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Determining Criteria for Supplier Selection in the Indonesian Oil and Gas Industry

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Abstract

Research Aims - This research aims to identify the main criteria of supplier selection in the oil and gas industry in Indonesia and their causal relationships by using the DEMATEL method.

Methodology - Based on the literature review and discussions with experts, ten supplier selection criteria were identified and used as the basis of questionnaire development. The questionnaire was distributed to 57 respondents representing supply chain management and other divisions in eight oil and gas companies in Indonesia, with 51 valid responses. The data was analyzed using the DEMATEL method.

Research Findings - The results show that product price is the most important criterion, while technical ability was the least important criterion. Moreover, six criteria (product quality, product price, technical ability, service, production capability, and financial situation) were identified as the cause criteria and require more attention compared to the other four effect criteria (delivery performance, stable delivery of goods, lead time, and reaction to demand change in time).

Theoretical Contribution/Originality - The research provides insights on the important criteria of supplier selection in oil and gas companies in Indonesia and their causal relationships.

Managerial Implications in the Southeast Asian Context - The results can be used by oil and gas companies to better select their suppliers.

Research Limitations and Implications - This study uses a non-stratified sample from eight oil and gas companies in Indonesia, which may not accurately represent the Indonesian oil and gas industry.

Keywords - Supplier Selection, Oil and Gas Industry, DEMATEL Method, Indonesia

INTRODUCTION

The oil and gas sector plays an important role in the Indonesian economy. Back in 2017, the Indonesian Ministry of Energy and Mineral Resources established a strategy to stimulate national oil and gas investment throughout the year. According to the data from the Indonesian Statistic Bureau (BPS), in 2018, the oil, gas, and geothermal mining sector contributed about USD 21.47 Billion, or about 2.86% of the country's GDP (BPS, 2020). In order to fulfill the Indonesian Government's target quota and to generate improved state revenue, oil and gas companies operating in Indonesia need to sustain production rates by running their operations properly and preventing any unplanned shutdowns. An important decision that must be made in the operations management of a company is supplier selection (Banker & Khosla, 1995). Supplier selection has a significant role in determining a company's success as it entails a large amount of the company's financial resources (Taherdoost & Brard, 2019).

According to the current guidelines issued by the Indonesian Special Task Force for Upstream Oil and Gas Business Activities (SKKMIGAS), the supplier selection is

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evaluated in three main areas: administrative, technical, and commercial (SKKMIGAS, 2017a). The evaluation is based on the minimum requirement stated by the guidelines. However, only administrative and commercial requirements that have specific criteria and minimum acceptance are considered. The minimum acceptance criteria for technical requirements are developed based on the nature of the goods or services required by the oil and gas companies.

To ensure the fulfillment of the minimum administrative requirements, SKKMIGAS has developed a platform of supplier database called Centralized Integrated Vendor Database (CIVD) since 2016. The purpose of this database is to shorten the administrative evaluation process. In 2018, there were 9,121 suppliers registered in the CIVD, representing 40,214 business fields. Based on the CIVD, 71.87% of suppliers were qualified to participate in the tender process of the oil and gas industry in Indonesia. For the minimum commercial requirements, SKKMIGAS has stated in the regulation regarding how to perform the commercial evaluation of the suppliers' proposals. The guidelines include how to evaluate the tender proposal compared to the Owner's Estimate (OE) before the tender announcement in CIVD, the step to assess the local content, and the domestic company preference to be included in determining the qualified suppliers.

The significant issues during the tender proposal evaluation are in the minimum technical requirements of the supplier, which are the most important part as they indicate the supplier's capability to support the oil and gas company activities. Even though some general information on how to conduct the technical evaluation has been indicated in the guidelines, there is still a need from the oil and gas company's perspective to identify important criteria and understand their relationships to ensure that all the important supplier selection criteria have been properly evaluated. As there are no minimum technical requirements regulated by SKKMIGAS in the current practice, it is expected that this study will provide insights to assist the oil and gas companies in properly identifying and prioritizing the variables to be used in the supplier performance evaluation in the future.

Studies on supplier selection have been done by researchers for different industrial sectors, such as automotive (such as Mohammadi et al., 2013), electronics (such as Lin et al., 2011), and oil and gas (such as Ashtarinezhad et al., 2018) sectors. However, the criteria cannot be directly used in the Indonesian oil and gas industry due to the different regulations and conditions. As stated by Ellram (1990), the relevance of the criteria and their weight vary in different situations. This paper aims to identify the main criteria of supplier selection in oil and gas companies in Indonesia and their weight and relationships by using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. The DEMATEL method was first introduced by Gabus and Fontela in 1972. It helps reveal the cause-and-effect relationships among a system's elements (Si et al., 2018). Thus, the paper will highlight the important criteria that must be considered when selecting the suppliers of oil and gas in Indonesia and their interdependencies.

