Location priority for non-formal early childhood education school based on promethee method and map visualization

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Abstract. Non-formal Early Childhood Education (non-formal ECE) is an education that is held for children under 4 years old. The implementation in District of Banyumas, Non-formal ECE is monitored by The District Government of Banyumas and helped by Sanggar Kegiatan Belajar (SKB) Purwokerto as one of the organizer of Non-formal Education. The government itself has a program for distributing ECE to all villages in Indonesia. However, The location to construct the ECE school in several years ahead is not arranged yet. Therefore, for supporting that program, a decision support system is made to give some recommendation villages for constructing The ECE building. The data are projected based on Brown’s Double Exponential Smoothing Method and utilizing Preference Ranking Organization Method for Enrichment Evaluation (Promethee) to generate priority order. As the recommendations system, it generates map visualization which is colored according to the priority level of sub-district and village area. The system was tested with black box testing, Promethee testing, and usability testing. The results showed that the system functionality and Promethee algorithm were working properly, and the user was satisfied.

1. Introduction
Non-formal ECE is an education for children who are under 4 years old which is formed as Daycare for children under 2 years old and Playgroup for children who are in 3 – 4 years old. In order to increase the total of children who got education in ECE and the total of the ECE distribution in each city, the government is very intense in socializing about ECE to the various regions in Indonesia. If the government wants to improve the quality of education through ECE, thus it needs to be completed by an increase of ECE infrastructures in Indonesia. Based on Head of SKB Purwokerto, there has been no government preparation for equipping Non-formal ECE for the next few years [1].

The planning for the next year development can be done by projecting the data that is related to Non-formal ECE development criterias. One of the best method for data projecting is Brown’s Double Exponential Smoothing Method. The projection results are used as consideration for the government in planning the education infrastructures.

The infrastructure can be planned by using decision support system of village priority determination for ECE construction. The method used in this research is Preference Ranking Organization Method for Enrichment Evaluations (Promethee) which giving village recommendation to construct new Non-formal ECE.
2. Methodology

2.1 Forecasting using Brown’s Double Exponential Smoothing Method

Brown’s Double Exponential Smoothing Method is one of method that used for moving data forecasting. This method can be calculated by 3 moving data and an $\alpha$ [2]. The equations of this method are:

1. Calculate the single exponential smoothing value

\[ S'_t = \alpha X_t + (1 - \alpha)S'_{t-1} \]  
\[ \text{(1)} \]

Details:
- $S'_t$: single exponential smoothing
- $\alpha$: alpha value, can be 0 until 1
- $X_t$: actual value in the $t$-year

2. Calculate the double exponential smoothing value

\[ S''_t = \alpha S'_t + (1 - \alpha)S''_{t-1} \]  
\[ \text{(2)} \]

Details:
- $S''_t$: double exponential smoothing

3. Calculate the $a$ and $b$ value

\[ a = 2S'_t - S''_t \]  
\[ \text{(3)} \]

\[ b = \frac{\alpha}{1 - \alpha} (S'_t - S''_t) \]  
\[ \text{(4)} \]

4. Calculate the forecasting value

\[ F_{t+m} = a + b_t m \]  
\[ \text{(5)} \]

Details:
- $F_{t+m}$: forecasting value in the $t+m$ year
- $m$: differences between period

When the $t$ value = 1, $S'_{t-1}$ and $S''_{t-1}$ value are not available. Thus, these value should be set at the begging of the calculation, which is set the $S'_t$ dan $S''_t$ equal to $X_t$. The $\alpha$ is recommended to set close to 0, but this value can be customized as the forecasting data accuracy.

2.2 Preference Ranking Organization Method for Enrichment Evaluation (Promethee)

Promethee is a priority determination method in multicriteria analysis [3]. The use of Promethee is purposed to find the best alternatives in a case. Promethee works as illustrated in figure 1.

![Figure 1. Promethee Flowchart](image-url)
2.2.1 Preference Type. The preference function will often be a function of the difference between the two evaluations [3], so it can be wrote as:

\[ P(a, b) = P(f(a) - f(b)) \]

Details:
- \( P \): preference function
- \( f \): criteria value
- \( a, b \): alternatives

Promethee has six types of generalized criteria. Below is mentioned two types that are used in this case [4] [5]:

1. Usual Criteria

\[ P(d) = \begin{cases} 0 & \text{if } d \leq 0 \\ 1 & \text{if } d > 0 \end{cases} \]

This criteria describes there is no differences (all is important) between \( a \) and \( b \) if \( f(a) = f(b) \).

2. Criteria with Linear Preference

\[ P(d) = \begin{cases} 0 & \text{if } d \leq 0, \\ \frac{d}{p} & \text{if } 0 < d \leq p, \\ 1 & \text{if } d < p \end{cases} \]

This criteria explains that if the \( P(d) \) value is less than the \( p \) value, the preference will increase linearly with the \( d \) value. If the \( d \) value is bigger than \( p \), the preference will be absolute.

