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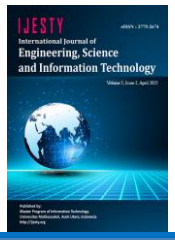

Electre Method Decision Support System for Concrete Type Selection in Building Structures

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Abstract

Choosing the correct type of concrete in building construction is a crucial step that significantly affects the structure's quality, durability, and safety. Concrete, as the most widely used building material, has various types with different characteristics, such as compressive strength, tensile strength, modulus of elasticity, and durability. During this time, people who make concrete often ignore the strength of the concrete itself. They do not care what will happen if the manufacture of concrete is not by the recommended concrete construction. Concrete is the primary material for constructing a building such as a building. The quality of concrete is determined by its constituent materials, which include hydraulic cement, coarse aggregate, fine aggregate, water, and other additives. The concrete mix determines the strength of the concrete. If the building is built with unsuitable concrete, it will be quickly destroyed during natural disasters such as earthquakes. Based on this, the concrete type selection must be precise and accurate. Decision Support Systems are used in this research to provide additional input to decision-makers. Decision support systems can deliver maximum results by using algorithms or methods. The Electre method is one of the multicriteria decision-making methods based on ranking by pairwise comparisons of existing alternatives based on appropriate criteria. Overall, this research is expected to significantly improve the quality of decision-making in selecting concrete types, resulting in a safer, more durable, and more efficient building structure. The results obtained after inputting criteria values and alternative values are concrete types such as reinforced concrete, precast concrete, and lightweight concrete.

Keywords: *Concrete, Electre, Criteria, Alternatives, Quality.*

1. Introduction

When creating a structure, selecting the right concrete is an important decision that significantly impacts the structure's quality, longevity, and safety. [1], [2]. The most popular building material, concrete, has several properties, including durability, modulus of elasticity, compressive strength, and tensile strength. [3], [4]. Each type of concrete has different advantages and limitations [5]. For instance, reinforced concrete is known for its high compressive strength but can be heavy. Precast concrete is durable and can be produced off-site but may require more complex transportation and installation. Lightweight concrete is easy to handle and can reduce the structure's overall weight but may have lower strength. Therefore, selecting the right kind of concrete must be adjusted to environmental conditions, working loads, and structural design requirements [6].
During this time, people making concrete often ignore the strength of the concrete itself. They do not care what will happen if the manufacture of concrete is not by the recommended concrete construction. Buildings built with unsuitable concrete are easily destroyed in an earthquake, and so on [7].

Meanwhile, concrete is an essential primary material for building development. Concrete is a function of its constituent materials consisting of hydraulic cement, coarse aggregate, fine aggregate, water, and other additives [8], [9]. Concrete mixtures determine the strength of the concrete [10].
Concrete has several types, such as cyclopean concrete, lightweight concrete, non-sand concrete, void concrete, reinforced concrete, pre-stressed concrete, precast concrete, mass concrete, Ferro cement concrete, and fibre concrete, where each concrete has different strengths and functions.
Decision Support Systems are also intended to provide additional input to the decision-maker. For the decision support system to deliver maximum results, it can use algorithms or methods [11].
To overcome the complexity of making decisions on the selection of concrete types, a tool is needed to assist decision-makers in evaluating various alternatives systematically and objectively. One of the tools that can be used is a Decision Support System (SPK). SPK is a computer-based system designed to assist decision-makers in choosing the best alternative from many existing alternatives by considering various relevant criteria [12], [13].
Thus, this research aims to develop a decision support system based on the ELECTRE method that can help construction experts choose the most suitable type of concrete for a building structure by considering various relevant factors and preferences of the decision-maker. The Electre method determines the ranking order through pairwise comparisons between alternatives on criteria according to priorities in Multi-Criterion Decision Making (MCDM) [14]. Electra is used to define and produce decisions based on several options. All the data is merged into one with the assessment weight obtained through the assessment of the test results. Overall, this research is expected to significantly improve the quality of decision-making in selecting concrete types, resulting in a safer, more durable, and more efficient building structure [15].

