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Development of Vendor Performance Evaluation and Strategies Design Systems Using Fuzzy Best Worst Method (FBWM) and TODIM in PT PLN (Persero)

Dania Sita Ardhiana Reswari[1,2] & Yosi Agustina Hidayat[1]

[1]Logistics Master Program, Faculty of Industrial Technology
Institut Teknologi Bandung, Bandung, Indonesia
[2]Supply Chain Management Division,
PT PLN (Persero) Kantor Pusat, Jakarta, Indonesia
*Email: 29423013@mahasiswa.itb.ac.id & dania.sita@pln.co.id, yosi@itb.ac.id

Abstract. In realizing its vision and mission, as well as in supporting electricity national fulfillment, PT PLN (Persero) is necessary to be supported by supply chain management, ranging from procurement to delivery activities. In the procurement process, one of the important aspects is the management of vendors, including the evaluation of their performance, to enable PT PLN (Persero) in selecting good performance vendors and determining appropriate development strategies for its vendor improvement. This paper discusses the development of vendor performance evaluation system by setting the criteria, sub criteria, and by a fuzzy multi-criteria decision making (MCDM). In the other hand, fuzzy best-worst method (BWM) is to determine importance weights of the evaluation criteria, while TODIM to asses vendor performance and subsequently to determine vendor development strategies based on its performance. Finally, this study is to develop framework in vendor performance evaluation system and strategies design.

Keywords: *Vendor Performance, Vendor Development, Strategies Design, Fuzzy, BWM, TODIM*

1 Introduction

PT PLN (Persero) engaged in the electricity supply business. According to the Company Profile published on the website pln.co.id, PT PLN (Persero)'s vision is to become the leading electricity company in Southeast Asia and the customers' number one choice for energy solutions. In realizing its vision and mission, as well as in supporting electricity provision, PT PLN (Persero) is supported, among other things, by supply chain management, ranging from procurement to logistics management. In the procurement process, one important aspect is the management of vendors, including the evaluation of their performance, to enable PT PLN (Persero) to select good performance vendors. In addition, the results of the vendor performance evaluation is then used as the basis for vendor development strategies to ensure that future procurement processes are carried out more effectively and efficiently.

In the management of vendors, the performance evaluation of vendors at PT PLN (Persero) has not yet been carried out optimally, as reflected in the very low percentage of vendor performance evaluations conducted. Based on historical data from 2023–2024 sourced from PLN's e-Procurement system, Vendor Performance Evaluation Reports, and interviews with the Vendor Management Department of the Supply Chain Management Division at PT PLN (Persero), the percentage of vendor performance evaluations remains very low compared to the total number of vendors. PT PLN (Persero) has 12.383 vendors. However, performance evaluations have only been conducted for 2,15% from all total vendors. Furthermore, based on these performance evaluations, vendor development strategies have not yet been formulated. This condition is illustrated in Figure 1.

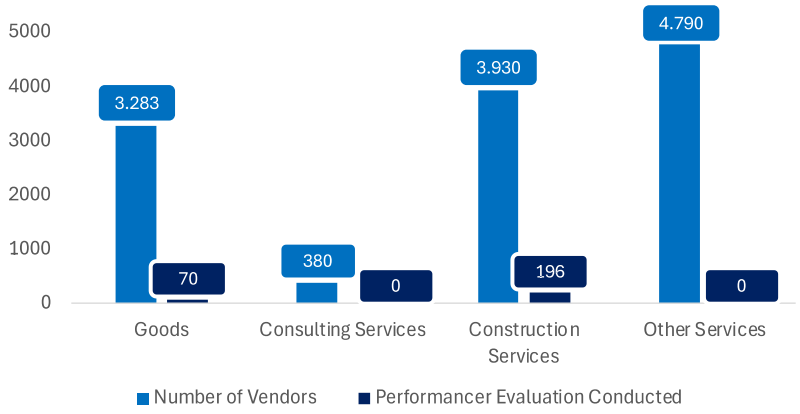

Figure 1 Implementation of Vendor Performance Evaluation by Procurement Type at PT PLN (Persero)

The cause of the suboptimal implementation of vendor performance evaluation is that, under the current conditions, the vendor performance evaluation system remains decentralized, with performance evaluation criteria and indicators not yet standardized across different types of work. Based on interviews with the Vendor Management Department of the Supply Chain Management Division at PT PLN (Persero), the determination of these criteria has so far been based on subjective judgment and has not yet been established through mathematical calculations.

