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Development of Factory Maintenance Services Provider's Evaluation Criteria, Case Study In Indonesian Fertilizer Company

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Abstract

To maintain or improve factory reliability, an effective maintenance program is needed both internally and externally. Quality factory maintenance service providers can be obtained through the procurement planning and implementation process with the best value-for-money performance. The research focuses on developing multicriteria used to select factory service providers and is decomposed successively into 3 dimensions, 13 elements, and 58 indicators. Determination of weights using the Analytical Hierarchy Process (AHP) method involved paired assessments by 26 experts within the company with the result of a technical dimension weight of 67.41% and a financial dimension weight of 32.59%. The assessment of the administrative dimension is carried out through a knockout system, while the assessment of the technical dimension and financial dimension is carried out through a combination of a knockout system and a system with parameters that have been developed so that the assessment can be carried out in a measurably and objectively. The testing results of the assessment instrument, which was carried out through five scenarios, prove that the assessment criteria and parameters can be used to obtain appropriate winners, which is a trade-off from technical and financial aspects.

Keywords
service procurement, factory maintenance, Analytical Hierarchy Process (AHP), the best value for money

1. Introduction
One of the causes of the company's targets not being achieved is the low reliability of production facilities (factories). According to Palmer (1999), a reliable factory can be provided through effective maintenance, so that the company can produce profitable products. Maintenance programs in companies can be carried out through internal workers or by using external workers obtained through the procurement process. However, based on data on the realization of company service procurement in 2021, only 78.95% of service providers were able to carry out the work according to the time required in the contract. Through interviews with Senior Goods and Services Contract Officers, most of the causes of service provider's failure to meet work execution times are mismatches between the specialist workforce in the contract and the specialist workforce carrying out the work. Apart from that, based on interviews with Condition Monitoring and Reliability Engineers, one example of work that failed to fulfill the contract was the work of repairing piston rods for gearboxes in one of the factories. Apart from not being able to meet the work completion time, there are results of work quality that are not under the agreement. This is caused by a mismatch in the competence of the work implementer and the completeness of the supporting equipment. Another example of failed work is mechanical seal repair work, where there was a failure several hours after the repair was carried out due to errors in purchasing materials and inadequate workshop facilities.

Service providers are selected through a service procurement process regulated by the company's internal guidelines. One of the objectives of these guidelines is to realize a procurement that produces value for money flexibly and innovatively but remains competitive, transparent, and accountable based on good procurement ethics. Furthermore, according to Bahagia (2021), the procurement performance consists of the lowest bid price, total cost of ownership, and the best value for money. Even though there is a rating system in the provider evaluation process with a proportion of technical aspects (60%-70%) and price aspects (30%-40%), the entire service procurement process is produced using the lowest bid price principle, which means that service providers are only selected based on price criteria, without considering the superiority of the technical aspects of the auction participants. According to Wynstra (2018), one of the distinctive characteristics of service procurement is heterogeneity, that is, there is variability in the same type of service. Thus, it is difficult for bidders represented by the sales team to properly understand the criteria from the technical aspect and only focus on winning the job auction by offering the lowest price.

According to Behera & Beura (2023), decision-making in Supply Chain Management usually faces difficulties involving many criteria. Furthermore, according to Yang et al. (2008), vendor selection is an unstructured, complex, and multicriteria decision problem. Therefore, vendor selection is one of the most important activities for many companies and selecting the wrong vendor can be quite detrimental to the company's financial and operational position while selecting the right vendor can significantly reduce purchasing costs and increase competitiveness (Faez et al., 2009). According to Bahagia (2021), to obtain providers of goods and/or services that meet all the requirements set out in the procurement document, at a reasonable price, and can be accounted for the results (fair and responsible bid), a bid evaluation process is needed. In principle, potential winners providing goods and/or services must fulfill (1) administrative and legal requirements; and (2) the lowest (financial) and responsible (technical). The evaluation method used in the evaluation is by examining and comparing the bidding documents against the fulfillment of the requirements and criteria set out in the goods and/or services procurement documents with the sequence of the evaluation process starting from assessing administrative requirements, technical requirements, and price requirements.