2. Literature Review

A decision support system is a system built to support the solution to a problem or an opportunity. The Decision Support System (SDM) application uses a flexible, interactive, and adaptable CBIS (Computer Based Information System) that can be developed to support the solution of specific unstructured management problems [16], [17].
Concrete consists of aggregates, cement, and water mixed in a plastic state and is easy to work with. Because of these properties, concrete can easily mould to the user's liking. Shortly after mixing, a chemical reaction occurs in the mix, which is generally hydration and results in hardening and strength gain [18].
The building structure is the pillar that centres the building's strength. A building consists of structural elements and nonstructural elements. The structural elements support the nonstructural elements so that the building can be sturdy, and the building settlement rate becomes smaller than the recommended settlement rate [19].
The Electre is one of the multicriteria decision-making methods based on outranking, which uses pairwise comparisons of alternatives based on appropriate criteria. The Electre method is used when alternatives that do not match the requirements are eliminated, and suitable options can be generated. In other words, The Electre is used for cases with many options, but few criteria are involved [20], [21].
DFD (Data Flow Diagram) or Data Flow Diagram is a system modelling language used to present the system logically; this diagram is helpful in communication between system analysts, programmers, and system users (users) [22].
ERD is a graphical notation in conceptual data modelling describing store relationships. ERDs are used to model data structures and relationships between data, which are relatively complex [23].
PHP stands for PHP: Hypertext Preprocessor. PHP is a programming language for creating web that is server-side scripting. PHP allows programmers to create dynamic web pages [24].
MySQL is an open-source database management system. MySQL was created and developed by MySQL AB in Sweden. MySQL can create and manage databases and their contents [25].

2. Research Method

a. Literature Study
   Literature study is a research method that studies books related to the system and algorithms used. In addition to books, I also have several papers or journals and other sources of information via the internet.
b. Interview
   Interviews are used to obtain information directly utilizing questions and answers with PT. XYZ to get information about the types of concrete that are often used.
c. Researchers analyze the problems found in determining the type of concrete and understand these problems before taking final action.

At this stage, the researcher designs the decision support system application to determine the type of concrete used in the building structure using the Electre method. Design using DFD (Data Flow Diagram) tools by describing the processes in the system/application to make it easier to complete the program. Web-based program using PHP programming language and access database.
Testing the program has been done by conducting several tests on the program, especially on the application of the algorithm used, and analyzing the resulting output to get errors so that these errors can be corrected again.

3. Result and Discussion

3.1. Electre Method

1. Manual Search Electre Method
   The decision support system for determining the type of metal to be used is the following criteria:

Table 1. Manual Calculation Criteria

No	Criteria	Labels	Value
1	Price	1.000.000-5.000.000	1
		5.000.000-10.000.000	2
		10.000.000-15.000.000	3
		15.000.000-20.000.000	4
		>20.000.000	5
2	Duration of Manufacture	10 Days - 15 Days	1
		>30 Days	3
			5
3	Quality of Concrete	K100 – K200	1
		K200 – K300	2
		K300 – K400	3
		K400 – K500	4
		>K500	5
4	Ground Structure	Solid and Sticky	1
		Mud	2
		Loose	3
		Solid	4
		Very Solid	5
5	Earthquake Resistance	Very Low	1
		Low	2
		Fair	3
		High	4
		Very High	5

The alternative values for each criterion used in this manual calculation are as follows:

Table 2. Table of Alternative Values for Each Criterion

Alternatives	Price	Duration of Manufacture	Quality of Concrete	Ground Structure	Earthquake Resistance
Reinforced Concrete	5	1	2	1	2
Precast Concrete	2	5	3	3	3
Lightweight Concrete	5	3	4	4	4

Preference weighting decision-making:

$w = (3,3,3,4,5)$

The decision matrix formed from the match table is as follows:

$$x = \begin{matrix} 5 & 1 & 2 & 1 & 2 \\ 2 & 5 & 3 & 3 & 3 \\ 5 & 3 & 4 & 4 & 4 \end{matrix}$$

To determine the above problem, the Electre method is as follows by normalization:

2. Normalization of the decision matrix:

$$r_{11} = \frac{x_{11}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{5}{\sqrt{5^2 + 2^2 + 5^2}} = 0.68041$$

$$r_{12} = \frac{x_{12}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{1}{\sqrt{1^2 + 5^2 + 3^2}} = 0.16903$$

$$r_{13} = \frac{x_{13}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{2}{\sqrt{2^2 + 3^2 + 4^2}} = 0.37139$$

$$r_{14} = \frac{x_{14}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{1}{\sqrt{1^2 + 3^2 + 4^2}} = 0.19612$$

$$r_{15} = \frac{x_{15}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{2}{\sqrt{2^2 + 3^2 + 4^2}} = 0.37139$$

$$r_{21} = \frac{x_{21}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{2}{\sqrt{5^2 + 2^2 + 5^2}} = 0.27217$$

