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Submission date: 03-Apr-2023 12:02PM (UTC+0700)
Submission ID: 2054300595
File name: plication_of_factor_analysis_FA_in_evaluating_supplier_2022.pdf (553.36K)
Word count: 3009
Character count: 15911

TECHNIUM

Technium Vol. 4, Issue 6 pp.11-17 (2022)
ISSN: 2668-778X
www.techniumscience.com

The application of factor analysis (FA) in evaluating supplier selection criteria in PT. Wijaya Karya Beton Tbk and ranking suppliers using Analytical Hierarchy Process (AHP) and Adaptive Ratio Assessment (ARAS)

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Abstract. The selection of a concrete iron supplier is critical for a long-term supply chain in the infrastructure industry. Due to the participation of various qualitative and quantitative elements, the evaluation process of concrete iron supplier selection is a difficult work for decision specialists. Because uncertainty is widespread in concrete iron supplier selection challenges, improving integrated criteria selection and supplier selection procedures has proven to be one of the most efficient and superior ways to represent practical difficulties. The current study presents a novel framework for evaluating and selecting a preferred concrete iron supplier based on Factor Analysis and the ARAS (Adaptive Ratio Assessment) method, as well as the AHP (Analytical Hierarchy Process) methodology. An enhanced technique is used in the proposed method to determine the criteria weights based on expert preferences. Next, an actual case study of the concrete iron supplier selection problem is conducted in a comprehensive setting to demonstrate the effectiveness and practicability of the suggested methodology. A sensitivity analysis is also undertaken to ensure that the stated methodology is stable. Finally, the strength of the resulting result is tested by comparing it to current methodologies. The final results show that the established framework is more consistent and powerful than other approaches already in use.

Keywords. Supplier selection, ARAS, AHP, Factor Analysis.

1. Introduction

PT Wijaya Karya Beton Tbk Indonesia is one of the manufacturing companies to produce concrete for infrastructure. The products that are often made are piles, power poles, rail bearings, bridge concrete products, retaining walls, water construction concrete, building concrete, and maritime building concrete. The products most often made by this company are piles to strengthen buildings and foundations for various types of buildings. During the 2018-2020 period, the company produced piles with an average monthly production of more than 2000 units. The more building construction, the more demand for piles. The main raw material for this pile is a connecting plate. This connection plate is supplied from several suppliers.

Supplier is one of the success factors of the company. Therefore, supplier performance needs special attention so that the products produced are in accordance with the needs and desires of the company [1]. Several times the company experienced disappointment with the supplier because it could not meet the expectations of the company [2]. Competition in the industrial world requires companies to build a good

supply chain, including maintaining relationships with suppliers [1]. To maximize the company's performance and minimize the disappointment of PT Wijaya Karya Beton Tbk, the company conducts an assessment to determine the priority of supplier selection. Problems in supplier selection are included in the decision making of many criteria [3]. One of the many criteria decision-making techniques that is *adaptive ratio assessment (*ARAS). ARAS requires criterion weight. Many supplier selection studies use AHP to calculate the weight of the criteria [4].

The use of AHP-ARAS integration has been done by many previous researchers. Streimikiene et al [5] used the AHP and ARAS methods to select the best power plant technology supplier. Tamošaitienė et al. [6] evaluate the construction company suppliers using the AHP and ARAS methods. Ozdagoglu et al [7] applied integration of AHP and ARAS in a study on supplier selection for water treatment facilities. The latest research was conducted by Fu and Yan-Kai [8], to find the best supplier for airline catering.

In previous studies, only focused on supplier selection. Meanwhile, the criteria used are from the company. In fact, there may be other influential criteria that have not been used in their studies. The methods that can be used in the selection of criteria are DEMATEL, ANOVA, Principal Component Analysis (PCA), ISM/Interpretive Structural Modeling), and SEM/Structural Equation Modeling [9]. Therefore, this study proposes the selection of criteria using factor analysis.

2. Method

Three stages of this research are (1) selection of criteria using factor analysis, (2) criteria weighting using AHP, and (3) supplier selection using ARAS. In the first stage, factor analysis technique used is Confirmatory Factor Analysis (CFA), so it's necessary to test the normality of the data. The purpose of the normality test is to find out whether criteria as variable is normal or not. Normal distributed data means data considered be representative of the population. The normality test technique used is One Sample Kolmogorov-Smirnov (K-S). In the factor analysis, KMO test used to find out whether all the data that has been taken is sufficient for taken into account. The factor rotation method used is vary-max. The validity of the correlation between variables is taken by analysing the result of Kaiser-Mayer-Oklin (KMO) Measure of Sampling Adequacy (SA) test.