From several company documents that regulate the process of procuring factory maintenance services, the factors that are of concern in selecting a factory maintenance service provider are competency & number of human resources, availability of equipment, availability of spare parts, cost efficiency, environment, and health & safety. However, in implementing the TOR, the scope of factory maintenance work is only limited to requirements related to work output, and there are no evaluation criteria for service providers that are structured in a structured manner based on the factors that determine the selection of factory maintenance service providers. In the end, procurement planners experience difficulties in formulating feasible assessment instruments at the technical evaluation and price evaluation stages, so technical evaluations are only carried out using the pass-and-fail method, and service providers are only based on the lowest bid price. Thus, to support the implementation of the Company's strategy, standardization of evaluation criteria for factory maintenance service providers is needed, which can effectively produce procurement results that have the best value for money performance.

1.1 Objectives

Based on the root cause of the real problem and the gap between previous research and real problems, the formulation of the problem in this research is: How to design the criteria and assessment indicators in the factory maintenance service procurement process at Fertilizer Company so that the procurement process can be carried out effectively to produce quality service providers?". The theoretical contribution of this research is to add to the body of knowledge related to the development of multicriteria factory maintenance service providers which are divided into administrative aspects, technical aspects that have integral system elements (man, machine, material, and method) as well as elements for measuring effectiveness and financial aspects. Furthermore, this research is expected to provide applicable benefits to the stakeholders involved, namely:

1. Procurement implementers can meet the best value-for-money performance targets.
2. Fertilizer companies can meet company targets related to production and efficiency levels because maintenance programs involving third-party services can be carried out effectively.
3. Service Provider Partners can prepare technical bid documents, price bids, and required resources because there are more detailed assessment criteria in the TOR.

2. Literature Review

The literature study was carried out by reviewing relevant research with the keywords, procurement, multi-criteria, service provider selection, and maintenance performance. Most previous research has been equipped with weight determination models such as the Analytical Hierarchy Process (AHP), Analytical Process Network (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and others. However, there has been no research that comprehensively discusses the need for evaluation criteria used in the vendor selection process for factory maintenance service objects.

The research reference model is Hu et al.'s model (2019). The output of the developed model has similarities with the real system, namely the criteria for selecting maintenance service providers. Apart from that, this model also considers elements in the integral system that are also required in the Company's internal procedures. Hu et al.'s model has assessment indicators related to Human Resources, equipment, and availability of spare parts which are elements of an integral system. In addition, the model of Hu et al. also considers the composition of maintenance costs which are a component of the cost of production or, when viewed from the user's perspective, are a component of preparing the estimated price itself.

This research complements the shortcomings of the reference model with the following adjustments:
First, in the research model, a conceptual model will be developed by considering administrative aspects which are the initial requirements of prospective service providers both during pre-qualification and during procurement. Second, in the research model, the K3LH element will be added which is a tool for measuring the service provider's commitment to implementing the K3LH management system in the work environment of the job owner. Third, this research model adds method elements that are part of the integral production floor system and tools for measuring the maintenance process and elements of work implementation effectiveness as a tool for measuring output from the implementation of maintenance activities. Fourth, this research model adds an element of price assessment offered by service providers so that procurement performance can not only be of high quality but also remain economical. Fifth, this research model will consider several factors to be added as an operational model, including guarantees from service providers and workshop or fabrication activities as one of the cost components that must be taken into account in maintenance costs.

The shortcomings of this reference model will be complemented by supporting models, namely Ananto (2018), Hadidi & Khater (2015), Chen. (2022), Olugu (2021), Igravwe & Oke (2019), Amrina et al. (2020), Dhanissety et al. (2018), Tjader et al. (2014), Deretarla et al. (2023) and Sondangi (2014) as well as benchmarks in the parent company and adopting several criteria that are relevant to the existing model. In detail, several previous studies can be seen in Table 1 below.

Table 1. Research's position

Author	Years	Scope	Object	Focus on Establishing Criteria	Method	Assessment Parameters
Sondangi et. al	2014	Performance	Maintenance Management	Multicriteria in general	RII	X
Tjader et.al	2014	Procurement	Good & Services	Balanced Scorecard (BSC)	ANP	X
Hadidi & Khater	2015	Procurement	Turn Around Maintenance	Safety Health & Environment (SHE)	AHP	√
Dhanissety et.al	2018	Procurement	Aeroplane Maintenance Services	Survivability, cost, downtime	WSM	√
Ananto	2018	Procurement	EPCC Subcontractors	legal, technical, price, (SHE), and capability	AHP	√
Hu et.al	2019	Procurement	Agricultural Machinery Maintenance Network	Balanced Scorecard	ANP	X
Ighravwe & Oke	2019	Strategy	Building's Maintenance	Economic, social, environment, capability	NGT	X
Amrina et.al	2020	Procurement	Maintenance Management	Economic, social & environmental	ANP	X
Olugu et.al	2021	Procurement	Maintenance Management	Sustainability	TOPSIS	X
Chen et.al.	2022	Kinerja	Information Industry Services	Sustainability Balanced Scorecard (S-BSC)	ANP	X

