Comparison of PROMETHEE –TOPSIS method based on SAW and AHP weighting for school e-learning readiness evaluation

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Abstract. As the demand for using e-learning rising for all subjects at schools in digital era, the successful implementation of e-learning is important to be well prepared. The successful is influenced by many factors, including the provision of technology infrastructure, Human Resources, organizational culture and leadership factors. For this reason it is necessary to evaluate the readiness of schools in implementing e-learning, which is known as e-learning readiness (ELR). Evaluation of school ELR is carried out to analyse the strengths, weaknesses and dominant factors in implementing e-learning in schools, so that it can be a reference in policy making by related parties. ELR evaluation is carried out using the PROMETHEE and TOPSIS methods based on the weighting of Simple Additive Weighting (SAW) and Analytical Hierarchy Process (AHP). The data used is the readiness for e-learning implementation on the specified criteria. There are eight criteria to measure e-learning readiness (ELR) of schools, namely Psychological readiness, Sociological readiness, Environmental readiness, Human resource readiness, Financial readiness, Technological skill (aptitude) readiness, Equipment readiness, Content readiness. The evaluation model using the PROMETHEE and TOPSIS methods will provide the results of a school's e-learning readiness ranking, based on the weighting of criteria determined using SAW and AHP. In addition, these results are expected to reveal the weaknesses that need improvement, as well as the strengths that support the implementation of e-learning.

1. Introduction
The development of information and communication technology (ICT) continues to invade various fields, expanding in various areas of society and life, including in education. In Indonesia, the use of ICT for learning is still lacking. The results of a survey on internet use based on work in 2016 by Indonesian Internet Service Providers Association (Asosiasi Pengusaha Jasa Internet Indonesia, APJII) it is known that of 132.7 million users (51.5% of the total population of Indonesia) there are 6.3% students who use the internet, and 9.2% internet use related to education. This finding shows that there are already Indonesian students who use the internet even though the use of the internet for education is still low.

One of the utilization of ICT in education is the existence of e-learning as a learning media that utilizes computer and internet technology. E-learning provides benefits for students to gain additional knowledge, provide space for discussion and question and answer. E-learning can provide benefits for
students who are difficult to communicate and ask questions in class, e-learning media also enhance the relationship between teachers and students and provide fun learning for teachers and students.

A previous research had been conducted to measure the level of readiness for the implementation of e-learning for junior high schools in the city of Yogyakarta using the ELR Chapnick model [1]. This model uses eight readiness factors to measure ELR [2]. The Chapnick model provides scores that indicate school rankings in e-learning readiness. This model can be used continuously to maintain the continuity of the e-learning application program in the learning process.

Many other models can be used to evaluate the level of readiness for implementing e-learning, including SORT (Student Online Readiness Tools) [3], RILO (Readiness Index for Online Learning) and e-learning Readiness Index (eLRI) models. On the other hand, the number of criteria considered in evaluating the level of readiness for the implementation of e-learning can be seen as a multi criteria decision making (MCDM).

Multiple Criteria Decision Making (MCDM) is one of the most widely used methods in the area of decision making. Consequently, this method is mostly used to evaluate a system in the fields of education, industry, and other objects. MCDM produces a final score that will be used as a basis for ranking, in deciding the best alternative choice of several mutually beneficial alternatives on the basis of general performance in a variety of criteria determined by decision makers [4].

Various MCDM methods such as Simple Additive Weighting (SAW), PROMETHEE and TOPSIS are often used to solve problems in the fields of science, business and government. An example of the application of PROMETHEE is for decision making in the determination of vegetable commodity crops that are appropriate to the characteristics of the land [5].

Most MCDM problems involve information that is not only quantitative but also qualitative, which is uncertain. In this case, the MCDM problem is considered as a fuzzy MCDM problem that involves objectives, aspects, attributes or criteria and the possibility of alternatives or strategies [6]. The MCDM problem is solved using artificial intelligence techniques and the last few decades have become intensive studies of soft computing because it involves the fuzzy set theory.

The MCDM method has never been used to evaluate the level of school readiness in terms of implementing e-learning in schools. Therefore, it is necessary to evaluate the level of school readiness in implementing e-learning by taking into account the values on the specified criteria, using the MCDM computational model. In this case the method chosen is PROMETHEE, TOPSIS which is varied with the direct, SAW and AHP weighting methods. The results of the two methods will be compared and analyzed to get the strengths and weaknesses of the computational methods developed and the factors that influence them.

2. Basic Concepts

2.1. E-learning Readiness (ELR)

Borotis & Poulomenakou defines e-learning readiness (ELR) as the mental or physical readiness of an organization for a learning experience [7]. The ELR model is designed to simplify the process of obtaining basic information needed in developing e-learning.