In the second stage, there are four steps, i.e. (1) define the problem and construct a hierarchy of problems; (2) determining the priority of elements using pair-wise comparison matrix; (3) synthesis; (4) measuring consistency. In the last stage, there are five steps, i.e. (1) create a supplier assessment matrix; (2) matrix normalization; (3) weighted matrix normalization; (4) optimization value; (5) utilization measurement.

In the synthesis step of pair-wise comparison matrix, it consists of (1) adding up the values in the column (total value of the column); (2) divide the value in the column by total value of the column; (3) add up the row values and divide by the number of elements to get the average value (relative priority element or relative weight of the criteria) [10]. In the measuring consistency, it consists of (1) multiply each value in the column by the relative priority of its element; (2) adding up the values in the row (total value of the row); (3) the total value of the row divided by its relative priority elements (λ value); and then (4) calculate average of the λ value (λ_{max} value); (5) calculate the consistency ratio using equation (1) [11]. If the consistency ratio is less than 0.1, the relative weight of the criteria is declared valid.

$$CR = \frac{\frac{(\lambda_{max}-n)}{(n-1)}}{IR} \quad (1)$$

In the step of matrix normalization, it consists of two conditions, following the two type of criteria. The first type of criterion is the cost criterion, that is, the larger the data, the smaller the value. The second type of criterion is the profit criterion, i.e. the larger the data, the greater the value. The normalization matrix for the cost criteria uses equation (2) [10]. The normalization matrix for the profit criteria uses equation (3) [12]. Equation (4) is used for weighted matrix normalization [13]. Optimization value calculation and utilization measurement using equation (5) and (6) [13].

TECHNIUM
Technium Vol. 4, Issue 6 pp.11-17 (2022)
ISSN: 2668-778X
www.techniumscience.com

$$\overline{x_{ij}} = \frac{\frac{1}{x_{ij}}}{\sum_{i=0}^{m}\left[\frac{1}{x_{ij}}\right]} \quad (2)$$

$$\overline{x_{ij}} = \frac{x_{ij}}{\sum_{i=0}^{m}[x_{ij}]} \quad (3)$$

$$\vec{x}_{ij} = \overline{x_{ij}} \,.\, w_j \quad (4)$$

$$S_i = \sum_{j=0}^{n} \vec{x}_{ij} \quad (5)$$

$$K_i = \frac{S_i}{S_0} \quad (6)$$

3. Result and Discussion

Table 1 lists the paragraph styles defined in this template. In the identification of criteria, a collection of criteria from various literatures is presented in the form of a questionnaire. Questionnaires were given to decision makers in the research object, namely PT. Wijaya Karya Beton Tbk. The summary of the criteria collection and results of the questionnaire can be seen in Table 1.

Table 1. Summary of the criteria collection.

Criteria	Significant	Normal	Literature
Price	0,024	X	[14]
Discount	0,087	√	[1]
Payment term	0,033	X	[15]
Quality	0,211	√	[16]
Certification	0,01	X	[14]
Delivery	0,078	√	[17]
Packaging	0,007	X	[15]
Flexibility	0,113	√	[16]
Shipment	0,034	X	[18]
Location	0,255	√	[19]
Accessibility	0,156	√	[15]
CS & Warranty	0,168	√	[18]
Relationship	0,224	√	[20]
Finance & Capital	0,205	√	[19]
Reputation & Experience	0,170	√	[15]
Organization & Management	0,063	√	[15]
HRD	0,073	√	[18]
Culture	0,358	√	[21]
Production Planning	0,070	√	[19]
Facilities Support System	0,183	√	[22]
Production Capacity	0,015	X	[16]
R & D	0,106	√	[20]
Technology Capability	0,334	√	[18]
Health & Safety	0,092	√	[23]
Welfare, equity & Stakeholder's right	0,060	√	[23]
Social assistance community	0,061	√	[23]

Disaster prone	0,289	√	[24]
Unrest social, economy & politic	0,075	√	[25]
Legality	0,012	X	[16]
Pollutant	0,371	√	[26]
Green Competence	0,378	√	[14]

In five iterations of KMO-MSA processing, the results obtained that meet the factor analysis. Tables 2 and 3 show a summary of the factor analysis results. It can be concluded from Figures 2 and 3 that the outcomes of factor analysis are the four primary factors or main criteria. The first main criteria consist of flexibility, location, organization and management, and social assistance community. The second main criteria consist of Accessibility, HRD, Production Planning, and Facilities Support System. The third main criteria consist of Reputation & Experience, Disaster Prone, Technology Capability, and Green Competence. The fourth major criterion consists of relationships.