$$r_{22} = \frac{x_{22}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{5}{\sqrt{1^2 + 5^2 + 3^2}} = 0.84515$$

$$r_{23} = \frac{x_{23}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{3}{\sqrt{2^2+3^2+4^2}} = 0.55709$$

$$r_{24} = \frac{x_{24}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{3}{\sqrt{1^2+3^2+4^2}} = 0.58835$$

$$r_{25} = \frac{x_{25}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{3}{\sqrt{2^2+3^2+4^2}} = 0.55709$$

$$r_{31} = \frac{x_{31}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{5}{\sqrt{5^2+2^2+5^2}} = 0.68041$$

$$r_{32} = \frac{x_{32}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{3}{\sqrt{1^2+5^2+3^2}} = 0.50709$$

$$r_{33} = \frac{x_{33}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{4}{\sqrt{2^2+3^2+4^2}} = 0.74278$$

$$r_{34} = \frac{x_{34}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{4}{\sqrt{1^2+3^2+4^2}} = 0.78446$$

$$r_{35} = \frac{x_{35}}{\sqrt{\sum_{i=1}^{m} x_i^2 1}} = \frac{4}{\sqrt{2^2+3^2+4^2}} = 0.74278$$

From the above calculations, the R matrix is obtained as follows:

$$R = \begin{matrix} 0.68041 & 0.16903 & 0.37139 & 0.19612 & 0.37139 \\ 0.27217 & 0.84515 & 0.55709 & 0.58835 & 0.55709 \\ 0.68041 & 0.50709 & 0.74278 & 0.78446 & 0.74278 \end{matrix}$$

3. Weighting V = RW

$$R = \begin{matrix} 0.68041 & 0.16903 & 0.37139 & 0.19612 & 0.37139 \\ 0.27217 & 0.84515 & 0.55709 & 0.58835 & 0.55709 \\ 0.68041 & 0.50709 & 0.74278 & 0.78446 & 0.74278 \end{matrix}$$

$$W = 3 \;\; 3 \;\; 3 \;\; 4 \;\; 5$$

$$V = \begin{matrix} 2.04123 & 0.50709 & 1.11417 & 0.78448 & 1.85695 \\ 0.81651 & 2.53545 & 1.67127 & 2.35340 & 2.78545 \\ 2.04123 & 1.52127 & 2.22834 & 3.13784 & 3.71390 \end{matrix}$$

4. Determine the Concordance and Discordance Index sets
   a. Concordance

$C_{kl} = \{j, V_{kj} \geq V_{ij}\}\ for\ j = 1,2,3, \ldots n$

$C_{12} = \{j, V_{1j} \geq V_{2j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{12} = \{1\}$

$C_{13} = \{j, V_{1j} \geq V_{3j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{13} = \{1\}$

$C_{21} = \{j, V_{2j} \geq V_{1j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{21} = \{2,3,4,5\}$

$C_{23} = \{j, V_{2j} \geq V_{3j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{23} = \{2\}$

$C_{31} = \{j, V_{3j} \geq V_{1j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{31} = \{1,2,3,4,5\}$

$C_{32} = \{j, V_{3j} \geq V_{2j}\}\ for\ j = 1,2,3, \ldots 5$

$C_{32} = \{1,3,4,5\}$

b. Discordance

$D_{kl} = \{j, V_{kj} < V_{ij}\}\ for\ j = 1,2,3,\ldots n$

$D_{12} = \{j, V_{1j} < V_{2j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{12} = \{2,3,4,5\}$

$D_{13} = \{j, V_{1j} < V_{3j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{13} = \{2,3,4,5\}$

$D_{21} = \{j, V_{2j} < V_{1j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{21} = \{1\}$

$D_{23} = \{j, V_{2j} < V_{3j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{23} = \{1,3,4,5\}$

$D_{31} = \{j, V_{3j} < V_{1j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{31} = \{\}$