The Web Forum organization issued a Global Information Technology Report (GITR) report containing analysis related to the strengths and weaknesses of ICT in a country and an evaluation of its development [3]. The report issued in this GITR uses the Networked Readiness Index (NRI) parameter which contains 3 main components as a measurement tool, namely: 1) ICT environment available both within the scope of the country or community; 2) Readiness of the main ICT players individually, business or government; 3) The use of ICT among stakeholders.
2.2. Simple Additive Weighting (SAW)

SAW is the most widely used method to solve the problem of Multi Attribute Decision Making (MADM) because of its simplicity. Tseng and Huang [6] state that the best solution in the SAW method is obtained by the equation

\[ A^* = \{ u_i(x) | \max_{i=1,2,\ldots,n} u_i(x) \} \]  

(1)

with

\[ u_i(x) = \sum_{j=1}^{n} w_j r_{ij}(x) \]  

(2)

where \( u_i \) denotes the utility of alternatives \( i \) and \( i=1,2,\ldots,n \); \( w_j \) shows the weight of the \( j \)th criterion; and \( r_{ij}(x) \) shows the normalization of the preference of the \( i \)th alternative in the \( j \)th criterion. The method is very useful for aggregating the weights of sub-criteria and criteria to be used in the next calculation process.

2.3. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

PROMETHEE is a method of determining the best alternative in multi-criteria analysis. The result of this method is an alternative ranking based on the selected criteria [8]. Following are the steps for calculating the PROMETHEE method:

1) Determine Preference and Assessment Types

The preference type is used to provide a more suitable description of each of the selected criteria. There are 2 types of objectives in the PROMETHEE method, i.e. maximizing and minimizing. If the objective is maximizing, then the function of preference value is:

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

(3)

Meanwhile, if the objective is minimize, then the function of preference is:

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

(4)

2) Calculating Preference Values

The function \( P_l(A_j, A_k) \) indicates preference \( A_j \) to \( A_k \) for the criterion \( C_i \). The value of the preference can be described as follows.

\[ P_l(A_j, A_k) = 0, \quad \text{indifferent between } A_j \text{ and } A_k \]
\[ P_l(A_j, A_k) \approx 0, \quad \text{Weak preference} \]
\[ P_l(A_j, A_k) \approx 1, \quad \text{Strong preference} \]
\[ P_l(A_j, A_k) = 1, \quad \text{preference of } A_j \text{ absolutely better than } A_k \]

3) Calculate the Multi Criteria Index

Multi Criteria Index \( \pi(A_j, A_k) \) indicates how much alternative \( A_j \) is better than alternative \( A_k \) by considering all the used criteria. The value of the multi criteria preference index is calculated using equation:

\[ \pi(A_j, A_k) = \sum_{i=1}^{n} \pi P_l(A_j, A_k), \forall A_j, A_k \in A \]  

(5)

3) Calculate Leaving and Entering Flow

Leaving flow shows that preference of other alternatives \( A_k \) is better than alternative \( A_j \) and calculated by equation:
\[ \Phi^+(A_j) = \frac{1}{n-1} \sum_{k=1}^{n} \pi(A_k, A_j) \]  \hspace{1cm} (6)

Entering flow shows that preference of other alternatives \( (A_j) \) is better than alternative \( (A_k) \) and calculated by equation:

\[ \Phi^-(A_j) = \frac{1}{n-1} \sum_{k=1}^{n} \pi(A_j, A_k) \]  \hspace{1cm} (7)

Net flow is used to produce the final decision in determining the order of problem solving so that a complete ranking is calculated by equation.

\[ \Phi(A_j) = \Phi^+(A_j) - \Phi^-(A_j) \]  \hspace{1cm} (8)

2.4. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is one of the multi-criteria decision making methods that were first introduced by Yoon and Hwang in 1981. This method is one of the most widely used methods for completing practical decision making. TOPSIS has the concept where the alternative chosen is the best alternative that has the shortest distance from the positive ideal solution and the distance from the negative ideal solution from a geometric point of view by using Euclidean distance to determine the relative proximity of an alternative to the optimal solution. However, the alternative which has the smallest distance from the positive ideal solution, does not have to have the largest distance from the negative ideal solution. Therefore, TOPSIS considers both the distance to the positive ideal solution and the distance to the negative ideal solution simultaneously. From its simple and easy to understand concept, its computation is efficient and has the ability to measure the relative performance of decision alternatives [9].

