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Development of Sustainability Framework and Assessment of Petroleum Refinery Process

Ola Y. Mohamed[a], Nabila F. Jamaludin[a,b,*], Muhammad F. Sukhri[b], Muhammad F. Hadipornama[c]

[a]Department of Chemical Engineering, Universiti Teknologi Petronas, Perak, Malaysia
[b]Centre of Advanced Process Safety, Institute of Contaminant Management, Universiti Teknologi Petronas, Perak, Malaysia
[c]KINETICS Systems Malaysia Sdn. Bhd., 40300, Shah Alam, Selangor, Malaysia
nabila.jamaludin@utp.edu.my

Malaysia Petroleum Management (MPM) through PETRONAS focus has been on creating and achieving a sustainable and safe petroleum industry in Malaysia. Therefore, this study was inspired by the need for improved sustainability for Petroleum Refineries in Malaysia, where most of the oil and gas industry players are still trying to achieve optimized sustainability. Sustainability assessment (SA) goes beyond a simple technical and scientific evaluation to support decision-making and policy in a broad environmental, economic, and social context. The establishment of the practice of sustainability framework and assessment for petroleum refineries in Malaysia will gain more trust from Malaysians. To achieve the above, this study seeks to develop a sustainability framework and to assess petroleum refinery process. The index score is based on how the industry is doing right now in relation to the present global problem. For the study conducted in two selected petroleum refinery plants in Terengganu-Gas Processing Kertih (GPK) and Gas Processing Santong (GPS), for the years 2019, until 2021 the results revealed that the index score was higher in the year 2020 compared to other years where COVID-19 pandemic's affected industrial activity by reducing the demand.

1. Introduction

Oil is versatile resource that may be used for a range of tasks and in various forms. Refineries are frequently acknowledged as significant polluters in the areas where they are located (Cetin et al., 2003). Due to its reliance on petroleum-based motor fuels, the road transportation sector accounts for more than a third of the world's oil consumption. According to OPEC, the demand for oil products would increase to 109 million barrels per day by 2045, with the most common ones being gasoline and diesel for transportation (Jessica, 2023). Due to increased demand, the oil and gas industry uses a lot of energy and leaves a big carbon footprint. Carbon dioxide levels in the atmosphere have risen to their highest point in at least 800,000 y, and they are continuously rising. 2.6 billion t/y out of the 37.1 billion t created by human activity accounted for the sector's own carbon footprint operations plus emissions from energy. The main problem is that the finished product will unavoidably release carbon dioxide and other greenhouse gases (GHG). For making global warming worse, the petroleum sector is held accountable. These companies are also in a great position to help with the fight against climate change. Sustainable development has long been a primary priority for the oil and gas industry. The focus of current sustainability strategies is on compliance with environmental, health, and safety regulations. Oil and gas businesses are under pressure to cut emissions due to changing government climate policies, direct public, and shareholder action, and shifting investment strategies by significant institutions. Sustainability concerns have an impact on major multinationals' reputations, and their attitude to these issues is frequently criticised. This study will look at ways for dealing with sustainability challenges from a business standpoint. Petroleum Refinery Industry (PRI) in Malaysia needs to develop a sustainability assessment framework for petroleum refinery industry. Companies must take efforts across a variety of operations to reduce emissions from oil and gas operations. The main objective of this study is to develop a sustainability framework and to assess the petroleum refinery process in Malaysia through establishing sustainability parameters according to the standard regulations.

