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RESEARCH DESIGN STRATEGY TO ESTABLISH PROCESS SAFETY KPI FOR MANAGING AGEING AND LIFE EXTENSION FACILITIES IN INDONESIA'S UPSTREAM OIL & GAS OPERATIONS

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Abstract

A substantial number of production facilities in the upstream oil and gas industry worldwide are facing ageing operations and beyond their original design life, which requires extended service life key performance indicators (KPI). Nowadays, the Indonesia's upstream oil & gas operations dealing with 70% ageing and life extension (ALE) facilities which have specific characteristics, factors, and criteria of process safety KPI. A systematic literature review confirms that there is not yet a fully sufficient process safety performance management system (PMS) framework for managing ALE facilities. Therefore, this paper demonstrates the selection of the most suitable research design strategy for developing a fit-for-purpose PMS framework by considering Saunders' research onion model. The contextual framework will enrich a knowledge-based performance measurement system and be developed by applying the pragmatism paradigm combined with deductive and inductive reasoning approaches. The chosen research strategy will examine statistical and longitudinal case studies with a mixed method of System Dynamics and Multi Criteria Decision Analysis applied to upstream oil & gas companies operating ALE facilities in Indonesia. Data are collected by distributing questionnaires, conducting observations, focus group discussions, and in-depth interviews among key personnel and decision-makers pertaining to the aspects of process safety.

Keywords: Key Performance Indicators, Performance Management System, Process Safety, Ageing and Life Extension (ALE).

1. Introduction

The upstream oil & gas industry has been dealing with constantly shifting business conditions and environmental challenges (Mataqi, 2013). A substantial number of the oil and gas production facilities worldwide are facing ageing operations and operating beyond their original design life (Jie et al, 2020, Animah et al, 2018). This tendency is anticipated to continue in the future because most production facilities have reached their end-of-life period, as projected by Tveit et al (2014).

Indonesia's oil and gas fields have continued to be ageing over the past few years (FEUI, B.R.L., 2014), and 70% of oil and gas production facilities have been classified as Ageing and Life Extension (ALE) because they are between 25 - 30 years old and continuing in use. According to Ministry of Energy and Mineral Resources (2011) and ATLAS Vol. 3 (2019), this historically has led to 153 unplanned shutdowns with a production loss of 22,000 BOPD and there were 183 accidents with 2 fatalities in 2019, an increase from 2018, when it came to the number of accidents in the upstream oil and gas company activities. As a result of this phenomenon, process safety major accident hazards (MAH), efficacy, costs, and social-environmental concerns have increased. However, in the business case, oil and gas companies are now very interested in extending the service life of critical production assets (Animah, 2018; Palkar and Markeset, 2012). Although safety and production are essential, life extension strategies must be evaluated according to their economic attractiveness and safety (Brown, 2006), since the conflicting trade-off between the two aims displays an interesting paradox (Reason, 2000).

According to research, inadequate process safety performance indicators have been identified as a contributing cause in several recent significant accidents (Hopkins, 2009). A recent sharp increase in the frequency and magnitude of losses in plants over 30 years old classified as ALE facilities is more likely with mechanical-integrity-related failures (Marsh, 2020). This is an indication that the oil and gas companies operating ALE facilities still have challenges and a long way to go when it comes to manage integrated process safety performance management system of ALE facilities. Therefore, it is currently unknown how performance measurement systems should be designed and modified to incorporate process safety high risk-based indicators across priority areas indicated as per a business case in Center for Chemical Process Safety (2021,2018), American Chemistry Council (2013) and National Safety Council (1994).

By taking into account Saunders' research onion model (2019), this research objective is to demonstrate the selection of the most suitable research design strategy to construct a fit-for-purpose process safety PMS framework by enriching a Knowledge-Based Performance Measurement System (Wibisono D, 2014) as illustrated in Figure 1 and successfully answer 5 (five) research questions by;

- Examining the characteristics of the integrated process safety PMS in the upstream oil & gas companies operating ALE facilities and determine the impact of such characteristics.
- Identifying factors that may affect the integrated process safety PMS in the upstream oil & gas companies operating ALE facilities and enable to create a structural model that illustrates how those factors relate to one another.
- Identifying the criteria of the integrated process safety PMS that fits the characteristics of ALE facilities in the upstream oil & gas companies and examine the existing PMS frameworks suit to those respective criteria.
- Designing the integrated process safety PMS framework that can be used to manage integration of process safety performance indicators, organizational capability and organizational performance including business conflict resolutions in the upstream oil & gas companies operating ALE facilities.
- Investigating the affect of applying contextual PMS framework developed in this research on improving both the effectiveness and efficiency of process safety performance measurement in the upstream oil & gas companies operating ALE facilities.