The suboptimal vendor performance evaluation process also impacts the development strategies for vendors. In fact, vendor development is essential for establishing procurement strategies that are more effective and efficient in the future.

According to Bahagia in [1], the procurement process generally consists of four stages: planning, execution, receipt and utilization of goods, and vendor

performance evaluation. Evaluating vendor performance is essential to assess their capabilities and potential, which informs their classification as strategic, preferred, or transactional vendors. This requires an effective vendor management system.

Vendor performance evaluation is not only for vendor selection but also as a basis for vendor development decisions. Vendor development is defined as any effort by the buying firm to enhance vendor performance and capabilities to meet its short- and long-term supply needs. It contributes to improved vendor satisfaction and overall supply chain performance. Buyers (procurement parties) can develop vendors through strategies derived from ongoing performance evaluations, including direct approaches such as education, training, investment, vendor monitoring, and knowledge transfer, as well as indirect approaches such as incentives, vendor visits, certification, and audits Coşkun, *et.al* in [2].

2 Literature Review

2.1 Vendor Performance Evaluation

Bahagia in [1] stated that vendor evaluation is conducted to assess vendor performance as a basis for either vendor development or replacement with new vendors. This process results in a performance rating or ranking of vendors. The evaluation begins with identifying assessment criteria, followed by performance evaluation, vendor ranking, and finally, using the results for vendor development or sourcing alternatives.

Many literatures that discuss about vendor performance evaluation. Pratiwi in [3] develop and establish evaluation indicators and corresponding weights to be used in assessing vendor performance where the assessment instrument covers delivery, quality, service, administration, security, occupational health and safety, environmental compliance, and financial performance. Niko in [4] also discus about vendor performance indicators using a benchmarking approach. Coşkun, *et.al* in [2], Govindan, *et.al* in [5], Afrasiabi, *et.al* in [6] conducting a study on vendor performance evaluation by determining criteria and sub-criteria, followed by calculating the evaluation weights using a mathematical method. Zhang, *et.al* in [7] conducting an in-depth literature review to provide a comprehensive overview that supports the company in evaluating vendor performance.

2.2 Vendor Development

Although numerous studies have discussed vendor performance evaluation, few have explored the implications of performance evaluation results on vendor development. The following are several references that address vendor development.

Coşkun, *et.al* in [2] stated that vendor performance evaluation is not only for vendor selection but also for making decisions regarding vendor development. Vendor development is defined as any effort by the buying firm to enhance the performance and capabilities of its vendors to meet both short-term and long-term supply needs. It contributes to increased vendor satisfaction and overall supply chain performance. Buyers can develop their vendors using strategies derived from ongoing performance evaluations. These strategies include direct approaches such as education, training, investment, vendor monitoring, and knowledge transfer, as well as indirect approaches such as incentives, vendor visits, vendor certification, and audits.

Govindan, *et.al* in [5] stated that vendor performance measurement is a fundamental method for aligning partnerships with the operational, strategic, and sustainability objectives of the buying firm. However, a key challenge for manufacturers lies in periodically monitoring the ongoing performance of existing vendors. In addition to assessing vendor capabilities, their willingness to engage in long-term collaboration must also be taken into account.

2.3 Multi Criteria Decision Making (MCDM)

Decision-making in any organization is a critical and essential process. It can be influenced by various factors, affecting both the speed and accuracy of decisions—particularly when addressing complex, dynamic, and poorly structured problems. Therefore, the integration of Multi-Criteria Decision Making (MCDM) methods with decision support systems offers an effective approach for generating alternative solutions. Based on the literature review, numerous studies have employed MCDM techniques such as the Analytical Hierarchy Process (AHP), Analytic Network Process (ANP), Best–Worst Method (BWM), and Techniques for Order Preference by Similarity to Ideal Solution (TOPSIS) used to address system development problems involving criteria and sub-criteria.

