SUSTAINABLE SUBCONTRACTOR SELECTION IN IRRIGATION PROJECTS: A WEIGHT PRODUCT MULTI-CRITERIA DECISION ANALYSIS

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ABSTRACT
This research aims to reveal the crucial role of subcontractor selection in irrigation projects, which require water resource management to increase agricultural productivity and ensure adequate water availability. The projects are complex, involving designing efficient water distribution systems, constructing structures such as dams, and tight coordination between various stakeholders. The selection of subcontractors significantly impacts the project’s success, affecting critical aspects such as time, quality, and cost. This research applies the Weight Product method as a multi-criteria decision-making approach to prioritize these aspects. The advantage of this method lies in its ability to handle multi-criteria decisions systematically. By modeling this method, this research aims to improve the effectiveness and efficiency of subcontractor selection in irrigation projects. The results are expected to provide directional guidance for the development of tractor selection applications to improve the quality of project implementation and reduce quality due to associated risks.

Keywords: Irrigation Project, Weight Product, Decision Support System.

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INTRODUCTION

Irrigation projects are water resource management efforts to increase agricultural productivity and ensure sufficient water availability for crops. The complexity of irrigation projects involves the design of efficient water distribution systems, constructing water structures such as dams and canals, and maintaining irrigation networks for optimal functioning. In addition, these projects often involve tight coordination between various stakeholders, including the government, farmers, and contractors. Recent developments in irrigation project management include the integration of risk-based approaches, the selection of more efficient technologies, and the emphasis on environmental sustainability. Hydraulic modeling and computer simulation models have also increased to ensure proper planning and better risk management (Sihombing et al., 2016).

Subcontractor selection has a significant impact on the success of irrigation projects. A competent sub-contractor can positively contribute to critical aspects such as time, quality, and cost. The right choice can improve project execution efficiency and reduce associated risks. The challenge in selecting subcontractors involves evaluating qualifications, experience, and financial capability. In addition, coordination between the main contractor and subcontractors must be well organized to ensure effective involvement in all project stages. Policy changes, regulations, and market fluctuations can also influence the selection of subcontractors (Al-Gahtani & King, 1999; Alzahrani & Emsley, 2013; Awad & Fayek, 2012; Fabbri, 2019; Santos et al., 2023).

The utilization of information technology in construction projects, including subcontractor selection, has proliferated. Cloud-based project management systems, collaborative software, and data analytics platforms help improve transparency, communication, and efficiency. In addition, technologies such as Building Information Modeling (BIM) can support subcontractor selection by providing a clear picture of the design and integration between various project elements (Alzahrani & Emsley, 2013; Hussain & Akbar, 2022; Lai et al., 2016; Trask & Linderoth, 2023). Utilizing online applications and platforms also simplifies the tendering process and evaluation of subcontractor performance.

Decision-making methods are approaches or techniques used to evaluate various options and select the best solution based on specific criteria. The main objective of the method is to ensure that the decision taken is the most rational and in line with the desired objectives. The Weight Product method is one of the multi-criteria decision-making methods used to assess and compare various options by assigning weights to each criterion. In subcontractor selection on irrigation projects, researchers or project managers assign relative importance to aspects such as time, quality, cost, team performance, and environment (Fahmi & Ali, 2022; Goodarzi et al., 2022; Ratnayake et al., 2022; Shojaeimehr & Rahman, 2022; Singh et al., 2022; Wang et al., 2023; Zakeri et al., 2022).

The advantage of the Weight Product method involves its ability to handle multi-criteria decisions systematically (Aulawi et al., 2023; Hamidah et al., 2022; Hidayat et al., 2023). By assigning weights to each criterion, the method helps identify priorities and rank options based on a predetermined level of importance. The clarity and structure of this method make it easily applicable in complex situations such as the selection of subcontractors in irrigation projects.

In selecting subcontractors on irrigation projects, the criteria used include time, which is the ability of the subcontractor to adhere to project deadlines—quality: Quality history of previous work and quality control approach. Cost: Estimated project cost and ability to keep within budget. Team Performance: Coordination and communication skills among team members. Environment: Sustainability policy and the project's impact on the environment.