The remainder of the paper is organized as follows. Section 2 discusses relevant supplier selection literature, while Section 3 explains the research methodology (including the DEMATEL method), Sections 4 and 5 discusses findings and discussions respectively, and Section 6 presents the conclusions of this research.

LITERATURE REVIEW

As the business environment becomes more competitive, companies need to form long-term relationships with suppliers (Chan et al., 2008). Selection of appropriate suppliers will have a significant effect on strategic and operational efficiency (Solgi et al., 2019), as most organizations spend a significant amount on purchasing (Cebi & Bayraktar, 2003). Hence, supplier selection is a very important activity as it can help them reduce their operating costs and improve their competitive advantage (Saen, 2007). At the operational level, selecting suitable suppliers will reduce the product development time, improve product quality, decrease the inventory level, lower the production costs and improve flexibility (Cebi & Otay, 2016).

Supplier selection is the process of finding the most suitable supplier to buy the raw materials/items that are needed for production (Ayhan and Kilic, 2015). It is the process that involves identifying, assessing and forming contracts with suppliers (Taherdoost & Brard, 2019). According to de Boer et al. (2001), supplier selection consists of two phases, namely the pre-qualification phase (which is the process of shortlisting the number of potential suppliers) and the final choice phase (whereby companies choose the suppliers). The decision-making problem involves multiple conflicting criteria, which are both qualitative and quantitative in nature as well as imprecise and uncertain data (Ghodsypour & O'Brien, 1998; Lin et al., 2011).

Ellram (1990) suggests that supplier selection criteria may vary across different situations. However, there are three essential criteria that are usually considered by companies. These include quality, on-time delivery, and performance history. However, Verma and Pullman (1998) indicate that companies actually select suppliers based on costs and delivery performance. Other scholars, such as Li (2007), state that the selection process is usually based on well-established criteria, such as price, quality, delivery promise and service.

Based on five relevant studies, the following supplier selection criteria are identified. The studies include Ashtarinezad et al. (2018), which analyzes the supplier selection criteria in the oil and gas industry; Chang et al. (2011), which develops supplier selection criteria in the electronic industry; Mohammadi et al. (2013) that analyzes supplier selection criteria in the railway industry; Gharakhani (2012) that investigates supplier selection in the automotive industry; and Mirmousa and Dehnavi (2016) which studies supplier selection criteria for the education sector. These studies are chosen because Ashtarinezad et al. (2018) specifically explain supplier selection criteria in the oil and gas industry based on expert interviews, while the other four studies propose supplier selection criteria based on literature reviews. Hence, our selected criteria represent the ones that are mostly discussed in the literature. Initially, a total of 45 criteria are identified from the studies. After the elimination of duplication, we shortlisted 20 supplier selection criteria, which are presented in Table 1.

With respect to supplier selection methods, there are several methods that can be applied. de Boer (2001) reviewed the supplier selection method and classified them based on the supplier selection phase. In the pre-qualification phase, data envelopment analysis (DEA), cluster analysis, and case-based reasoning systems are used, while linear weighing, total cost of ownership (TCO), mathematical programming, statistical models and artificial intelligence-based models are used in the final choice phase. Wu and Olson (2008), Gheidar-Kheljani et al. (2009), and Lin et al. (2011) state that there are several methods in multi-criteria decision-making that have been applied to evaluate the supplier selection problems. These include analytic hierarchy process (AHP; Saaty,1980), analytic network process (ANP; Saaty,1990), and decision-making trial and evaluation laboratory (DEMATEL) method (Gabus & Fontela, 1972).

RESEARCH METHOD

The objective of this research is to identify the criteria of supplier selection and then determine their interdependency by using the DEMATEL method as it is very useful to reveal the relationship between criteria, including the intensity of their effects on each criterion (Seker and Zavadskas, 2017). The foundation of the DEMATEL method is graph theory. It enables the realization of causal relationships by dividing important and related issues into causes and effects (Li & Tzeng, 2009), as well as making it possible to visualize the causal relationships of criteria in the

Table 1
Supplier Selection Criteria From the Literature

No	Criteria	(Ashtarinezhad et al., 2018)	(Chang et al., 2011)	(Mohammadi et al., 2013)	(Gharakhani, 2012)	(Mirmousa & Dehnavi, 2016)
1	Possessing Quality Assurance Certificate	X				
2	After-sales Services	X				
3	Specification/Size Limit	X			X	
4	Logistic Cost			X		
5	Capability of R&D Design			X	X	X
6	Product Quality		X		X	X
7	Product Price		X	X	X	X
8	Technical Ability		X	X	X	X
9	Service		X		X	X
10	Delivery Performance		X	X	X	X
11	Stable Delivery of Goods		X		X	
12	Lead Time		X	X	X	X
13	Reaction to Demand Change in Time		X		X	X
14	Production Capability		X		X	
15	Financial Situation		X			X
16	Reputation				X	X
17	Allocation in doing tasks					X
18	Trust and Confidence					X
19	Security					X
20	Performance Evaluation					X

form of causal diagram (Yang & Tzeng, 2011; Wu & Lee, 2007; Chiu et al., 2006). The methodology is also able to verify the interdependence among the unpredictable features or attributes and reflects the interrelationship between variables by using the directed graph (Hori & Shimizu, 1999). Si et al. (2018) stipulates that the DEMATEL method offers the following advantages compared to the most commonly used methods in Multi-Criteria Decision Making (MCDM) such as Analytic Hierarchy Process (AHP), Grey Relational Analysis (GRA), technique for order performance by similarity to ideal solution (TOPSIS), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and ELimination Et Choix Traduisant la REalit´e (ELECTRE):