Author	Years	Scope	Object	Focus on Establishing Criteria	Method	Assessment Parameters
This research	2023	Procurement	Fertilizer Factory Maintenance Services	Administrative aspects, integral workstation system elements, effectiveness, cost composition, price, SHE.	AHP	√

3. Methods

Conceptual Model Development

The conceptual model describes the researcher's ideas about how the concepts (variables) in the research model are related. Schematic diagrams of conceptual models help readers visualize the theoretical relationships between variables in the research model and thereby obtain a brief idea of how the researcher thinks the management problem can be solved (Sekaran & Bougie 2016). The output from this stage is the proposed dimensions (criteria) and elements (sub criteria) that will be used for selecting service providers.

Operational Development (indicators)

The aim of developing operationalization is to obtain measurable and specific criteria in the form of indicators. Indicators are selected from reference models, supporting models, and benchmarks. The selected indicators are criteria/ subcriteria /indicators that can be measured and are then grouped into elements that have been developed in the previous stage.

Determination of Weight using the AHP Method

In supplier selection, AHP has been used for both criteria weight determination and performance evaluation (Fallahpour, 2017). According to Saaty (2012), there are three basic principles used to solve various problems through explicit logical analysis, namely the principle of hierarchical construction, the principle of prioritization, and the principle of logical consistency. Criteria weighting using the AHP method begins with a pairwise comparison assessment by experts, calculating the mean geometric of all expert assessments, forming a pairwise comparison matrix, forming a normalization matrix, determining the weight (priority) for each criterion, and measuring the consistency of the assessment by the experts. By calculating the consistency ratio (CR) where the CR value cannot be more than 10%. The reference used for providing pairwise comparison assessments can be seen in Table 2 below.

Table 2. Pairwise comparison (Saaty, 2012)

Importance Intensity	Definition
1	Equal important
3	Moderately important
5	Strong Important
7	Very strongly important
9	Absolutely important
2,4,6,8	Intermediate values

According to Saaty (2012), to eliminate debate when assessing pairs through group discussions, this can be done by providing assessments through questionnaires. Next, the pairwise assessments are processed using the geometric mean formula as follows:

$$x_{ij} = \sqrt[n]{x_{ijk} + \ldots + x_{ijn}} \forall_k = 1,2,\ldots,n \quad (1)$$

Where:

x_{ij} : Pairwise comparison value (geometric mean) of criterion i against criterion j

x_{ijk} : Pairwise comparison value of criterion i against criterion j by respondent k

n : Number of respondents

After the assessment is carried out by selected respondents, an assessment is then carried out to assess local priorities. Numerically, the priority of each criterion is shown in weight. The following is the weight calculation process using the AHP method:

1. Formation of a pairwise comparison matrix

$$X = [x_{ij}]_{m\,x\,n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

Where:

$$x_{ij} = 1/x_{ji} \quad (2)$$

2. Formation of the normalization matrix

$$X^* = [x_{ij}]^*_{m\,x\,n} = \begin{bmatrix} x^*_{11} & x^*_{12} & \dots & x^*_{1n} \\ x^*_{21} & x^*_{22} & \dots & x^*_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x^*_{m1} & x^*_{m2} & \dots & x^*_{mn} \end{bmatrix}$$

The value x^*_{ij} is obtained using the formula:

$$x^*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \forall_i = 1,2,\dots,m \quad (3)$$

Where:

x^*_{ij}: normalization value of criterion i against criterion j

3. Determining the weight (priority) for each criterion

$$w_i = \left(\frac{1}{n}\right)\sum_{i=1}^{n} x^*_{ij} \quad (4)$$

Where:

w_i : local weight of criteria i

n : number of criteria

Determination of Assessment Parameters:

For it to be implemented effectively, assessment parameters are then developed. The assessment parameters are prepared based on the fulfillment of the TOR requirements by the selection participants. In the final stage of development, trials were carried out through several scenarios to prove that the assessment instrument could be used to produce procurement performance on the principle of best value for money.