The main advantages of TOPSIS compared to other MCDM methods in making complex problem decisions are that they are easy to use, can take into account all types of criteria (subjective and objective), rational logic and easy to understand for practitioners, very easy process calculations, concepts allow the pursuit of the best alternative criteria depicted in mathematics simply and important weights can be entered easily. TOPSIS has been used in many applications including financial investment decisions, performance comparisons from companies, comparisons in specific industries, operating system selection, customer evaluation, and robot design.

3. Research Method

The research was conducted through the development of a computational model to evaluate the readiness for implementing e-learning in schools using the PROMETHEE and TOPSIS methods. The computational model is varied using direct weighting (DW), SAW and AHP weighting. The results of the two models are then compared and analyzed to determine the strengths, weaknesses and dominant factors in implementing e-learning in schools.

Schools used as samples were selected based on purposive sampling techniques that is based on specific characteristics that are considered to have a relationship with the population. The specific characteristics are: 1) is a public school; 2) having computer laboratory facilities; 3) the laboratory are equipped with internet networks; 4) most of the teaching staff are S1 graduates. Therefore, there are nine schools are involved in this research.

4. Result and Discussion

This study used the data of E-learning Readiness (ELR) score of nine public senior high schools (HS) in Yogyakarta, which involved eight criteria as presented in Table 1.
In order to determine the ranking of high schools in the readiness to implement E-Learning, it is necessary to determine the weight of each criterion first. In this study weights for each criterion were generated using 3 weighting methods namely direct weighting (DW), SAW, and AHP. The direct weighting method is performed by assigning an equal weight to each criterion. In this case, there are 8 criteria so the weight for each criterion is 0.125.

The SAW weighting method uses 3 preliminary criteria to determine the weighting of the ELR aspects, namely priority needs, carrying capacity, and availability/easiness obtained. The initial criteria are weighted as needed, i.e. 0.25, 0.35, and 0.4 respectively. Then, every aspect of the ELR was scored in connection with the three initial criteria for calculating their respective weights. The final results of the SAW calculation for each aspect of ELR are as follows: Human resource (0.173025), Equipment (0.167335), Technological skill (0.145777), Financial (0.141689), Content (0.159002), Environmental (0.148066), Psychological (0.089918), and Sociological (0.083106).

The AHP weighting method uses a priority sequence of ELR criteria, successively from the most important: Human resources, Equipment, Financial, Technological skills, Content, Psychological, Environmental, and Sociological. By using the steps in the AHP, the weight for each criterion are obtained as follows: Psychological (0.333334), Sociological (0.032301), Equipment (0.033334), Human resource (0.340993), Financial (0.159002), Technological skills (0.159002), Equipment (0.167335), and Content (0.074688).

First, the determination of ELR ranking of high schools in Yogyakarta is conducted using the PROMETHEE methods and the results are presented in Table 2 and depicted in Figure 1.

### Table 1. The data of ELR score of nine public senior high schools in Yogyakarta

| Aspect of ELR       | High School | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|---------------------|-------------|----|----|----|----|----|----|----|----|----|
| A. Psychological    | 13.75       | 14.25 | 16.75 | 16.75 | 17.00 | 13.75 | 15.50 | 19.33 | 15.25 |
| B. Sociological     | 10.75       | 11.25 | 12.50 | 12.25 | 12.25 | 10.75 | 10.25 | 12.67 | 10.25 |
| C. Environmental    | 17.25       | 15.00 | 17.50 | 16.00 | 16.50 | 17.25 | 16.50 | 17.00 | 18.00 |
| D. Human resource   | 6.00        | 8.00  | 8.75  | 7.75  | 8.00  | 7.75  | 7.25  | 10.67 | 8.00  |
| E. Financial        | 5.00        | 7.00  | 8.50  | 7.00  | 9.25  | 7.00  | 6.75  | 7.33  | 7.75  |
| F. Technological skill | 11.00    | 13.00 | 12.50 | 13.00 | 11.50 | 13.00 | 11.50 | 14.67 | 16.25 |
| G. Equipment        | 13.25       | 14.67 | 16.25 | 14.25 | 16.00 | 14.25 | 14.25 | 17.33 | 15.75 |
| H. Content          | 13.75       | 16.75 | 17.00 | 17.25 | 15.25 | 17.25 | 16.00 | 16.67 | 17.50 |