The chosen research design strategy will focus on the process safety KPI to manage the performance degradation of upstream oil & gas production facilities that survives through life extension as illustrated in Figure 2 (Hart, 2009). It will determine how well the effects of ALE are managed and when required processes are well maintained. So that, the integrated process safety Performance Standards (PSs) will be maintained to safely operate ALE facilities.

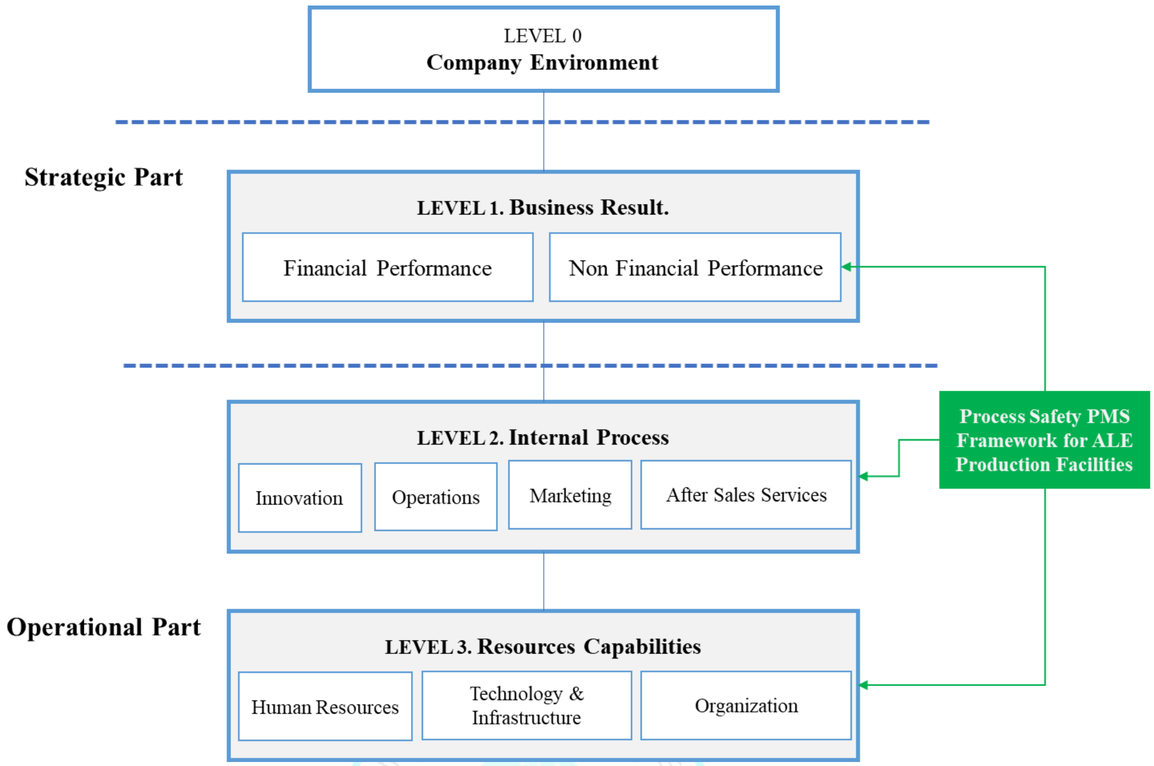

Figure 1: The Enrich of Knowledge-Based Performance Measurement System Model Framework (Wibisono D, 2014)

