Using DEMATEL and ANP for development of post-mining area at sub-district Pongkor gold mining, West Java

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Abstract. The objective of this paper proposes strategy for development of post-mining area at sub-district Pongkor gold mining, Bogor, West Java. The strategy of development designed using DEMATEL and ANP. The DEMATEL used to determine of important and influence level, then ANP used to determine potency weighted for development strategy. From the DEMATEL, 5 (five) potency from 8 (eight) is feasible to develop while post-mining of Pongkor gold mining, namely: training and education area, tourism of underground mine, natural & culture tourism, conservation area, and sports facilities. The development priority can determine based on weight of potency by ANP. Based on rank of weight by ANP, potencies for development are training and education area, tourism of underground mine, natural & culture tourism and conservation area.

1. Introduction

Area of sub-district Pongkor gold mining was managed by Business Unit of Gold Mining, PT. Aneka Tambang (Persero) Tbk (PT. ANTAM Tbk). This area located in District of Nanggung, Bogor, West Java, Indonesia. Area of sub-district Pongkor gold mining is part of the Taman Nasional Gunung Halimun & Salak (TNGHS). The exploration licenses of Pongkor gold mining will expire March 9, 2021[1]. Based on regulations, PT. ANTAM Tbk must have programmed as post-mining responsibility and reclamation. PT. ANTAM Tbk must recover from mining area with sustainable development program. The sustainable development programs aim to sustain the economic, environmental and social.

Roadmap of the sustainable development of the post-mining at the sub-district Pongkor gold mining has been introduced by the name AGROGEOEDUTOURISM concept. The AGROGEOEDUTOURISM concept will try integration of agronomy, geology, education, and tourism in the area post-mining. The AGROGEOEDUTOURISM designed for 2 (two) zone, namely mining tourism and natural (environmental) tourism [2].

This article proposes of development strategy of the post-mining area at district Pongkor gold mining based on environmental and social potency and society perception. The methodology in this article uses survey with in depth interviews. The output of the survey processed by the decision-making trial and evaluation laboratory (DEMATEL) and the analytical network process (ANP). DEMATEL used to determine important, influence level and relations between variable or attribute [3] then ANP used to determine of potency weighted for development strategy.
2. Literature review

2.1. The decision-making trial and evaluation laboratory (DEMATEL)

The DEMATEL is a multi-attribute decision making (MADM) method that is used as a tool to help in decision making [4]. The DEMATEL is used to analyze the component structure from decision variables. The DEMATEL can be used to view direct or indirect relationships between variables or attributes [5]. Furthermore, the DEMATEL can describe the important level and level of influence of an attribute or a variable on system and then the DEMATEL uses matrix system to get all causal relationships of an attribute or a variable with the others [3], [5].

2.2. The analytical network process (ANP)

ANP is a general theory of relative measurement used to derive a composite priority ratio from individual ratio that represents relative measurement of the influence of elements that interact with control criteria [6]. The ANP provides a way to input judgment and measurements to derive ratio of priorities scale for the distribution of influence among the criteria and groups of criteria in the decision making process [5]. ANP is a qualitative multi-attribute decision-making approach that provides structured communication to address business model [7]. The weight of indicators on performance measurement can be determined by ANP. The ANP can help decision-makers to determine strategy to improve performance based on relationship between indicators and weight of indicator. On the performance measurement, ANP usually combined with the DEMATEL [4], where the DEMATEL is used to relate indicators and perspective and then the relationship created is used to make the ANP model. Finally, the ANP model can determine weight of attributes or criteria.

3. Methodology

This study has applied DEMATEL and ANP. The DEMATEL used to determine the relationship between the potency of development, and then the weight of potency of development calculated by ANP. The following steps were utilized in this study:

a. Survey to identify the potency of development
b. Survey to identify important level of potency with Likert Scale (1 = very unimportant, 2 = unimportant, 3 = neutral, 4 = important, 5 = very important).
c. Validation of pre survey results by calculating the weighted average (WA) and level of consensus (LC) using the criteria cut off: WA ≥ 4.2 & LC ≥ 0.5 (economic) and WA ≥ 4.5 & LC ≥ 0.7 (environmental and social aspects) [8].

\[ WA_n = \frac{\sum (R_i \times LS)}{\sum R} \]  
\[ LC_n = \frac{\sum LS}{\sum R} \]

Where, \( LC_n \) = LC of criteria n, \( R_i \) = respondent i, \( LS \) = Likert score, \( R \) = total of respondent

d. Survey to identify level of influence between potency with 0 – 4 scale (0 = no influence, 1 = low, 2 = normal, 3 = strong, 4 = very strong). Survey result were processed to the DEMATEL steps [5].

e. Building direct relation matrix (A) based on average of influence value from \( a_i \) to \( a_j \). 
\[ A = [a_{ij}]_{n \times n} \]
1. Building normalization matrix (X)

$$X = A \times s$$

(4)

2. Building total relationship matrix (T),

$$T = X (I - X)^{-1}$$, $I$ as identity matrix.

