

## Model Development of Procurement Performance Measurement on EPC Contractor by Using Bayesian Network Modelling

Bimbi Suharyanti<sup>1</sup>, Suparno<sup>2</sup>

<sup>1,2,3</sup>*Department of Industry Management, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia*  
*Corresponding Author: Bimbi Suharyanti*

**Abstract:** In engineering, procurement, and construction (EPC) business process, procurement process is a process that greatly influences the success of getting projects and completing projects that have been acquired in addition to the engineering, construction and commissioning processes. To find out whether a procurement organization in EPC contractors has performed its function properly, a method of performance measurement is needed by establishing Key Performance Indicator and by performing performance measurements on predetermined indicators. The method used is Bayesian Network Modelling by selecting experts as respondents for the questionnaire, determining the Key Performance Indicator, collecting data and forming cycles and links between nodes so that the Bayesian Network Modelling construction is formed. The next step is calculating the probability of each node which can then form a performance measurement model, and a suitability test was done by using the chi-square test.

The result of the model development was that the procurement performance measurement based on the Key Performance Indicator was good with a percentage of 52.06% with the largest influence of Tender Support node with a probability of 0.70 or having a percentage of 70% in influencing the procurement performance measurement. On the other hand, the relation to the external viewpoint influenced the procurement performance measurement was not good that was as much as 60.29%, with the greatest influence of nodes regarding the company's web maximized for integrated procurement and accelerating the procurement process had a probability of 0.60 or has a percentage of 60% in influencing procurement performance measurement which was not good. The model suitability test by using the chi-square test can be concluded that Bayesian Network model on Key Performance Indicator corresponded to the significance level of 0.184 and Bayesian Network model on Key Result Indicator was in accordance with the significance level of 0.852.

**Keywords:** EPC, Procurement, Key Performance Indicator, Key Result Indicator, Bayesian Network Modelling.

Date of Submission: 13-01-2019

Date of acceptance: 29-01-2019

### I. INTRODUCTION

Engineering, Procurement and Construction (EPC) project is a process-based project with the scope of responsibility for Engineering, Procurement and Construction activities carried out by contractors. The contractors are responsible for completing the project in accordance with the technical and performance specifications set by the project owner (Hosen, 2007). In EPC business process, the procurement process is a process that greatly influences the success of getting a project and completing a project that has been obtained in addition to the process of engineering, construction and commissioning. To find out whether a Procurement organization in EPC Contractors has performed its function properly, a method of performance measurement is needed by establishing a Key Performance Indicator and performing measurements of performance on predetermined indicators. Currently, the EPC Procurement Department of PT. X already has a Key Performance Indicator, but the Key Performance Indicator that currently exists has undergone many changes and still has many weaknesses that the determination of Key Performance Indicator has not used a proven method or frame works, the Key Performance Indicator has not been able to categorize the staff procurement expertise level (scale), lack of measurable parameters as procurement performance indicators, and lack of an integrated approach to the procurement process.

The methods used in performance measurement research have evolved, including Data Envelopment Analysis (DEA), cluster analysis, categorical models, linear weighting models, Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), and Bayesian Network (BN). However, the BN method so far is a method that is close to suitability in the case of performance measurement because the method adopts a modeling approach to achieve procurement excellence and replace other popular classical models, as in the study of Abolbashari et al. (2017) with the method approach used can present the Smart Buyer framework

proposed based on the BN model that is able to capture and integrate various Key Performance Indicators with four scenarios presented to show how the proposed BN model can be used further for analysis and decision making in organization.

In this study, the researcher presented how the Key Performance Indicator of Procurement division organization is planned, determined, and measured by using Bayesian Network (BN) Modeling. The performance measurement results were expected to be able to know the overall performance of the organization, which performance needed to be improved, produce recommendations and policies, and the Key Performance Indicator will be used as the official Key Performance Indicator of EPC Procurement Department of PT. X.