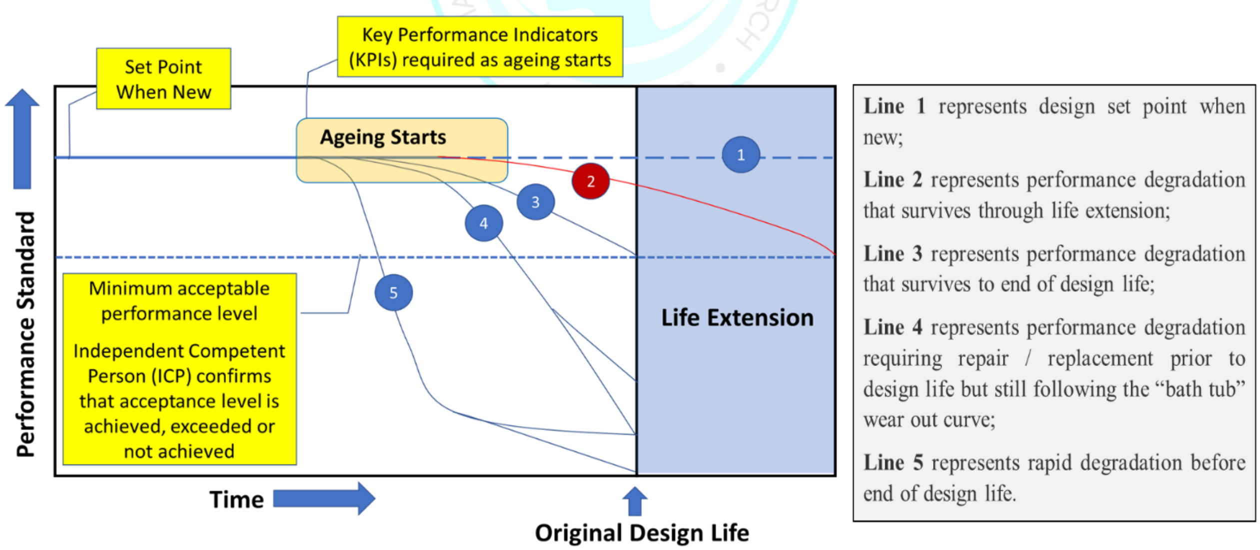

Figure 2: Ageing and Life Extension Trends (Hart, 2009)

2. Literature Review

Research Model

Saunders' research onion (2019), a helpful tool for considering research methodology holistically, describes the various decisions from the outside of the onion inwards, ranging from philosophical to tactical and practical in nature. As part of constructing an appropriate research strategy, these onion layers must be peeled back one at a time.

Additionally, the reflexive tool HARP (Heightening you Awareness of your Research Philosophy), created by Bristow and Saunders, enables further in-depth questioning to aid in discovering a strong research philosophy paradigm. Deductive reasoning is applied to build the framework from theory literatures. Meanwhile, inductive approach is used to enhance the framework design based on the constructs gathered from the field-based observations with the bottom-up model building. The mixed-method approach, which combines quantitative and qualitative data collecting and processing methodologies, is supported by Saunders et al (2019). The proposed framework shall be put to the test in the context of longitudinal case-study research.

Systematic Literature Review

A systematic literature review (SLR) methodology is being used to perform literature survey associated with previous studies and current research. The objective of a SLR is to provide the state of the art (SOTA) and understanding about the development of research topic (Palmatier et al, 2018). According to Donthu et al (2021), SLR is useful when the focus of review is narrow, and dataset is small enough to be manually reviewed.

Process Safety KPIs of ALE Production Facilities

To ensure the upstream industry benefits from these efforts, International Association of Oil and Gas Producers (IOGP) 456's guidance builds a framework and definitions based on a recent American Petroleum Institute (API) 754 standard on process safety performance indicators and guidelines on metrics published by UK Health Safety Environment (2007), Center for Chemical Process Safety (2007) and Organization for Economic Coordination and Development (2008). There are 4 tiers framework introduced by API 754 and recommended by IOGP 456 as a structure of process safety KPIs measures to monitor barrier performance within the process safety management (PMS) system, covering tier 1: LOPC events of greater consequence, tier 2: LOPC events of lesser consequence, tier 3: Challenges to safety systems and tier 4: Operating discipline & management system performance indicators.

The success of the KPI measurement will rely heavily on the transparency of reporting and gaining a true picture of company PSM performance that provides the stakeholders with accurate information to act upon (Brown, 2009). Additionally, according to IOGP 456 (2018), process safety KPIs can be developed to concentrate more on Tier 3 and Tier 4 leading indicators to provide management systems with more specific indicators for monitoring facility process safety performance, as well as omissions of safety activities or demands on safety systems, as well as management system flaws (CCPS, 2021).