4. Data Collection

Data collection is carried out by assigning values using pairwise comparison. The process of giving paired scale scores is carried out by the respondents and guided by the author. A total of 26 respondents have provided pairwise comparisons at the level of Senior Vice President, Vice President, Assistant Vice President, Manager, Senior Engineer, and Staff involved in the procurement cycle in the Supply Chain, Operations Division. Division, Maintenance Planning Division and Factory Maintenance Services Division.

5. Results and Discussion

Conceptual Model

The development of dimensions (criteria) is carried out based on the direction of development, namely, so that the procurement process can demonstrate the best value for money. To obtain a service provider, in the existing procurement implementation process, there are generally three aspects that are evaluated, namely, the administrative aspect, technical aspect, and financial aspect.

The development of elements (sub criteria) for administrative aspects in this model aims to structure the criteria from supporting models and benchmarks into standard elements that can be used when compiling work reference frames, procurement documents, and assessment instruments when carrying out administrative evaluations. Elements developed in technical aspects are developed based on elements in integral systems. According to Anderson (1994) in Bahagia (2018) four factors influence production activities, namely man (labor), machine (equipment), material, and methods (management).

Furthermore, elements of the effectiveness of work implementation are also added to measure the level of understanding of bidders regarding the scope of work so that they can prepare elements in other technical aspects appropriately. In general, the assessment of financial aspects is seen from the value of the auction participant's bid price. The lowest price bidder will have the highest value. To help evaluators analyze the fairness of price offers provided by auction participants, additional elements are proposed in the financial dimension that consider the composition or structure of maintenance costs. The results of conceptual development are presented in Table 3 below.

Table 3. Conceptual model development

Dimensions		**Elements**		
No	**Description**	**No**	**Element**	**Reference**
A	Administration	A01	The legality of the company	Ananto (2018)
		A02	Company Organization	Benchmark
		A03	Company Financial Capability	Benchmark
		A04	Company Experience	Benchmark
		A05	Company Facilities	Benchmark
		A06	SHE Management System	Khadidi & Khater (2015) & Olugu et.al (2021)
T	Technical	T01	Human Resources (HR)	Bahagia (2018)
		T02	Equipment & Machine	Bahagia (2018)
		T03	Sparepart & Material	Bahagia (2018)
		T04	Method	Bahagia (2018)
		T05	Effectiveness of Work Implementation	Existing Model
F	Financial	F01	Composition of Maintenance Costs	Hu et.al (2019) & Dhanissety et.al (2018)
		F02	Price	Deretarla et.al (2022)

Indicators.

In contrast to the development of criteria which is generally carried out using the AHP and ANP methods, the development of indicators in this model aims to ensure that the assessment of alternative service providers can be carried out more objectively. In the AHP and ANP methods, alternative service providers are carried out by providing subjective assessments by comparing alternative options through paired assessments with the same steps as the priority determination process. The proposed indicators, descriptions, and reference sources in this research can be seen in Table 4, Table 5, and Table 6 below.

Table 4. Proposed indicators of administrative dimension

No	**Proposed Indicators**	**Reference**
A01: Element Company Legality Element		
A0101	Copy of Company Deed document	Benchmark & Ananto (2018)
A0102	Copy of NPWP document	Benchmark & Ananto (2018)
A0103	Copy of SIUP/TDP/NIB document	Benchmark & Ananto (2018)
A0104	Copy of SITU/SKDU/Location Permit document	Benchmark & Ananto (2018)
A0105	Copy of Annual Tax Return document	Benchmark & Ananto (2018)
A0106	Bank Account Copy	Benchmark
A02: Company Organizational Element		
A0201	Copy of Company Organizational Chart	Benchmark
A0202	Shareholder Profile	Benchmark
A0203	Company Management Profile	Benchmark
A0204	Expert Workforce Profile	Benchmark
A0205	Copy of Competency Certificate	Benchmark
A03: Company Financial Capability Element		
A0301	Copy of Financial Balance Document	Benchmark
A0302	Copy of Income Statement Document	Benchmark
A0303	Copy of SPPKP Document	Benchmark
A0304	Copy of Information Document Fiscal	Benchmark
A0305	Company Health Level (Altman Z Score Method)	Existing Model
A04: Company Experience Element		
A0401	Length of experience in the Industrial Services field	Ananto (2018)
A0402	Employment history data (complete with contract value)	Benchmark & Ananto (2018)
A0403	Customer satisfaction	Hu et.al (2019), Tjader et.al (2014) & Chen et.al (2022)
A0404	List of loyal (loyal) customers	Hu et.al (2019) & Chen et.al (2022)
A05: Company Facility Element		
A0501	Main Equipment List (Quantity & Specifications)	Benchmark