## II. METHODOLOGY

This research was conducted through four stages. The first stage was the preparation stage including the problem identification process, literature study, and problem formulation by determining the objectives of the research based on the background of the problem. The second stage was the stage of data collection including determining the type of research data, making observations of respondents, and distributing questionnaires. The third stage was the data analysis phase which consists of recapitulation of questionnaire data, model building, and model suitability test with chi-square test by using Minitab 17 software. For model development, it is done by forming a cycle and constructing Bayesian Network Modelling, calculating the probability of each node and conditional probability using Bayes theorem, and model formation by using Bayes Server software. The formula used in Bayes theorem is as follows:

$$P(A|B)P(B) = P(A, B) = P(B|A)P(A) \tag{1}$$

Where  $P(A, B)$  is Joint Probability Distribution (JPD)  $A$ ,  $P(A|B)$  is the joint probability of events  $A$  and  $B$  or Conditional Probability  $A$ . By dividing both sides with  $P(B)$  or Prior Probability  $B$ , the following formula can be obtained:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \tag{2}$$

In general, the Bayes theorem can be written as follows:

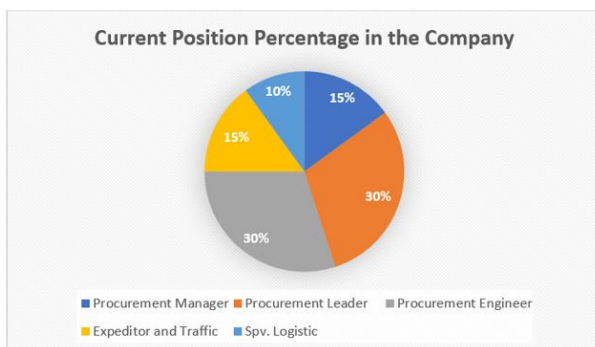
$$P(A_i|B) = \frac{P(B|A_i)P(A_i)}{\sum P(B|A_i)P(A_i)} \tag{3}$$

The fourth stage was the stage of model interpretation of the model that has been formed and conclusion.

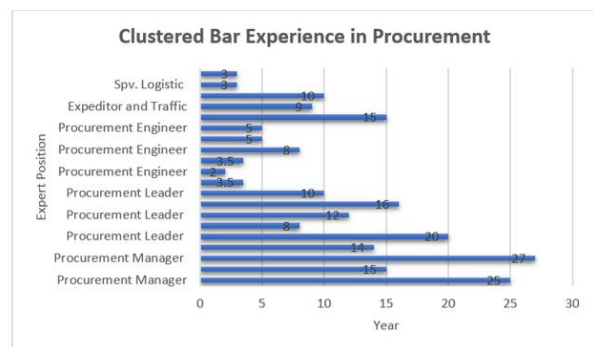
## III. RESULT

### Formulation of Key Performance Indicator, Key Result Indicator, and Expert Identification

This study used questionnaires as the research instrument that were delivered directly to the respondents or, in this study, were called as experts. The indicators listed in the questionnaire consist of 10 indicators that form the Key Performance Indicator and 10 indicators related to the external point of view that forms the Key Result Indicator. The experts in this study were employees of the EPC Procurement Department of PT. X who had experience in EPC Procurement on Purchasing & Sub-Contracting (PSC) sub-division or Procurement Planning & Control (PPC) for at least 2 years and handled a project running and/or tenders. The number of experts in this study were 20 people. The identification of the experts was based on their current position in the company and their experience in procurement with the grouping of positions in the company at the time the research was conducted that can be seen through the pie chart and clustered bar as follows.



**Figure no 1:** Current Position Percentage in the Company



**Figure no 2:** Clustered Bar Experience in Procurement

### Data Analysis

The data collected was obtained from distributing questionnaires to the experts to combine knowledge from various expertise used in the elicitation process and developing a single level of confidence for certain BN

nodes. There were as many as 10 Key Performance Indicators which were used as data for determining Procurement performance measurements that included three major groups, namely system development, human resource development, and services. After the recapitulation of the indicators chosen by the experts, then the next selection of indicators with opportunities 0.5 or more was based on the contents of the questionnaires chosen to be considered as the measurement of Procurement performance.