Deretarla, *et.al* in [8] studied the Multi-Criteria Decision Making Problem of selecting the most suitable vendor. AHP and COPRAS methods allow the evaluation of many criteria. In addition, these methods were found suitable for use in the study due to their effective, easy-to-understand, and flexible structure that can be easily adapted to changes. Wang, *et.al* in [9] stated AHP is often preferred over other decision-making methods due to its hierarchical structure, consideration of consistency within acceptable limits, and the ability to assess the robustness of decision outcomes through sensitivity analysis.

Govindaraju, *et.al* in [10] and [11] stated Analytic Network Process (ANP) was developed to address a key limitation of AHP—namely, the assumption of independence among criteria. While AHP treats all criteria as independent, in

reality, interdependencies often exist. ANP accounts for these dependencies, making it more suitable for complex decision-making environments.

Khazaei, *et.al* in [12], Liou, *et.al* in [13], Govindan, *et.al* in [5], Afrasiabi, *et.al* in [6] used Best-Worst Method (BWM) in the study. Goodarzi, *et.al* in [14] stated that this method addresses the limitations of pairwise comparison-based approaches (such as AHP and ANP), including the issue of inconsistency. It significantly reduces the number of pairwise comparisons by requiring only reference comparisons, where experts are asked to determine the priority of the best criterion over others and the priority of all criteria over the worst one. Overall, this method is more efficient and faster than existing techniques for determining weights in multi-criteria decision-making problems, as it eliminates the need for secondary comparisons.

Govindan, *et.al* in [5] stated that TODIM is a discrete multi-criteria decision-making method that incorporates the psychological behavior of decision-makers. Based on Prospect Theory, this method calculates the dominance of each alternative over others to determine the final ranking of alternatives.
Other methods used for alternative selection include the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Coşkun, *et.al* in [2] used PROMETHEE to calculating vendor's performance while Liou, *et.al* in [13] and Afrasiabi, *et.al* in [6] used TOPSIS. Afterall, based on literature review, Table 1 and 2 represent comparison among all the methods.

Table 1 BWM, AHP, and ANP Comparison

Weighting criteria methods			
Comparison Aspect	BWM	AHP	ANP
Number of Comparisons	⊕Fewer (2n − 3 comparisons)	⊖More (n(n − 1)/2 comparisons)	⊖Many, depending on the interdependencies
Consistency of Judgments	⊕Higher consistency, minimizes deviation	⊖Prone to inconsistency, measured by Consistency Ratio (CR)	⊖More difficult to ensure consistency
Time and Cognitive Efficiency	⊕High – faster and less demanding for decision-makers	Moderate – requires more time and effort	⊖Low – highly complex and time-consuming
Stability of Results	⊕More stable to changes in input values	⊖Results are sensitive to input changes	⊖Results may be influenced by network feedback

Table 2 TODIM, PROMETHEE, and TOPSIS Comparison

Generate Alternatives			
Comparison Aspect	TODIM	PROMETHEE	TOPSIS
Behavioral Consideration	⊕Accounts for decision-maker psychology via Prospect Theory	⊖Does not consider psychological factors	⊖Does not consider psychological factors
Risk Attitude Modeling	⊕Captures risk-averse and risk-seeking behavior	⊖Assumes rational, linear preferences	⊖Assumes rational, linear preferences
Dominance Concept	⊕Uses dominance degree among alternatives	⊕Uses preference flows, but not based on loss/gain perception	⊖Relies on geometric distance, lacks behavioral nuance
Sensitivity to Gains/Losses	⊕Differentiates between gains and losses in value function	⊖Does not distinguish gains/losses explicitly	⊖Considers only closeness to ideal/anti-ideal solutions
Flexibility for Subjectivity	⊕Flexible in modeling subjective preferences	Moderate – through preference functions	⊖Limited – relies on normalized distances

Based on the literature review, the research conducted by Pratiwi in [3] focuses solely on determining the weights of criteria, sub-criteria, and indicators in supplier performance evaluation, without including a sensitivity analysis of the supplier performance results. The study by Niko, A in [4] related to the performance evaluation of goods/services providers only goes as far as determining the criteria and weights, without any mathematical calculations. In the studies by Coşkun, *et.al* in [2] and Govindan, K, *et.al* in [5] have already addressed vendor development, but objects are limited to criteria, without sub-criteria, which may lead to less precise results.

