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Stanković, M. and Nikolić, V.

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# Using the Weighted Sum Preferred Levels of Performances in House Selection

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*Abstract*—**The selection of a house for purchasing represents a very important decision that influences the quality of the future life of a customer. Various dimensions expressed through different criteria impact the final choice of the house. The Multiple-Criteria Decision-Making (MCDM) methods provide a possibility of involving of all criteria influencing the particular decision. The main intention of this paper is to propose the Weighted Sum Preferred Levels of Performances (WS PLP method) as a useful tool that will contribute to increasing the reliability of the performed selection. The applicability of the proposed methodology is demonstrated through the real case study that involves 5 houses in 5 different parts of the city of Zaječar that are evaluated against 9 criteria. The obtained results confirmed that the given method increases the reliability and enables the making of appropriate decisions.**

**Keywords** – MCDM, WS PLP method, Entropy method, house selection, Zaječar

## I. Introduction

The selection of a house for living represents a very important decision for a customer. The particular house should comply with the different requirements of the future owner. These requirements sometimes could be conflict because satisfying one of them goes at the expense of others. The MCDM methods could contribute to successfully overcoming this problem.

In recent years, the MCDM methods have become very popular for the facilitation of the decision-making process and their popularity still growths. Until now, many different MCDM methods are proposed. The comprehensive overview of developed MCDM methods could be found in the papers of many eminent authors [1-3]. Also, these methods are used for resolving different real-world problems [4-6].

In this case, we propose the application of the WS PLP method [7] for the selection of house for purchasing. The case of the application of the MCDM methods in house selection was, also, observed by the authors [8-11]. We assessed 5 houses in Zaječar against the 9 evaluation criteria. With the main aim of presenting the applicability of the given method, the rest of the paper is organized as follows: in section II the methodology is explained; section III contains the numerical example; that is followed by the conclusion.

## II. Methodology

The selection of the optimal house is performed by applying the Entropy method [12] for determining the criteria significance and the WS PLP method for ranking of alternatives and final selection [7]. The WS PLP method is based on the earlier developed Simple Additive Weight (SAW) or Weighted Sum (WS) methods [13-14]. The WS PLP method makes a distinction between the best alternative and that one which has the best matching with the decision-maker's (hereinafter marked as DM) preferred performance ratings (*ppr* values). In that way, the DM knows what alternative is the best from all and which is in accordance with expressed requirements. In some cases, one alternative has a good ranking position because some criteria have extremely good performances while others could be quietly unsatisfying. The WS PLP method that clearly indicates and this is its main advantage relative to the other MCDM methods.

The calculation procedure used in this paper can precisely be presented through the following steps:

*Step* 1. Select the set of the representative criteria and form decision matrix $X$ as follows:

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$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{12} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, \qquad (1)$$

where $x_{ij}$ represents the performance rating of the alternative $i$ with respect to the criterion $j$, $m$ denotes the number of the alternatives and $n$ the number of the criteria.

*Step* 2. Determine the criteria weights. In the present case, we use the Entropy method [12]. The main reason for this relies in the fact that the Entropy method could be considered as very objective. Determining of the criteria weights is performed by using the following equation:

$$w_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)}, \qquad (2)$$

where $j = 1,..n.$

The output entropy $e_j$ of the $j_{th}$ factor is calculated as:

$$e_j = -\frac{1}{\ln(m)}\sum_{j=1}^{n} r_{ij} \ln(r_{ij}), \qquad (3)$$

where $j = 1,\ldots,n.$

The term: $\sum_{j=1}^{n} w_j = 1$, should be fulfilled.

*Step* 3. Define the *ppr* values for all criteria. The *ppr* values are determined according to the DM's preferences, which represent the elements of the virtual alternative $A_0 = \{x_{01}, x_{02}, \ldots, x_{0n}\}$. If the *ppr* value of any criterion is not determined by the DM, then it is determined as follows:

$$x_{0j} = \begin{cases} \max_i x_{ij} \,|\, j \in \Omega_{\max} \\ \min_i x_{ij} \,|\, j \in \Omega_{\min} \end{cases}, \qquad (4)$$

where $x_{0j}$ represents the optimal *ppr* of the criterion $j$; $\Omega_{\max}$ is set of benefit and $\Omega_{\min}$ is set of cost criteria.