(6)

3. Calculation of the level of importance and influence between potency.

$$T = \begin{bmatrix} t_{ij} \end{bmatrix}, \quad i, j = 1, 2, ..., n \quad \text{where,} \quad i = \text{rows and} \quad j = \text{column}$$

(7)

D and R represent direct and indirect relationships from row and column.

$$D = \left[ \sum_{j=1}^{n} t_{ij} \right]_{i=1}^{n}, \quad (i = 1, 2, ..., n)$$

(8)

$$R = \left[ \sum_{i=1}^{n} t_{ij} \right]_{j=1}^{n}, \quad (j = 1, 2, ..., n)$$

(9)

Where, $(D + R)$ indicates level of importance and $(D - R)$ indicates influence level.

4. Building significant matrix to describe the relationship between potency. Steps to prepare for significant matrix:

- Calculation of average of $T$:

$$\bar{T} = \frac{1}{\sum_{j=1}^{n} t_{ij}} \sum_{j=1}^{n} T_{ij}$$

(10)

Where, $i = \text{sum of row}$ and $j = \text{sum of column}$

- Reduction of all $T$ with $\bar{T}$ or $(T - \bar{T})$, the value of significant matrix indicate the level of relationship

5. Development of the ANP structure model based on the significant matrix. This step uses super decision software.

$$W = \begin{bmatrix} W_{11} & \ldots & W_{1j} & W_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ W_{i1} & \ldots & W_{ij} & W_{in} \\ \vdots & \vdots & \vdots & \vdots \\ W_{n1} & \ldots & W_{nj} & W_{nn} \end{bmatrix}$$

(11)

6. Survey to perform pair-wise comparison between the potency of development with scale 1 – 9. The survey result was processed to ANP steps [7]. The validity of the pair-wise comparison could be considering the inconsistency value. If value of inconsistency $< 1$ so the pair-wise comparison is valid [6].

7. Calculation of potency weight.

4. Results and discussions

4.1. Identification of potency

Identification potency for development of post-mining area at district Pongkor gold mining based on survey with location mapping and in depth interview. Besides that, identification of potency based on AGROGEOEDUThoURISM concept and sustainability aspects. The relations of potency with AGROGEOEDUThoURISM concept and sustainability aspects were descript in table 1.
Table 1. The potency relations with AGROGEOEDUTOURISM concept and sustainability aspects

| Potency of development | Concept-based | Sustainability aspects |
|------------------------|---------------|------------------------|
| Agriculture            | AGRO – EDU    |                        |
| Breeding ruminants and aquaculture | AGRO – EDU    | Economic               |
| Centre of a small and medium enterprise (SME) | AGRO – GEO – EDU – TOURISM | |
| Conservation area      | (ECO) – EDU – TOURISM | Environmental         |
| Tourism of underground mine | GEO – EDU – TOURISM | |
| Natural & culture tourism | (ECO) – EDU – TOURISM | |
| Training and education area | AGRO – GEO – EDU | Social                |
| Sport facilities       | EDU – TOURISM  |                        |

4.2. Potency validation
Validation of potency on development of post-mining area at sub-district Pongkor gold mining has been done with processed survey output. The survey was conducted through focus group discussion (FGD) followed by 109 respondents. Respondents consisted of village officials, community leaders and youth leaders around the mining area of the sub-district Pongkor. Validation of output survey based on value of weighted average (WA) and level of consensus (LC). Then, valid potency on table 2 can be processed to determine the importance and influence level.