Due to this, prior to designing an integrated process safety PMS framework, the corporation must be aware about the acceptable ALE performance level requirements which should include the understanding of ALE management critical safety aspects, such as material degradation, obsolescence, human competency, organizational capability (Palkar, 2012), knowledge-based organization (Sumbal, 2017) and safety-critical elements (HSE KP4, 2013).

3. Methodology

A SLR technique is used, which includes 3 (three) primary journal databases, Scopus, ScienceDirect, and Proquest, and is carried out according to Thomé et al (2016)'s adapted step-by-step, which can be separated into: (1) research delineation; (2) literature search; (3) data collection; (4) data analysis; and (5) interpretation. *Vosviewer* bibliometric analysis was performed to identify research gaps, research position, scope of the research and State of The Art (SOTA). The defined keywords, tittles, topics, and abstracts were classified into four categories with labels A, B, C and, D as illustrated in following table 1, to accommodate relevant limiting results and avoid too many unwanted results (Bakker, 2010). SOTA research was obtained as a result of the SLR selection process and *vosviewer* analysis.

Table 1: Search Strings / Query

No	Category A	Category B	Category C	Category D
1	Performance Management System	Organizational Objective	Process Safety Management	Human Performance
2	Performance Measurement System	Organizational Performance	Process Safety Performance	Human Factor
3	Performance	Organizational	Process Safety Indicator	Abnormal
4	Performance Measurement	Integration Management System	Process Safety Metric	Emergency
5	Performance Indicator		Process Safety System	Emergency
6	Performance Metric		Process Safety	Major Accident
7	Performance		Safety Management	

The Saunders' research onion is made up of 6 layers, namely research philosophy, approach, methodological choice, strategy, time horizon and, techniques and procedures. These layers need to peel back one at a time as developing a suitable research design strategy that will accommodate the preliminary stage completion and support further methodology selection for exploratory stage, descriptive stage, and explanatory stage.

This research design scope is considered as complex systems; thus, research methods will combine qualitative and quantitative as mixed methods by applying System Dynamics and Multi Criteria Decision Analysis tools (Santos et al, 2001, Kunc, 2017; Bianchi and Rivenbar, 2012) to produce both tangible and profound results. Furthermore, these methods will facilitate explorations that can be used to frame the time and space trade-offs associated with a variety of alternative scenarios, including managing conflicting objectives to promote decision-making.

Ultimately, the best research design strategy will enrich a Knowledge-Based Performance Measurement System as a fit-for-purpose process safety PMS that is suitable to manage ALE production facilities in the Indonesia's upstream oil & gas operations.

4. Results

The chosen research design strategy consisted of 4 stages, namely preliminary stage, exploratory stage, descriptive stage, and explanatory stage. The preliminary stage confirmed research scope, gaps and positions pertaining process safety performance management system through *vosviewer* bibliometric analysis illustrated in Figure 3, studies that discuss the characteristics, affected factors, and criteria to design process safety PMS for managing ALE facilities have not been published recently. Additionally, the existing design PMS frameworks have not been entirely suitable to be applied to the context of integrated process safety PMS for managing ALE facilities in the upstream oil & gas industry.