2.2.2 Multicriteria Preference Index. Multicriteria preference index is determined based on the weight average from the preference function \( P_i \).

\[ \phi(a, b) = \sum_{i=1}^{n} \pi_i P_i(a, b): \forall a, b \in A \]

Details:
- \( \phi(a, b) \): multicriteria preference index that \( a \) is better than \( b \)
- \( \pi_i \): relativity of criteria importance
- \( P_i(a, b) \): alternative preference of \( a \) towards \( b \)

2.2.3 Promethee Ranking

The calculation of preference’s direction is considered based on the index value of leaving flow (\( \phi^+ \)), entering flow (\( \phi^- \)) and net flow. Leaving flow and entering flow are the Promethee I, whereas the net flow is the Promethee II.

1. Leaving Flow

Leaving flow is calculated as the equation below:

\[ \phi^+ = \frac{1}{n-1} \sum_{x \in A} \phi(x, a) \]

2. Entering Flow

Entering flow is calculated as the equation below:

\[ \phi^- = \frac{1}{n-1} \sum_{x \in A} \phi(x, a) \]

3. Net flow

Net flow is calculated based on leaving flow and net flow value. The equation of net flow is:

\[ \phi(a) = \phi^+ - \phi^- \]

3. Method and Interface Implementation

3.1 Method Implementation

The system that implement Promethee is a system that generate village recommendations in Banyumas Regency for Non-formal ECE construction based on Promethee outranking. The criteria
data are taken from the total of under 4 years old children, the total of Non-formal ECE buildings, and the total of ECE teachers which are projected by Brown’s Double Exponential Smoothing Method and processed by Promethee Method to generate village priority. The village priority results are displayed in map form.

3.1.1 Criteria for Determining Village Priority to Initiate The Development of New Non-formal ECE

1. The Total of Under 4 Years Old Children
   This criteria is important because the Non-formal ECE’s students are children aged under 4 years old.

2. The Total of Non-formal ECE Building
   The construction of Non-formal ECE itself will be more prioritized on a village that has not had Non-formal ECE yet, in order to spread the Non-formal ECE evenly.

3. The Total of ECE Teachers
   ECE teachers are teachers of formal and non-formal ECE.

| Table 1. Criteria for Determining Village Priority to Construct Non-formal ECE |
|-----------------------------------------------|
| Criteria                                      | Weight | Preference Type | Rule   |
| Total of Non-formal ECE buildings (K1)        | 55%    | I               | Minimize |
| Total of ECE teachers (K2)                    | 15%    | III              | Maximize |
| Total of under 4 years old children (K3)      | 30%    | III              | Maximize |

3.1.2 Manual Calculation Process for Brown’s Method and Promethee

1. Brown’s Double Exponential Smoothing. Given 3 data from 2013 until 2015 (mentioned on Xt). The forecasting result based on 1st until 5th equation calculation are mentioned on Table 2.

| Table 2. Brown’s Double Exponential Smoothing Data Example |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Year | Xt | S't | S''t | At | Bt | Forecasting | Rounding Value |
|------|----|-----|------|----|----|-------------|----------------|
| 2013 | 1157 | 1157 | 1157 | 1157 | 0 | 1157 | 1157 |
| 2014 | 1163 | 1157,96 | 1160,84 | 0,96 | 1157,00 | 1161,80 | 1162 |
| 2015 | 1160 | 1159,64 | 1158,632 | 1160,648 | 0,672 | 1161,32 | 1161 |
| 2016 | 1161,99 | 1162,66 | 1163,34 | 1164,01 | 1164,68 | 1165 |
| 2017 | 1161 | 1161 | 1161 | 1161 | 1161 | 1161 |
| 2018 | 1162,66 | 1163,34 | 1164,01 | 1164,68 | 1165 |
| 2019 | 1163,34 | 1164,01 | 1164,68 | 1165 |
| 2020 | 1164,01 | 1164,68 | 1165 |
| 2021 | 1164,68 | 1165 |

2. Promethee
   Given sub district data sample in 2017 below:

| Table 3. Sub District data sample in 2017 |
|------------------------------------------|
| Number | Variable | Sub District | K1  | K2  | K3   |
|--------|----------|---------------|-----|-----|------|
| 1      | A        | Karanglewas   | 24  | 185 | 6131 |
| 2      | B        | KedungBanteng| 14  | 126 | 4807 |
| 3      | C        | Baturaden     | 6   | 131 | 4585 |
| 4      | D        | Sumbang       | 12  | 85  | 7301 |
| 5      | E        | Kembaran      | 16  | 151 | 6616 |
| 6      | F        | Purwokerto Selatan | 16 | 222 | 6191 |
The next step is calculating the preference function for each criterias. This calculates preference function for $K_n(A, B)$.

$$P(A, B) = P(f(a) - f(b))$$

$$P_{K_1}(A, B) = P(24 - 14) = P(10)$$

$$P_{K_2}(A, B) = P(185 - 126) = 59$$

$$P_{K_3}(A, B) = P(6131 - 4807) = 1324$$

$K_1$ uses the first preference type and minimize role, thus $P_{K_1}(A, B) = 0$ and $P_{K_1}(B, A) = 1$, whereas the $P_{K_2}$ and $P_{K_3}$ use the third preference type and maximize role, therefore:

$K_2$ has $p = 3$. Because of $P_{K_2} > p$, thus $P_{K_2}(A, B) = 1$ and $P_{K_2}(B, A) = 0$.