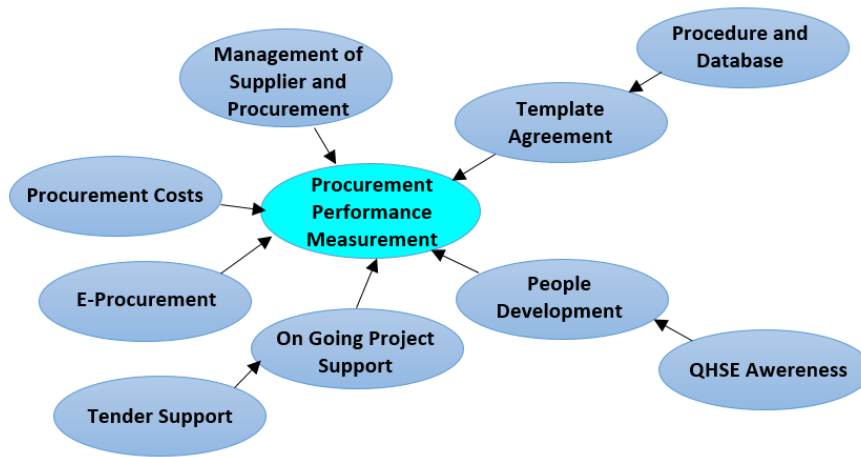
**Table no 1:** Key Performance Indicator Score Summary Table selected by the Experts

Key Performance Indicator	Expert																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<b>1. System Development</b>																				
<b>1.1. Procedure and Database</b>	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1
Procurement Procedure																				
Work Instruction																				
VAL/SAL																				
Planning procurement documentation																				
<b>1.2. Template Agreement</b>	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1
Purchase Order Agreement (POA)																				
Sub-Contract Agreement (SCA)																				
<b>2. Human Resource Development</b>																				
<b>2.1. People Development</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
FGDP Recruitment																				
FGDP Mentoring																				
Procurement staff capability																				
Promotion Lv.2 Project																				
Coffe Morning																				
<b>2.2. QHSE Awareness</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Safety Moment																				
Quality																				
<b>3. Services</b>																				
<b>3.1. Maverick Procurement dan Portofolio</b>	1	1	1	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0
Maverick Procurement																				
Portofolio Procurement																				
<b>3.2. Procurement Costs</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Price transparency																				
Costs																				
Value of money																				
<b>3.3. Management of Supplier and Procurement</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Supplier Management																				
Procurement Management																				
Supplier selection																				
<b>3.4. E-Procurement</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Implementation																				
E-Procurement system and Paperless																				
<b>3.5. Tender Support</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Procurement Representative																				
Price Sourcing																				
Price Competitiveness																				
<b>3.6. On Going Project Support</b>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Procurement Planning																				
Procurement Representative																				
Procurement Integrity																				
Inventory Control																				
Custom Clearance Assistance																				
Efficient																				
Effective																				
Time of procurement cycle																				
Urgent procurement																				
Sustainable procurement																				
Centralized procurement decision making																				
Procurement transparency																				
Customer satisfaction																				
Supplier satisfaction																				
Forecasting																				

Based on Table no 1, indicator 3.1. Maverick Procurement and Portofolio were eliminated and not included in the subsequent data processing because they did not match the opportunity criteria 0.5 or more based on the questionnaire result.

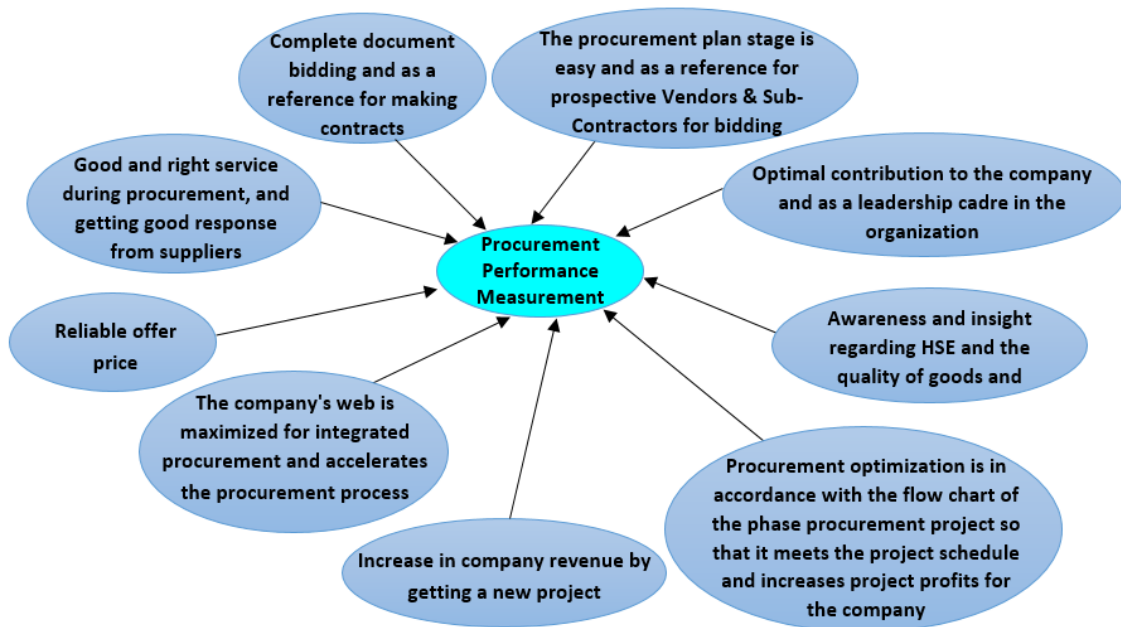
**The Establishment of Bayesian Network Modelling Cycle and Construction**