Table 2. Explained of total variance.

Criteria	Initial of value eigen			Squared loadings extraction sums	
	Total	*% of Var.*	*Cum. %*	Total	*% of Var.*
1	4,84	37,26	37,268	4,84	37,26
2	1,83	14,14	51,409	1,83	14,14
3	1,39	10,74	62,158	1,39	10,74
4	1,23	9,46	71,618	1,23	9,46
5	,98	7,61	79,228		
6	,65	5,05	84,284		
7	,55	4,28	88,567		
8	,43	3,37	91,938		
9	,33	2,53	94,478		
10	,26	2,06	96,541		
11	,19	1,48	98,024		
12	,14	1,12	99,147		
13	,11	,853	100,00		

Table 3. Rotated component matrix(a).

Criteria	Main Criteria			
	1	2	3	4
1	0,766	-0,250	0,153	-0,056
2	0,729	-0,029	-0,275	0,338
3	-0,366	0,394	0,350	-0,213
4	0,073	-0,153	-0,107	0,911
5	-0,091	0,381	0,760	-0,015
6	0,863	-0,041	-0,114	-0,013
7	-0,139	0,778	0,224	-0,317
8	0,012	0,858	0,103	-0,011
9	-0,280	0,723	0,162	0,028
10	-0,533	0,184	0,554	-0,108
11	0,582	-0,514	-0,051	-0,343
12	0,112	0,018	0,907	-0,207
13	-0,415	0,202	0,604	0,363

A pairwise comparison matrix was created using the four main criteria and the sub-criteria. The decision maker from the research item filled in the pairwise comparison matrix (PT. Wijaya Karya Beton

Tbk). The weight of the primary criteria and the weight of the sub-criteria were calculated using AHP and the pairwise comparison matrix.

Table 5 is supplier data based on sub-criteria. This data is obtained from the supplier. Then the data is processed using equation (2) to equation (6). The weights in equation (4) are obtained from Table 4. The results of processing using these equations are Figure 1.

Table 4. The weight of the main criteria and sub criteria.

No	Main criteria	Sub criteria	Local priority	Global priority
1	A = supplier essential	A1 = flexibility	0.4984	0.21984
		A2 = location	0.2800	0.12351
		A3 = Organization and Management	0.1181	0.05209
		A4 = Social Community Assistance	0.1035	0.04567
2	B = supplier capability	B1 = accessibility	0.5132	0.15006
		B2 = HRD	0.1754	0.05127
		B3 = Production planning	0.2247	0.06571
		B4 = Facilities support system	0.0866	0.02533
3	C = supplier sustainability	C1 = Reputation and Experience	0.05127	0.01097
		C2 = Disaster prone	0.20474	0.04382
		C3 = Technology capability	0.34699	0.07426
		C4 = Green competence	0.39700	0.08496
4	D = relationship	D1 = relationship	0.05250	0.05250

Table 5. Supplier assessment.

Sub criteria	PT. ISBS	PT. MS	PT. CBS	PT.ICT
A1 = flexibility	3.44	3.25	2.77	3.73
A2 = location	0.24	0.29	0.40	0.53
A3 = Organization and Management	2.70	3.59	3.73	2.49
A4 = Social Community Assistance	2.86	3.73	2.93	2.49
B1 = accessibility	0.31	0.29	0.56	0.32
B2 = HRD	3.44	4.13	2.17	3.59
B3 = Production planning	3.59	2.70	3.95	4.13
B4 = Facilities support system	3.73	2.86	2.93	3.90
C1 = Reputation and Experience	1.78	2.77	3.73	3.78
C2 = Disaster prone	0.46	0.40	0.32	0.31
C3 = Technology capability	3.95	3.73	3.25	2.35
C4 = Green competence	2.93	2.93	3.25	2.70
D1 = relationship	4.57	4.13	3.95	3.73

4. Conclusion

Important criteria in supplier selection are the main criteria consisting of sub-criteria flexibility, location, organization and management, as well as social community assistance. The other criteria are supplier capability, supplier sustainability, and supplier relationship. The trial results of the proposed method in real conditions (concrete industry) produce consistent solutions that are faster and simple.

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