*Step* 4. Form the normalized decision matrix. Stanujkic et al. [15] proposed the normalization procedure that enables DMs to express their preferences for the *ppr* more effectively. That is done by using the following (5) and (8):

$$r_{ij} = \frac{x_{ij} - x_j^*}{x_j^+ - x_j^-}; j \in \Omega_{\max}, \text{ and} \qquad (5)$$

$$r_{ij} = \frac{x_j^* - x_{ij}}{x_j^+ - x_j^-}; j \in \Omega_{\min}, \qquad (6)$$

where $r_{ij}$ denotes the normalized performance rating of the alternative $i$ with respect to the criterion $j$, $x_j^*$ is the *ppr* value of the criterion $j$, and $x_j^+$ and $x_j^-$ are the largest and the smallest performance ratings of the criterion $j$, respectively.

*Step* 5. Calculate the overall performance ratings for all alternatives in the following way:

$$S_i = \sum_{j=1}^{n} w_j \cdot r_{ij}, \qquad (7)$$

where $S_i$ denotes the overall performance rating of the alternative $i$, and $S_i \in [0,1]$.

The calculations should be continued thorough the following steps in the case when the overall performance ratings for two or more alternatives satisfying the condition: $S_i > 0$. Otherwise, the alternative with the largest $S_i$ is optimal, and the ranking is performed in ascending order.

*Step* 6. Calculate the compensation coefficient for all alternatives that fulfill the term: $S_i > 0$, as follows:

$$c_i = \lambda d_i^{\max} + (1-\lambda)\,\overline{S}_i^+, \qquad (8)$$

where:

$$d_i^{\max} = \max_i d_i = \max_i r_{ij} w_j, \quad (9)$$

$$\bar{S}_i^+ = \frac{S_i^+}{n_i^+}, \quad (10)$$

where $d_i^{\max}$ is the maximum weighted normalized distance of the alternative $i$ relative to the *ppr* values of all the criteria so that $r_{ij} > 0$, $\bar{S}_i^+$ denotes the average performance ratings obtained on the basis of the criteria so that $r_{ij} > 0$, $n_i^+$ is the number of the criteria of the alternative $i$ so that $r_{ij} > 0$, $\lambda$ is the coefficient ($\lambda = [0,1]$) and is usually set at 0.5.

*Step* 7. Compute the adjusted performance rating for all the alternatives in which $S_i > 0$ in the following way:

$$S_i' = \sum_{j=1}^{n} w_j r_{ij} - \gamma c_i, \quad (11)$$

where $S_i'$ denotes the adjusted overall performance rating of the alternative $i$, $c_i$ represents the compensation coefficient ($c_i > 0$), and $\gamma$ is the coefficient ($\gamma = [0,1]$).

*Step* 8. Rank the considered alternatives and select the most appropriate one. The alternative with the highest $S_i'$ value is the most appropriate and the ranking is performed in ascending order.

## III. Case Study

In this section, the application of the proposed methodology pointed to the selection of the optimal house for purchase in Zaječar is presented. The alternative houses are located in different parts of Zaječar which are presented in Tab. 1.

TABLE I. THE LOCATION OF THE CONSIDERED HOUSES

| **Alternative** | **Part of the city** |
|---|---|
| $A_1$ | Podliv |
| $A_2$ | City center |
| $A_3$ | Ključ |
| $A_4$ | Šljivarski put |
| $A_5$ | Beli breg |

The set of the evaluation criteria relies on that one presented in the paper of Li [16]. For the needs of this paper, the given set is slightly modified and adjusted for the application in this particular case. The main dimensions and evaluation criteria are presented in Tab. 2.