The relationship between nodes were formed based on the previous research or prior knowledge related to the indicators used as measurements of Procurement performance. All indicators that have been chosen by the experts and become final sets of Key Performance Indicators and final set of Key Result Indicators then became nodes that have correlations so that they can be said to be interconnected by ignoring the strength of the relationship between indicators.



**Figure no 3:** Acyclic Graph of Key Performance Indicator and Procurement Performance Measurement

Based on Figure no 3, Directed Acyclic Graph (DAG) was formed or can be called as an acyclic graph that can connect links between nodes. All these node pairs have been considered against the Procurement performance measurement. The pair of nodes that have formed a link can form a BN construction. Likewise with the indicators found in the Key Result Indicator, the node relationship found in the Key Result Indicator also formed a DAG that connected it to the Procurement performance measurement.



**Figureno 4:** Acyclic Graph of Key Result Indicator and Procurement Performance Measurement

The acyclic graph in Figure no 4 connects each Key Result Indicator in each Key Performance Indicator, which can be explained that the linkages in the external viewpoint in procurement performance directly influenced the Procurement performance measurement. The linkage of external viewpoints of performance indicators can produce judgments that affect whether the Procurement performance measurement is good.

**Calculating the Probability of Each Node**

Calculating the probability of each node was done to determine the probability of a joint occurrence for all possible values contained in a variable, including the probability of linking the prior probability results of the Key Performance Indicator and Key Result Indicator.

**Table no 2:** Probability Table for Each Node in the Key Performance Indicator

Key Performance Indicator	Prior Probability	Frequency	Probability	Key Performance Indicator	Prior Probability	Frequency	Probability
<b>1. System Development</b>				<b>3. Services</b>			
1.1. Procedure and Database	Low	2	0.11	3.2. Procurement Costs	Low	6	0.30
	Medium	4	0.22		Medium	6	0.30
	High	12	0.67		High	8	0.40
	<b>Total</b>	<b>18</b>	<b>1</b>		<b>Total</b>	<b>20</b>	<b>1</b>
1.2. Template Agreement	Low	3	0.17	3.3. Management of Supplier and Procurement	Low	12	0.60
	Medium	6	0.33		Medium	6	0.30
	High	9	0.50		High	2	0.10
	<b>Total</b>	<b>18</b>	<b>1</b>		<b>Total</b>	<b>20</b>	<b>1</b>
<b>2. Human Resource Development</b>							
2.1. People Development	Low	8	0.42	3.4. E-Procurement	Low	15	0.75
	Medium	6	0.32		Medium	3	0.15
	High	5	0.26		High	2	0.10
	<b>Total</b>	<b>19</b>	<b>1</b>		<b>Total</b>	<b>20</b>	<b>1</b>
2.2. QHSE Awareness	Low	5	0.26	3.5. Tender Support	Medium	6	0.30
	Medium	12	0.63		High	14	0.70
	High	2	0.11		<b>Total</b>	<b>20</b>	<b>1</b>
	<b>Total</b>	<b>19</b>	<b>1</b>		3.6. On Going Project Support	Low	7
			Medium	6		0.30	
			High	7		0.35	
			<b>Total</b>	<b>20</b>		<b>1</b>	

While the probability calculation table for each node on the Key Result Indicator, can be seen as follows:

**Table no 3:** Calculation of Probability of Each Node on Key Result Indicator

Key Performance Indicator	State of Key Result Indicator	Key Result Indicator	Frequency	Probability
<b>1. System Development</b>				
1.1. Procedure and Database	The procurement plan stage is easy and as a reference for prospective Vendors & Sub-Contractors for bidding.	Low	3	0.17
		Medium	6	0.33
		High	9	0.50
		<b>Total</b>	<b>18</b>	<b>1</b>
1.2. Template Agreement	Complete document bidding and as a reference for making contracts.	Low	2	0.12
		Medium	8	0.44
		High	8	0.44
		<b>Total</b>	<b>18</b>	<b>1</b>
<b>2. Human Resource Development</b>				
2.1. People Development	Optimal contribution to the company and as a leadership cadre in the organization.	Low	6	0.31
		Medium	10	0.53
		High	3	0.16
		<b>Total</b>	<b>19</b>	<b>1</b>
2.2. QHSE Awareness	Awareness and insight regarding HSE and the quality of goods and services.	Low	4	0.21
		Medium	13	0.68
		High	2	0.11
		<b>Total</b>	<b>19</b>	<b>1</b>
<b>3. Services</b>				
3.2. Procurement Costs	Reliable offer price.	Low	5	0.25
		Medium	9	0.45
		High	6	0.30
		<b>Total</b>	<b>20</b>	<b>1</b>
3.3. Management of Supplier and Procurement	Good and right service during procurement, and getting good response from suppliers.	Low	9	0.45
		Medium	10	0.50
		High	1	0.05
		<b>Total</b>	<b>20</b>	<b>1</b>
3.4. E-Procurement	The company's web is maximized for integrated procurement and accelerates the procurement process.	Low	12	0.60
		Medium	6	0.30
		High	2	0.10
		<b>Total</b>	<b>20</b>	<b>1</b>
3.5. Tender Support	Increase in company revenue by getting a new project.	Medium	12	0.60
		High	8	0.40
		<b>Total</b>	<b>20</b>	<b>1</b>
3.6. On Going Project Support	Procurement optimization is in accordance with the flow chart of the phase procurement project so that it meets the project schedule and increases project profits for the company.	Low	3	0.15
		Medium	10	0.50
		High	7	0.35
		<b>Total</b>	<b>20</b>	<b>1</b>

Next is calculating Conditional Probability for each node that was affected by other nodes, including Template Agreement affected by Procedure and Database as system development, People Development was affected by QHSE Awareness as human resource development, and On Going Project Support was affected by Tender Support as services in procurement performance measurement.

**Table no 4:** Conditional Probability Template Agreement

Key Performance Indicator		Freq.	Probability
Procedure and Database	Template Agreement		
Low	Low	0	0
Low	Medium	2	1
Low	High	0	0
Medium	Low	0	0
Medium	Medium	3	0.75
Medium	High	1	0.25
High	Low	3	0.25
High	Medium	1	0.08
High	High	8	0.67

**Table no 5:** Conditional Probability People Development

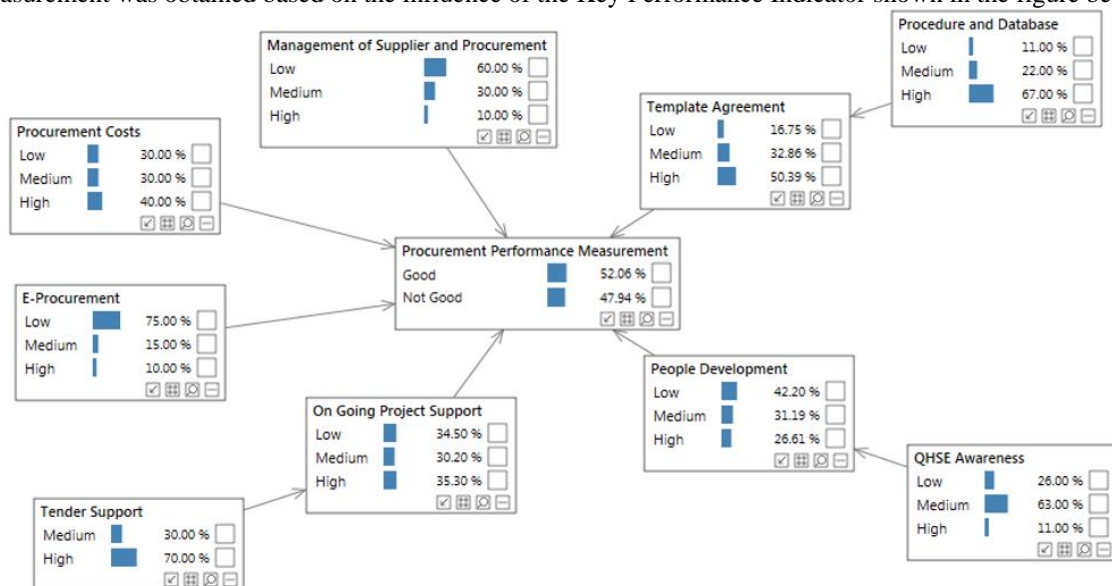
Key Performance Indicator		Freq.	Probability
QHSE Awareness	People Development		
Low	Low	1	0.20
Low	Medium	2	0.40
Low	High	2	0.40
Medium	Low	6	0.50
Medium	Medium	4	0.33
Medium	High	2	0.17
High	Low	1	0.50
High	Medium	0	0
High	High	1	0.50

