first introduced by Churchman and Ackoff to overcome the problem of portfolio selection.

This SAW method can be used to solve multi-criteria decision-making problems because the concept is simple, easy to understand, calculations are efficient, and can measure the relative performance of alternative decisions [17]. The most recommended alternative is the alternative that has the highest score of all alternatives [22].

The steps of the SAW method to find the most recommended alternative are as follows [6]:

Step 1: Define a set of decision-making criteria.
Make an alternative decision matrix A_i on each C_i criterion and then normalize it to the matrix R (r_{ij}) according to (4).

$$r_{ij} = \begin{cases} \frac{x_{ij}}{X_{ij}^{max}}, & j \in \textit{the set of positive criteria} \\ \frac{X_{ij}^{min}}{x_{ij}}, & j \in \textit{the set of negative criteria} \end{cases} \quad (4)$$

Where $r_{ij}$is a normalized matrix, $x_{ij}$is a decision matrix, $X_{ij}^{max}$is the largest value of each criterion, $X_{ij}^{min}$is the smallest value of each criterion, the positive criterion if the largest value is the best, and the negative criterion if the smallest value is the best.

Step 2: Identify the decision weights w_j for each criterion.

Step 3: Calculate the preference value for alternative value V_i based on (5).

$$V_i = \sum_{j=1}^{n} W_j r_{ij} \quad (5)$$

where V_i is rank for each alternative and W_j is the decision weight of each criterion, $W_j \in (0,1)$. The greatest value of V_i is the most recommended alternative.

3. RESULTS AND ANALYSIS

This section presents case studies that show how the BWM and SAW approaches are applied in this research. In detail, the steps using the BWM and SAW approaches are explained as follows:

3.1 Specify the weights using the BWM approach

Step 1: Find all the criteria for decision-making.
All criteria are determined based on literature studies and opinions from experts who are housing marketers who have long experience. In this first step, twenty-two criteria were identified and only ten criteria validated based on a consensus from experts would be taken to finalize the preference ranking, namely, C_1: Location, C_2: Public Facilities, C_3: Land Area, C_4: Down Payment (DP), C_5: Price, C_6: House Design, C_7: Booking Fee, C_8: Quality, C_9: House Specifications, and C_{10}: Household Loan Credit (KPR). These ten criteria will be the main criteria that will be determined the degree of preference in the second step.

Step 2: Specify the best and the worst criterion of BWM.
In the second step, the best and worst criterion are determined based on the opinion of experts. The best criterion is the criteria chosen by each expert as the most dominant criterion in the selection of subsidized housing, while the worst criterion is the least dominant criterion in the selection of subsidized housing. A list of the best and worst criteria that were collected through a short questionnaire is listed in Table 2 and Table 3 where ten experts were asked to state their preference values.

Step 3: Specify the preference of the best criterion against other criteria.
The third step will be to select preferences for the best criteria for all criteria. This process is carried out using a questionnaire. Respondents were asked to state their preference values for the best criterion against other criteria using a number ranging from 1 to 9. The results of the questionnaire for the Best-to-Others (BO) are listed in Table 2.

Table 2: BO Vectors from experts

Experts	Best Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
1	Location	1	3	2	2	4	7	5	6	8	9
2	Location	1	5	2	2	5	7	8	9	2	4
3	Location	1	2	3	4	5	6	9	7	8	7
4	Location	1	5	3	3	2	6	4	7	8	9
5	Location	1	5	2	2	4	6	3	8	7	8
6	Location	1	3	2	3	5	7	4	6	8	9
7	Location	1	2	2	3	5	8	4	6	7	9
8	Location	1	3	4	3	2	6	5	9	8	7
9	Location	1	2	3	5	4	5	6	8	7	9
10	Location	1	4	2	3	5	6	5	8	9	7

Step 4. Specify the preference of all criteria over the worst criterion.

In this fourth step, respondents were asked to state the value of their preferences for all other criteria against the worst criterion. As in the third step, the assessment uses a number ranging from 1 to 9. The results of the questionnaire for the Other-to-Worst (OW) are listed in Table 3.