TABLE II. EVALUATION CRITERIA [16]

| **Dimensions** | **Criteria** | | **Measure** |
|---|---|---|---|
| Transportation network | $C_1$ | Transportation connection | Grade from 1 to 5 |
| | $C_2$ | Proximity to work | Grade from 1 to 5 |
| Neighborhood infrastructure | $C_3$ | Landscape | Grade from 1 to 5 |
| | $C_4$ | Education and healthcare facilities | Grade from 1 to 5 |
| Community environment | $C_5$ | Security | Grade from 1 to 5 |
| | $C_6$ | Population density | Grade from 1 to 5 |
| House attributes | $C_7$ | Size | $m^2$ |
| | $C_8$ | Age | year |
| | $C_9$ | Value | € |

As can be seen from Tab. 2, we take into account 9 evaluation criteria that cover 4 dimensions important for a house customer. The estimation of the houses against the first 6 criteria will be expressed over grades from 1 to 5 (1 as the worst grade and 5 as the best). Besides, this list of criteria is not the ultimate; depending on the needs, a greater number of criteria could be included.

The demonstration of the proposed methodology is based on the data regarding the houses in Zaječar taken from the website of a real-estate agency (http://nekretnine-zajecar.co.rs/). It is presumed that one customer (in further text marked as DM) is interested in the purchase of the house in Zaječar. There are 5 houses in 5 different parts of the city that satisfies his requirements. First, by using (2) and (3), the weights of criteria are determined. Besides the defined criteria weights and all input data, Tab. 3 contains the *ppr* values that show the desired values of the considered criteria according to the DM (customer in this particular case).

Table 4 represents the normalized performance ratings, obtained by using (5) and (6). By applying the normalization procedure, the various measures are reduced to a single measure.

TABLE III. THE INITIAL DECISION MATRIX

| **Criteria / Alternatives** | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| *optimization* | *max* | *max* | *max* | *max* | *max* | *max* | *max* | *min* | *min* |
| $w_j$ | 0.1338 | 0.1345 | 0.1994 | 0.1338 | 0.0281 | 0.0698 | 0.0661 | 0.1994 | 0.0351 |
| *ppr* | ***3*** | ***2*** | ***3*** | ***4*** | ***4*** | ***2*** | ***160*** | ***35*** | ***55000*** |
| $A_1$ | 3 | 2 | 3 | 3 | 4 | 3 | 150 | 30 | 46000 |
| $A_2$ | 5 | 5 | 3 | 5 | 4 | 5 | 189 | 45 | 61000 |
| $A_3$ | 4 | 3 | 4 | 4 | 4 | 4 | 150 | 15 | 52000 |
| $A_4$ | 3 | 2 | 3 | 2 | 3 | 3 | 260 | 20 | 59000 |
| $A_5$ | 2 | 2 | 4 | 2 | 3 | 3 | 180 | 30 | 40000 |

TABLE IV. THE NORMALIZED PERFORMANCE RATINGS

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0.0000 | 0.0000 | 0.0000 | -0.3333 | 0.0000 | 0.5000 | -0.0909 | 0.1667 | 0.4286 |
| $A_2$ | 0.6667 | 0.0000 | 0.0000 | 0.3333 | 0.0000 | 1.5000 | 0.2636 | -0.3333 | -0.2857 |
| $A_3$ | 0.3333 | -0.6667 | 1.0000 | 0.0000 | 0.0000 | 1.0000 | -0.0909 | 0.6667 | 0.1429 |
| $A_4$ | 0.0000 | -0.6667 | 0.0000 | -0.6667 | -1.0000 | 0.5000 | 0.9091 | 0.5000 | -0.1905 |
| $A_5$ | -0.3333 | -0.6667 | 1.0000 | -0.6667 | -1.0000 | 0.5000 | 0.1818 | 0.1667 | 0.7143 |

TABLE V. THE RANKING RESULTS OBTAINED ON THE BASIS OF $S_i$

| **Alternatives** | $S_i$ | **Rank** |
|---|---|---|
| $A_1$ | 0.0325 | **4** |
| $A_2$ | 0.1795 | **2** |
| $A_3$ | 0.3560 | **1** |
| $A_4$ | -0.0191 | **5** |
| $A_5$ | 0.0529 | **3** |

The ranking results obtained on the basis of $S_i$, which are calculated by using (7), are given in Tab. 5.

In this step, we decide whether to continue with the evaluation or to stop here. In the case when $S_i > 0$ it is acceptable to continue with the procedure. Because the overall performance rating for alternative $A_4$ – *Šljivarski put* – is lower than 0, it will be excluded from the further assessment. The other alternatives will be submitted to further evaluation procedure because they fulfilled the desired conditions.