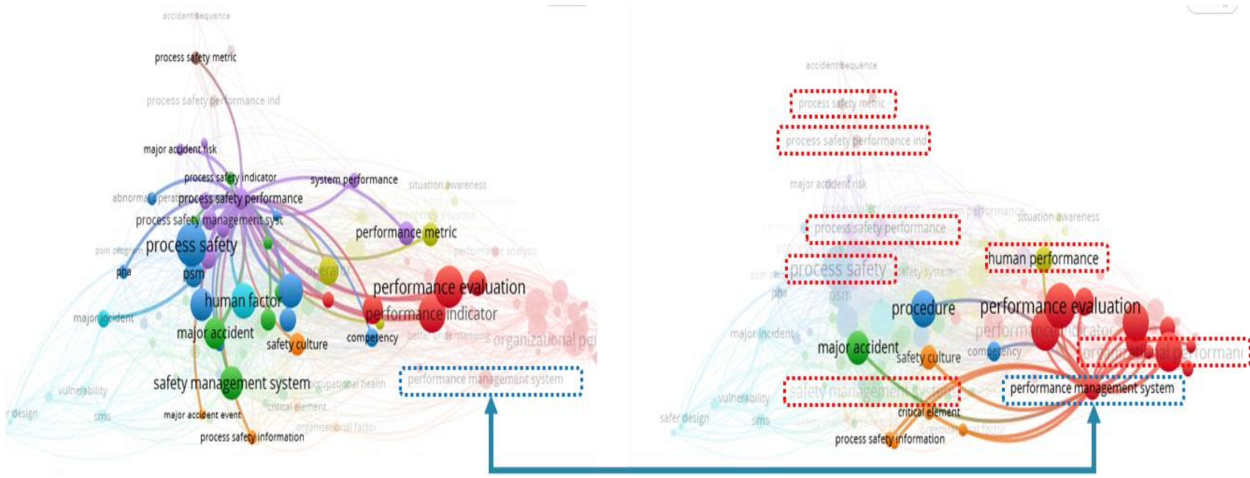

Figure 3: The Vosviewer Bibliometric Analysis of Process Safety PMS

Furthermore, the *vosviewer* density visualization depicted in Figure 4 and previous PMS framework process mapping in table 2 confirmed some popular frameworks are originally developed for managing organizational performance but not specifically aimed to measure process safety performance indicators.

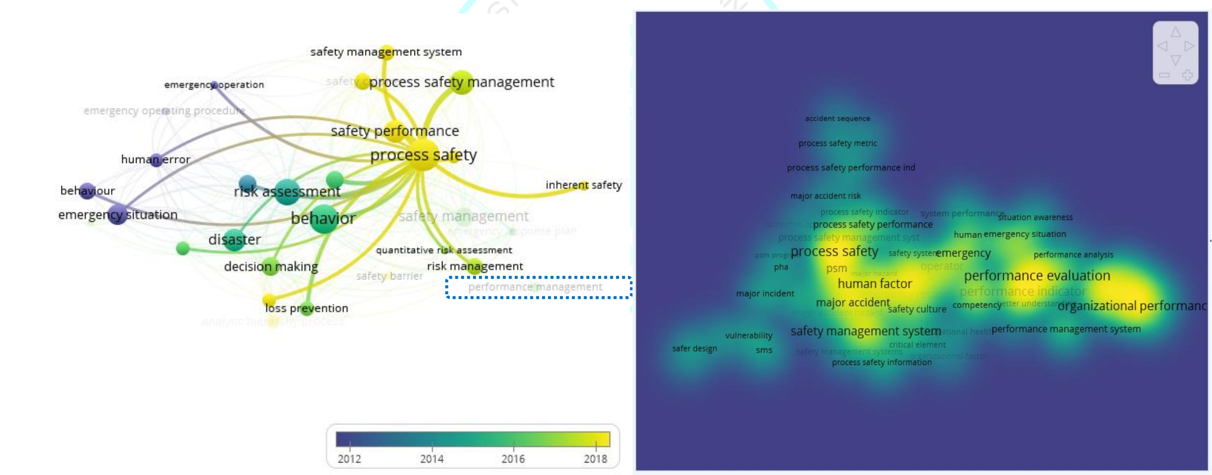

Figure 4: The Vosviewer Density Visualization of Process Safety PMS

Table 2: Mapping of Previous PMS Frameworks

Aaspect / Criteria	Balanced Scorecard	Prism	Knowledge-Based PMS	Lean Six Sigma	Proposed PMS
Formulation of Performance Varible	Each Variable's formulation in detail	Each Variable's formulation in detail	Each Variable's formulation in detail	Each Variable's formulation in detail	Each Variable's formulation in detail PS Tier 3 & 4
Number of Performance Variable	4 groups w/ sub-variables	More than 200 individual variables	Grouped into 3 levels consisting of several variables	6 performance variables	Determined by credible high risk-based sceanrio
Stakeholder	No	Ys	Yes	Yes	Yes
Benchmarking	No	No	Yes	Yes	Yes
Conflict	No	No	No	No	Yes
Strategy	Yes	No	Yes	Yes	Yes
Dynamic	No	No	No	No	Yes
Expert System	No	No	Yes	No	Yes
Impleemntation	All Industry	All Industry	All Industry	All Industry	Upstream O&G

The research State of The Art (SOTA) dimensions illustrated in table 3, is obtained through the combined 4 categories generating 1,470 search strings applied in Scopus, ScienceDirect and ProQuest produced 85,024 initial papers which were screened and scrutinized, eventually yielding 98 relevant papers. Table 3: SOTA Dimensions