The study by Afrasiabi, A, *et.al* in [6] is considered sufficiently sharp in terms of its objects and methods, but its scope does not extend to categorizing provider assessments and determining development strategies. The research by Zhang, L.J., , *et.al* in [7] provides comprehensive information on criteria, sub-criteria, and indicators for green supplier performance evaluation, but it is limited to a literature review.

3 Methodology and Proposed Framework

This research begins with empirical study and literature review in preliminary study. After the literature review is conducted, the next step in the research refers to what has been designed in the research methodology. After the research results are obtained, analysis and managerial implications are carried out. The overall flowchart of this study become proposed framework is presented in Figure 2.

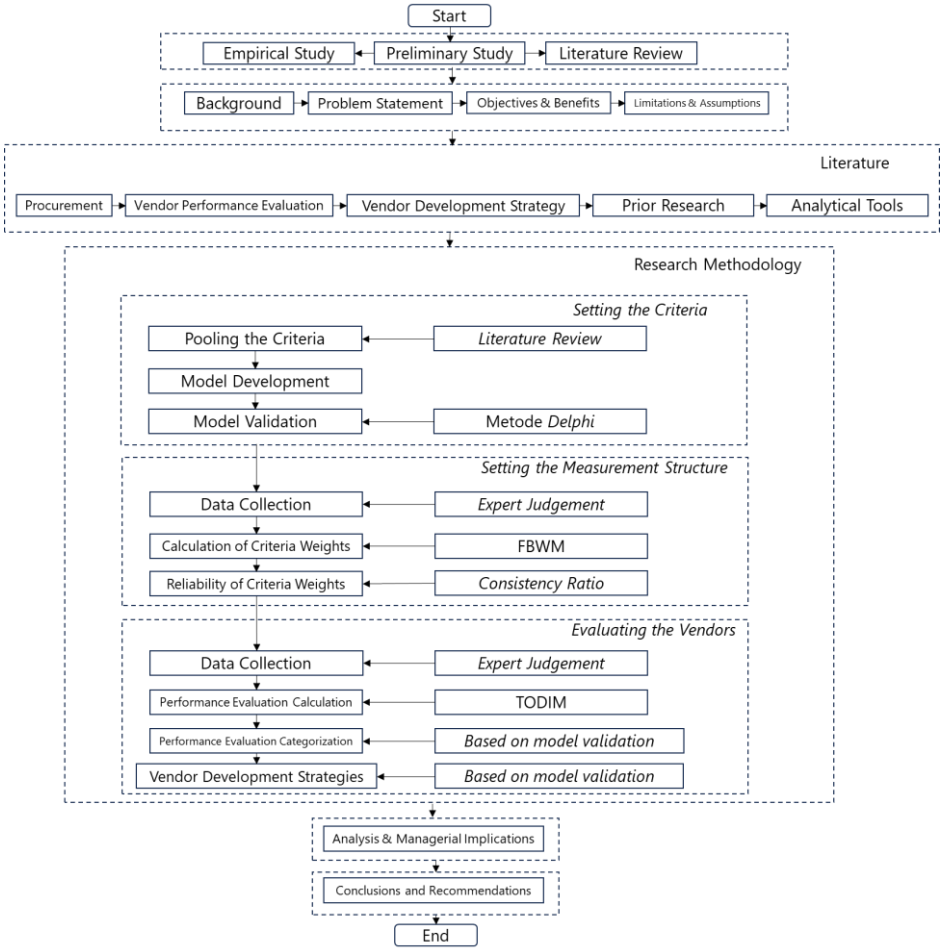

Figure 2 Research Flowchart

Here is a detailed explanation of the research methodology.

3.1 Setting the Criteria

In this study, the first step was the collection of criteria data for both the vendor performance evaluation system and the vendor development strategy through a literature review. Based on the conducted literature review, a model was developed and proposed for this study. The developed model is presented in Figure 3.