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2. Literature review

2.1 Overview of petroleum refinery industry

Approximately 2500 refined products are produced by the petroleum refining industry. As of 2019, Malaysia is the second-largest producer of oil and natural gas in Southeast Asia and the world's third-largest exporter of liquefied natural gas (LNG) (Wahil et al., 2020). All oil and gas exploration and production projects in Malaysia are exclusively owned by the nation's national oil and gas company, and its Petroleum Management Unit (PMU) is in control of all upstream licensing procedures (Zawawi et al., 2014). Malaysia has invested significantly in refining over the past 20 y and can today source the majority of the petroleum products it needs from domestic producers. Seven refineries in Malaysia have a combined daily capacity of 880,000 barrels (Yeo et al., 2023). Malaysia's gas industry helps the country's overall socioeconomic well-being. In 2017, Malaysia's gas sector produced and sold gas worth more than 10 B MYR into the local market, which accounted for more than one-fifth of the country's GDP over the previous ten years. A royalty is the portion of income that the government receives from companies that generate gas in the country (Gentile, 2015). Critical government services including education, healthcare, infrastructure, and social programs that benefit all Malaysians are financed in part by taxes and royalties (Roemer and Haggerty, 2022). From 2021 to 2030, the global oil refining market is expected to develop at a CAGR of 5.3 %, from 1,345.0 B USD in 2020 to 3,751.5 B USD in 2030. Asia-Pacific oil refining market accounted for a significant market share in 2020 (Mohammed, 2020). The COVID-19 epidemic resulted in lockdown measures being implemented in major cities and economies, which caused most industries to suspend production. The majority of vehicles in Malaysia are fuelled by gasoline, accounting for more than 80 % of new vehicle sales. Vehicle sales powered by diesel are slowly rising. In 2020, it is anticipated that Malaysia would consume 2.5 B gallons of jet fuel.

2.2 Current issues regarding petroleum refinery industry

Due to rising worldwide demand, wildly fluctuating prices, and strict environmental rules, the petroleum refinery industry (PRI) faces three issues: environmental effect, industrial base humanitarian assets performance concerns, and environmental footprint.
Environmental Impact: In most places where they are found, refineries are regarded as serious polluters. The Clean Air Act, Clean Water Act, and Safe Drinking Water Act are some of the laws that have an impact on the refining business (Cetin et al., 2003).
Guaranteeing the health and safety of employees: Employee safety is a problem at every job, but process manufacturing facilities have greater risks than a typical office.
Environmental footprint: One of the signatories to the Paris Agreement is Malaysia. Greenpeace Malaysia and Klima Action Malaysia opposed the using of carbon offsetting programs to reach net-zero emissions goals.

2.3 Effect of COVID-19 Pandemic on Petroleum Refinery Industry Sustainability

Due to the importance of travel and commuting in generating demand for oil in the APEC region, changes in transportation activities have a significant impact on oil prices. Along with the emergence of COVID-19 Pandemic the biggest declines in oil demand happened in April 2020, when APEC demand was 20 % lower than in 2019 (APERC, 2022). This fall in demand has caused environmental noise emissions to significantly reduce, and as a result, environmental pollution has decreased significantly (Mofijur et al., 2021) which in turn made positive impact on sustainability index.

2.4 Current sustainability framework and assessment for petroleum refinery industry

As a powerful tool for public communication and policymaking, sustainability indicators and composite indices are gaining popularity. By conceptualizing phenomena and showing patterns, sustainability indicators make complicated information easier to understand, quantify, and convey. Despite the many available approaches, indicators-based evaluation is one of the most widely used platforms as it quantifies sustainability in a framework that is in line with the evolving definition of sustainability (Abdul Murad et al., 2019). The identification and integration of indicators within a framework are necessary for quantitatively evaluating sustainability assessment methods. Decision-makers can monitor the advancement of energy projects toward long-term viability by using sustainability assessment techniques (Shortall et al., 2015). The three pillars of sustainability (economic, social, and environmental) must be considered concurrently to help managers make more informed decisions (Labuschagne et al., 2005). PETRONAS' four sustainability lenses include sustained value creation, environmental preservation, positive social impact, and responsible governance, lead them in this endeavor (PETRONAS, 2020). Despite PETRONAS's consistently published sustainability reports since 2007, it only emphasize qualitative sustainability evaluations with no quantitative sustainability assessment method. (Naimi, 2011) has conducted a study to assess Shell's performance as a case study towards sustainability issues. However only social and environmental pillars were considered without a clear assessment for the economic pillar. Another study conducted by (Ali, 2009) to analyze the current Malaysian petroleum laws that promote sustainability in the industry, but again the scope covered one pillar that is environment neglecting the other two sustainability pillars. While the study conducted by (Bathrinath et al., 2021) to assess the sustainability challenges faced by petroleum industry particularly in India considered all the three pillars, no quantitative assessment was considered in the study. This current study seeks to fill these gaps by developing a wholistic quantitative sustainability assessment framework that considers the environmental, social and economic pillars.