Dimension	Sub Simension	Proposed Research	Dimension	Sub Simension	Proposed Research
Philosophy of Management	Positivism		Performance Drivers	Collaboration	√
	Critical Realism			Capability	√
	Interpretivism			Competence	√
	Postmodernism			Integration	√
	Pragmatism	√		Management Support	√
Reasearch Approach	Induction	√		Digitalization	√
	Deduction	√		Subjective Judgment	√
	Abduction			Non-Subjective Judgment	√
Method Choice	Mono-Method		Empirical Test	Contextual PMS on	√
	Mono-Method			Digitalization on	√
	Multi-Method		Indicators	Leading Indicators	√
	Multi-Method			Lagging Indicators	
	Mixed-Method Simple	√	Process Safety Tier-Based	Tier 1: Major PS Incidents	
	Mixed-Method Complex			Tier 2: Severe PS Incidents	
Strategies	Experiemnt			Tier 3: Safety System	√
	Survey / Questionnaire	√		Tier 4: Operational	√
	Case Study	√	Focus Area	Process Safety	√
	Action research			Occupational Safety	
	Grounded Theory			Health	
	Ethnography			Environment	
	Archival	√		Security	
	Narrative Inquiry		Industry of Application	Manufactures	
Time Horizaon	Cross Sectional			Health / Medical	
	Longitudinal	√		Petrochemical / Chemical	
System Dynamics	Qualitative Model	√		Nuclear	
	Quantitative Model	√		Oil & Gas	√
	Simulation	√	Operation Stage	Upstream	√
Criteria of Good PMS Framework	Benchmarking	√		Midstream	
	Contextual	√		Downstream	
	Multi-Criteria	√	Contextual Facility	Project or New Facility	
	Problem Identification	√		Operating Facility (Not	
	Prioritization	√		Ageing & Life Extension	√
	Enabling Coordiation	√	Operation Mode	Normal Operation	√
	Information Sharing	√		Abnormal Operation	√
Behavioral Science	Organizational System	√		Emergency	√
	Group / Team Level	√			
	Individual level	√			

Table 4 depicts the research design strategy in the preliminary stage that was ultimately selected after carefully examining all the layers of Saunders' research onion model.

Table 4: The Saunders' Onion Layers Examination

Research Onion	Decision	Justification
Philosophy	Pragmatism	▪ The ontology is complex, flux of process, experience and reality practices. ▪ The epistemology covers practical meaning of knowledge in specific contexts and focus on problems. ▪ A reflective tool HARP (Saunders, 2019) was applied to exercise the fit for purpose research philosophy
Approach	Deductive & Inductive	▪ Model building: Deductive reasoning is applied to build the framework from theory literatures, meanwhile inductive approach is used to enhance the framework design based on the constructs gathered from the field-based observations with the bottom-up model building. ▪ Model testing: Deductive reasoning through confirmatory research (Ritcher, 2016; Wagenmakers, 2012) to empirically validate of the model in the real world.
Methods Choice	Mixed Methods	A quantitative method in general does not explain the detailed context of an issues while a qualitative method is being less tangible. The research scope is complex systems; thus, the research methods will combine qualitative and quantitative methods or mixed-method to produce both tangible and profound results (Kunc, 2017; Santos, 2001).
Strategies	Case Study	The research strategy combines statistical and longitudinal case studies with mixed methodologies. Case study facilitates an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple methods of data collection (Yin, 2009).
Time Horizon	Longitudinal	Longitudinal time horizon study provides better to establish the correct sequence of events, identify changes over time and provide insight into cause-and-effect relationships.
Techniques and Procedures	Qualitative & Quantitative	Data Collections ▪ Qualitative: Systematic Literature Review, Interview, Focus Group Discussion, Field Observations. ▪ Quantitative: Questionnaire Analysis Tools ▪ Qualitative: System Dynamics – Causal Loop Diagram ▪ Quantitative: System Dynamics – Stock Flow Diagram; Multi Criteria Decision Analysis – Analytical Hierarchy Process

Figures 6 and 7 illustrate the final proposed research methodology and chosen design strategy that will be applied further covering exploratory stage, descriptive stage, and explanatory stage to accomplish the ultimate research objective.