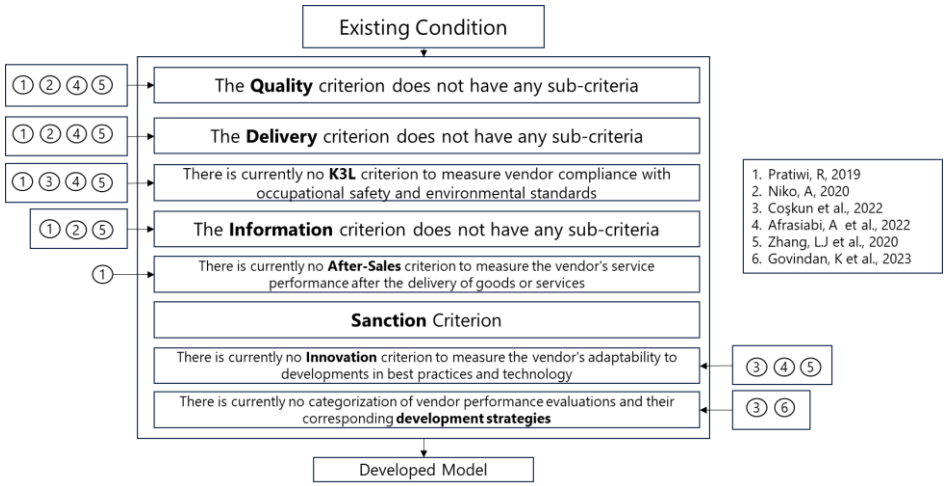

Figure 3 Criteria Model

After the model to be developed was established, model validation was conducted. The validation was carried out using the Delphi method through questionnaires distributed to experts. The questionnaires were divided into two parts: validation of the vendor performance evaluation system model and validation of the vendor development strategy model.

3.2 Setting the Measurement Structure

At this stage, the data is sourced from expert judgment collected through questionnaires. The scale used in the assessment instrument is a Linguistic Scale, which is then converted into a Numerical Scale in a Triangular Fuzzy Number (TFN). The scale used is presented in Table 3.

Table 3 Linguistic Terms and CI for Evaluating Criteria

Linguistic Terms	Equally important (EI)	Weakly important (WI)	Fairly important (FI)	Very important (VI)	Absolutely important (AI)
TFNs	(1,1,1)	(2/3,1,3/2)	(3/2,2,5/2)	(5/2,3,7/2)	(7/2,4,9/2)
CI	3	3,80	5,29	6,69	8,04

Rezaei in [15] initially introduced a mathematical model for the Best Worst Method (BWM) that could yield multiple optimal solutions. Later, Rezaei in [16] proposed a linear formulation that ensures a unique set of weights. In this study, the linear model is adopted to determine the unique optimal weights u1, u2, ..., uH of criteria by minimizing the maximum absolute deviation.

$$\min max_h \{\left|\frac{u_B}{u_h} - a_{Bh}\right|, \left|\frac{u_h}{u_W} - a_{hW}\right|\} \tag{1}$$

In order to reach optimized weight of criteria, the most absolute difference must be minimized for every h.

Subject to

$$\sum_h u_h = 1 \tag{2}$$

The constraint in Eq. (2) means requirement that the sum of the criteria weights must be 1.

$$u_h \geq 0, \forall_h \in \{1,2,\dots,H\} \tag{3}$$

This model is transformed into the following linear programming problem Rezaei in [16]:

$$\min \mathcal{E} \tag{4}$$

Subject to

$$\{|u_B - a_{BhUh}|\} \leq \mathcal{E}, , \forall_h \in \{1,2,\dots,H\} \tag{5}$$

The constraint in Eq. (5) means requirement that the absolute difference not more than $\mathcal{E}$. It also means to Eq. (6).

$$\{|u_h - a_{hwUw}|\} \leq \mathcal{E}, , \forall_h \in \{1,2,\dots,H\} \tag{6}$$

$$\sum_h u_h = 1 \tag{7}$$

The constraint in Eq. (7) means requirement that the sum of the criteria weights must be 1.

$$u_h \geq 0, \forall_h \in \{1,2,\ldots,H\} \tag{8}$$

Moreover, the requirement in Eq. (8) means that the criteria weights must be greater than or equal to zero because negative values are not permitted.