Table 3: OW Vectors from experts

Experts	1	2	3	4	5	6	7	8	9	10
	Worst Criterion									
Criteria	KPR	Quality	Booking Fee	KPR	Quality	KPR	KPR	Quality	KPR	House Spec.
C_1	9	9	9	9	9	9	9	9	9	9
C_2	7	8	8	4	4	7	8	7	8	3
C_3	8	6	7	7	8	8	8	6	7	8
C_4	8	7	6	7	8	7	7	7	6	7
C_5	6	5	5	8	5	5	4	8	4	6
C_6	3	2	4	6	6	3	2	5	5	5
C_7	5	1	1	5	7	6	6	4	4	4
C_8	4	3	3	3	1	4	5	1	2	2
C_9	2	4	2	2	3	2	3	2	3	1
C_{10}	1	2	3	1	2	1	1	3	1	3

The next step is calculating the weights for priority.

Step 5. Specify the optimal weights.

The weight of each criterion from ten experts was calculated using (2) as shown in Table 4 and the average weight of each criterion is shown in Figure 2.

Table 4: Overall weights from the ten experts (w_j)

Criteria		Weights priority for each of the experts									
		1	2	3	4	5	6	7	8	9	10
C_1^*	Location	0.26	0.24	0.30	0.27	0.18	0.28	0.26	0.19	0.29	0.28
C_2^*	Facilities	0.11	0.07	0.18	0.07	0.07	0.11	0.16	0.13	0.18	0.09
C_3^*	Land Area	0.16	0.16	0.12	0.11	0.18	0.17	0.16	0.09	0.12	0.18
C_4^*	DP	0.16	0.16	0.09	0.11	0.18	0.11	0.11	0.13	0.07	0.12
C_5^*	Price	0.08	0.07	0.07	0.17	0.09	0.07	0.06	0.19	0.09	0.07
C_6^*	Design	0.05	0.05	0.06	0.06	0.06	0.05	0.04	0.06	0.07	0.06
C_7^*	BookFee	0.06	0.02	0.03	0.09	0.12	0.08	0.08	0.08	0.06	0.07
C_8^*	Quality	0.05	0.04	0.05	0.05	0.04	0.06	0.05	0.04	0.04	0.03
C_9^*	Spec.	0.04	0.12	0.05	0.04	0.05	0.04	0.05	0.05	0.05	0.04
C_{10}^*	KPR	0.02	0.08	0.05	0.02	0.04	0.02	0.02	0.05	0.02	0.05
	ξ^*	0.58	0.76	0.77	0.63	0.71	0.55	0.54	0.72	0.57	0.73

ξ^* is a consistency indicator for pairwise comparisons. If the average ξ^* in Table 4 is calculated then the comparison results of each housing have a high consistency where the average value is close to zero (0.6557).

Then, the final weights of each criterion can be calculated by solving (1) and (2) for pairwise comparisons of all criteria. This weight is used to determine the ranking of all criteria as shown in Figure 2, where the main criteria in the selection of subsidized housing are Location, Land Area, Down Payment, Public Facilities, Prices, Booking Fee, House Design, House Specifications, Quality, and Household Loan Credit (KPR).

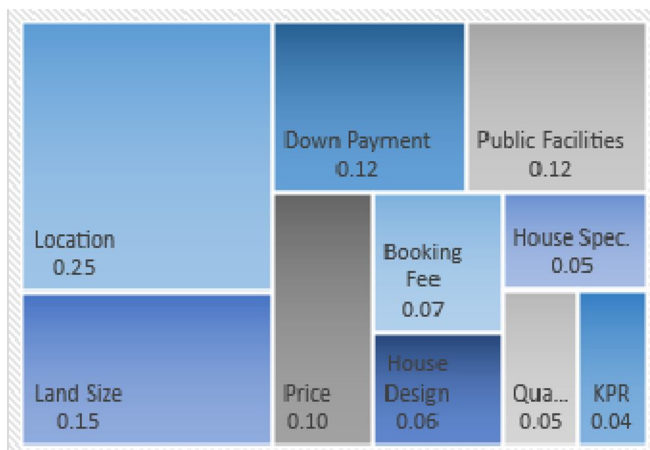

Figure 2: The main criteria in the selection of subsidized housing

3.2 Specify subsidized housing recommendations using the SAW Method

Testing of the decision support system for subsidized housing is implemented in the case of ten subsidized housing. Prospective buyers of subsidized housing are asked to fill out questionnaires on a scale of 0-4 for each criterion in each housing. Table 5 shows the assessment matrix for each subsidized housing (r_{ij}) obtained from potential consumers calculated based on (4).

