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Method for Estimating the Performance of Enterprise Architecture Implementation in an Upstream Petroleum Industry

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Abstract: ***Global oil prices have encouraged the development of the oil and gas industry. The passion for the revival of the oil and gas industry needs to be followed by solid steps. Efficiency is a theme in all business aspects. Enterprise Architecture (EA) is believed to be able to help realize the achievement of the company's goal. But EA implementation is challenging. The company must provide sufficient resources to ensure the EA implementation goal is achieved. It is therefore necessary to estimate the EA implementation to detect any gaps. This research offers a method to estimate the EA in the upstream petroleum industry. The method is a combined approach of Systematic Literature Review (SLR) and structured interviews. Interviews were conducted with a modified System Usability Scale (SUS) using the perspective of effectiveness, efficiency, agility, and durability. The evaluation results concluded that the EA implementation was still below the usability threshold. This fact encourages further EA development efforts, including the selection and utilization of specific and simple EA components.***

Keywords: ***Enterprise Architecture, Enterprise Architecture Evaluation, Structured Interview, System Usability Scale.***

I. INTRODUCTION

The rapid industry development provides many benefits in human life. But on the other hand, this phenomenon requires large amounts of energy resources. One of the world's primary energy resources is oil. The high demand for oil availability has led to increasing world oil prices. This fact happened until 2014 with global oil prices experiencing stability at around 100 USD per barrel [1], [2].

The global oil demand encourages various countries to increase exploration and exploitation activities. This activity can be suspected by increasing oil production in several countries, especially America. The factor of lifting the Iranian oil export embargo also affected the level of global oil inventories. Instantly the global oil supplies became abundant.

By the law of demand and supply, the abundance of oil production has an impact on the correction of global oil prices. Global oil prices plummeted to 27 USD per barrel in 2015 [1], [2]. The phenomenon of the oil crisis has had a global impact. Oil countries experienced a drastic drop in foreign exchange. This crisis also greatly affected the oil and gas industry in Indonesia. Efficiency measured are carried out on various elements, namely the reduction in workforce, budget, and transfer of oil well management to other companies that are more financially prepared.

The global oil crisis raises a lot of speculation and debate. Until an agreement emerged between oil producing countries to reduce their production, this step is taken to reduce the amount of global oil production. This agreement is slowly succeeding in correcting global oil prices. The impact can be felt to date. The oil and gas industry rose again with world oil prices in the range of 60-70 USD per barrel[1], [2].

This fact encourages the Indonesian oil and gas industry. By continuing to prioritize efficiency, the performance of the Indonesian oil and gas industry is increasing. The targeted and planned use of the budget is an essential element.

Several Indonesian oil and gas companies apply the Enterprise Architecture concept to support efficiency in the planning, budgeting and operational stages. Enterprise Architecture (EA) is believed to be able to help achieve company targets through budgeting mechanisms that are in line with medium and long-term planning.

But the EA management must be done carefully and consistently. Generally the failure of EA development is caused by the inconsistency of EA management [3], the level of complexity that is not handled and the lack of anticipation of the impact of very rapid business changes [4], the selection of frameworks and methodologies that are not in line with company characteristics [5][6], and metamodels that are not in accordance with company requirements [7].

This study attempts to evaluate the EA implementation in the Indonesian upstream petroleum industry. EA evaluation uses a combined method that combines SLR and structured interviews. An interview involved EA practitioners in five Indonesian upstream petroleum companies that have developed EA.

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II. RELATED WORKS

Discussions related to previous research were conducted with Systematic Literature Review (SLR). SLR is done with two reviews. The first review was an SLR related to the EA implementation in the upstream petroleum industry. The second review is an SLR related to the EA development evaluation mechanism.

The SLR uses "Enterprise Architecture" and "upstream petroleum" as a search string. The search database refers to the ACM library, IEEE Xplore, Elsevier Science Direct, SpringerLink, and Scopus. The literature review is only limited to publications published between 2014 and 2019. This is to ensure the review is addressing the latest trend.