$D_{32} = \{j, V_{3j} < V_{2j}\}\ for\ j = 1,2,3,\ldots 5$

$D_{32} = \{2\}$

c. Calculating the Concordance Matrix and Discordance Index

1. Calculating the Concordance Matrix

$C_{12} = w1 = 3$

$C_{13} = w1 = 3$

$C_{21} = w2 + w3 + w4 + w5 = 3 + 3 + 4 + 5 = 15$

$C_{23} = w2 = 3$

$C_{31} = w1 + w2 + w3 + w4 + w5 = 3 + 3 + 3 + 4 + 5 = 18$

$C_{12} = w1 + w3 + w4 + w5 = 3 + 3 + 4 + 5 = 15$

So, the Concordance Matrix is

$$\begin{bmatrix} - & 3 & 3 \\ 15 & - & 3 \\ 18 & 15 & \end{bmatrix}$$

2. Calculating the Discordance Matrix

$$D_{Kl} = \frac{\max\{|V_{kj} - V_{ij}|\}\, j \in D_{kl}}{\max\{|V_{kj} - V_{ij}|\}\forall_i}$$

$$D_{12} = \frac{\max\{|V_{1j} - V_{2j}|\}\, j \in D_{kl}}{\max\{|V_{1j} - V_{2j}|\}\forall_i}$$

$$= \frac{\max\{|0.50709 - 2.53545|; |1.11417 - 1.67127|; |0.78448 - 2.35340|; |1.85695 - 2.78545|\}}{\max\{|2\ 04123 - 0\ 81651|: |0\ 50709 - 2\ 53545|: |1\ 11417 - 1\ 67127|: |0\ 78448 - 2\ 35340|: |1\ 856958 - 2\ 78545|\}}$$

$$D_{12} = \frac{\max\{|-2.02836|; |-0.5571|; |-1.56892|; |-0.928492|\}}{\max\{|1\ 22472|: |-2\ 02836|: |-0\ 5571|: |-1\ 56892|: |-0\ 928492|\}}$$

$$D_{12} = \frac{\max\ \{|-2.02836|\}}{\max\{|-2\ 02836|\}} = 1$$

$$D_{13} = \frac{\max\{|V_{1j} - V_{3j}|\}\, j \in D_{kl}}{\max\{|V_{1j} - V_{3j}|\}\forall_i}$$

$$= \frac{\max\{|0.50709 - 1.52127|; |1.11417 - 2.22834|; |0.78448 - 3.13784|; |1.85695 - 3.71390|\}}{\max\{|2\ 04123 - 2\ 04123|: |0\ 50709 - 1\ 52127|: |1\ 11417 - 2\ 22834|: |0\ 78448 - 3\ 13784|: |1\ 856958 - 3\ 71390|\}}$$

$$D_{13} = \frac{\max\{|-1.01418|; |-1.11417|; |-2.35336|; |-1.85695|\}}{\max\{|0|: |-1\ 01418|: |-1\ 11417|: |-2\ 35336|: |-1\ 85695|\}}$$

$$D_{13} = \frac{\max\{|-2.35336|\}}{\max\{|-2.35336|\}} = 1$$

$$D_{21} = \frac{\max\{|V_{2j} - V_{1j}|\}\, j \in D_{kl}}{\max\{|V_{2i} - V_{1i}|\}\forall_i}$$

$$= \frac{\max\{|0.81651 - 2.04123|\}}{\max\{|0.81651 - 2.04123|; |2.53545 - 0.50709|; |1.67127 - 1.11417|; |2.35340 - 0.78448|; |2.78545 - 1.85695|\}}$$

$$D_{21} = \frac{\max\{|-1.22472|\}}{\max\{|-1.22472|; |2.02836|; |0.5571|; |1.56892|; |0.928492|\}}$$

$$D_{21} = \frac{\max\{|-1.22472|\}}{\max\{|2.02836|\}} = 0.604$$

$$D_{23} = \frac{\max\{|V_{2j} - V_{3j}|\}\, j \in D_{kl}}{\max\{|V_{2i} - V_{3i}|\}\forall_i}$$

$$= \frac{\max\{|0.81651 - 2.04123|; |1.67127 - 2.22834|; |2.35340 - 3.13784|; |2.78545 - 3.71390|\}}{\max\{|0.81651 - 2.04123|; |2.53545 - 1.52127|; |1.67127 - 2.22834|; |2.35340 - 3.13784|; |2.78545 - 3.71390|\}}$$

$$D_{23} = \frac{\max\{|-1.22472|; |-0.55707|; |-0.78444|; |-0.92845|\}}{\max\{|-1.22472|; |1.01418|; |-0.55707|; |-0.78444|; |-0.92845|\}}$$

$$D_{23} = \frac{\max\{|-1.22472|\}}{\max\{|-1.22472|\}} = 1$$

$$D_{31} = \frac{\max\{|V_{3j} - V_{1j}|\}\, j \in D_{kl}}{\max\{|V_{3i} - V_{1i}|\}\forall_i}$$