Table 5: The normalized decision matrix for each criterion (r_{ij})

Criteria		The subsidized housing									
		H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**H10**
C_1^*	Location	1.00	1.00	0.75	0.75	0.50	0.75	0.75	0.50	0.75	1.00
C_2^*	Facilities	0.75	0.75	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.75
C_3^*	Land Area	0.50	0.50	0.75	1.00	0.75	0.75	0.50	0.50	0.50	0.50
C_4^*	DP	0.75	0.75	0.50	1.00	1.00	0.50	0.75	0.75	0.75	0.75
C_5^*	Price	0.75	0.75	1.00	1.00	1.00	0.75	0.75	1.00	0.75	0.75
C_6^*	Design	1.00	1.00	1.00	1.00	0.67	1.00	1.00	0.67	1.00	1.00
C_7^*	BookFee	0.50	0.50	1.00	0.50	0.75	0.25	0.75	1.00	0.75	0.50
C_8^*	Quality	1.00	1.00	1.00	1.00	0.75	0.75	1.00	0.75	0.75	1.00
C_9^*	Spec.	0.75	0.75	1.00	1.00	0.75	0.75	0.75	0.75	0.75	0.75
C_{10}^*	KPR	1.00	1.00	0.75	1.00	0.50	0.75	0.75	0.75	0.75	1.00

The preference value for each alternative (V_i) shown in Table 6 is obtained by multiplying the average weight of each criterion (w_j) from Table 4 with the normalized decision matrix for each criterion (r_{ij}) from Table 5 based on (5).

Table 6: The preference value matrix for alternatives V_i

Criteria		The subsidized housing									
		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
C_1^*	Location	0.25	0.25	0.19	0.19	0.13	0.19	0.19	0.13	0.19	0.25
C_2^*	Facilities	0.09	0.09	0.12	0.12	0.09	0.09	0.09	0.09	0.09	0.09
C_3^*	Land Area	0.07	0.07	0.11	0.15	0.11	0.11	0.07	0.07	0.07	0.07
C_4^*	DP	0.09	0.09	0.06	0.12	0.12	0.06	0.09	0.09	0.09	0.09
C_5^*	Price	0.07	0.07	0.10	0.10	0.10	0.07	0.07	0.10	0.07	0.07
C_6^*	Design	0.06	0.06	0.06	0.06	0.04	0.06	0.06	0.04	0.06	0.06
C_7^*	Book Fee	0.03	0.03	0.07	0.03	0.05	0.02	0.05	0.07	0.05	0.03
C_8^*	Quality	0.05	0.05	0.05	0.05	0.03	0.03	0.05	0.03	0.03	0.05
C_9^*	Spec.	0.04	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
C_{10}^*	KPR	0.04	0.04	0.03	0.04	0.02	0.03	0.03	0.03	0.03	0.04
	Σ	0.80	0.80	0.83	0.90	0.73	0.70	0.74	0.69	0.73	0.80

If the total preference values of each alternative is ranked then the subsidized housing rating will be obtained as shown in Figure 3.

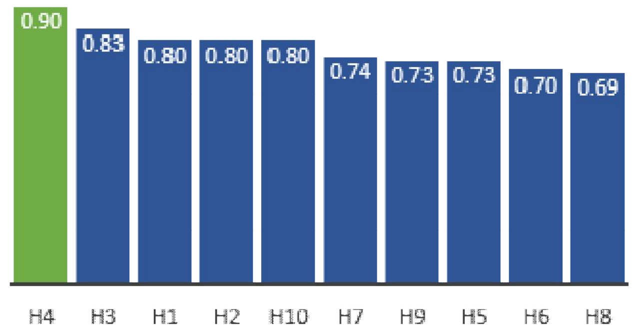

Figure 3: The ranking of subsidized housing recommendations

Test results from this decision support system show that the fourth subsidized housing is the most recommended subsidized housing for the person who is the sample in this case.

4. CONCLUSION

This study reveals that BWM and SAW can be used as a decision support system in the selection of subsidized housing so that it can help underprivileged people who are generally less informed in making practical decisions. This research has also contributed to the development of the MCDM method which integrates BWM with other MCDM methods which is still very small so that this becomes an exciting opportunity for future research.

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