**Table no 6:** Conditional Probability on Going Project Support

Key Performance Indicator		Freq.	Probability
Tender Support	On Going Project Support		
Medium	Low	1	0.17
Medium	Medium	2	0.33
Medium	High	3	0.50
High	Low	6	0.42
High	Medium	4	0.29
High	High	4	0.29

**Model Formation**

After calculating the probability, the calculation results were then included into the Procurement Performance Measurement Model, so that the probability of the occurrence of Procurement Performance Measurement was obtained based on the influence of the Key Performance Indicator shown in the figure below.



**Figure no 5:** Testing Bayesian Network Model on Procurement Performance Measurement based on the Effect of Key Performance Indicator



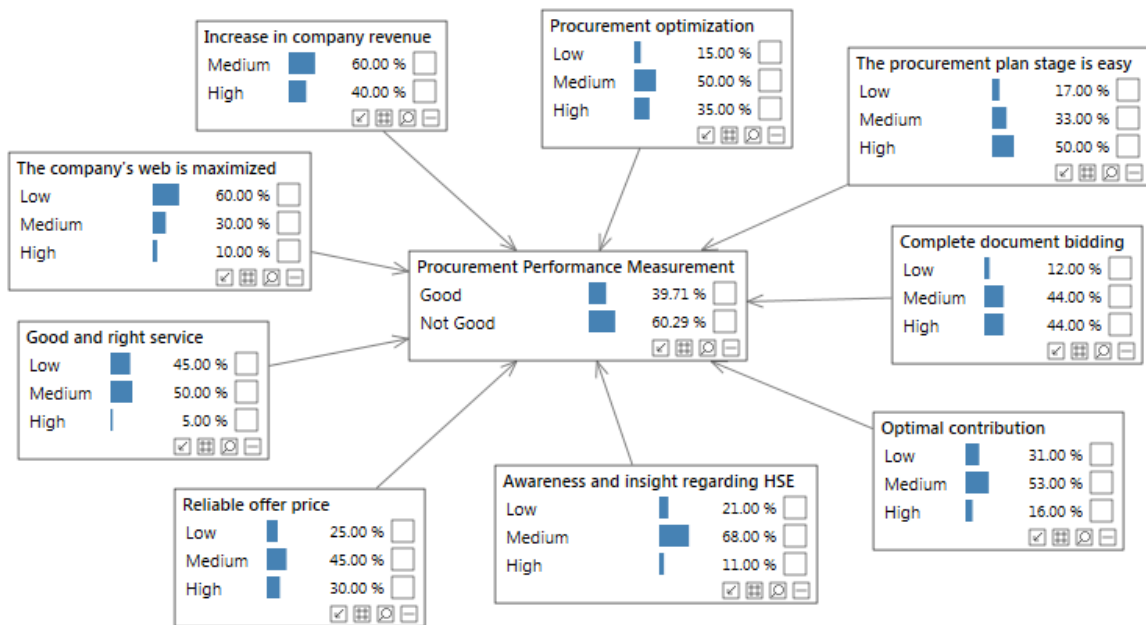
Based on the above model, 20 experts said that the procurement performance measurement obtained was good with the performance measurement result of 52.06% based on the questionnaire survey or around 11 experts who stated that the procurement performance measurement was good, while 47.94% of the procurement performance measurement was not good which means that around 9 experts stated that it was not good at procurement performance measurement.