### Table 2. Results of leaving, entering, and net flow values using PROMETHEE

| High School# | Direct weighting | SAW | AHP |
|--------------|-----------------|-----|-----|
|              | Leaving | Entering | Net | Leaving | Entering | Net | Leaving | Entering | Net | Leaving | Entering | Net |
| HS 1         | 0.063    | 0.531    | 0.469 | 0.562    | 0.045    | 0.517 | 0.595    | 0.0165    | 0.578 |
| HS 2         | 0.141    | 0.313    | 0.172 | 0.281    | 0.147    | 0.134 | 0.218    | 0.151    | 0.067 |
| HS 3         | 0.391    | 0.063    | -0.328 | 0.066    | 0.389    | -0.323 | 0.070    | 0.396    | -0.326 |
| HS 4         | 0.188    | 0.195    | 0.008 | 0.199    | 0.172    | 0.028 | 0.196    | 0.143    | 0.052 |
| HS 5         | 0.266    | 0.195    | -0.070 | 0.194    | 0.268    | -0.074 | 0.175    | 0.264    | -0.089 |
| HS 6         | 0.164    | 0.227    | 0.063 | 0.219    | 0.157    | 0.062 | 0.204    | 0.137    | 0.066 |
| HS 7         | 0.086    | 0.391    | 0.305 | 0.395    | 0.080    | 0.315 | 0.417    | 0.066    | 0.351 |
| HS 8         | 0.5      | 0.094    | -0.406 | 0.088    | 0.509    | -0.420 | 0.067    | 0.538    | -0.471 |
| HS 9         | 0.359    | 0.148    | -0.211 | 0.128    | 0.366    | -0.238 | 0.110    | 0.338    | -0.228 |
Figure 1. Final score of net flow obtained using PROMETHEE

The algorithm of the PROMETHEE method is as follows: (1) Determine criteria and weights; (2) Calculate the value of sub-criteria and criterion values; (3) Calculating the preference value between alternatives; (4) Calculate the index value; (5) Calculating entering flow and leaving flow; (6) Calculating net flow; and (7) Showing ranking results.

Based on the final score of net flow, the ranking of the high school is determined, as shown in Table 3. It can be seen that with any weighting method, PROMETHEE gives the same ranking results.

Table 3. Ranking results of nine high schools using PROMETHEE

| Rank | Weighting methods |
|------|-------------------|
|      | DW | SAW | AHP |
| 1    | HS 1 | HS 1 | HS 1 |
| 2    | HS 7 | HS 7 | HS 7 |
| 3    | HS 2 | HS 2 | HS 2 |
| 4    | HS 6 | HS 6 | HS 6 |
| 5    | HS 4 | HS 4 | HS 4 |
| 6    | HS 5 | HS 5 | HS 5 |
| 7    | HS 9 | HS 9 | HS 9 |
| 8    | HS 3 | HS 3 | HS 3 |
| 9    | HS 8 | HS 8 | HS 8 |

The second method applied is TOPSIS. The two ranking methods, PROMETHEE and TOPSIS use the weighting criteria which are obtained from the three weighting methods as described above. The results of the ranking are analyzed by comparing the two methods.

There are procedures that must be performed to use the TOPSIS method, including these steps: (1) create a decision matrix X; (2) make a normalized decision matrix; (3) make a normalized weighted decision matrix; (4) determine a positive ideal solution matrix and a negative ideal solution; (5) calculate distance measure; (6) determine the preference value for each alternative; and (7) perform rank.

Since the value of $V_i^+$ is obtained then alternatives can be ranked according to the order of $V_i^+$. Alternatives are sorted descending based on $V_i^+$ value. The alternative with the biggest $V_i^+$ is the best solution. The results of $V_i^+$ are presented in Table 4, and graphically is pictured in Figure 2.
Table 4. Results of $V_i^+$ values using TOPSIS Method

| High School# | DW  | SAW  | AHP  |
|--------------|-----|------|------|
|              | $V_i^+$ | $V_i^+$ | $V_i^+$ |
| HS 1         | 0.925037 | 0.92260 | 0.980169 |
| HS 2         | 0.757903 | 0.57647 | 0.570197 |
| HS 3         | 0.639690 | 0.38178 | 0.397066 |
| HS 4         | 0.731767 | 0.57373 | 0.608944 |
| HS 5         | 0.654916 | 0.45071 | 0.497957 |
| HS 6         | 0.752991 | 0.59538 | 0.610423 |
| HS 7         | 0.811028 | 0.69416 | 0.715299 |
| HS 8         | 0.581005 | 0.24096 | 0.176850 |
| HS 9         | 0.642899 | 0.42084 | 0.485428 |

Figure 2. Final score of $V_i^+$ obtained using TOPSIS

The final score of $V_i^+$ is used to determine the ranking of nine high schools, and the results are displayed in Table 5.