1. The DEMATEL method can help understand the complicated relationship between cause and effect in the decision-making problem by analyzing both direct and indirect effects effectively.
2. The DEMATEL method clearly describes the causality between elements by visualizing the interrelationships through the impact relationship map,which empowers the decision-maker with better understanding.
3. The DEMATEL method can provide more than a ranking of alternatives as it is able to identify the critical evaluation criteria and measure the impact of each criterion.

As mentioned in the literature review section, we identified 20 supplier selection criteria from previous studies. We then conducted interviews with three experts (SCM Manager with 20+ years of experience, Contract Coordinator with 15+ years of experience, and Warehouse and Material Management Coordinator with 10+ years of experience within the Indonesian oil and gas industry) to further refine the remaining criteria, which resulted in 10 criteria (see Table 2). The selection is carried out based on the relevance of the criteria with supplier selection in the oil and gas industry in Indonesia. In addition, the definitions of criteria in Table 2 are also obtained from the interview results with the above-mentioned experts.

Table 2
Selected Supplier Selection Criteria

No	Criteria	Description
A	Product quality	The supplied goods are delivered as per the specifications with no defect, proper packaging that is suitable for transportation and storage and supporting document and material certificate.
B	Product price	The supplier provides a fair and reasonable price according to the market trends and is willing to negotiate on the proposed price.
C	Technical ability	The supplier always provides the latest version of the goods according to the most advanced technology to ensure quality.
D	Service	The supplier promptly submits a quotation after receiving a request, quickly responds when a claim/problem is reported, is willing to support and share information, has a knowledgeable sales team who can accurately and courteously support the company's procurement activity.
E	Delivery performance	Goods are delivered accurately with no missing or excess items.
F	Stable delivery of goods	The supplier promptly arranges replacement delivery if a product defect or discrepancy is found.
G	Lead time	Goods are delivered to the required destination as per the date of the purchase order (PO).
H	Reaction to demand change in time	The supplier always has inventory on-hand to meet any unexpected demands.
I	Production capability	The supplier has the ability to provide the required goods as per a company's request.
J	Financial situation	The supplier has the financial capability to support the company's demand.

The survey questionnaire was developed based on this information. It consisted of two parts; the first part included questions about the importance of each criterion (to be rated on a scale of 1-4, indicating no importance, low importance, high importance, and very high importance), while the second part contained pairwise comparisons of the criteria. We used a 5-scale pairwise comparison to know whether one criterion influences another criterion (with a 0-4 scale, indicating no influence, very low influence, low influence, strong influence, and very strong influence). The questionnaire was distributed to 57 respondents from supply chain management and other divisions in eight oil and gas companies in Indonesia.

The survey results were processed using DEMATEL as follows (Shieh et al., 2010):

1. Step 1 - Creating the average matrix A

   To create the direct relation (average) matrix, we combined all the results of the pairwise comparison for each criterion into the *n x n* non-negative matrix, where *n* was the number of criteria. The responses from the respondents illustrated the degree of influence of criterion *i* in effecting criterion *j* according to their understanding. The *n x n* average matrix or average matrix *A* was computed using the following equation.

   $$\left[a_{ij}\right]_{nxn} = \frac{1}{H}\sum_{k=1}^{H}\left[x_{ij}^{k}\right]_{nxn} \quad (1)$$

   Whereby *H* is the number of respondents and x_{ij}^{k} is the pairwise comparison of criteria *i* and *j* by respondent *k*.

2. Step 2 - Normalizing the average matrix *A* to create the initial direct relation matrix *D*

   To be able to normalize the average matrix *A*, we calculated the maximum value of the total sum value of each row and each column in the average matrix *A*. The normalized initial direct relation matrix *D* was calculated using the following equation.

   $$D = \frac{A}{S} \quad (2)$$

   $$S = max\left(\max_{1\le i\le n}\sum_{j=1}^{n} x_{ij}, \max_{1\le j\le n}\sum_{i=1}^{n} x_{ij},\right) \quad (3)$$

3. Step 3 - Calculating the total relation matrix *T*

   After obtaining the initial direct relation matrix *D*, we calculated the total relation matrix *T* using the following formula:

   $$T = D + D^2 + D^3 ... D^m = \sum_{m=1}^{\infty} D^i \quad (4)$$

   $$T=D(I-D)^{-1} \quad (5)$$

   Whereas:

   I: Identity matrix

   T: Total relation matrix $T([T]_{nxn})$

The next step was to calculate the sum of rows and sum of columns of the total relation matrix T according to the following formula:

$$[r_i]_{nx1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{nx1} \quad (6)$$

$$[c_j]_{1xn} = \left(\sum_{i=1}^{n} t_{ij}\right)_{1xn} \quad (7)$$

$[r_i]_{nx1}$ demonstrates the total effects, both direct and indirect, given by criterion i to the other criteria $j = 1, 2, \ldots, n$. Similarly, $[c_j]_{1xn}$ represents the total effects (direct and indirect) received by criterion j from the other criteria $i = 1, 2, \ldots, n$.

The value of (r_i+c_j) is the centrality, which indicates the strength of the influence among criteria. A higher value means that criterion i shows a stronger influence in the system. The value of (r_i-c_j) is the degree of causality; a positive value means criterion i is the cause of other criteria, and a negative value means criterion i is the effect of other criteria.

4. Step 4 – Creating a causal digraph

   Based on the Total Relation Matrix T, the causal relationship among the criteria was developed. The dataset of $((r_i+c_j),(r_i-c_j))$ was mapped on a cartesian graph to create the causal digraph.,

5. Step 5 – Calculating the weight of all criteria (see Kobryn,2017)

   $$rc_i^{average} = \tfrac{1}{2}\left(\left(r_i + r_j\right) + \left(r_i - r_j\right)\right) \quad (8)$$

   The normalized weight for each criterion is calculated as follows.

   $$w_i = \frac{rc_i^{average}}{\Sigma_{i=1}^{n} rc_i^{average}} \quad (9)$$

6. Step 6 – Creating the inner dependence matrix and impact relationship map

   Since Matrix T provides information on how one factor affects another, the threshold value was determined by computing the average elements in Total Relation Matrix T. After eliminating the value which effects lower than the threshold, the inner dependence matrix was determined by implementing the following conditions:

   If t_{ij}=0, it means that criterion i does not have any effect on criterion j. Based on this, the causal effect between each pair of criteria was visualized by drawing an impact relationship map based on the inner dependence matrix.

RESULTS

The questionnaire was distributed to 57 respondents from supply chain management and other divisions in eight oil and gas companies in Indonesia. However, responses from only 51 companies were considered valid. The profile of the respondents is described in Figure 1. The majority of the respondents (55%) were in the junior management level, had a bachelor's degree (69%), with more than five years of working experience (84%). Most of them (72%) were between the ages of 30-49 years, and 39% of them were from the Supply Chain Management Department in their respective companies. 73% of the respondents worked at companies with 101-500 employees

We averaged the importance level of the ten selected criteria from the 51 respondents. The results are presented in Table 3. As per the results, product quality had the highest importance level (3.94), while product price had the least importance level (3.31).

The results of pairwise comparisons of the criteria were analyzed using the DEMATEL method. The result of Step 1 (Average Matrix *A*, found by applying Equation 1) is presented in Table 4, while the result of Step 2 (Direct Relation Matrix *D*), found by applying Equations 2 and 3) is presented in Table 4. The letters A to J in Tables 5 to 9 and in Figure 1 refer to the criteria in Table 3.

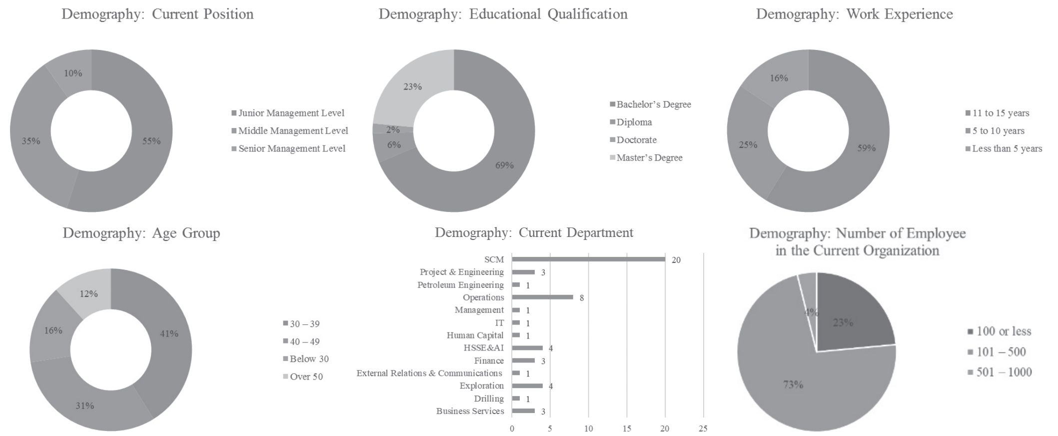

Figure 1
Respondent Profile

Table 3
The Importance Level of Criteria

	Average Value	Ranking
A. Product quality	**3.94**	1
E. Delivery performance	**3.79**	2
D. Service	**3.69**	3
F. Stable delivery of goods	**3.65**	4
G. Lead time	**3.60**	5
I. Production capability	3.35	6
C. Technical ability	3.33	7
H. Reaction to demand change in time	3.33	8
J. Financial situation	3.33	9
B. Product price	3.31	10