2.5 Methods for sustainability framework and assessment

Sustainability evaluation is a method of evaluation that uses an iterative and pluralistic process. The need for measurements or indexes is built on the idea that "you can't manage what you don't measure" (Abdul Murad et al., 2019). Risk assessment, life cycle assessment (LCA), benefit cost analysis, and ecosystem services evaluation are some tools that are helpful for managing and assessing sustainability (Peña et al., 2022).

3. Methodology

This project is divided into three stages: establishing the sustainability pillars (environmental, social, and economic) for the petroleum refinery industries, refinery operations, and choosing the indicator, parameter, and features that are appropriate for the Malaysian PRI situations.

3.1 Identifying Environment, Social and Economic trends in PRI

Environment: Malaysia agreed to reduce greenhouse gases by 45% by 2030 as a signatory to the Paris Agreement (Azni and Khalid, 2021) in addition to implementing a series of legal frameworks, to propel the country into a sustainable, green, and low-carbon future. Social: Refiners are implementing initiatives to promote their local communities and share their success through voluntarism, altruism, and the financial benefits of being a good employer. Economic: Building robust and varied corporate governance is a top priority for refining firms in order to achieve operational excellence and target ESG results (Singh, 2021).

3.2 Refinery Operation and Process

After being retrieved and transported, crude oil must be refined in order to be converted into goods with a marketable value. Including the environmental component in productive operations has been a significant problem for the oil sector.

3.3 Identifying Indicator, Parameter and Aspect

The indicator, parameter, and aspect layers are the three assessment layers that make up the PRI sustainability assessment. Three aspects—environment, economy, and social—are used to assess a refinery's sustainability performance. According to relevance, performance, orientation, transparency, data quality, data sustainability, and data custodian, the indicators are chosen (Ahamad et al., 2014). In this study, the Department of Environment (DOE), refineries' Best Practice (BP), and Industry Target (IT) are just a few examples of contemporary refineries schemes on which the selection of indicators is based. For the three aspects eight DOE, five BP and six IT indicators were selected. Both ultimate consequences and sustainability-related elements have been quantified using indicators. It is challenging to select a set of indicators that provides an in-depth view of the system under review (Reisi et al., 2013) so trade-offs are used. The indicators' applicability to local rules must be taken into account.

3.4 Data collection

For the years 2019 through 2021, data collecting was done at two Terengganu petroleum refinery plants, Gas Processing Kertih (GPK) and Gas Processing Santong (GPS) with operation at an average of 2,345 mmscfd. Per metric tonne of ethane production serves as the foundation for data collecting.

3.5 Data collection and standardization of the target value

The DOE and other pertinent organizations offer a standard value. The performance of each indication in this study is evaluated using a standard value rather than the objective or a specific benchmark, referring to local authorities first, then industry targets (IT), and finally best performance (BP).

3.6 Evaluation against standard regulations

The units and sizes of the data that were obtained varied. Each indicator can either be categorized as type A or type B, with type A indicating a high value that corresponds to good performance and type B indicating a high value that corresponds to poor performance. To standardize the data, the Proximity-to-Target (PTT) method is employed. All variables are standardized from zero to 100, with zero indicating that an industry is the least competitive overall and 100 indicating that it has already achieved its aim. Eq(1) and Eq(2) are used by PTT to normalize indicator data. With Eq(1) is used for Type A denoting high value corresponds to good performance and Eq(2) used for Type B denoting high value corresponds to bad performance. The performance of the indication closest to the goal value is shown by the indicator with the smallest distance; the closer, the better. m_{ij} is the jth refinery's ith indicator's data value. The maximum and minimum values in the m_{ij} data set are used to calculate the $max_{(m_{ij})}$ and $min_{(m_{ij})}$, which represents the lowest benchmark. In essence, type A employs $min_{(m_{ij})}$ and m_{ij}, whereas type B employs $max_{(m_{ij})}$ and m_{ij}. The standard or goal value of the ith indicator is represented by ti. The number of tonnes of carbon dioxide equivalent (t CO2-eq; i =1t).

$$PTT_{ij} = \frac{[\left(t_i - min_{(m_{ij})}\right) - (t_i - m_{ij})] X\ 100}{(t_i - min_{(m_{ij})})} \tag{1}$$

$$PTT_{ij} = \frac{[\left(max_{(m_{ij})} - t_i\right) - (m_{ij} - t_i)] X\ 100}{\left(max_{(m_{ij})} - t_i\right)} \tag{2}$$