A. EA for Upstream Petroleum

The SLR results for the first review collecting eight publications. Review for each publication will be discussed in this sub section.

Study in [8] reviews the framework for evaluating Enterprise Data Models (EDM) as part of EA implementation. The framework proposed in [8] is based on the Grounded Delphi Method (GDM) [9][10]. This method is the development of the Delphi method that is enriched with specific data collection methods. Data collection is done by collecting comments and recommendations from experts and sorted by rank based on particular parameters. Review considering an EA implementation in various industry had been explored in [11].

The study [12] conducted an EA evaluation based on Internal Control Effectiveness in the oil and gas industry. Evaluation is based on the Evidence-Based Management (EBM) methodology. The study proposed a framework for EA evaluation called the Internal Control Effectiveness Measurement Framework (ICEMF). The framework is designed to improve corporate governance in the oil and gas domain. Evidence on EBM is collected based on data and input from practitioners and researchers.

EA has a role in supporting business network planning through developing methods to represent multi-partner networks. The integrated scenario model defines the novation requirements [13]. In the upstream petroleum industry, novations are used to explore operational characteristics in the upstream petroleum industry collaboration network.

The harmony between business needs and IT services is frequently connected in the form of business services. The quality of the business service has an impact on the level of user satisfaction for both direct users, work partners and the government. The quality of business services at the corporate level is influenced by the quality of business processes and data objects [14], including for the upstream petroleum industry. EA provides a visual representation in understanding the relationship between organizational structure, business processes, and IT services. EA can be used as a strategic asset and a tool in managing business processes. Increasing levels of control in business processes have an impact on the level of user satisfaction.

The implementation of the latest technologies, such as Augmented Reality (AR) and Virtual Reality (VR) has been carried out in various industries, including the upstream petroleum sector. AR and VR offer convenience in the decision making the process at the business executive level. EA plays an essential role in determining the development of the latest technology which will be implemented and according to business needs. The study on [15] uses the philosophy of Holons and Informons in the implementation of AR and VR in supporting business decision making.

Sociotechnical studies as a model of global natural gas dependence can be done using EA. Furthermore, the EA study is carried out in understanding regional and global reliance, including its impact on the changing landscape of natural gas. The complex framework of enterprise sociotechnical modelling represents the development of natural gas landscapes. Sociotechnical enterprise [16] modelled to evaluate fundamental phenomena and aspects of social behaviour.

B. EA Evaluation

The SLR results for the second review collecting eight publications. Review for each publication will be discussed in this sub section.

EA evaluation is generally carried out with a top-down approach with an emphasis on test units based on theory. In the study [17], an EA evaluation study was conducted based on practical aspects with interviewees from enterprise architects and project managers. When EA evaluation has been carried out with a standardized approach, the organization has succeeded in evaluating the project by using informal and ad hoc evaluations with project analysis from various perspectives. In the study [17] proposed an EA evaluation carried out from multiple perspectives, informal, ad hoc and qualitative evaluation carried out together with stakeholders.

Business people need the ability of EA to be modified. In publication [18], the method of evaluating the modifiability level of EA development is based on previously defined scenarios. This method is called the Enterprise Architecture Modifiability Analysis Method (EAMAM) [18]. This method is designed to measure the modifiability and adaptability of an architecture.

One of the roles of EA is to provide the ability to determine various architectural scenarios as an alternative target architecture. In the study [19] proposed a quantification method to assess the diversity of EA components. This method facilitates the determination of various target scenarios.

The level of complexity and agility of the target scenario tested in [19], [20]. The testing component can use multi-criteria decision making (MCDM). In [19] uses the analytical hierarchy process (AHP) was used to determine the size of agility and complexity of the target architecture.