Table 4.
Average Matrix *A*

A =

	A	B	C	D	E	F	G	H	I	J
A	0.0000	3.5098	3.2549	3.1961	3.0784	3.0000	3.0588	2.8627	3.1569	3.1569
B	3.5490	0.0000	3.3333	3.2745	3.2941	3.1569	3.0392	2.9020	3.0980	3.0784
C	3.2745	3.3529	0.0000	2.9216	2.6471	2.7843	2.8235	2.8627	3.0000	2.9412
D	3.3333	3.3137	2.8627	0.0000	3.4314	3.3333	3.2745	3.0784	3.0392	2.9412
E	2.8039	3.1569	2.8431	3.3333	0.0000	3.3137	3.4314	3.2549	3.0980	2.9020
F	2.7843	2.9608	2.5490	3.2157	3.5098	0.0000	3.3333	3.1961	3.0392	2.8235
G	2.8235	3.0196	2.8235	3.2549	3.4902	3.3333	0.0000	3.1176	3.1569	2.8235
H	2.9608	3.0000	2.8431	3.0588	3.0980	3.1373	3.1765	0.0000	2.9804	2.8824
I	3.2941	3.1765	3.1373	3.0000	3.1176	3.0196	3.1373	3.0196	0.0000	2.9020
J	3.0392	3.2157	2.9412	3.0392	2.9608	2.9804	2.9412	2.9804	3.1961	0.0000

Tables 6 to 8 depict matrices in Step 3 (found by applying Equation 5). Specifically, Table 6 presents Matrix (*I-D*), while Table 7 depicts the inverse of Matrix (*I-D*), and Table 8 is the Total Relation Matrix *T* with the sum of rows and the sum of columns computed using Equations 6 and 7, denoted as *r* and *c*.

In Step 4, in order to create the causal digraph, the average of the elements in Ma-

		A	B	C	D	E	F	G	H	I	J
	A	0.0000	0.1222	0.1133	0.1113	0.1072	0.1044	0.1065	0.0997	0.1099	0.1099
	B	0.1235	0.0000	0.1160	0.1140	0.1147	0.1099	0.1058	0.1010	0.1078	0.1072
	C	0.1140	0.1167	0.0000	0.1017	0.0922	0.0969	0.0983	0.0997	0.1044	0.1024
	D	0.1160	0.1154	0.0997	0.0000	0.1195	0.1160	0.1140	0.1072	0.1058	0.1024
D =	E	0.0976	0.1099	0.0990	0.1160	0.0000	0.1154	0.1195	0.1133	0.1078	0.1010
	F	0.0969	0.1031	0.0887	0.1119	0.1222	0.0000	0.1160	0.1113	0.1058	0.0983
	G	0.0983	0.1051	0.0983	0.1133	0.1215	0.1160	0.0000	0.1085	0.1099	0.0983
	H	0.1031	0.1044	0.0990	0.1065	0.1078	0.1092	0.1106	0.0000	0.1038	0.1003
	I	0.1147	0.1106	0.1092	0.1044	0.1085	0.1051	0.1092	0.1051	0.0000	0.1010
	J	0.1058	0.1119	0.1024	0.1058	0.1031	0.1038	0.1024	0.1038	0.1113	0.0000

Table 5
Direct Relation Matrix *D*

		A	B	C	D	E	F	G	H	I	J
	A	1.0000	-0.1222	-0.1133	-0.1113	-0.1072	-0.1044	-0.1065	-0.0997	-0.1099	-0.1099
	B	-0.1235	1.0000	-0.1160	-0.1140	-0.1147	-0.1099	-0.1058	-0.1010	-0.1078	-0.1072
	C	-0.1140	-0.1167	1.0000	-0.1017	-0.0922	-0.0969	-0.0983	-0.0997	-0.1044	-0.1024
	D	-0.1160	-0.1154	-0.0997	1.0000	-0.1195	-0.1160	-0.1140	-0.1072	-0.1058	-0.1024
(I-D)=	E	-0.0976	-0.1099	-0.0990	-0.1160	1.0000	-0.1154	-0.1195	-0.1133	-0.1078	-0.1010
	F	-0.0969	-0.1031	-0.0887	-0.1119	-0.1222	1.0000	-0.1160	-0.1113	-0.1058	-0.0983
	G	-0.0983	-0.1051	-0.0983	-0.1133	-0.1215	-0.1160	1.0000	-0.1085	-0.1099	-0.0983
	H	-0.1031	-0.1044	-0.0990	-0.1065	-0.1078	-0.1092	-0.1106	1.0000	-0.1038	-0.1003
	I	-0.1147	-0.1106	-0.1092	-0.1044	-0.1085	-0.1051	-0.1092	-0.1051	1.0000	-0.1010
	J	-0.1058	-0.1119	-0.1024	-0.1058	-0.1031	-0.1038	-0.1024	-0.1038	-0.1113	1.0000