Table 2. Criteria validation by WA and LC

| Potency                        | Disagree | Agree | Respondents | WA     | LC     | Validation |
|-------------------------------|----------|-------|-------------|--------|--------|------------|
| **ECONOMIC ASPECTS**          |          |       |             |        |        |            |
| Agriculture                   | 3        | 106   | 109         | 4.890  | 0.972  | Valid      |
| Breeding ruminants and aquaculture | 6           | 103   | 109         | 4.780  | 0.945  | Valid      |
| Centre of small and medium enterprise (SME) | 6           | 103   | 109         | 4.780  | 0.945  | Valid      |
| **ENVIRONMENTAL ASPECTS**     |          |       |             |        |        |            |
| Conservation area             | 13       | 96    | 109         | 4.523  | 0.881  | Valid      |
| **SOCIAL ASPECTS**            |          |       |             |        |        |            |
| Tourism of underground mine   | 1        | 108   | 109         | 4.963  | 0.991  | Valid      |
| Natural & culture tourism     | 1        | 108   | 109         | 4.963  | 0.991  | Valid      |
| Training and education area   | 4        | 105   | 109         | 4.853  | 0.963  | Valid      |
| Sport facilities              | 13       | 97    | 109         | 4.569  | 0.890  | Valid      |

4.3. Level of importance and influence
The DEMATEL stage was used to make relationships started from building direct relationship matrix based on average values from respondents [5] and finished at establishing relationships between criteria or attributes [9]. Table 3 shows initial matrix as direct relationship matrix and called matrix A. Table 4 shows normalization matrix, and Table 5 shows the inverse matrix. Finally, table 6 shows total relation matrix. The total relation matrix can be processed to determine level of importance and influence of potency.
### Table 3. Initial matrix (A)

|                              | Tourism of underground mine | Natural & culture tourism | Training and education area | Agriculture | Breeding ruminants and aquaculture | Conservation area | Sport facilities | Centre of SME | Sum |
|------------------------------|-----------------------------|---------------------------|----------------------------|-------------|----------------------------------|-------------------|-----------------|---------------|------|
| Tourism of underground mine  |                             |                           |                            |             |                                  |                   |                 |               |      |
| Natural & culture tourism    | 2                           |                           |                            |             |                                  |                   |                 |               |      |
| Training and education area  | 3                           | 3                         | 3                          | 2           |                                  |                   |                 |               |      |
| Agriculture                  | 2                           | 2                         | 2                          | 2           |                                  |                   |                 |               |      |
| Breeding ruminants and aquaculture | 2                 | 2                         | 2                          | 2           |                                  |                   |                 |               |      |
| Conservation area            | 3                           | 3                         | 3                          | 3           |                                  |                   |                 |               |      |
| Sport facilities             | 2                           | 2                         | 2                          | 2           |                                  |                   |                 |               |      |
| Centre of SME               | 3                           | 3                         | 3                          | 3           |                                  |                   |                 |               |      |
| Sum                          | 17                          | 19                        | 21                         | 20          | 18                               | 18                | 16              | 19            |      |

### Table 4. Normalization matrix (X)

|                              | Tourism of underground mine | Natural & culture tourism | Training and education area | Agriculture | Breeding ruminants and aquaculture | Conservation area | Sport facilities | Centre of SME |
|------------------------------|-----------------------------|---------------------------|----------------------------|-------------|----------------------------------|-------------------|-----------------|---------------|
| Tourism of underground mine  |                             | 0.146                     | 0.146                      | 0.146       |                                  |                   |                 |               |
| Natural & culture tourism    | 0.097                       | 0.146                     | 0.146                      | 0.146       |                                  |                   |                 |               |
| Training and education area  | 0.146                       | 0.146                     | 0.146                      | 0.122       |                                  |                   |                 |               |
| Agriculture                  | 0.097                       | 0.146                     | 0.146                      | 0.146       |                                  |                   |                 |               |
| Breeding ruminants and aquaculture | 0.097                  | 0.097                     | 0.146                      | 0.122       |                                  |                   |                 |               |
| Conservation area            | 0.146                       | 0.146                     | 0.146                      | 0.146       |                                  |                   |                 |               |
| Sport facilities             | 0.097                       | 0.097                     | 0.146                      | 0.097       |                                  |                   |                 |               |
| Centre of SME               | 0.146                       | 0.146                     | 0.122                      | 0.146       |                                  |                   |                 |               |
From (D+R) on Table 4 indicates that the existence of all potency is important. Besides, from (D – R) indicates that tourism of underground mine, conservation area, natural & culture tourism, sports facilities, and training & education area have value positive (+). It means that its potency has influence on development post-mining at sub-district Pongkor gold mining. Furthermore, the five of potency can be application for development area post-mining. Finally, the five potencies need to calculate to determine development priority. The development priority can be determined based on weight of potency. The ANP method can determine the potency weight because the ANP method accommodates the relation between potency for calculating the potency weight.