Improving the Effectiveness and Efficiency of Subcontractor Selection in Irrigation Projects:
Improving the effectiveness and efficiency of subcontractor selection involves using the Weight Product method to optimize decision-making. By considering relevant criteria, this research aims to provide more targeted guidance in selecting subcontractors that best suit the needs of irrigation projects, with the hope of improving overall project outcomes (Fredriksson & Huge-Brodin, 2022; Lai et al., 2016; Marzouk, 2011; Nguyen & Robinson Fayek, 2022; Pan, 2008).

This research aims to determine the weight product method as a Decision-making Tool; the main objective is to establish the Weight Product method as an effective decision-making tool in the context of subcontractor selection on irrigation projects. The research aims to provide a solid basis for a more systematic and targeted decision-making process by identifying and applying this method. Analyzing the Impact of Subcontractor Selection on Time, Quality, Cost, Team Performance, and Environmental Criteria: This objective involves an in-depth analysis of the impact of subcontractor selection on various crucial criteria, including time, quality, cost, team performance, and environment. By understanding these impacts, the research can provide deep insight into how subcontractor selection can affect the overall outcome of an irrigation project.

Improving the Effectiveness and Efficiency of Subcontractor Selection in Irrigation Projects: This research aims to improve the effectiveness and efficiency of selecting subcontractors in irrigation projects. By applying the Weight Product method, this research is expected to provide better guidance, make more informed decisions, and improve overall project outcomes. Modeling Weight Product for Further Application Development on Subcontractor Selection in Construction Companies: This objective focuses on the development aspect of modeling the Weight Product method so that it can be integrated into an application that construction companies can use in the selection of subcontractors. Thus, this research provides theoretical insights and contributes practical contributions by creating a tool that can assist companies in a better decision-making process.

This research will directly contribute to industry practice by providing more targeted guidance in selecting subcontractors for irrigation projects. Better and informed decisions in selecting subcontractors can result in more efficient and successful project execution. One of the main benefits of this research is improving the quality of irrigation project implementation. With the Weight Product method effectively applied, the selection of subcontractors can be guided by crucial criteria, such as time, quality, cost, team performance, and environment. This will help ensure that the selected subcontractors have capabilities matching the project’s needs, leading to higher-quality outcomes. The results of this study will help reduce risks related to subcontractor selection by providing a more substantial basis for the decision-making process. Project risks, such as delays, additional costs, or low quality, can be minimized with a more appropriate selection of subcontractors. This will have a positive impact on the overall success of the project. This research will contribute to knowledge in project management, particularly in the context of subcontractor selection on irrigation projects. By modeling the Weight Product method and analyzing its impact, this research can open the door to a deeper understanding of the critical factors that influence the success of construction projects. The findings can be a foundation for further research and developing innovative project management concepts.

METHOD

This research provides a systematic and structured approach for construction companies to prioritize projects. Using the Weight Product method, this research facilitates informational decision-making and enables companies to optimize their resource allocation per their strategic
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This research has four main stages, as shown in Figure 1: data collection, analysis, modeling, and ranking.

1. Data Collection
   In this stage, Criteria Identification is carried out: Determining relevant criteria for subcontractor selection, such as time, quality, cost, team performance, and environment, and collecting data related to each subcontractor, including performance history, cost estimates, adherence to deadlines, and sustainability practices.

2. Analysis
   This stage normalizes the data to ensure that all criteria are measured uniformly to be compared with objectivity. It then assigns weights to each criterion based on its importance in subcontractor selection. Calculates the result of multiplying the weights by the normalized values for each subcontractor and each criterion. Sums up the multiplication results for each sub-contractor, providing a total score as the basis for ranking.

3. Modelling
   At this stage, the Weight Product method is applied as a multi-criteria decision-making model for selecting sub-contractors in irrigation projects. Furthermore, it adapts the Weight Product model to the specific context and needs of the irrigation project under study.

