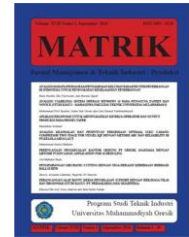




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Implementation of an Integrated BWM-TOPSIS Model for Decision-Making in Cloudy Diesel Prevention

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ABSTRACT

The Refinery Development Master Plan (RDMP) program at PT XYZ increased refinery processing capacity from 125 to 150 MBPSD, but introduced a new quality issue: diesel products with a cloudy appearance deviating from the Clear & Bright specification, reaching 41% during 2023–January 2024. Previous decision-making relied solely on the cost criterion and was considered suboptimal. This study develops an integrated Best-Worst Method (BWM) and TOPSIS model to select the best prevention alternative among four alternatives based on seven criteria. Primary data were collected from five expert respondents through pairwise-comparison (BWM) and alternative-assessment (TOPSIS) questionnaires. The results show that Impact obtained the highest weight (0.2532), followed by Cost (0.2476) and Installation Duration (0.2300). Upgrading the clay treater into a salt dryer was selected as the best alternative with a preference value of 0.7748, and sensitivity analysis across 42 weight-perturbation scenarios confirmed that this recommendation is robust..



1. Introduction

Diesel is a petroleum distillate fuel widely used in the transportation and power generation sectors in Indonesia. National diesel consumption continues to increase along with industrial and transportation growth, requiring oil refineries to expand their production capacity. The Refinery Development Master Plan (RDMP) program at PT XYZ is one manifestation of this effort, which successfully increased the processing capacity from 125 MBPSD to 150 MBPSD.

However, this capacity increase has caused a new problem. The Gasoil (intermediate) product cannot be fully absorbed by the Hydrotreating Unit (HTU) for purification from contaminants, so part of the off-spec Gasoil flows directly into the diesel product tank. As a result, the visual appearance of the diesel product becomes cloudy, deviating from the Clear & Bright specification established by the Directorate General of Oil and Gas. Laboratory data show that the percentage of slightly cloudy and cloudy diesel reached 41% during the period from 2023 to January 2024.

So far, decision-making to address this problem has been based on only one dominant criterion, namely cost, through a Focus Group Discussion (FGD) mechanism. This approach is considered suboptimal because it overlooks other important criteria such as effectiveness, ease of operation, operational risk, and impact on the production process. Therefore, a systematic multi-criteria approach is needed to produce more comprehensive decisions.

The Best-Worst Method (BWM) introduced by Rezaei [1] is a criteria weighting method with the advantages of a higher level of consistency and fewer pairwise comparisons compared with the Analytic Hierarchy Process (AHP). Meanwhile, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is an alternative ranking method based on the distance to positive and negative ideal solutions [2]. The integration of BWM and TOPSIS has been widely applied in various fields such as tour guide selection [3], energy

storage technology selection [4], and supplier selection [5], and has proven to provide reliable results.

This study aims to: (1) identify the decision-making criteria for cloudy diesel prevention; (2) develop an integrated BWM and TOPSIS model for decision-making; and (3) produce recommendations for the best alternative based on multi-criteria considerations. The contribution of this study consists of a practical contribution in the form of a concrete solution to the cloudy diesel problem at the PT XYZ refinery, and a theoretical contribution in the form of developing an integrated BWM-TOPSIS model for the oil and gas processing industry.

2. Research Methods

This study uses a quantitative approach with the integration of the BWM method for criteria weighting and TOPSIS for ranking alternatives. The research object is the cloudy diesel problem at PT XYZ following the implementation of the RDMP program. Primary data were obtained through Focus Group Discussions (FGD) and questionnaires involving five expert respondents selected through purposive sampling from the Process Engineering, Refinery Business Optimization (RBO), and Production functions. Secondary data include Piping and Instrumentation Diagrams (P&ID), equipment data sheets, unit reports, and chemical dehazer laboratory test results.