Table 6
Matrix (*I-D*)

		A	B	C	D	E	F	G	H	I	J
	A	3.9579	3.1468	2.9375	3.1015	3.1324	3.0738	3.0907	2.9936	3.0474	2.9211
	B	3.1094	4.0806	2.9795	3.1460	3.1811	3.1202	3.1323	3.0356	3.0872	2.9586
	C	2.9023	2.9801	3.6844	2.9333	2.9579	2.9084	2.9239	2.8384	2.8854	2.7643
	D	3.0938	3.1744	2.9572	4.0344	3.1759	3.1161	3.1298	3.0317	3.0763	2.9458
$(I-D)^{-1}$ =	E	3.0329	3.1225	2.9123	3.0916	4.0220	3.0694	3.0878	2.9916	3.0321	2.9006
	F	2.9645	3.0475	2.8390	3.0197	3.0616	3.8979	3.0166	2.9237	2.9631	2.8339
	G	3.0057	3.0902	2.8852	3.0613	3.1019	3.0420	3.9530	2.9606	3.0062	2.8720
	H	2.9425	3.0207	2.8215	2.9876	3.0217	2.9686	2.9844	3.7966	2.9343	2.8096
	I	3.0149	3.0904	2.8903	3.0496	3.0866	3.0284	3.0467	2.9532	3.9028	2.8702
	J	2.9604	3.0428	2.8393	3.0026	3.0336	2.9796	2.9932	2.9057	2.9558	3.7332

Table 7
Matrix $(I-D)^{-1}$

		A	B	C	D	E	F	G	H	I	J	r
	A	2.9579	3.1468	2.9375	3.1015	3.1324	3.0738	3.0907	2.9936	3.0474	2.9211	**30.4028**
	B	3.1094	3.0806	2.9795	3.1459	3.1811	3.1202	3.1323	3.0356	3.0872	2.9586	**30.8305**
	C	2.9023	2.9801	2.6844	2.9333	2.9579	2.9084	2.9239	2.8384	2.8854	2.7643	**28.7784**
	D	3.0938	3.1743	2.9572	3.0344	3.1759	3.1161	3.1298	3.0317	3.0763	2.9458	**30.7353**
T =	E	3.0329	3.1225	2.9124	3.0916	3.0220	3.0694	3.0878	2.9916	3.0321	2.9007	**30.2630**
	F	2.9645	3.0475	2.8390	3.0197	3.0616	2.8979	3.0166	2.9237	2.9631	2.8339	**29.5675**
	G	3.0057	3.0902	2.8852	3.0613	3.1019	3.0419	2.9530	2.9606	3.0062	2.8720	**29.9780**
	H	2.9425	3.0207	2.8215	2.9876	3.0218	2.9686	2.9844	2.7966	2.9343	2.8096	**29.2875**
	I	3.0149	3.0904	2.8903	3.0496	3.0865	3.0284	3.0467	2.9532	2.9028	2.8702	**29.9331**
	J	2.9604	3.0428	2.8393	3.0026	3.0336	2.9796	2.9932	2.9057	2.9558	2.7332	**29.4461**
c		**29.9843**	**30.7960**	**28.7462**	**30.4276**	**30.7747**	**30.2044**	**30.3584**	**29.4307**	**29.8906**	**28.6093**	

Table 8
Total Relation Matrix T With Additional *r* and *c* Column

trix T is calculated and considered as the threshold value (Si et al., 2018), which in this case is 2.9922. Based on Table 8, we construct Table 9 that contains the calculation of (r_i+c_j), (r_i-c_j), and the weights of all criteria (using Equations 8 and 9). We mapped the dataset of (r_i+c_j), (r_i-c_j) as depicted in Figure 2, and constructed the inner dependence matrix by eliminating the supplier selection criteria that have a lower effect than the average value of Total Relation Matrix T. The average value of matrix T is 2.9922. The Inner Dependence Matrix is shown in Table 10. Based on this, the impact relationship map is developed in Figure 3.