Determination of test components for EA implementation can also be extracted using a combined method between Systematic Literature Review (SLR) and semi-structured interviews with EA practitioners as discussed in [21][22][23]. An EA implementation evaluation approach can also be made using a workflow model [24]. Next evaluation refers to each predetermined workflow. This model is expected to be a bridge of communication between architects, EA users, and other stakeholders.

III. METHODOLOGY

This research attempts to analyze the results of EA implementation in the upstream petroleum industry. Data collection was carried out at five upstream petroleum companies in Indonesia involving interviewees consisting of users and managers of EA. This study combining a Systematic Literature Review (SLR) and structured interviews with related sources.

Details of the SLR results have been discussed in section 2 using two search words "Enterprise Architecture" and "Upstream Petroleum". Based on the results of the SLR, it points out that the study on the effects of the EA implementation received significant attention from the researchers. But until now, there is no specific methodology to assess the results of EA implementation, especially in the upstream petroleum industry. Most researchers estimate EA implementation by evaluating the complexity aspects of EA artefact modelling.

Compared to examining the EA model as a basis for evaluation, this study uses structured interviews by referring to the general objectives of why EAs should be implemented. The development goals of EA consist of four elements, namely effectiveness, efficiency, agility, and durability as mention on [25], [26]. The four perspectives are assessed using the System Usability Scale (SUS) [27], [28]. Usability is not a discrete quality unit but is a general quality approach from the statement following the objectives of a particular artefact [27]. The usability of EA can assess from the context used and the appropriateness of the context. Based on references in the information system domain, the translation of usability refers to the international standard ISO 9241-11: 2018 [29].

The combination of EA goal and SUS perspectives is done to ensure the usefulness of EA based on perspective. The stages in this study can be described as follows:

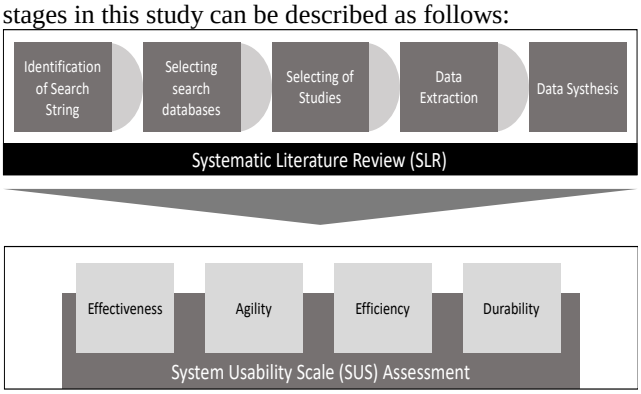

Fig. 1. Proposed Method

SUS considers a Likert scale. The respondent defines the level of agreement or disagreement in the five rating scales. SUS generates a value that corresponds to the composite rating from usability scales from the results of EA development by referring to the EA goals.

The SUS questionnaire can be tailored according to the field of research, such as the SUS questionnaire modification for product usability analysis in [30]. Usability rating on EA implementation also applies changes to the SUS questionnaire statement as in Table-I.

Table- I: Modification of SUS statements [27] for EA implementation assessment

No	Original SUS Statements	Modified SUS Statements
Q1	I think that I would like to use this system frequently	I think that I would like to use the EA frequently
Q2	I found the system unnecessarily complex	I found the EA implementation unnecessarily complex
Q3	I thought the system was easy to use	I thought the EA implementation was easy to use
Q4	I think that I would need the support of a technical person to be able to use this system	I think that I would need the support of a technical person to be able to use this EA structure
Q5	I found that the various functions in this system were well integrated	I found that the various functions in this EA were well integrated
Q6	I thought that there was too much inconsistency in this system	I thought that there was too much inconsistency in this EA
Q7	I would be imaging that most people would learn to use this system very quickly	I would be imaging that most people would learn to use this EA very quickly
Q8	I found the system very cumbersome to use	I found the EA very cumbersome to use
Q9	I felt very confident using the system	I felt very confident using the EA
Q10	I needed to learn a lot of things before I could get going with this system	I needed to learn a lot of things before I could get going with this EA