3.3 Evaluating the Vendors

This stage involves measuring the performance of vendors and clustering them based on their performance levels using TODIM. At this stage, the data is sourced from experts collected through questionnaires. The scale used in the assessment instrument is a Linguistic Scale, which is then converted into a Numerical Scale. The scale used is presented in Table 4.

Table 4 Linguistic Terms for Evaluating Vendors Performance

Very Good (VG)	4
Good (G)	3
Medium (M)	2
Poor (P)	1
Very Poor (P)	0

Govindan, *et.al* in [5] stated TODIM is an acronym derived from Portuguese words meaning interactive and multicriteria decision making. The TODIM method is a discrete multicriteria decision-making approach that incorporates the psychological behaviour of decision makers. Based on prospect theory, this method computes the dominance of each alternative over others to determine the ranking of alternatives.

TODIM is applied to evaluate the set of G vendors $S = \{S_g : g = 1,2,\ldots G\}$ based on the set of H criteria (C_s), $C = \{C_h : h = 1,2,\ldots H\}$. In this method, the decision makers need to indicate the reference criteria for calculation of relative weights of criteria. Usually, reference criteria is the criteria with the highest weight according to its importance. In this case, the reference criteria is taken from results of FBWM. Let the criteria with the highest weight be denoted by C_r. Next, the value of evaluation of the vendors in relation to the criteria is required to be numerical and normalized. As a result, the qualitative criteria are evaluated in a verbal scale and converted into a cardinal scale. The evaluation of vendors in relation to all the criteria produce the performance matrix, where all the values are numerical. The evaluation weights of vendors are obtained using the following steps:

Step a Calculate the relative weight of each criteria with respect to reference C_r using the following expression:

$$u_h^r = \frac{u_h}{u_r} \; \forall h \in \{1,2,..H\} \tag{9}$$

And the weight of reference criteria, $u_r = \max \{u_h | h \in \{1,2,..H\}\}$

Step b Obtain the performance matrix

$$X = [X_{gh}]_{GXH} \tag{10}$$

Step c Obtain the normalized performance matrix

$$Y = [Y_{gh}]_{GXH} \; where \; Y_{gh} = \frac{X_{gh}}{\sum_{g=1}^{G} X_{gh}} \tag{11}$$

Step d For each criteria, calculate the pairwise dominance degree of each vendor over other vendors using the following expression:

$$\phi_h(S_f, S_g) = \begin{cases} \sqrt{\frac{u_h^r}{\sum_{h=1}^{H} u_h^r} (Y_{fh-} Y_{gh})} \; if \; (Y_{fh-} Y_{gh}) \geq 0 \\ -\frac{1}{\theta} \sqrt{\frac{\sum_{j=1}^{p} u_h^r}{u_h^r} (Y_{gh-} Y_{fh})} \; if \; (Y_{fh-} Y_{gh}) < 0 \end{cases} \quad \forall f, g \in \{1,2,..G\} \tag{12}$$

Where θ is the attenuation factor of the losses. If θ>1, then the losses are reduced while if θ<1, the losses are intensified. In this case, θ = 1is considered.

For h^{th} criteria, the term $y_{fh} - y_{gh} \geq 0$ indicates the gain of vendor S_f over vendor S_g and the term $y_{fh} - y_{gh} < 0$ shows the loss of vendor S_f over vendor S_g.

Step e Calculate the pairwise overall dominance degree of vendors using the following expression:

$$\delta(S_f, S_g) = \sum_{h=1}^{H} \phi_h(S_f, S_g) \;\; \forall f, g \in \{1,2,..G\} \tag{13}$$

Step f Obtain the global value of each vendor using the following expression:

$$v_g = \frac{\sum_{g=1}^{G} \delta(S_f, S_g) - \min_g \sum_{g=1}^{G} \delta(S_f, S_g)}{\max_g \sum_{g=1}^{G} \delta(S_f, S_g) - \min_g \sum_{g=1}^{G} \delta(S_f, S_g)} \quad g \in 1,2,..,G \tag{14}$$

Finally in Eq. (14), the vendors are ranked according to their global values. The vendor having the minimum global value has the worst performance evaluation and the vendor having the maximum global value becomes the best.