Table 9 shows that product price has the highest strength of influence over other criteria with a value of centrality of 61.6265, while technical ability shows the lowest strength of influence over other criteria, with a value of centrality of 57.5245. The results are in line with the weights, whereby the weights of all criteria are more or

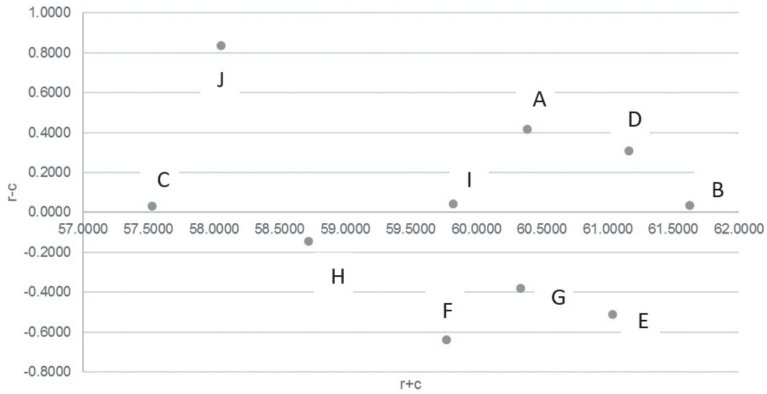

Figure 2
Causal Digraph

Table 9
Calculation of (r_i+c_j), (r_i-c_j), and the Weights

Dimensions	*r*	*c*	Centrality (*r*+*c*)	Degree of Causality (*r*-*c*)	Weights	Rank of Centrality	Cause/ Effect
A. Product Quality	30.4028	29.9843	60.3871	0.4185	0.1016	4	Cause
B. Product Price	30.8305	30.796	**61.6265**	0.0345	**0.1030**	1	Cause
C. Technical Ability	28.7784	28.7462	57.5245	0.0322	0.0962	10	Cause
D. Service	30.7353	30.4276	61.1629	0.3077	0.1027	2	Cause
E. Delivery Performance	30.2630	30.7747	61.0377	-0.5117	0.1011	3	Effect
F. Stable Delivery of Goods	29.5675	30.2044	59.7719	-0.6369	0.0988	7	Effect
G. Leadtime	29.9780	30.3584	60.3364	-0.3804	0.1002	5	Effect
H. Reaction to Demand Change in Time	29.2875	29.4307	58.7182	-0.1432	0.0979	8	Effect
I. Production Capability	29.9331	29.8906	59.8237	0.0425	0.1000	6	Cause
J. Financial Situation	29.4461	28.6093	58.0554	**0.8368**	0.0984	9	Cause

Table 10
Inner Dependence Matrix

	A	B	C	D	E	F	G	H	I	J
A	0.0000	3.1468	0.0000	3.1015	3.1324	3.0738	3.0907	2.9936	3.0474	0.0000
B	3.1094	3.0806	0.0000	3.1459	3.1811	3.1202	3.1323	3.0356	3.0872	0.0000
C	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D	3.0938	3.1743	0.0000	3.0344	3.1759	3.1161	3.1298	3.0317	3.0763	0.0000
E	3.0329	3.1225	0.0000	3.0916	3.0220	3.0694	3.0878	0.0000	3.0321	0.0000
F	0.0000	3.0475	0.0000	3.0197	3.0616	0.0000	3.0166	0.0000	0.0000	0.0000
G	3.0057	3.0902	0.0000	3.0613	3.1019	3.0419	0.0000	0.0000	3.0062	0.0000
H	0.0000	3.0207	0.0000	0.0000	3.0218	0.0000	0.0000	0.0000	0.0000	0.0000
I	3.0149	3.0904	0.0000	3.0496	3.0865	3.0284	3.0467	0.0000	0.0000	0.0000
J	0.0000	3.0428	0.0000	3.0026	3.0336	0.0000	2.9932	0.0000	0.0000	0.0000

less the same, in the range of 0.0962 to 0.1030, where product price has the highest weight, and technical ability has the lowest weight. Table 9 and Figure 2 also reveal that the six criteria consist of product quality, product price, technical ability, service, production capability, and financial situation are the causes of other criteria, while the criteria of delivery performance, stable delivery of goods, lead time, and reaction to demand change in time are the effects of other criteria.

Discussion

As outlined in Table 3, five criteria have an importance level of more than 3.5, namely, product quality, delivery performance, service, stable delivery of goods, and lead time. The results are somewhat similar to Chang et al. (2011), in which product quality, service, and stable delivery of goods also had an importance level of more than 3.5. The results indicate that the respondents feel that the five criteria are the most important supplier selection criteria in the oil and gas industry as these criteria ensure that the procured goods and services are of high quality and delivered in the right quantity and at the right time, thus ensuring a smooth operation.

However, when considering the role of each criterion, the survey results in Table 9 show that product price has the highest centrality, or the highest total of influences (dispatch and received from other criteria). This is similar to what is stated by Lin et al. (2011) that price is the main reason behind supplier selection as cost reduction is still a key factor underlying this decision. The results also support Li (2007) that states supplier selection is mainly conducted based on price, quality, and service. In terms of the Indonesian oil and gas industry, it shows that in current practice, the price of the product is still considered the most important criterion when selecting a supplier to support operational activities. It is also aligned with the regulation of SKKMIGAS, whereby price is the defining factor of the tender winner (SKKMIGAS, 2017b).