No	Proposed Indicators	Reference
A0502	List of Supporting Equipment (Quantity & Specifications)	Benchmark
A06: SHE Management System Element		
A0601	Copy of occupational health and safety management system certificate	Ananto (2018)
A0602	Copy of occupational health and safety Organizational Structure	Hadidi & Khater (2015& Ananto (2018)
A0603	Copy of occupational health and safety expertise Certificate	Hadidi & Khater (2015
A0604	Work accidents in the last 3 years	Ananto (2018)
A0605	Job Safety Analysis (JSA) Document	Hadidi & Khater (2015 & Ananto (2018)
A0606	Copy of ISO 14001 certificate	Ananto (2018)
A0607	Waste management methods	Ananto (2018) & Amrina et.al (2020)

Table 5. Proposed indicators of technical dimension

No	Proposed Indicators	Reference
T01: Human Resources Element		
T0101	Formal education of the person carrying out the work	Hu et.al (2019) & Amrina et.al (2020)
T0102	Work experience	Hu et.al (2019) & Olugu et.al (2021)
T0103	The total number of workers carrying out the work	Hu et.al (2019) & Olugu et.al (2021)
T0104	Number of specialist workers implementing the work	Hu et.al (2019) Ananto (2018), Igravwe & Oke (2019) & Sondangi et.al (2014)
T0105	Completeness of types of job specialization	Hu et.al (2019) Ananto (2018), Igravwe & Oke (2019) & Sondangi et.al (2014)
T0106	Employee health conditions	Olugu et.al (2021)
T02: Human Resources Element		
T0201	Number of main Equipment	Hu et.al (2019) & Ananto (2018)
T0202	Main Equipment Specifications	Hu et.al (2019) & Ananto (2018)
T0203	Condition of main equipment	Hu et.al (2019) & Ananto (2018)
T0204	Number of Supporting Equipment	Hu et.al (2019) & Ananto (2018)
T0205	Supporting Equipment Specifications	Hu et.al (2019) & Ananto (2018)
T0206	Condition of supporting equipment	Hu et.al (2019) & Ananto (2018)
T0207	Supporting fabrication facilities	Dhanissety et.al (2018)
T03: Equipment Element		
T0201	Number of main Equipment	Hu et.al (2019) & Ananto (2018)
T0202	Main Equipment Specifications	Hu et.al (2019) & Ananto (2018)
T0203	Condition of main equipment	Hu et.al (2019) & Ananto (2018)
T0204	Number of Supporting Equipment	Hu et.al (2019) & Ananto (2018)
T0205	Supporting Equipment Specifications	Hu et.al (2019) & Ananto (2018)
T0206	Condition of supporting equipment	Hu et.al (2019), & Ananto (2018)
T0207	Supporting fabrication facilities	Dhanissety et.al (2018)
T03: Spare parts & Materials Element		
T0301	Quantity and specifications of spare parts and materials	Hu et.al (2019), Ananto (2018), Tjader et.al (2014) & Amrina et.al (2020)
T0302	Parts & material control procedures	Hu et.al (2019), Ananto (2018), Tjader et.al (2014) & Amrina et.al (2020)
T0303	Use of renewable materials	Chen et.al (2022) & Olugu et.al (2021)
T04: Method Element		
T0401	Work implementation procedures	Ananto (2018)
T0402	Inspection and testing procedures	Ananto (2018)
T0403	Work quality control procedures	Ananto (2018) & Sondangi et.al (2014)
T05: Effectiveness Element		
T0501	Improved equipment performance	Olugu et.al (2021), Hu et.al (2019) & Igravwe & Oke (2019)
T0502	Job completion time	Hu et.al (2019), Dhanissety et.al (2018) & Deretarla et.al (2023
T0503	Fault diagnosis accuracy	Hu et.al (2019)
T0504	Job guarantee	Existing model

Table 6. Proposed indicators of financial dimension

No	Proposed Indicators	Reference
F01: Maintenance Cost Composition Element		
F0101	Labor wage costs	Hu et.al (2019), Ananto (2018) Dhanissety et.al (2018)& Olugu et.al (2021)
F0102	Material costs	Ananto (2018), Dhanissety et.al (2018)& Olugu et.al (2021)
F0103	Spare parts costs	Hu et.al (2019), Dhanissety et.al (2018)& Olugu et.al (2021)
F0104	Cost of fabrication work	Ananto (2018)& Dhanissety et.al (2018)
F0105	Shipping costs	Hu et.al (2019) & Ananto (2018)
F02: Price Element		
F0201	Price offer for factory maintenance services	Deretarla et.al (2023) & Existing model

5.1 Numerical Results

Criteria weight

After 26 respondents had given paired assessments between the technical dimension and the financial dimension, between elements in the technical dimension, between elements in the financial dimension, and all indicators in the same element, CI calculations were carried out for each assessment by the respondents. If the CI result is >10%, then the respondent is asked to provide a reassessment until the CI value obtained is <10%. In detail, the weighting results can be seen in Table 7.