IV. DATA ANALYSIS

Based on the collection of assessment data with interviewees from five upstream petroleum companies in Indonesia, data analysis was conducted based on *effectiveness*, *efficiency*, *agility*, and *durability* [25], [26]. The interviewees are a pioneer and an initiator of EA program from each company. They are very important to this research since they have experiences how to develop an EA for upstream petroleum companies. Each interviewees will fill out the SUS questionnaire with four different perspectives for each EA goal. Each EA goal will be a perspective of how assessment questions asked to the respondent. To avoid ambiguity, the interviews for each interviewees were not conducted at once but were carried out regularly in four interviews with different schedules. An additional sentences insert before each question in Table- 1. The sentence is "Considering the effectiveness / efficiency / agility / durability of EA Implementation". Furthermore, each upstream petroleum company assessed is labelled EP1, EP2, EP3, EP4, and EP5.

A. Effectiveness

Effectiveness is the EA goal that indicates the ability of EA users to use EA artefact structures quickly and accurately to deliver solutions to business problems. Based on the perspective of effectiveness, all SUS assessment questions in Table- I will refer to the parameters of the speed and accuracy of the problem solution.

Table- II: Effectiveness Assessment Result

	EP 1		EP 2		EP 3		EP 4		EP 5	
Q	U	S	U	S	U	S	U	S	U	S
Q1	4	3	2	1	1	0	4	3	4	3
Q2	2	3	3	2	2	3	3	2	1	4
Q3	3	2	1	0	2	1	3	2	3	3
Q4	4	1	4	1	4	1	4	1	4	1
Q5	2	1	2	1	1	0	2	1	1	0
Q6	1	4	3	2	3	2	4	1	2	3
Q7	3	2	2	3	1	0	4	3	3	2
Q8	2	3	2	3	0	5	1	4	2	3
Q9	3	2	4	3	4	3	2	4	2	4
Q10	4	1	3	2	4	1	4	1	4	1
	S	**55**	**S**	**45**	**S**	**40**	**S**	**55**	**S**	**60**
SUS SCORE				**46.50**						

U : User's Rating
S : SUS Score
Q : Questions

Table- II presents the assessment results of five upstream petroleum companies. In this result, the users and managers of EA have a high dependence on the technical person to use the EA artefact structure. The EA component structure has been trusted to provide alternative solutions to business problems, but the use of EA is considering complicated. Based on the SUS score distribution guidelines on [28], the perspective effectiveness score (46.50) is below the acceptable score (68). This low score represents that the implementation of EA in the upstream petroleum industry is currently not effective.

B. Efficiency

Efficiency is the EA goal with an indicator of the minimum level of resource use in developing EA based on business objectives. Based on the Efficiency perspective, all SUS assessment questions in Table-I will refer to the parameters of optimization of resource used.

Table- III: Efficiency Assessment Result

	EP 1		EP 2		EP 3		EP 4		EP 5	
Q	U	S	U	S	U	S	U	S	U	S
Q1	4	3	3	2	4	3	4	3	3	2
Q2	4	1	4	1	1	4	4	1	1	4
Q3	2	1	2	1	2	1	3	2	2	1
Q4	4	1	3	2	4	1	4	1	4	1
Q5	1	0	4	3	1	0	1	0	2	1
Q6	1	4	2	3	4	1	2	3	2	3
Q7	4	3	1	0	1	0	2	1	1	0
Q8	1	4	3	2	3	2	2	3	2	3
Q9	3	2	4	3	4	3	4	3	4	3
Q10	4	1	4	1	4	1	4	1	4	1
	S	**50**	**S**	**45**	**S**	**40**	**S**	**45**	**S**	**48**
SUS SCORE				**45.50**						

U : User's Rating
S : SUS Score
Q : Questions

Based on the distribution of data from Table- III, it can be concluded that the users and managers of EA have great confidence that EA resources can be utilized efficiently. But the use of EA resources is considered to be less consistent. EA resources consist of structures of artifacts, models and metamodels. An artifact is an architectural work product that describes an architecture from a specific viewpoint[31]. A model is a detailed scale, simplified, and abstract of subject matter. The subject matter is a whole element of an enterprise and particular concern to the stakeholders[31]. A metamodel is a model that describes how and with what the architecture will be described in a structured way[31].