### Table 5. Inverse matrix

|                              | Tourism of underground mine | Natural & culture tourism | Training and education area | Agriculture | Breeding ruminants and aquaculture | Conservation area | Sport facilities | Centre of SME |
|------------------------------|-----------------------------|--------------------------|----------------------------|-------------|-----------------------------------|-------------------|-----------------|---------------|
| Tourism of underground mine  | 1.93085                    | 1.15804                  | 1.21944                    | 1.18083     | 1.07099                           | 1.08388           | 0.94803         | 1.15226       |
| Natural & culture tourism    | 1.04964                    | 2.06133                  | 1.25547                    | 1.21326     | 1.14095                           | 1.11276           | 1.01379         | 1.18477       |
| Training and education area  | 1.11393                    | 2.12869                  | 1.25823                    | 1.24313     | 1.14840                           | 1.14057           | 1.03792         | 1.21432       |
| Agriculture                  | 0.98972                    | 1.12343                  | 1.18466                    | 2.01871     | 1.07819                           | 1.03288           | 0.92007         | 1.11863       |
| Breeding ruminants and aquaculture | 0.83997 | 0.91988                  | 1.00907                    | 0.95800     | 1.79177                           | 0.86053           | 0.76209         | 0.91569       |
| Conservation area            | 1.05137                    | 1.15026                  | 1.21373                    | 1.17373     | 1.10308                           | 1.95051           | 0.94207         | 1.10735       |
| Sport facilities             | 0.88238                    | 0.96537                  | 1.05705                    | 0.98502     | 0.92333                           | 0.90183           | 1.73132         | 1.00067       |
| Centre of SME               | 1.00795                     | 1.10274                  | 1.14334                    | 1.12482     | 1.03774                           | 0.99493           | 0.92027         | 1.97112       |

### Table 6. Total relation matrix (T)

|                              | Tourism of underground mine | Natural & culture tourism | Training and education area | Agriculture | Breeding ruminants and aquaculture | Conservation area | Sport facilities | Centre of SME |
|------------------------------|-----------------------------|--------------------------|----------------------------|-------------|-----------------------------------|-------------------|-----------------|---------------|
| Tourism of underground mine  | 0.93                       | 1.158                    | 1.181                      | 1.071       | 1.084                             | 0.948             | 1.152           | 8.744         |
| Natural & culture tourism    | 1.049                      | 1.061                    | 1.255                      | 1.213       | 1.141                             | 1.112             | 1.013           | 9.032         |
| Training and education area  | 1.114                      | 1.218                    | 1.158                      | 1.243       | 1.148                             | 1.14              | 1.038           | 9.275         |
| Agriculture                  | 0.989                      | 1.123                    | 1.184                      | 1.018       | 1.078                             | 1.033             | 0.92            | 8.466         |
| Breeding ruminants and aquaculture | 0.839 | 0.923                    | 1.01                       | 0.958       | 0.79                              | 0.86              | 0.762           | 7.057         |
| Conservation area            | 1.051                      | 1.115                    | 1.213                      | 1.173       | 1.103                             | 0.95              | 0.942           | 8.692         |
| Sport facilities             | 0.882                      | 0.962                    | 1.057                      | 0.985       | 0.923                             | 0.902             | 0.731           | 7.447         |
| Centre of SME               | 1.008                      | 1.114                    | 1.114                      | 1.125       | 1.03                              | 0.99              | 0.902           | 1.008         |
| Sum (R)                     | 7.86                       | 8.699                    | 9.241                      | 8.89        | 8.295                             | 8.078             | 7.257           | 8.665         |

From (D+R) on Table 4 indicates that the existence of all potency is important. Besides, from (D – R) indicates that tourism of underground mine, conservation area, natural & culture tourism, sports facilities, and training & education area have value positive (+). It means that its potency has influence on development post-mining at sub-district Pongkor gold mining. Furthermore, the five of potency can be application for development area post-mining. Finally, the five potencies need to calculate to determine development priority. The development priority can be determined based on weight of potency. The ANP method can determine the potency weight because the ANP method accommodates the relation between potency for calculating the potency weight.
4.4. Relation between potency

The relation between potency can determine based on the significant matrix of DEMATEL. The significant matrix can build based on the total relation matrix. Table 7 shows the significant matrix.