4. Ranking
   The subcontractors are ranked at this stage based on the total score generated from the Weight Product method. The subcontractor with the highest total score is given a higher rank. Next, evaluate the ranking results to ensure the decisions are consistent with the objectives and criteria set. Interpret the ranking results to support informational and contextualized decision-making.
RESULTS AND DISCUSSION

Data Collection

In the data collection stage, relevant data related to construction projects in one of the construction companies in North Sumatra. The information collected includes aspects of project costs, estimated implementation time, measured construction quality criteria, and risk factors that can affect the course of the project. The data acquisition approach aims to ensure that the dataset used in the analysis reflects the actual conditions in the field. Information on various construction projects was carefully collected in the data collection stage. The data collected includes:
1. Time:
2. Quality:
3. Cost:
4. Team Performance:
5. Environment:

Analysis

Once the data was collected, the construction project analysis was carried out using the Weight Product (WP) method. The following analysis results provide an in-depth insight into the relative contribution of each project to the company's prioritized goals:
1. Criteria Weights: Weights have been successfully assigned to each criterion, such as cost, execution time, construction quality, and risk, according to their importance.
2. Weighted Score: The WP method is applied to each project to calculate a weighted score based on the criteria weights. The weighted score provides each project's relative value, calculating each project's contribution to the predefined criteria.
3. Ranking of projects: The projects are scored based on the weighted scores, and the ranking of the projects is determined. The project with the highest final score gets a higher rank, signifying a higher priority in the company context.
4. Identification of Priority Projects: The analysis results help identify the projects that significantly contribute to the company's priority goals. Projects that rank higher are considered priority projects for greater resource allocation.

Through this analysis stage, the research successfully identified the projects most aligned with the construction company's prioritized goals. These results will be the basis for ranking and determining the next steps in efficient construction project management.

Modeling

Object/Alternative Identification

The results of object identification are shown in Table 1.

Table 1. List of Project Alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcontractor 1</td>
<td>SC1</td>
</tr>
<tr>
<td>Subcontractor 2</td>
<td>SC2</td>
</tr>
<tr>
<td>Subcontractor 3</td>
<td>SC3</td>
</tr>
<tr>
<td>Subcontractor 4</td>
<td>SC4</td>
</tr>
</tbody>
</table>
Criteria Determination
Based on the results of the analysis stage, the criteria used in this research consist of the following:
C1: Time,
C2: Quality,
C3: Cost,
C4: Team Performance, and
C5: Environment

Calculating the Weight Value
The next step is calculating each criterion's initial relative weight value using Equation 1.

\[ W_j = \frac{w_j}{\sum w_j} \]  

...(1)

Total weight value = 21, then obtained
W1 = 5/21 = 0.238
W2 = 3/21 = 0.143
W3 = 4/21 = 0.190
W4 = 4/21 = 0.190
W5 = 5/21 = 0.238

Creating a Comparison Matrix of Alternatives and Criteria
The next stage is to determine the alternative value of each criterion after weighting, then write in the form of a comparison matrix of alternatives and criteria. The values in the matrix are obtained through questionnaires filled out by decision-makers in the company.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>SC2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>SC3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>SC4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>SC5</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>SC6</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
Calculating Alternative Preference Value (S Vector)

The calculation of the S vector value aims to normalize the numbers used. The S vector value is obtained by equation 2.

\[ S_i = \prod_{j=1}^{n} x_{ij}^{w_j} \]  

With \( S_i \) being the alternative preference value analogous to the S vector, \( X_{ij} \) is the alternative value of each criterion, \( W_j \) is the weight value of each criterion, and \( n \) is the number of criteria. Then, the S value for each alternative is obtained, as shown in Table 3.