Based on the guideline for the distribution of SUS scores on [28], the perspective efficiency score (45.50) is below the acceptable value threshold (68). Scores below this threshold represent that the EA resources has not been used optimally.

C. Agility

Agility is the EA goal with an indication of the speed of a service delivered and the speed of adapting to business changes. Enterprise Architecture agility providing the necessary change to speed and change to plan. Agility level is the management of the combination of parameters effectiveness and efficiency. Based on the agility perspective, all SUS assessment questions in Table- I will refer to service delivery speed parameters and EA's ability to adapt to business changes.

Table- IV: Agility Assessment Result

	EP 1		EP 2		EP 3		EP 4		EP 5	
Q	U	S	U	S	U	S	U	S	U	S
Q1	4	3	4	3	2	1	4	3	3	2
Q2	1	4	4	1	4	1	2	3	3	2
Q3	3	2	3	2	2	1	2	1	1	0
Q4	4	1	3	2	3	2	3	2	4	1
Q5	2	1	3	2	1	0	3	2	1	0
Q6	2	3	4	1	4	1	2	3	3	2
Q7	3	2	2	1	1	0	1	0	1	0
Q8	2	3	3	2	2	3	2	3	4	1
Q9	4	3	4	3	3	2	3	2	3	2
Q10	4	1	4	1	4	1	4	1	4	1

S	58	S	45	S	30	S	50	S	28

SUS SCORE 42.00

U : User's Rating
S : SUS Score
Q : Questions

Table- IV illustrates the condition of EA implementation based on the agility perspective. This perspective is a combination of effectiveness and efficiency. In addition to problems in the complexity of the EA structure and inconsistency factors, another challenge that arises is the integration of functions in EA. Integration factors are critical to this perspective. Based on the guideline for the distribution of SUS scores in [28], the agility perspective score (42.00) is below the acceptable value threshold (68). Scores below this threshold represent that the implementation of EA has not been able to accommodate business changes. Changes can be made but require significant resources. This score reinforced by the effectiveness and efficiency scores, which are also below the threshold value.

D. Durability

Durability is the organization's ability to survive and manage changes in business needs by balancing effectiveness, efficiency, and agility. This ability is a response to changing demands that come from various aspects of the cause. Based on perspective durability, all questions of knowledge survive and adapt to changing business needs.

Table- V: Durability Assessment Result

	EP 1		EP 2		EP 3		EP 4		EP 5	
Q	U	S	U	S	U	S	U	S	U	S
Q1	4	3	3	2	1	0	4	3	2	1
Q2	3	2	4	1	3	2	4	1	3	2
Q3	4	3	1	0	1	0	3	2	1	0
Q4	4	1	4	1	4	1	4	1	4	1
Q5	1	0	3	2	1	0	3	2	3	2
Q6	3	2	1	4	3	2	2	3	3	2
Q7	1	0	2	1	1	0	1	0	1	0
Q8	4	1	2	3	3	2	3	2	4	1
Q9	4	3	3	2	3	2	2	1	3	2
Q10	4	1	4	1	4	1	4	1	4	1
	S	40	S	43	S	25	S	40	S	30

SUS SCORE 35.50

U : User's Rating
S : SUS Score
Q : Questions

The assessment results of perspective durability in Table-V are influenced by the perspective of effectiveness, efficiency, and agility. The low SUS score in the previous perspective indirectly resulted in a low score of perspective durability. Based on the guideline for the distribution of SUS scores on [28], the perspective score durability (35.50) is below the acceptable value threshold (68). This score represents that the implementation of EA in the upstream petroleum industry has not been responsive and reactive in facing the challenges of change both from external and internal.