The exploratory stage results will be a conceptual framework and initial relationships between identified constructs in a logical order. Hereinafter, the descriptive stage established a model building stage of novel PMS framework in a more narrative form. Eventually, the explanatory stage will verify and validate the new process safety PMS framework through model testing prior to embedding it into the Knowledge-Based PMS model.

4. Conclusions

Saunders' research model (2019) was successfully applied to provide the most suitable research design strategy that consists of 4 stages, namely preliminary stage, exploratory stage, descriptive stage and explanatory stage that support a triangulation technique for answering 5 research questions and accomplishing research objective (Benbasat et al., 1987; Markus, 1983; Amaratunga and Baldry, 2001; Yin, 2009). The chosen research design strategy must accommodate a variety of methods and data collection methods such as structured interviews, focus group discussions, documentary evidence, and archival records. Thus, it will ensure the consistency of the evidence and increase the researcher's confidence in understanding the significance of the findings.

In an effort to answer research questions 1, 2 and 3, the researcher applies an exploratory sequential approach (Creswell, 2009) combined with a confirmatory approach (Green, 2008) to understand relationships between variables holistically. Meanwhile, the exploratory approach is to find answers of research questions based on the data collected which also helps developing new theories and expand existing theories. This research may need more data to encourage more exploration, so, the research design will be empirically representative. Hereafter, the descriptive research stage (Lans and Vooordt, 2002) aims to arrange the constructs a framework in an orderly narrative form for identifying general patterns and testing hypotheses to answer research question 4. A contextual process safety PMS framework is expected to enrich a knowledge-based PMS (Wibisono, 2014) covering strategic, tactical, and operational levels. Finally, the explanatory research (Fisher and Ziviani, 2004) is a suitable approach to verify and validate the application of the new process safety PMS framework to answer research question 5 in real cases of the Indonesia's upstream oil & gas companies operating the ALE facilities to prove its validity, reliability, and robustness.

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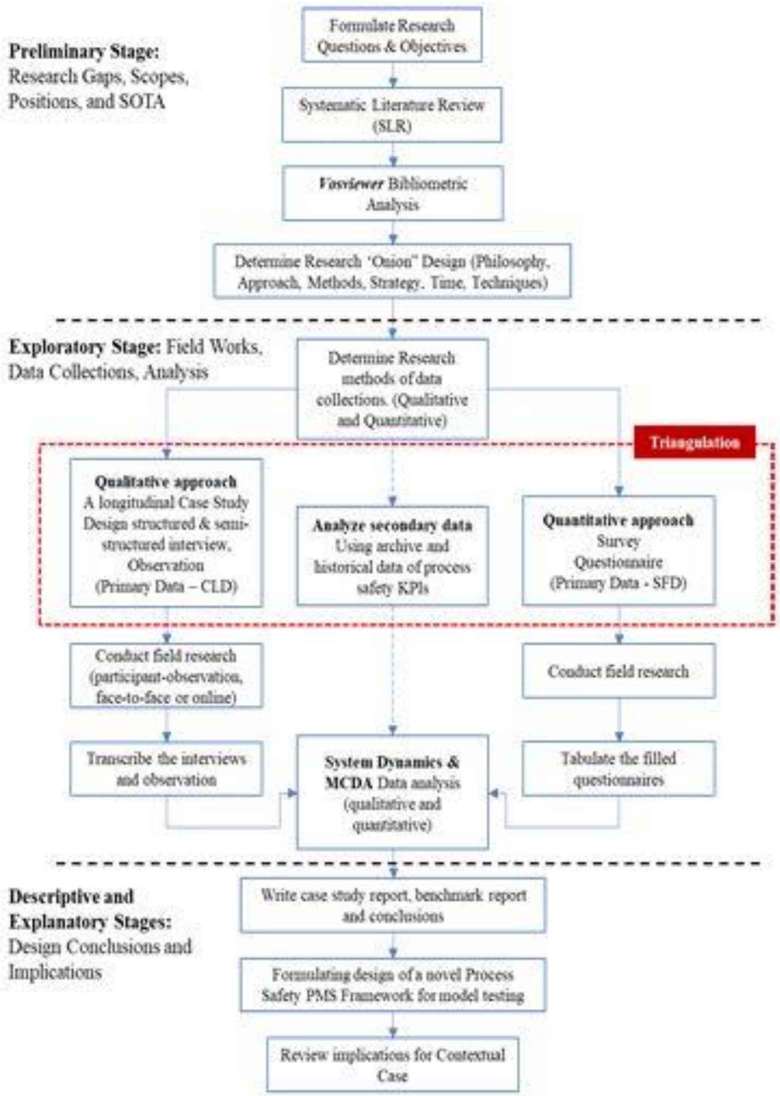

