Decision making analysis for water distribution improvement projects

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Abstract. Regional water utility company at Jakarta is determined to improve the quality of service to its customers. The water distribution system must have criteria for quantity, quality, and continuity of flow. To maintain the criteria of company, it continues to make improvements. Based on the evaluation of water utility company that they could decrease of non-revenue water was 1% per year with company target was 2% per year. Decision support systems increasingly play an important role in the area of area control that will be used as improvement project on pipes to customers. Some supporting methods that will be used are electre and linear programming (LP). Electre will be used in decision making analysis on determining the repair area. Based on the results of electre analysis, it can be seen that B01, B02, B13, and B20 have the highest priority that can be recommended for improvement projects. LP can be used as tools for selecting the project to get maximum profit from limited of budget. Based on the results of LP analysis, it can be seen that it selected 13 projects from 16 projects with the constraint’s budget of maintenance is 16.7 BIDR.

1. Introduction
The Problem- As water distribution system that they had problems such as corrosion of the pipe and pipe leakage. Therefore preventive action is the most appropriate step that a history of maintenance can be used to produce maintenance standards on a regular basis. The purpose of these preventive action is an important objective for future water distribution maintenance planning. At the same time, steps to increase capital for the rehabilitation of the pipeline became a concern of the management. Maintenance management systems by integrating routine maintenance and capital improvement planning are important goals for future water distribution system.

2. Method and materials
This study provides an electre method and linear programming for the problem of water maintenance project. This study presents an approach for budgeting maintenance costs in water distribution networks. The decision making process starts to choose project which it will be plan by company in 2020. Rehabilitation and replacement of alternatives were evaluated for each pipeline, based on field study.

2.1. Object sample
The sample was selected at West Jakarta. Water utility company have divided 20 permanent service areas. Permanent services area can make it easy to find out what the value of water loss is for each area, so that priority can be made on data as shown below on Table 1 and mapping area on figure 1.
Table 1. Permanent area of water distribution

| PA  | LOCATION      | PA  | LOCATION      |
|-----|---------------|-----|---------------|
| B01 | Kelapa Dua    | B11 | Teluk Gong    |
| B02 | Meruya Ilir   | B12 | Rawa Buaya    |
| B03 | Sukabumi Utara| B13 | Permata Buana |
| B04 | Perjuangan    | B14 | Semanan       |
| B05 | Tanjung Duren | B15 | Jelambar      |
| B06 | Kedoya        | B16 | Perternakan   |
| B07 | Taman Kota    | B17 | Rawa Gabus    |
| B08 | Moneter       | B18 | Cengkareng Timur|
| B09 | Puri Indah    | B19 | Cengkareng Barat|
| B10 | Tosiga        | B20 | Kalideres     |

Figure 1. Permanent area

2.2. Method
The method in the decision making process are electre and linear programming. The electre will use to select three permanent area which it will analysis on the field. The linear programming will use to choose projects with the objective target is maximum sales. The final result from this method are project decision maker and the cost of project. Its purpose is maximum profit for company with the constraint’s budget.

2.2.1. Electre
Make a decision matrix based on consideration of making a decision and normalizing the values in the decision matrix. A set of categories must be a priority defined. The definition of a category is based on the fact that all potential action which are assigned to it will be considered further in the same way. In
sorting problematic, each action is considered independently from the others in order to determine the categories [3]. Then the best alternative is the alternative that dominates the other alternatives.

2.2.2. Linear Programming
Linear programming is a mathematical method that has a linear characteristic to find solution with the step of maximizing the objective function of an arrangement of constraints [1]. The models is binary problems. Binary problem, each variable can only take on the value of 0 or 1. This may represent the selection or rejection. The objective of target from linear programming is maximum sales in the potency sales of project.

3. Results

3.1. Evaluation of Water System Distribution
The evaluation data can show the root problems. The period of data is January 2018 until to August 2019. From Figure 2, it can show the average supply and sales. The value of NRW (non-revenue water) is 42.1%.

![Figure 2. Supply VS Sales](image)

3.2. Electre
The step in the decision making process used six criteria. The six criteria are supply, sales, non-revenue water, complaint, number of standard customers, and number of key account customers. The criteria is shown below on Table 2. The criteria will use to convert with the primary data and the result of conversion will be used by electre formula. The primary data can be shown on Table 3 and the result of conversion can be show on Table 4.

| Supply | Sales | NRW | Average Complaint | \( \sum \) STD | \( \sum \) KA | Rating | Information |
|--------|-------|-----|-------------------|----------------|-------------|--------|------------|
| On below agreement 10% | Achievement 95-96% from target | NRW > 50% | Complaint > 70 | > 15000 | > 60 | 5 | Very Bad |
| On below agreement | Achievement 97-99% from target | NRW 41-50% | Complaint 51-70 | 10001 - 15000 | 41 - 60 | 4 | Bad |
| In the middle agreement | Achievement 100% from target | NRW 31-40% | Complaint 31-50 | 5001 - 10000 | 31 - 40 | 3 | Enough |
| Above agreement | Achievement 101-102% from target | NRW 20-30% | Complaint 11-30 | 1001 - 5000 | 11 - 30 | 2 | Good |
Above Agreement 10%
Achievement 103-105% from target
NRW < 20%
Complaint < 1000 < 10 1 Well