V. RESULT AND DISCUSSION

Based on the data analysis on the four EA goals, which became the SUS assessment perspective, the SUS score was obtained as in Table- VI.

Table- VI: SUS Score

EA Goals	SUS Score	SUS Threshold
Effectiveness	46,50	68
Agility	45,50	68
Efficiency	42,00	68
Durability	35,50	68

The SUS score in all perspectives was below the acceptable threshold. The effectiveness perspective has the highest SUS score compared to efficiency, agility and durability. This phenomenon illustrates, within the context of EA implementation in Indonesian upstream petroleum industry, that:

1. The structure of the EA component already structured, but had not been able to provide fast and rigorous analysis in managing a business problem,
2. The EA component had been structured, not yet efficient in providing business solutions,
3. Agility and Durability had a SUS score below the threshold. This result were influenced by the relation to the perspective of effectiveness and efficiency.

Table- VI can be illustrated as a spiderweb diagram as below:

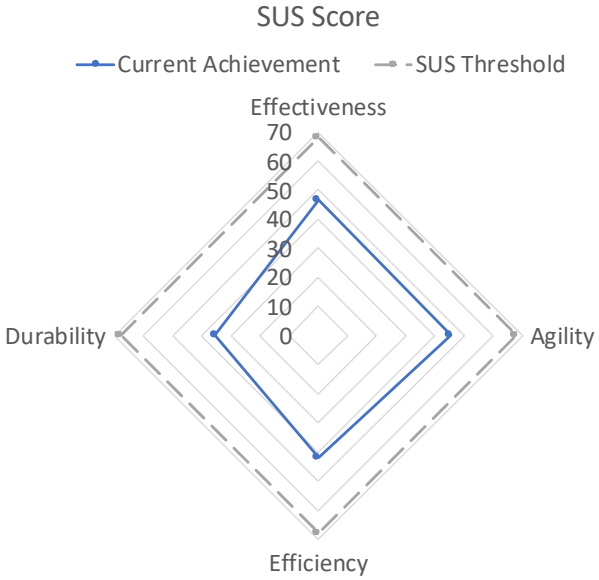

Fig. 2.EA goals assessment result

Usability analysis on the EA implementation in this study had not examined the influence of other aspects, such as the effect of EA implementation time, resource availability, and external influences. How long EA has been implemented by an organization, is likely to affect the assessment of the SUS assessment. Availability of resources, including personnel and budget, is expected to have a significant influence on assessment justification. Likewise, external influences, including regional regulation policies and oil price changes, considering will be influenced the trend of EA development.

VI. CONCLUSION

This study uses a combination method to estimate and evaluate the implementation of EA in the upstream petroleum industry. The combination method used consists of a systematic literature review (SLR) and a structured interview. SLR is conducted to examine the latest developments in the use of EA in the upstream petroleum industry and the exploration of EA evaluation methods. Based on the results of the SLR, it concludes that there is no specific evaluation method for evaluating the implementation of EA in the upstream petroleum industry. Evaluation methods generally refer to the evaluation of the complexity of the EA component structure. Based on the results of the SLR, the structured interview was conducted based on the modified SUS assessment according to the needs of the EA implementation evaluation analysis. The SUS assessment is carried out, referring to the four EA goals [25], [26].

Considering the assessment results, it concludes that the EA implementation in the upstream petroleum industry had not met business needs. The assessment SUS score below the SUS acceptable threshold in all EA goals perspectives. Simplification of the EA component structure is essential in reducing the complexity of EA management and enhancing the ease of learning and increasing the EA implementation success rate.

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