Figure 6: The Proposed Research Methodology

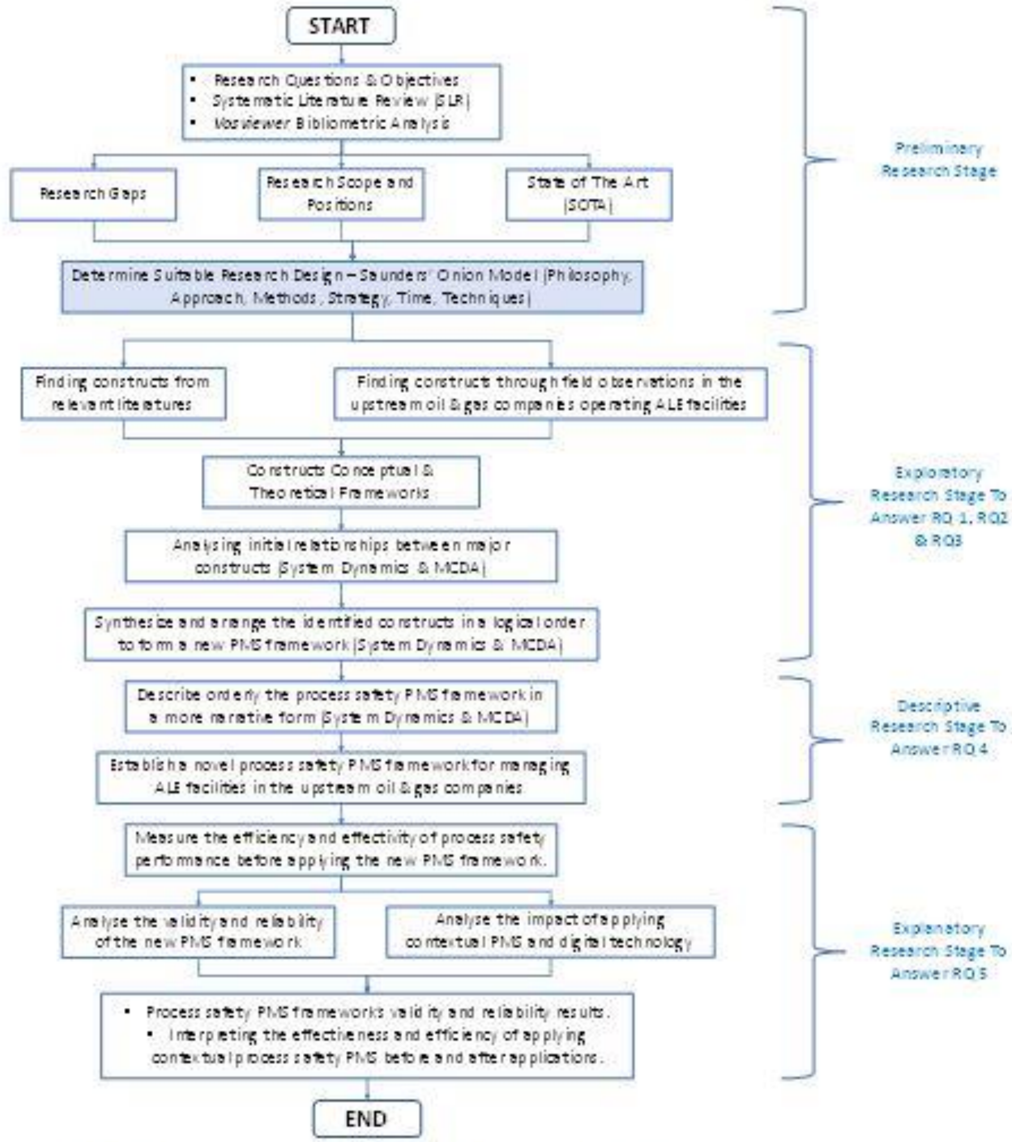

Figure 7: The Chosen Research Design Strategy

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