Table 7. Results of criteria weighting

Dimensions		Elements			Indicators		
No	**Weight**	**No**	**Global weight**	**Local weight**	**No**	**Global weight**	**Local weight**
T	67.41%	T01	31%	21%	T0101	11%	2.4%
					T0102	28%	5.8%
					T0103	11%	2.4%
					T0104	20%	4.1%
					T0105	16%	3.3%
					T0106	14%	3.0%
		T02	21%	14%	T0201	20%	2.7%
					T0202	19%	2.6%
					T0203	24%	3.4%
					T0204	10%	1.3%
					T0205	8%	1.1%
					T0206	8%	1.1%
					T0207	12%	1.7%
		T03	17%	11%	T0301	45%	5.1%
					T0302	40%	4.5%
					T0303	14%	1.6%
		T04	14%	9%	T0401	42%	3.9%
					T0402	27%	2.5%
					T0403	32%	3.0%
		T05	18%	12%	T0501	22%	2.6%
					T0502	34%	4.1%
					T0503	20%	2.4%
					T0504	25%	3.0%
F	32.59%	F01	62%	20%	F0101	20%	4.0%
					F0102	28%	5.7%
					F0103	22%	4.5%
					F0104	19%	3.9%
					F0105	10%	2.0%
		F02	38%	12%	F0201	12%	12.4%

Based on Table 7 above, it can be seen that the technical dimension weights 67.41% greater than the financial dimension of 32.59%. Based on this comparison, the technical dimension has a higher priority than the financial aspect. For elements in the technical dimension, human resources elements have the highest assessment priority with a local weight of 31% and a global weight of 21%. Of all the indicators in the technical dimension, the experience of work implementers has the highest assessment priority with a local weight of 27% and a global weight of 6%. In addition, based on the proposed model, the work value element which was previously the sole criterion in making decisions on selecting a factory maintenance service provider has had its priority reduced to 12%.

5.2 Proposed Improvements

Assessment Parameters and Scenario Testing

The administration dimension assessment is carried out at the earliest and all indicators contained in the Administration dimension are requirements that must be met by service providers, so the assessment parameters are divided into two, namely pass or fail. A service provider is declared to have passed the administrative dimension if it can complete all requirements in the indicators. If one of the requirements cannot be fulfilled (fails) then the prospective service provider is deemed not to have passed the administrative selection stage.

Indicator assessment in technical and financial dimensions is developed using a ratio scale and based on existing models. Most assessments consider a minimum value for technical aspects that must be met by the service provider, however, there is a tolerance of 20% for the price assessment, so fulfilling the requirement of ≥80% is still acceptable for an assessment. The use of tolerance is caused by service characteristics, namely intangibility, and heterogeneity, so that planners or users have difficulty preparing accurate requirements in the TOR.

The object assessed for each indicator is the percentage of fulfillment of the requirements contained in the TOR, which will then be denoted in the formula with the notation "x". In general, the lowest rating for each indicator is "0%" or "failed" and the highest value is 100% which will then be denoted with the notation "y". This assessment will then be multiplied by the global weight of each indicator. Indicators have different characteristics so there are variations in the assessment formulation (Table 8).

Table 8. Assessment parameters for technical dimension and financial dimension indicators