3.4 Vendor Categorization and Development Strategies

The categorization of evaluation results is conducted based on research findings related to the weighting of criteria and sub-criteria. The development of the evaluation categorization is based on a review of previous literature. The categorization refers to the model proposed by Govindan, *et.al* in [5], in which categorization is performed using a matrix divided into four quadrants. In this study, the categorization is further developed into a three-dimensional graph with eight octants, where the x-axis represents the vendor's spend value, the y-axis represents vendor performance, and the z-axis represents financial rating. The development of the evaluation categorization is illustrated in Figure 4.

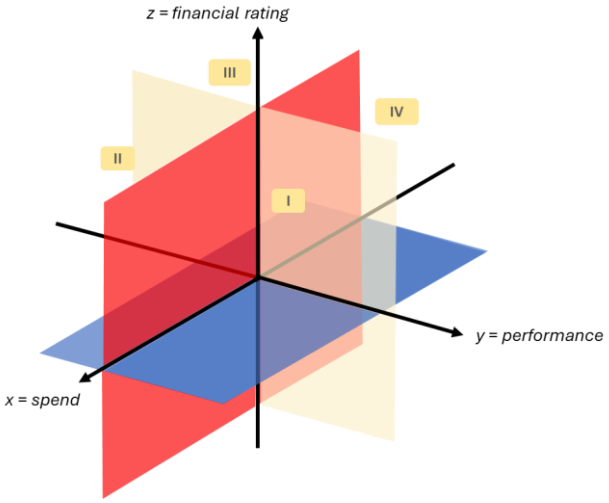

Figure 4 Development of Evaluation Categorization

The contract value (as x=spend) plays a significant role in determining the strategy for vendor development, serving as a consideration for future collaborations in assessing whether the vendor, based on the defined strategy, still possesses the vendor's financial capacity to undertake new projects.

Financial rating (z) also influences the determination of vendor development strategies. The applied development strategy should be evaluated to determine whether it aligns appropriately with the vendor's financial capability. Commonly, PLN utilizes financial ratings provided by Dun & Backstreet or equivalent agencies. An example of financial rating classifications is presented in Table 5.

Furthermore, the vendor performance score also determines how the company should formulate its development strategy for the vendor. Naturally, different strategies are required for vendors with high versus low performance scores.

Table 5 Financial Strength Indicator

Financial Strength		**Composite Credit Apprisal**			
Rating	**IDR**	**High**	**Good**	**Fair**	**Limited**
5A	85,000,000,000 - over	1	2	3	4
4A	18,000,000,000 – 84,999,999,999	1	2	3	4
3A	3,600,000,000 - 17,999,999,999	1	2	3	4
2A	1,800,000,000 - 3,599,999,999	1	2	3	4
1A	1,00,000,000 - 1,799,999,999	1	2	3	4
A	900,000,000 - 999,999,999	1	2	3	4
B	815,000,000 - 899,999,999	1	2	3	4
C	725,000,000 - 814,999,999	1	2	3	4
D	550,000,000 - 724,999,999	1	2	3	4
E	450,000,000 - 549,999,999	1	2	3	4
F	280,000,000 - 449,999,999	1	2	3	4
G	100,000,000 - 279,999,999	1	2	3	4
H	0 - 99,999,999	1	2	3	4
N	Financial Strength is negative				
O	Financial Strength is undisclosed				
NB	New Business less than 24 months old				
NQ	Ceased Trading				

Vendor development strategies for each octant based on the validation of the vendor development strategy model.

4 Conclusion

In the development of a vendor performance evaluation system, the determination of criteria and sub-criteria can be carried out based on a comprehensive literature review. This approach also applies to formulating vendor development strategies. Both issues can be addressed using Delphi, FBWM and TODIM. For further research, the model must undergo expert judgment input, mathematical calculations, and evaluation to ensure its validity and reliability.

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