$K_3$ has $p = 40$. Because of $P_{K_3} > p$, thus $P_{K_3}(A, B) = 1$ and $P_{K_3}(B, A) = 1$.

The multicriteria preference index is calculated below:

$$\phi_{K_1}(a, b) = \pi P_{K_1}(A, B) = 55 / 100 x 0 = 0$$

$$\phi_{K_2}(a, b) = \pi P_{K_2}(A, B) = 15 / 100 x 0 = 0$$

$$\phi_{K_3}(a, b) = \pi P_{K_3}(A, B) = 30 / 100 x 0 = 0$$

Based on the calculation above, obtained the preference total index formed as matrix.

### Table 4. Matrix of the preference total index

| A  | B     | C    | D     | E    | F    | G    | H    | I    |
|----|-------|------|-------|------|------|------|------|------|
| A  | 0     | 0,45 | 0,45  | 0,15 | 0,15 | 0    | 0,45 | 0,3  | 0,45 |
| B  | 0,55  | 0    | 0,3   | 0,15 | 0,55 | 0,55 | 0,3  | 0,85 | 0,85 |
| C  | 0,55  | 0,7  | 0     | 0,7  | 0,55 | 0,55 | 0,85 | 0,85 | 0,85 |
| D  | 0,85  | 0,85 | 0,3   | 0    | 0,85 | 0,85 | 0,85 | 0,85 | 0,85 |
| E  | 0,85  | 0,45 | 0,45  | 0,15 | 0    | 0,85 | 0,3  | 0,85 | 0,3  |
| F  | 1     | 0,45 | 0,45  | 0,15 | 0,7  | 0    | 0,45 | 0,85 | 0,45 |
| G  | 0,55  | 0,7  | 0,15  | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 |
| H  | 0,7   | 0,15 | 0,15  | 0,15 | 0,15 | 0,15 | 0,15 | 0,45 | 0    |
| I  | 0,55  | 0,15 | 0,15  | 0,15 | 0,7  | 0,55 | 0,3  | 0,85 | 0    |

The next step is calculating leaving flow, entering flow, dan net flow. The results are mentioned on table 5.

### Table 5. Table of Leaving flow, entering flow, and net flow

| Variable | Sub District   | Leaving Flow | Entering Flow | Net Flow | Ranking |
|----------|----------------|--------------|---------------|----------|---------|
| A        | Karanglewas    | 0,3          | 0,7           | -0,4     | 8       |
| B        | KedungBanteng  | 0,5125       | 0,4875        | 0,025    | 4       |
| C        | Baturaden      | 0,7          | 0,3           | 0,4      | 2       |
| D        | Sumbang        | 0,78125      | 0,21875       | 0,5625   | 1       |
| E        | Kembaran       | 0,525        | 0,54375       | -0,01875 | 6       |
| F        | Purwokerto Selatan | 0,5625 | 0,50625       | 0,05625  | 3       |
3.2 Interface Implementation
Promethee method is implemented as sub district and village maps. The priority results are sorted by the distinguish colors of the areas. This interfaces can be shown on figure 2 and figure 3.

|   |   |   |   |   |
|---|---|---|---|---|
| G | Purwokerto Barat | 0.50625 | 0.49375 | 0.0125 | 5 |
| H | Purwokerto Timur | 0.25625 | 0.74375 | -0.4875 | 9 |
| I | Purwokerto Utara | 0.425 | 0.575 | -0.15 | 7 |

3.3 Result
Based on the user observation and testing, The Decision Support System of Village Priority Determination for Non-Formal Early Childhood Construction Recommendation shows that Promethee Method is very good to be implemented because of the priority sorting that has been generated were appropriate to the real condition in Banyumas Regency. The maps visualize the Promethee ranking into many different colours that makes the user easily to analize the result.
4. Conclusion
Based on this research, the system of location priority for Non-Formal ECE School based on Promethee Method and Map Visualizationis had been implemented. The data are projected based on Brown’s Double Exponential Smoothing Method and utilized Preference Ranking Organization Method for Enrichment Evaluation (Promethee) to generate priority order. The system gives recommendations that are appropriate to the real condition in Banyumas Regency so the SKB Purwokerto could use this system to plan the development of new Non-formal ECE school in several years ahead. As the recommendations system, it generates map visualization which is colored according to the priority level of sub-district and village area. The system was tested with black box testing, Promethee testing, and usability testing. The results showed that the system functionality and Promethee algorithm were working properly, and the user accept it with satisfied.

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