Table 5. Ranking results of nine high schools using TOPSIS

| Rank | Weighting method |
|------|-----------------|
|      | DW  | SAW  | AHP  |
| 1    | HS 1 | HS 1 | HS 1 |
| 2    | HS 7 | HS 7 | HS 7 |
| 3    | HS 2 | HS 6 | HS 6 |
| 4    | HS 6 | HS 2 | HS 4 |
| 5    | HS 4 | HS 4 | HS 2 |
| 6    | HS 5 | HS 5 | HS 5 |
| 7    | HS 9 | HS 9 | HS 9 |
| 8    | HS 3 | HS 3 | HS 3 |
| 9    | HS 8 | HS 8 | HS 8 |

Based on table 5, it can be seen that the difference in weighting method causes an exchange of ranking of 3, 4, 5 to the three high schools. Whereas in the order of 1, 2 and 6 to 9, the ranking order does not change.
The scale of the readiness level of the E-learning Readiness proposed by Chapnick is divided into 3 levels of readiness, i.e. ready, simply ready and not ready. The each of eight aspects of ELR has different interval value of readiness level. Chapnick also provided the interval value of total score of eight aspects of ELR which is refer to the three readiness level, as shown in Table 6.

### Table 6. The interval value of total score for the readiness level

|       | Ready | Simply ready | Not ready |
|-------|-------|--------------|-----------|
| Total score | 65 – 89 | 90 – 160 | 161 – 194 |
|        | (Home Free) | (Proceed with Caution) | (Danger Zone) |

From Table 1 it can be obtained the total score of the eight aspects of ELR of each school, which is in range of 90.75 to 115.67. Based on Table 6, the score means that all of nine schools are in simply ready, and the rank of school readiness is school number 1, 7, 2, 6, 4, 5, 9, 3, 8 successively. This result are the same as the results obtained by the PROMETHEE method, but slightly different with the TOPSIS result. It means that TOPSIS is more sensitive in considering the weighting of the criteria in determining the final results.

Either by using PROMETHEE or TOPSIS, and either the weighting method, the results shows that the school that ranks first, meaning the school that is most ready to implement e-learning is HS number 1. The ranking results by TOPSIS and PROMETHEE methods did not show a significant difference, although the weighted criteria used were obtained from 3 weighting methods.

5. Conclusion

Based on the results, it can be seen the ranking of high schools from the most ready to those not yet ready by using two ranking methods namely PROMETHEE and TOPSIS. The weighting methods used are direct weighting, the SAW method, and the AHP method. The results obtained are then compared, and it can be concluded that the PROMETHEE method shows more consistent ranking results compared to the TOPSIS method.

6. References

[1] Waryanto NH 2010 *Evaluasi E-Readiness untuk Penerapan E-learning dalam Proses Pembelajaran Sekolah Menengah Pertama di Kota Yogyakarta* (UGM MTI Library Thesis Document not published)

[2] Chapnick S 2000 *E-learning Readiness TM Assessment* http://www.researchdog.com.

[3] Prayudi Y 2009 *Kajian Awal: E-Learning Readiness Index (ElRI) Sebagai Model Bagi Evaluasi E-Learning Pada Sebuah Institusi* Prosiding Seminar Nasional Aplikasi Teknologi Informasi 2009 Yogyakarta.

[4] Chen Z 2005 *Consensus in Group Decision Making Under Linguistic Assessments. Dissertation* College of Engineering Kansas State University Manhattan Kansas.

[5] Anjasmaya R, dan Andayani S 2018 Sistem Pendukung Keputusan Penentuan Komoditi Sayuran Berdasarkan Karakteristik Lahan Menggunakan Metode PROMETHEE *Jurnal Informatika JUITA Vol. 6 Nomor 2*, November 2018 e-ISSN 2579-8901 p-ISSN 2086-9398 http://jurnalnasional.ump.ac.id/index.php/JUITA/article/view/3505 DOI: 10.30595/juita.v6i2.3505

[6] Tseng GH and Huang JJ 2011 *Multiple Attribute Decision Making. Methods and Application* CRC Press Boca Raton.

[7] Priyanto 2008 *Model E-Learning Readiness Sebagai Strategi Pengembangan E-Learning International Seminar Proceedings, Information And Communication Technology (ICT) In Education* The Graduate School Yogyakarta State University

[8] Brans JP and Mareshal 1985 *A Preference Ranking Organisation Method* USA: The Institute of Management Sciences

[9] Mohammed HJ, Mat Kasim M, and Shaharamee IN 2018 Evaluation of E-Learning Approaches Using AHPTOPSIS Technique *Journal of Telecommunication, Electronic and Computer Engineering* e-ISSN: 2289-8131 Vol. 10 No. 1-10