Expert respondents were used because BWM is designed as an expert-judgment elicitation method rather than a population survey, so the validity of its results is determined by the competence and consistency of the experts rather than by sample size [1]. This practice is consistent with previous BWM-TOPSIS studies, which generally employ small expert panels of three to ten experts [3], [5]. Moreover, the cloudy diesel problem is highly technical and specific to the configuration of the PT XYZ refinery, so valid judgments can only be provided by personnel with direct operational knowledge of the affected units. Data collection was carried out in five stages: (1) an initial briefing to align the respondents' understanding of the operational definitions of the seven criteria and four alternatives; (2)

completion of the BWM questionnaire in the form of Best-to-Others and Others-to-Worst pairwise comparisons on a 1–9 scale; (3) verification of response consistency through the Consistency Ratio (CR), with reconfirmation requested from respondents whenever the threshold was exceeded; (4) completion of the TOPSIS questionnaire assessing the performance of each alternative with respect to each criterion; and (5) aggregation of the individual judgments to construct the criteria weights and the decision matrix.

2.1 Criteria Identification

The decision-making criteria were obtained through a literature review and confirmed via FGD. The seven criteria used are presented in Table 1.

Table 1. Decision-Making Criteria

No	Criterion	Description	Source
1	Installation Duration	The length of time required for the alternative to be ready for full operation, covering procurement, installation/construction, and commissioning	Görçün & Doğan [6]
2	Cost	The total cost required to implement the alternative, covering investment and/or operating costs over the evaluation period	Otay et al. [7]
3	Operation	The ease of operating the alternative in the refinery's daily operating routine once installed	Görçün & Doğan [6]
4	Handling	The ease of handling the materials or equipment involved in implementing the alternative (e.g., chemicals, materials, or equipment)	Temiz & Calis [8]
5	Impact	The effectiveness of the alternative in overcoming cloudy diesel, i.e., the extent to which the diesel product returns to or remains within the Clear & Bright clarity specification	Tavana et al. [9]
6	Maintenance	The ease of maintaining the alternative	Tuzkaya et al. [10]

No	Criterion	Description	Source
		throughout its operating period	
7	Operational Risk	The level of risk or exposure arising from the operation of the alternative	Rahim et al. [19]

2.2 Alternative Identification

Four technical alternatives were evaluated based on field conditions and implementation feasibility: (A1) Installation of water removal equipment on the straight run CGO ex CDU stream; (A2) Injection of chemical dehazer into the diesel product stream toward 42-T-203A; (A3) Upgrading and repurposing of the ex clay treater into a salt dryer; and (A4) Revamping of salt dryer 14-V-108.

2.3 Best-Worst Method (BWM) Stages

Following Rezaei [1], the BWM is conducted in five steps: (1) determining the set of criteria; (2) identifying the best (Best) and worst (Worst) criteria; (3) determining the preference of the Best criterion over the other criteria (Best-to-Others vector); (4) determining the preferences of all criteria with respect to the Worst criterion (Others-to-Worst vector); and (5) calculating the optimal weights through the following formulation:

$$\min \max \{ |w_B/w_j - p_{Bj}|, |w_j/w_W - p_{jW}| \} \quad \text{s.t.} \\ \sum w_j = 1, w_j \geq 0$$

2.4 TOPSIS Stages

TOPSIS [2] is performed in six steps: (1) constructing the decision matrix; (2) normalizing the matrix; (3) weighting the normalized matrix using the BWM-derived weights; (4) determining the positive ideal solution (A+) and negative ideal solution (A-); (5) computing the Euclidean distance of each alternative to A+ and A-; and (6) calculating the preference value (Ci+) and ranking the alternatives. The highest preference value indicates the best alternative.

2.5 Sensitivity Analysis

Sensitivity analysis was conducted by varying the weight of each criterion by $\pm 10\%$, $\pm 20\%$, and $\pm 25\%$ alternately, resulting in 42 perturbation scenarios (six scenarios for each of

the seven criteria), then recalculating the TOPSIS scores to test the stability of the alternative rankings against weight changes.