$$= \frac{\max\{0\}}{\max\{|2.04123 - 2.04123|; |1.52127 - 0.50709|; |2.22834 - 1.11417|; |3.13784 - 0.78448|; |3.71390 - 1.85695|\}}$$

$$D_{31} = \frac{\max\{0\}}{\max\{|0|; |1.01418|; |1.11417|; |2.35336|; |1.85695|\}}$$

$$D_{31} = \frac{\max\{|0|\}}{\max\{|2.35336|\}} = 0$$

$$D_{32} = \frac{\max\{|V_{3j} - V_{2j}|\}\, j \in D_{kl}}{\max\{|V_{3i} - V_{2i}|\}\forall_i}$$

$$= \frac{\max\{|1.52127 - 2.53545|\}}{\max\{|2.04123 - 0.81651|; |1.52127 - 2.53545|; |2.22834 - 1.67127|; |3.13784 - 2.35340|; |3.71390 - 2.78545|\}}$$

$$D_{32} = \frac{\max\{-1.01418\}}{\max\{|1.22472|; |-1.01418|; |0.55707|; |0.78444|; |0.92845|\}}$$

$$D_{32} = \frac{\max\{|-1.01418|\}}{\max\{|1.22472|\}} = 0.828$$

The discordance matrix is:

$$\begin{bmatrix} - & 1 & 1 \\ 0.604 & - & 1 \\ 0 & 0.828 & - \end{bmatrix}$$

3. Determine the Dominant Matrix of concordance and discordance

a. Determining the dominant concordance matrix

Threshold value c is:

$$c = \frac{\sum_{k=1}^{m}\sum_{l=1}^{m} c_{kl}}{m(m-1)}$$

$$c = \frac{3+3+15+3+18+15}{3(3-1)}$$

$$c = \frac{57}{6} = 9.5$$

The matrix element f is defined as follows:

$$f_{kl} = \begin{cases} 1, Jika\ c_{kl} \geq c \\ 0, Jika\ c_{kl} < c \end{cases}$$

So the Dominant Concordance Matrix is:

$$f = \begin{bmatrix} - & 0 & 0 \\ 1 & - & 0 \\ 1 & 1 & \end{bmatrix}$$

b. Determining the dominant discordance matrix

The Threshold d value is:

$$d = \frac{\sum_{k=1}^{m} \sum_{l=1}^{m} d_{kl}}{m(m-1)}$$

$$d = \frac{1 + 1 + 0.608 + 1 + 0 + 0.828}{3(3-1)}$$

$$d = \frac{4.436}{6} = 0.74$$

The matrix element f is defined as follows:

$$g_{kl} = \begin{cases} 1, Jika\ d_{kl} \geq c \\ 0, Jika\ d_{kl} < c \end{cases}$$

So the Dominant Concordance Matrix is:

$$g = \begin{bmatrix} - & 1 & 1 \\ 0 & - & 1 \\ 0 & 1 & \end{bmatrix}$$

c. Determining the Aggregate Dominance Matrix

$$e_{kl} = f_{kl} x g_{kl}$$

$$e_{12} = f_{12} x g_{12} = 0x1 = 0$$

$$e_{13} = f_{13} x g_{13} = 0x1 = 0$$

$$e_{21} = f_{21} x g_{21} = 1x0 = 0$$

$$e_{23} = f_{23} x g_{23} = 0x1 = 0$$

$$e_{31} = f_{31} x g_{31} = 1x0 = 0$$

$$e_{32} = f_{32} x g_{32} = 1x1 = 1$$

So the aggregate dominance matrix is:

$$E = \begin{bmatrix} - & 0 & 0 \\ 0 & - & 0 \\ 0 & 1 & \end{bmatrix}$$

d. Elimination of less favourable alternatives

The matrix above is the order of choice of criteria. The matrix row worth 1 becomes the best alternative to other alternatives. Based on the matrix above, the best alternative is **Lightweight Concrete**.

4. Conclusion

From this description, based on the results of the discussion, the researcher can draw several conclusions, among others, as follows:

1. With a decision support system for determining the type of concrete using the electric method, performance can be improved, more efficient, and developed.
2. This electre method is more appropriate for cases with many alternatives, but only a few criteria are involved.
3. This application can assist project owners on what type of concrete to use according to budget and soil structure.
4. The data processing system is faster and more accurate, and the data is organized structurally.
5. Reports are generated from concrete types such as reinforced concrete, precast concrete, and lightweight concrete.

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