Based on the model formed in Figure no 5, it can be seen that the measurement of procurement performance at this time has been good with a percentage of 52.06%, affected by several indicators on the Key Performance Indicator, including:

1. Procedure and Database
2. Template Agreement
3. On Going Project Support
4. Tender Support
5. Procurement Costs

The measurement of procurement performance is good, but there are still things that need to be corrected with indicators that have a high percentage of parameters that are quite high, which means that the indicator that causes the measurement of procurement performance is not good. The parameter percentage is not good for measuring procurement performance by 47.94%. Even though the percentage is below 50%, it is still quite high, therefore an evaluation and improvement must be made on the Key Performance Indicator indicators. The percentage of 47.94% is influenced by several indicators on the Key Performance Indicator, including:

1. People Development
2. QHSE Awareness
3. E-Procurement
4. Management of Supplier and Procurement



**Figure no 6:** Bayesian Network Model Testing on Procurement Performance Measurement based on the Effect of Key Result Indicator

According to the above model, 20 experts said that the procurement performance measurement from an external point of view was good with the result of 39.71% obtained from the questionnaire survey or 8 experts stated that the procurement performance measurement from external perspective was good, while the procurement performance measurement from external point of view in Procurement performance with the results of unfavorable performance measurement of 60.29% means that around 12 experts stated that it was not good at measuring procurement performance from an external perspective.

The model formed on the Key Result Indicator in Figure no. 6, results that the procurement performance measurement from an external viewpoint is currently not good with a percentage of 60.29% affected by several indicators on the Key Result Indicator, including:

1. The company's web is maximized for integrated procurement and accelerates the procurement process
2. Increase in company revenue by getting a new project
3. Good and right service during procurement, and getting good response from suppliers

4. Reliable offer price
5. Awareness and insight regarding HSE and the quality of goods and services
6. Optimal contribution to the company and as a leadership cadre in the organization
7. Procurement optimization is in accordance with the flow chart of the procurement phase project

While the model formed on the Key Result Indicator in Figure no. 6 for measuring procurement performance with good results has a percentage of 39.71% and is influenced by several indicators on the Key Result Indicator, including:

1. The procurement plan stage is easy and as a reference for prospective Vendors & Sub-Contractors for auction
2. Complete document bidding and as a reference for making contracts

#### **Model Suitability Test**

The result of Bayesian Network model test on measuring Procurement performance based on the influence of Key Performance Indicators based on Minitab software output 17 produced a significance level of 0.184 greater or equal to 0.05 ( $p\text{-value} \geq 0.05$ ). Likewise with the results of testing Bayesian Network model on measuring Procurement performance based on the effect of the Key Result Indicator based on Minitab software output 17 resulted a significance level of 0.852 greater or equal to 0.05 ( $p\text{-value} \geq 0.05$ ). The test results of the two models indicated that  $H_0$  was accepted, it can be concluded that Bayesian Network model on Key Performance Indicator was appropriate, as well as Bayesian Network model on the corresponding Key Result Indicator.

### **V. CONCLUSION**

The indicators contained in Key Performance Indicator influenced the measurement of procurement performance, the result was good that the percentage was 52.06% with the contribution of 5 nodes which can affect good results and 4 nodes that affect the other way. Whereas the indicators contained in Key Result Indicator to see the relevance of the external point of view had an effect on the measurement of procurement performance which resulted not good, as much as 60.29%, with the contribution of 7 nodes which can affect bad results and 2 nodes which affect good results.

The nodes that produced the greatest probability that influenced the measurement of procurement performance which result were good based on the indicators contained in the Key Performance Indicator was the Tender Support node with a percentage of 70%. While the nodes that produce the greatest probability that influenced the measurement of procurement performance was not good based on the indicators found in the Key Result Indicator were the company's web for integrated procurement and speeding up the procurement process with a percentage of 60%.

Procurement Division of PT. X can focus more on performance from an external perspective for improvement, and can indicate whether the direction of the procurement organization's performance is appropriate. In addition, indicators that influence the measurement of procurement performance whose results are not good, including indicators that have a large percentage of low and medium parameters can be immediately evaluated and corrected, and taken into consideration for improving the performance of the procurement organization.

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Bimbi Suharyanti. "Model Development of Procurement Performance Measurement on EPC Contractor by Using Bayesian Network Modelling." *IOSR Journal of Engineering (IOSRJEN)*, vol. 09, no. 01, 2019, pp. 55-62.