3. Results and Discussions

3.1 Criteria Weights from BWM

The aggregation of BWM questionnaire responses from five expert respondents produced the criteria weights shown in Table 2. The Impact criterion obtained the highest weight (0.2532), followed by Cost (0.2476) and Installation (0.2300). These three top criteria together account for more than 73% of the overall weight, indicating that the main considerations in selecting a cloudy diesel prevention strategy are the resulting impact, the cost incurred, and the installation time.

Table 2. Criteria Weights and Rankings from BWM

No	Criterion	Weight	Ranking
1	Installation Duration	0.2300	3
2	Cost	0.2476	2
3	Operation	0.0893	4
4	Handling	0.0455	7
5	Impact	0.2532	1
6	Maintenance	0.0727	5
7	Operational Risk	0.0617	6

Conversely, the Handling criterion obtained the lowest weight (0.0455), because across the four alternatives evaluated, the operational handling is relatively unproblematic. The Consistency Ratio (CR) values of all respondents were below the threshold of 0.25 set by Rezaei [1], so the weighting results can be declared consistent.

3.2 TOPSIS Calculation

After obtaining the criteria weights, the next step is to evaluate the alternatives using TOPSIS. The decision matrix was constructed based on the techno-economic data of the alternatives (estimated installation time, investment cost calculated using Aspen HYSYS

V15, and laboratory test results) and expert perceptions of qualitative attributes. The scores were converted to a 1–9 scale, with 9 representing the most favorable condition. The decision matrix is presented in Table 3.

Table 3. Alternatives Decision Matrix

Alt.	Install.	Cost	Oper.	Handl.	Impact	Maint.	Risk
A1	5	26	5	5	5	5	3
A2	3	4.7	5	5	5	5	5
A3	1	4.3	1	1	4	3	1
A4	5	40	1	1	3	3	1
Type	Cost	Cost	Benefit	Benefit	Benefit	Benefit	Cost

After vector normalization and weighting using the BWM weights, the positive ideal solution (A+) and negative ideal solution (A−) were determined. Then the Euclidean distance of each alternative to A+ and A− was calculated, and the preference value (Ci+) was obtained as shown in Table 4.

Table 4. Preference Values and Alternative Rankings

Code	Alternative	Ci+	Rank
A1	Installation of water removal equipment	0.4042	3
A2	Chemical dehaizer injection	0.7422	2
A3	Upgrading clay treater into a salt dryer	0.7748	1
A4	Revamp of salt dryer 14-V-108	0.1497	4

Based on Table 4, alternative A3 (Upgrading clay treater into a salt dryer) was selected as the best alternative with a preference value of 0.7748. Alternative A2 (Chemical dehaizer injection) is ranked second with a relatively small margin (0.7422). Meanwhile, A1 and A4 are ranked third and fourth, respectively.

3.3 Discussion

The selection of alternative A3 as the best solution can be explained from several

perspectives. First, from a cost perspective, A3 has the lowest total cost (IDR 4.29 billion) because it utilizes an existing asset (ex clay treater), so the modification investment is not too large. Second, from an impact perspective, A3 is able to purify diesel directly inside the purification unit, making it more effective in maintaining product quality compared with A2, which relies on a chemical additive, and A4, which only enlarges the capacity of existing equipment without changing the process scheme.

Although A2 (chemical dehazer) has the shortest implementation time (1 month), its long-term operating cost is relatively high (IDR 4.74 billion/year due to continuous chemical consumption) and it increases operational dependence on chemicals. Meanwhile, A4 ranks last because it requires the largest investment (IDR 39.5 billion) without a commensurate increase in impact.

These results are consistent with the findings of Putra et al. [3] and Ma et al. [4], which show that BWM-TOPSIS integration is effective in determining the best alternative for multi-criteria problems, especially when the decision dimensions cover technical, economic, and operational aspects simultaneously.