Table 6 demonstrates the ranking results based on the $S_i'$ value, obtained by using (8)-(11), respectively, for $\gamma = 1$ and $\lambda = 0.5$.

TABLE VI. THE RANKING RESULTS BASED ON THE $S_i'$ VALUE

| | $d_i^{\max}$ | $S_i^+$ | $n_i^+$ | $\bar{S}_i^+$ | $c_i$ | $S_i$ | $S_i'$ | **Rank** |
|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0.0349 | 0.0832 | 3 | 0.0108 | 0.0229 | 0.0325 | 0.0097 | **3** |
| $A_2$ | 0.1047 | 0.2560 | 4 | 0.0449 | 0.0748 | 0.1795 | 0.1047 | **2** |
| $A_3$ | 0.1994 | 0.4517 | 5 | 0.0712 | 0.1353 | 0.3560 | 0.2207 | **1** |
| $A_5$ | 0.1994 | 0.3046 | 5 | 0.0106 | 0.1050 | 0.0529 | -0.0521 | **4** |

According to the obtained results presented in Tab. 6, the most suitable house for purchasing is the alternative $A_3$ – *Ključ*. This alternative fulfills all of the requirements expressed through the *ppr* values and some of them even exceed. In this case $\gamma$ =1, which means that the priority is given to the alternative that has the best matching with *ppr* values while the last ranked is the alternative $A_5$ – *Beli breg*.

The influence of the compensation coefficient $\gamma$ on the final ranking order is shown in Tab. 7.

TABLE VII. THE RANKING RESULTS OBTAINED ON THE BASIS OF DIFFERENT VALUES OF $\gamma$

| | $\gamma = 0$ | | $\gamma = 0.5$ | | | $\gamma = 1$ | | |
|---|---|---|---|---|---|---|---|---|
| | $S_i'$ | **Rank** | $c_i$ | $S_i'$ | **Rank** | $c_i$ | $S_i'$ | **Rank** |
| $A_1$ | 0.0325 | **4** | 0.0114 | 0.0211 | **3** | 0.0229 | 0.0097 | **3** |
| $A_2$ | 0.1795 | **2** | 0.0374 | 0.1421 | **2** | 0.0748 | 0.1047 | **2** |
| $A_3$ | 0.3560 | **1** | 0.0676 | 0.2883 | **1** | 0.1353 | 0.2207 | **1** |
| $A_5$ | 0.0529 | **3** | 0.0525 | 0.0004 | **4** | 0.1050 | -0.0521 | **4** |

Varying of the $\gamma$ brings some changes in the ranking order of the alternatives. While the alternative $A_1$ remained in the first position, the fourth position changed in the case when $\gamma$ =0. Namely, in that case, the alternative $A_1$ - *Podliv* is the last ranked because it has the worst overall performance ratings.

The given example exactly shows that the WS PLP method gives the DM the possibility to choose among the alternative that has the good matching with set requirements and that which has the best performances of all considered alternatives. Additionally, DM is aware of that which alternative does not satisfy the requirements and could exclude it from further evaluation in the early stage.

## IV. CONCLUSION

The main aim of this paper is to emphasize the applicability of the WS PLP method in the case of a house selection. The decision process is based on the 9 criteria that belong to the 4 main dimensions important for house selection that are: transportation network, neighborhood infrastructure, community environment, and house attributes. The 5 potential houses in the Zaječar are submitted to the evaluation procedure. The significance of the criteria is determined by using the Entropy method. The main reason for using the mentioned method for obtaining the criteria weights is reducing subjectivity to the minimum possible level.

The obtained results proved that the proposed WS PLP method is useful and contributes to the facilitation of the decision process. We consider that this technique could be helpful to the real estate agents because they could determine in an easy way which real estate should have the priority for offering to the particular client.

The proposed methodology is based on the use of crisp numbers and this represents the main constraint of the paper. Because the uncertainty and vagueness are immanent to real-world problems, it is very hard to express them by using only crisp numbers. Incorporation of the fuzzy, intuitionistic or neutrosophic numbers into proposed methodology would increase its convenience for application in the unpredictive and changeable business environment.

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