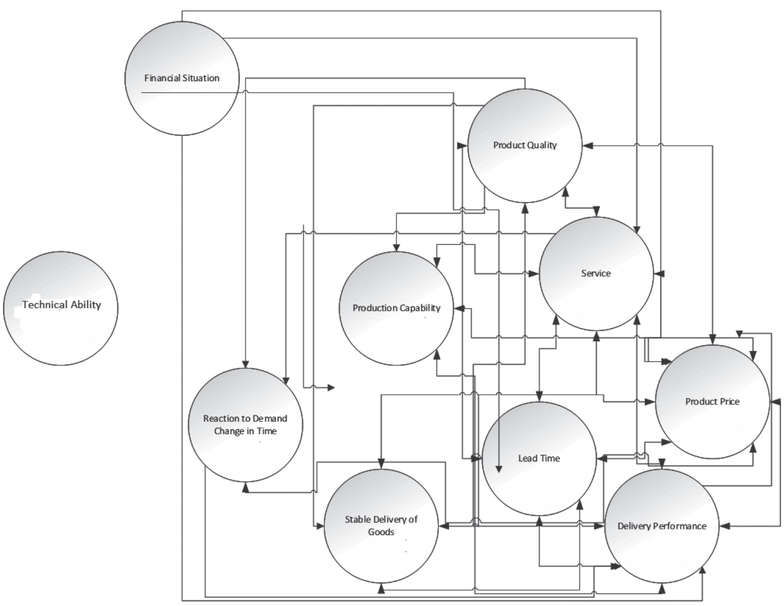

Figure 3
The Impact Relationship
Map

Table 9 also shows that six criteria (product quality, product price, technical ability, service, production capability, and financial situation) are categorized as the causes of other criteria (delivery performance, stable delivery of goods, lead time, and reaction to demand change in time), with financial situation having the highest degree of causality. The results are different from Chang et al. (2011), in which financial situation is classified as the effect criterion. This is maybe due to the difference in the research context. Chang et al. (2011) analyzed supplier selection criteria in the electronic industry, where suppliers do need to have large capital to supply products to manufacturers. However, the oil and gas industry utilizes large-scale and complex equipment. Therefore, the suppliers must have sufficient financial resources to ensure a smooth procurement process. Also, Figure 3 indicates that financial situation affects four other criteria, namely, product price, service, delivery performance and lead time. However, this criterion is not affected by the other criteria. This means that financial situation plays an important role in ensuring good supplier performance as suppliers who are financially sound are more likely to guarantee competitive price, good service and delivery performance, and will supply products with acceptable lead time.

Figure 3 also shows that product price, as the most important criterion, affects and is affected by product quality, service, delivery performance, stable delivery of goods, lead time, reaction to demand change in time, and production capability. This result is in line with Li (2007) and indicates that the combination of good product price and the aforementioned criteria will increase the supplier performance in service execution that can lead to better operational performance.

However, Figure 3 also reveals that the technical ability criterion is not connected to other criteria. It means that even though it is a cause criterion, its influence on other criteria is not significant (below the threshold). This is because, in the Indonesian oil and gas industry, the ability of the suppliers in terms of technology is distributed equally. There are currently no major suppliers that are technologically dominant in the Indonesian oil and gas industry.

In addition, other cause criteria, product quality, service and production capability, need more attention in supplier selection due to their relationship with other criteria. Summarizing the results, a detailed evaluation of product quality, product price, technical ability, service, production capability, and financial situation could have an impact on supplier performance.

Managerial Implications in the South East Asian Context

This study provides empirical evidence of supplier selection criteria and their interrelationships in the Indonesian oil and gas industry that can help companies to better select their suppliers. The results imply that oil and gas companies should pay more attention to the cause criteria to ensure better supplier performance. These results can be used by SKKMIGAS to determine the minimum acceptance criteria for the technical requirements for supplier selection.

Theoretical Implications

This study shows further evidence of the applicability of the DEMATEL method to support multi-criteria decision making. Results of this study also strengthen previous findings related to supplier selection, in which price, quality and service are the main considerations. However, this study also provides new insight that in an industry with large capital investment, the suppliers' financial condition needs to be closely monitored as it can affect other important aspects, such as product price, service, delivery performance, and lead time.

CONCLUSION

This paper aimed to identify the main criteria of supplier selection in the Indonesian oil and gas companies. Based on literature review and interviews with SCM practitioners, ten supplier selection criteria were identified: product quality, product price, technical ability, service, delivery performance, stable delivery of goods, lead time, reaction to demand change in time, production capability, and financial situation.

An evaluation of the identified supplier selection criteria was conducted using the DEMATEL method with 51 respondents. The results indicate that product price is the most important criterion with a value of centrality of 61.6265, while technical ability is the least important criterion with a value of 57.5245. The results also show that six supplier selection criteria (product quality, product price, technical ability, service, production capability, and financial situation) are the causes and require more attention compared to the four effects (delivery performance, stable delivery of goods, lead time, and reaction to demand change in time) as the causes impact supplier performance when carrying out their services.

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