No	Formula	Characteristics	Indicator Code
1	$if\ x > 100\%,\quad y = 100\%$ $if\ x < 80\%,\quad y = fail$ $if\ 80\% \leq x \leq 100\%,\quad y = x$	The higher the percentage value, the better. Indicators with a fulfillment percentage of more than 100% do not provide a significant difference and have a minimum tolerance limit value so if they are not met, the potential service provider will fail in carrying out the evaluation.	T0101, T0105, T0202, T0203, T0205, T0206, T0207
2	$if\ x > 120\%,\quad y = 100\%$ $if\ x < 80\%,\quad y = fail$ $if\ 80\% \leq x \leq 100\%,\quad y = x/120\%$	The higher the percentage value, the better. Indicators with a fulfillment percentage of more than 100% (maximum 120%) can provide a significant difference and have a minimum tolerance limit value (20%) so that if they are not met, the potential service provider will fail in carrying out the evaluation.	T0102, T0103, T0104, T0201, T0204, T0501, T0503, T0504
3	$if\ x = 100\%,\quad y = 100\%$ $if\ x < 100\%,\quad y = if$	The higher the percentage value, the better. Indicator with a minimum limit of 100% and has no tolerance.	T0106, T0301
4	$if\ x > 100\%,\quad y = 100\%$ $if\ x \leq 100\%,\quad y = x$	The higher the percentage value, the better. Indicators with a percentage fulfillment of more than 100% do not provide a significant difference and do not have a minimum threshold value.	T0302, T0401, T0402, T0403
5	$if\ x > 120\%,\quad y = 0$ $if\ x < 80\%,\quad y = 100\%$ $if\ 80\% \leq x \leq 100\%,\quad y = 80\%/x$	The lower the percentage value the better. Indicators with presentation compliance of less than 80% do not have a significant impact and have a maximum tolerance limit value (20%),	F0101, F0102, F0103, F0104, F0105
6	$if\ x > 120\%,\quad y = fail$ $if\ x < 80\%,\quad y = fail$ $if\ 80\% \leq x \leq 100\%,\ y = 80\%/\mathrm{x}$	The lower the percentage value the better, but it has a tolerance limit of ± 20%.	T0502, F0201

5.3 Validation

Instrument trials were carried out for the evaluation process of service providers for bucket elevator replacement and line clay manufacturing at the NPK Factory. The purpose of testing the decision model is to test the ability of the assessment instrument to produce winners with the best value-for-money performance. The author brainstorms with the job owner to develop requirements to suit the proposed model. The requirements prepared are limited to indicators in the technical dimension and financial dimensions because all selection participants are assumed to be able to fulfill all aspects of administration. Next, the assessment process is carried out on five alternative service providers with the development of alternative scenarios for each service provider as follows:

1. Vendor A: When compared with the requirements in the TOR, Vendor A provides an offer with lower scores on several indicators in the technical dimension. However, on the other hand, Vendor A offers the lowest price, which is only 80% of the owner's estimated value.
2. Vendor B: When compared with the requirements in the TOR, Vendor B provides an offer with the same value for several indicators in the dimensions. Apart from that, Vendor B also offers the lowest price, which is only 80% of the owner's estimated value.
3. Vendor C: When compared with the requirements in the TOR, Vendor C provides an offer with the same value on several indicators in the technical dimension. In line with the offer in the technical dimension, Vendor B also offers a higher price than Vendor A and Vendor B's price offer, namely 85% of the owner's estimated value.
4. Vendor D: When compared with the requirements in the TOR, Vendor D offers a higher value for several indicators in the technical dimension. In line with the offer in the technical dimension, Vendor D also offers a higher price compared to the price offered by Vendor A, Vendor B, and Vendor C, namely equal to 90% of the owner's estimated value.
5. Vendor E: When compared with the requirements in the TOR, Vendor E offers offers with higher scores on several indicators in the technical dimension. All of Vendor E's offers in the technical dimension have the same value as Vendor D's, but Vendor E offers a higher price compared to Vendor D's offer, namely, 90% of the owner's estimated value.

Based on five vendor scenarios that include technical and commercial bid documents, data processing is then carried out by comparing vendor bids and requirements in the procurement documents. Next, trials were carried out for the five vendors using the formula presented in Table 8 and the results can be seen in Table 9.

Table 9. Scenario test results

Element		Weight	Score				
			Vendor A	**Vendor B**	**Vendor C**	**Vendor D**	**Vendor E**
T01	Human Resources	21%	16.7%	18.7%	18.7%	20.8%	20.8%
T02	Equipement & Machine	14%	11.9%	13.2%	13.2%	13.7%	13.7%
T03	Sparepart & Material	11%	7.4%	9.6%	9.6%	9.6%	9.6%
T04	Method	9%	6.9%	9.3%	9.3%	9.3%	9.3%
T05	Effectiveness of Work Implementation	12%	9.1%	10.0%	10.0%	11.0%	11.0%
Subtotal		67%	51.9%	60.9%	60.9%	64.4%	64.4%
F01	Composition of Maintenance Costs	20%	20.2%	19.9%	19.0%	17.9%	17.0%
F02	Price	12%	12.4%	11.7%	11.7%	11.0%	10.5%
Subtotal		33%	32.6%	31.6%	30.7%	29.0%	27.4%
Total		**100%**	**84.5%**	**92.6%**	**91.6%**	**93.4%**	**91.8%**