Table 7. The significant matrix

|                     | Tourism of underground mine | Natural & culture tourism | Training and education area | Agriculture | Breeding ruminants and aquaculture | Conservation area | Sport facilities | Centre of SME |
|---------------------|-----------------------------|---------------------------|-----------------------------|-------------|-----------------------------------|-------------------|----------------|--------------|
| Tourism of underground mine | 0.111                       | 0.173                     | 0.134                       | 0.024       | 0.037                             | -0.099            | 0.105          |              |
| Natural & culture tourism       | 0.003                       | 0.209                     | 0.166                       | 0.094       | 0.066                             | -0.033            | 0.138          |              |
| Training and education area     | 0.067                       | 0.172                     | 0.196                       | 0.102       | 0.094                             | 0.009             | 0.167          |              |
| Agriculture                    | -0.057                      | 0.077                     | 0.138                       | 0.031       | -0.014                            | -0.127            | 0.072          |              |
| Breeding ruminants and aquaculture | -0.207                     | -0.127                    | -0.038                      | -0.089      | -0.186                            | -0.285            | -0.131         |              |
| Conservation area              | 0.005                       | 0.103                     | 0.167                       | 0.127       | 0.056                             | -0.105            | 0.060          |              |
| Sport facilities               | -0.164                      | -0.081                    | 0.010                       | -0.062      | -0.124                            | -0.145            | -0.046         |              |
| Centre of SME                 | -0.039                      | 0.056                     | 0.096                       | 0.078       | -0.009                            | -0.052            | -0.145         |              |

From table 7, a minus (-) value on a significant matrix indicates that there is no relationship of influence between perspectives. Equally, a positive (+) value indicates that a row perspective influences a column perspective.

4.5. Weight of potency

Weight potency can calculate based on the pair-wise comparison between potency using ANP method. The ANP method can process by super decision software. Pair-wise comparison between potency was based on the average values of respondents. Before entering the data, the structure model had been created. The structure model of ANP by super decision software described in figure 1. Then, average values from respondents by super decision software described in figure 2. Inconsistency index from pair-wise comparison between potency is 0.088 (0.088 < 1), it means the perception of respondents is valid.

Figure 1. Structure model ANP by super decision software
2. Pair-wise comparison between criteria’s

After the pair-wise comparison, super decision software can process the weight of potency. Weight of potency described on priorities icon of the computation menu. Figure 3 shows the potency weight on the development of post-mining area at sub-district Pongkor gold mining.

Figure 3. Weight of potency

Figure 3 shows that the training and education area (0.31011), tourism of underground mine (0.21599) natural & culture tourism (0.19532) and conservation area (0.18594) can be alternatives on development of post-mining area at sub-district Pongkor. Based on weight of criteria, training and education area has highest weight more than other criteria. It means, the district Pongkor gold mining very relevant for training and education centers, likes formal education and or non-formal education.

4.6. Discussion
Based on survey with location mapping and in depth interviews with some stakeholders, we found 8 (eight) potency of development for post-mining at sub-district Pongkor gold mining. The potencies need confirm to respondents before processed by the DEMATEL. From confirmation to 109 respondents, we need validation with WA and LC and we found that all of potency is valid. It is mean, the potencies are suitable for development in post-mining at sub-district Pongkor. The valid potencies were processed by the DEMATEL to determine of importance and influence level.

From the DEMATEL, all of the potency is important. Besides, only 5 (five) potency has influence on other potencies. Furthermore, 5 (five) potency from 8 (eight) valid potency were selected to develop on the post-mining at sub-district Pongkor. Finally, the 5 (five) potency need priority for developed. The development priority can be determined based on weight of potency. The ANP method can be used to determine the potency weight because the ANP accommodates the relation between potency in the set of the potency weight. The relation between potency was determined based on significant matrix.
Based on rank potency by ANP, potencies of training and education area (0.31011), tourism of underground mine (0.21599), natural & culture tourism (0.19532) and conservation area (0.18594) can be alternatives on development of post-mining area at sub-district Pongkor gold mining.

5. Conclusions
We found 3 (three) phenomena in this study. First, all of potency of development for post-mining at sub-district Pongkor were valid potency. Its mean, 8 (eight) potency will relevance with community requirements and relevance with AGROGEOEDUTOURISM concept by PT. ANTAM (Persero) Tbk. Second, based on influence level, only 5 (five) from 8 (eight) potency relevance to develop, namely: training and education area, tourism of underground mine, natural & culture tourism, conservation area, and sport facilities. Third, based on weight of potency, only 4 (four) potency is feasible to develop on post-mining at sub-district Pongkor gold mining, namely: training and education area, tourism of underground mine, natural & culture tourism and conservation area. The limitation of this paper is every potency need alternative for developed. Finally, exploration alternatives for each potency that feasible to develop need for future research. For example, natural & culture tourism has development alternatives: free fall, forestry, tourism village, etc.

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