Table 3. S Vector Value of each alternative

<table>
<thead>
<tr>
<th>Alternative</th>
<th>S Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1</td>
<td>2.95968369</td>
</tr>
<tr>
<td>SC2</td>
<td>3.48791068</td>
</tr>
<tr>
<td>SC3</td>
<td>3.393645137</td>
</tr>
<tr>
<td>SC4</td>
<td>3.383049778</td>
</tr>
<tr>
<td>SC5</td>
<td>3.071721926</td>
</tr>
<tr>
<td>SC6</td>
<td>2.570625849</td>
</tr>
<tr>
<td>SC7</td>
<td>2.806541617</td>
</tr>
<tr>
<td>SC8</td>
<td>2.877349513</td>
</tr>
<tr>
<td>SC9</td>
<td>3.383049778</td>
</tr>
<tr>
<td>SC10</td>
<td>3.903725117</td>
</tr>
</tbody>
</table>

Calculating Relative Preference Value (Vector V)

The last calculation stage is to calculate the relative preference value, also called the V vector, using equation 3; the results of this stage are shown in Table 4.

\[ Vi = \frac{\prod_{j=1}^{n} x_{ij}^{w_j}}{\prod_{j=1}^{n} x_{ij}^{w_j}} \]  

Table 4. Vector V value of each alternative

<table>
<thead>
<tr>
<th>Alternative</th>
<th>S Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1</td>
<td>0.092962764</td>
</tr>
<tr>
<td>SC2</td>
<td>0.109554213</td>
</tr>
<tr>
<td>SC3</td>
<td>0.106593361</td>
</tr>
<tr>
<td>SC4</td>
<td>0.106260564</td>
</tr>
<tr>
<td>SC5</td>
<td>0.096481851</td>
</tr>
<tr>
<td>SC6</td>
<td>0.080742576</td>
</tr>
<tr>
<td>SC7</td>
<td>0.088152618</td>
</tr>
<tr>
<td>SC8</td>
<td>0.090376672</td>
</tr>
</tbody>
</table>
Ranking

The last stage is to sort the rating or ranking based on the value of the V vector result obtained from the previous stage. Ranking results:

<table>
<thead>
<tr>
<th>Alternative</th>
<th>S Value</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC10</td>
<td>0.122614818</td>
<td>1</td>
</tr>
<tr>
<td>SC2</td>
<td>0.109554213</td>
<td>2</td>
</tr>
<tr>
<td>SC3</td>
<td>0.106593361</td>
<td>3</td>
</tr>
<tr>
<td>SC4</td>
<td>0.106260564</td>
<td>4</td>
</tr>
<tr>
<td>SC9</td>
<td>0.106260564</td>
<td>5</td>
</tr>
<tr>
<td>SC5</td>
<td>0.096481851</td>
<td>6</td>
</tr>
<tr>
<td>SC1</td>
<td>0.092962764</td>
<td>7</td>
</tr>
<tr>
<td>SC8</td>
<td>0.090376672</td>
<td>8</td>
</tr>
<tr>
<td>SC7</td>
<td>0.088152618</td>
<td>9</td>
</tr>
<tr>
<td>SC6</td>
<td>0.080742576</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on the results of calculations using the WP method, the selected sub-contractor is SC code 10, with a weight value of 0.123. The results of this calculation become a recommendation for selecting sub-contractors, and this method will used in further application development.

CONCLUSION

This research is for subcontractor selection in the context of irrigation projects. In a complex irrigation project environment, the Weight Product method has been proven effective as a multi-criteria decision-making tool for assessing subcontractors. The research identified that the success of irrigation projects is greatly influenced by the ability of subcontractors to meet crucial criteria such as time, quality, cost, team performance, and environment. Applying the Weight Product method provides a clear and systematic framework, enabling a more informed and targeted selection of subcontractors. By analysing the impact of subcontractor selection on these criteria, this research provides an in-depth insight into how these decisions can affect the overall outcome of an irrigation project. Efforts to improve the effectiveness and efficiency of subcontractor selection through the Weight Product method are expected to provide better guidance, make more informed decisions, and, ultimately, improve the project’s overall outcome. This research also contributes to industry practice by reducing risks related to subcontractor selection, ensuring the project goes according to plan, and resulting in quality project implementation.

REFERENCES


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