Discussion

Based on the recapitulation of the assessment results presented in Table 9 above, the alternative service provider with the highest score is Vendor D with a score of 93.36%. Vendor B with a score of 92.57%, Vendor E with a score of 91.84%, Vendor C with a score of 91.61%, and Vendor A with a score of 84.46%. If the assessment process is used using a process normally used in real systems, Vendor B will be the winner because it can fulfill all requirements and provide the lowest bid price. However, by using the proposed model, Vendor D can be recommended as the winner because it is a trade-off point from the technical dimension and price dimension so Vendor D is the result of procurement performance based on the principle of best value for money and can then be explained based on several considerations as follows:

1. Intangible characteristics in service procurement

In most service procurement processes, there is no physical exchange of objects, which results in difficulties for planners in determining service requirements accurately. Thus, even though Vendor B has fulfilled all requirements in the TOR, the assessment instrument developed has accommodated the level of planning accuracy by considering a better offer from Vendor D.

2. Excellence in Human Resources elements

When compared with Vendor B's technical offer on equipment elements, Vendor D has the advantage of offering more experienced work implementers for similar work. With these advantages, it is hoped that the work carried out can run effectively and efficiently because it can minimize the risk of errors in carrying out the work. Apart from that, working with experienced workers can be useful in developing the competence of the internal workers involved.

3. Advantages of equipment elements

When compared with Vendor B's technical offer on equipment elements, Vendor D has the advantage of offering a larger number of main equipment while having specifications that meet the requirements. With these advantages, it is hoped that the risk of stopping activities due to equipment damage can be mitigated quickly. Damage to the main equipment during work implementation can cause delays in work completion and/or low quality of work results.

4. Excellence in the element of effectiveness of work implementation

When compared with Vendor B's technical offer on the effectiveness of work implementation, Vendor D has the advantage of offering a faster completion time and a longer guarantee period. Thus, by using Vendor D's services, it is hoped that the factory can operate more quickly and reliably.

5. Offer a price that is still within the limits set by the authorized official

With the advantages possessed by Vendor D by offering superiority in the HR element and equipment element as well as better output results in the effectiveness element of work implementation, the price offered is higher compared to Vendor D's offer. Apart from having superiority in the technical aspect which has priority higher, Vendor D has a price offer that is still within the limits set by the authorized official (90% of the owner estimate value).

6. Conclusion

In developing an assessment model for selecting factory maintenance service providers, a conceptual model development stage consisting of dimensions and elements is required before entering the operationalization stage in determining the development of assessment indicators. From the results of developing the conceptual model on the existing model, there are changes from the administrative aspect, technical aspect, and price aspects to the administrative aspect, technical aspect, and financial aspects. The administrative dimension consists of seven elements, namely the company legality element, company organization element, company financial capability element, company experience element, company facility element & SHE management system element. Furthermore, all elements in the administrative dimension are decomposed into 29 indicators which are assessed using the knockout method.

Criteria weighting was carried out using the AHP method for the technical dimension and financial dimension, so that there was a change in the weight of the technical dimension, which was originally weighted 60-70%, changed to 67.41%, while the financial dimension originally weighted of 30-40%, changed to 32. 59%. The technical dimension consists of five elements, namely, HR element (21%), equipment elements (14%), spare parts & material elements (11%), method elements (9%), and elements of maintenance implementation effectiveness (12%). Next, all elements in the next dimension, all elements in the technical dimension are decomposed into 23 indicators. The financial dimension consists of two elements, namely the maintenance cost composition element (20%) and the work value element (12%). Next, all elements in the financial dimension are decomposed into 6 indicators. The assessment parameters for all indicators in the technical dimension and financial dimensions are formulated objectively using a combination of a knockout system and a rating system.

The research that has been carried out has limitations, namely that it has not considered the dependency between elements or between indicators. If the proposed model can be implemented consistently, future research can be carried out by considering the dependencies between elements or indicators, so that more accurate methods such as Analytical Network Process (ANP) can be used. Apart from that, research objects can also be carried out on the maintenance of more specific factory equipment in the fertilizer industry, such as rotating, non-rotating, electrical, instrument equipment, and so on.

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Biographies

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