3.4 Sensitivity Analysis

Sensitivity analysis was carried out by varying the weight of each criterion by $\pm 10\%$, $\pm 20\%$, and $\pm 25\%$ alternately, producing 42 scenarios in total. The results, summarized in Table 5, show that the alternative rankings are relatively stable: A3 remains ranked first in 40 of the 42 scenarios, and A4 consistently ranks last. Ranking changes occur only when the weight of the Installation Duration criterion is reduced by 20% and 25%, in which case A2 rises to the first rank and A3 drops to the second rank.

Table 5. Ranking of Alternative A3 under 42 Weight-Perturbation Scenarios

Criterion Varied	-25%	-20%	-10%	+10%	+20%	+25%
Installation Duration	2	2	1	1	1	1
Cost	1	1	1	1	1	1
Operation	1	1	1	1	1	1
Handling	1	1	1	1	1	1
Impact	1	1	1	1	1	1

Criterion Varied	-25%	-20%	-10%	+10%	+20%	+25%
Maintenance	1	1	1	1	1	1
Operational Risk	1	1	1	1	1	1

Table 5 shows the rank obtained by A3 when the weight of each criterion is varied while the remaining weights are normalized proportionally.

The limited rank reversal observed in this study is consistent with Alinezhad and Amini [18], who demonstrated analytically that changing the weight of a single criterion in TOPSIS can alter the final ranking of alternatives; the reversal between A3 and A2 reflects their narrow preference gap (0.7748 versus 0.7422) and occurs only under substantial reductions of the Installation weight. Comparable robustness checks are also reported in previous BWM-TOPSIS applications [3], [4], in which the top-ranked alternative remained stable under moderate weight variations. Accordingly, the recommendation of A3 can be considered robust, while decision-makers should re-examine the ranking if the installation-time consideration becomes substantially less important.

3.5 Managerial Implications for PT XYZ

For PT XYZ, this study has two main impacts. Operationally, the recommendation to upgrade the ex clay treater into a salt dryer (A3) provides a concrete basis for investment decisions that can reduce the frequency of Clear & Bright specification deviations, minimize the need for reprocessing off-spec diesel, and maintain the reliability of diesel supply in accordance with the specification of the Directorate General of Oil and Gas. Managerially, the BWM-TOPSIS model offers a structured, transparent, and auditable multi-criteria decision-making framework that replaces the previous practice of relying solely on the cost criterion in FGD forums.

Based on these results, three strategies are recommended for the company as consideration material for making the best decisions: (1) prioritizing alternative A3 in the short-term investment program, with chemical dehazer injection (A2) as a transitional measure during the modification period; (2) adopting the BWM-derived criteria weights as a standard

reference for evaluating future product-quality improvement projects, so that impact, cost, and installation time are considered proportionally alongside other criteria; and (3) institutionalizing sensitivity analysis as a feasibility test prior to investment execution, so that decisions remain accountable even when corporate priorities change.

4. Conclusion and Suggestions

Based on the research results, it can be concluded that there are seven criteria relevant to decision-making for cloudy diesel prevention, namely Installation Duration, Cost, Operation, Handling, Impact, Maintenance, and Operational Risk. The integrated BWM-TOPSIS model was successfully developed and produced consistent criteria weights, with Impact (0.2532) as the most important criterion, followed by Cost (0.2476) and Installation (0.2300). Based on the TOPSIS calculation, the alternative of upgrading the clay treater into a salt dryer (A3) was selected as the best solution with a preference value of 0.7748, followed by chemical dehazer injection (A2) at 0.7422, installation of water removal equipment (A1) at 0.4042, and revamping of the salt dryer (A4) at 0.1497. The sensitivity analysis shows that the model is robust against changes in the criteria weights.

For the company, the results of this study are recommended as the basis for implementing a cloudy diesel prevention solution, with priority placed on modifying the clay treater. Chemical dehazer injection may serve as a transitional solution during the modification period. For future researchers, the BWM-TOPSIS model developed here can be extended by integrating it with other methods such as BWM-VIKOR, or by adding a sustainability dimension for broader applications in the oil and gas processing industry.

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