| PA   | Supply (lps) | Sales (lps) | NRW (%) | Complaint (cust) | ∑ STD (cust) | ∑ KA (cust) |
|------|--------------|-------------|---------|------------------|--------------|-------------|
| B01  | 63           | 16          | 74%     | 2                | 1959         | 7           |
| B02  | 55           | 36          | 33%     | 17               | 4526         | 22          |
| B03  | 38           | 10          | 75%     | 34               | 1611         | 1           |
| B04  | 33           | 17          | 48%     | 8                | 462          | 9           |
| B05  | 421          | 230         | 45%     | 181              | 19386        | 57          |
| B06  | 198          | 121         | 39%     | 27               | 11599        | 15          |
| B07  | 88           | 57          | 35%     | 9                | 5438         | 10          |
| B08  | 17           | 14          | 15%     | 3                | 1080         | 2           |
| B09  | 46           | 33          | 28%     | 17               | 2869         | 10          |
| B10  | 31           | 12          | 61%     | 16               | 1679         | 5           |
| B11  | 177          | 85          | 52%     | 61               | 9115         | 17          |
| B12  | 135          | 95          | 30%     | 42               | 11604        | 11          |
| B13  | 58           | 32          | 45%     | 7                | 3312         | 4           |
| B14  | 186          | 133         | 28%     | 34               | 16302        | 9           |
| B15  | 386          | 164         | 57%     | 105              | 21801        | 76          |
| B16  | 263          | 134         | 49%     | 52               | 13854        | 34          |
| B17  | 70           | 43          | 39%     | 15               | 6246         | 5           |
| B18  | 250          | 141         | 44%     | 57               | 19794        | 25          |
| B19  | 242          | 171         | 29%     | 1163             | 20550        | 33          |
| B20  | 241          | 161         | 33%     | 1019             | 20394        | 40          |

The data processing in this research is the ranking of the water service areas for the recommendation of project area by using the electre formula. The process produces concordance and dis-concordance values for each alternative. Based on the results of electre, it can be seen that B01, B02, B13, and B20...
have the highest priority that can be recommended for improvement projects. The result can be shown on Table 5 and mapping area can be show on Figure 3.

| PA | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | ∑   |
|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| B01| - 1 0 1 0 0 0 0 1 0 1 0 1 1 1 0 1 0 0 1 9 |
| B02| 1 - 0 0 0 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 6 |
| B03| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 |
| B04| 0 0 0 - 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B05| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B06| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B07| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B08| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B09| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B10| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B11| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B12| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B13| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B14| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B15| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B16| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B17| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B18| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B19| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 |
| B20| 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 5 |

Figure 3. Mapping area

Table 5. Result of electre

3.3. Linear Programming
A total budget of 16.7 BIDR for maintenance and capital improvement measures is available in this year. The budget projections are given in Table 6. It is the outputs of the model. The first column
Table 6. Result of linear programming

| PROJECTS CODE | PA LENGTH (m) | CAPITAL REQUIRED BIDR | POTENSIAL SALES (M3) | PROJECT TAKEN/NOT |
|---------------|---------------|------------------------|----------------------|-------------------|
| B01-001       | 0.7           | 2,940                  | 1                    |
| B01-002       | 1.5           | 22,380                 | 1                    |
| B01-003       | 0.3           | 1,260                  | 0                    |
| B01-004       | 0.9           | 17,940                 | 1                    |
| B01-005       | 0.02          | 3,540                  | 1                    |
| B02-001       | 0.9           | 16,956                 | 1                    |
| B13-001       | 3.9           | 70,920                 | 1                    |
| B13-002       | 1.7           | 30,120                 | 1                    |
| B13-003       | 0.8           | 14,280                 | 1                    |
| B13-004       | 0.6           | 8,400                  | 0                    |
| B13-005       | 2.8           | 28,980                 | 0                    |
| B20-001       | 2.4           | 94,908                 | 1                    |
| B20-002       | 0.7           | 115,860                | 1                    |
| B20-003       | 1.1           | 9,000                  | 1                    |
| B20-004       | 0.8           | 8,820                  | 1                    |
| B20-005       | 1.2           | 33,780                 | 1                    |
| BUDGET        | 16.74         | 441,444                | 13                   |
| CAPITAL REQUIRED (BIDR) | 16.58           |                        |                      |

4. Conclusion
The decision making process is not decided by only one participant, but by many participants. This is because decision making covers the interests of many participants that must be considered, so that the decisions made can be satisfactory for all participants. In decision making there are many alternative decisions [3]. Often decision makers in making decisions use intuition, so the results of decision making are not always right. Based on the results of electre analysis, it can be seen that B01, B02, B13, and B20 have the highest priority that can be recommended for improvement projects. Examination of these results shows that the project in which implementation was most deferred are project B01-001, B01-002, B01-004, B02-001, B13-001, B13-002, B13-003, B20-001, B20-002, B20-003, B20-004, and B20-005.

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