3.7 Index calculation

Eq(3) is utilized to obtain the parameter scores $P_{j,k}$ by total up $PTT_{k(i,j)}$ for the kth parameter in relation to the jth refinery, $PTT_{i,j}$ indicator, divided by $No.of\ indicator_k$, and the kth parameter. In order to calculate the Parameter Aggregation Score, $PAS_{j.k}$ for the jth year, kth parameter, Eq(4) below requires multiplying the aforementioned value, $P_{j,k}$ by $Weightage_k$ for the kth parameter.

$$P_{j,k} = \sum \frac{PTT_{i,j}}{No.of\ indicator_k} \tag{3}$$

$$PAS_{j.k} = P_{j,k} X\ Weightage_k \tag{4}$$

$A_{i,j}$ for the jth refinery, lth aspect, is calculated based on the Eq(5) below by averaging the $PAS_{j,k}$. The index score Ij for the jth refinery will be calculated using the below Eq(6), $A_{j,l}$ for the jth refinery, which aggregates the lth aspect.

$$A_{i,j} = \sum PAS_{j,k} \tag{5}$$

$$I_j = \sum A_{j,l} \tag{6}$$

4. Results and discussion

4.1 Weightage determination

It is essential to give each parameter a weight given the importance associated with it. All parameters are given equal weight in this case study, as explicit weights cannot be employed (Singh et al., 2012). The outcome of dividing 100 % evenly by the total number of parameters (8) is 12.5 % for each parameter. The social component is weighted at 25 %, the economic aspect at 25 %, and the environmental aspect at 50 %.

4.2 Index Results

Figure 1a shows the index score for the Gas Processing Kertih (GPK) and Gas Processing Santong (GPS). Index score in 2020 top the rankings as the most sustainable refinery with a score of 82.51 %. While, in 2019 ranks the lowest with a total score of 77.35 %. The index score is depending on current global situation.

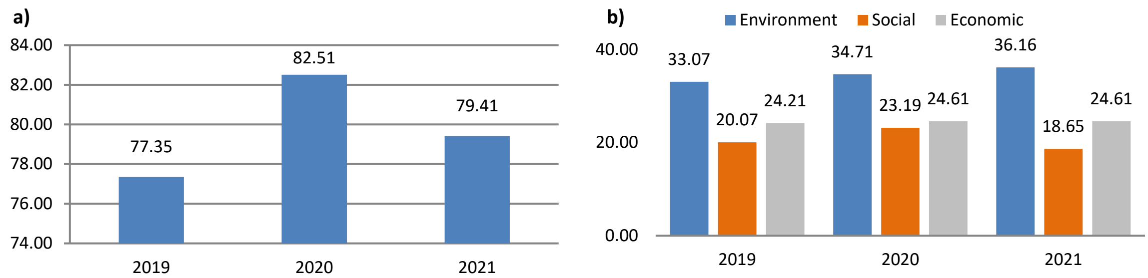

Figure 1: Illustration of (a) Index Score for 2019,2020, & 2021; (b) Aspect Score for year 2019,2020 and 2021

Assessed year sustainable performance can be figured out through aspect score. Based on Figure 1b, the environment and social element had the greatest impact on index score evaluated years. Due to the COVID-19 epidemic, Malaysia is seeing lower product demand in 2020 compared to that in 2019 and 2021. GPK and GPS therefore have the chance to lower their air emissions and avoid any social discontent. The negative adjustment in commodity price expectations is made worse by the fast rates of the energy transition. The economic continue to remain constant at 5.6 B MYR for the year of 2020 and 2021 but in year 2019 the company revenue is 5.5 B MYR. Figure 2a shows the parameter score for each of the aspects. The parameters shown in this graph that affect the 2019 score are EN1 and EN3 for the environment aspect and SO1 and SO2 for the social component. This is not surprising given the huge demand for GPK and GPS goods and the fact that the COVID-19 epidemic that will affect demand won't start until 2020. At this time, the Malaysian government began enforcing Movement Control Orders (MCO) and placing domestic and international travel restrictions.

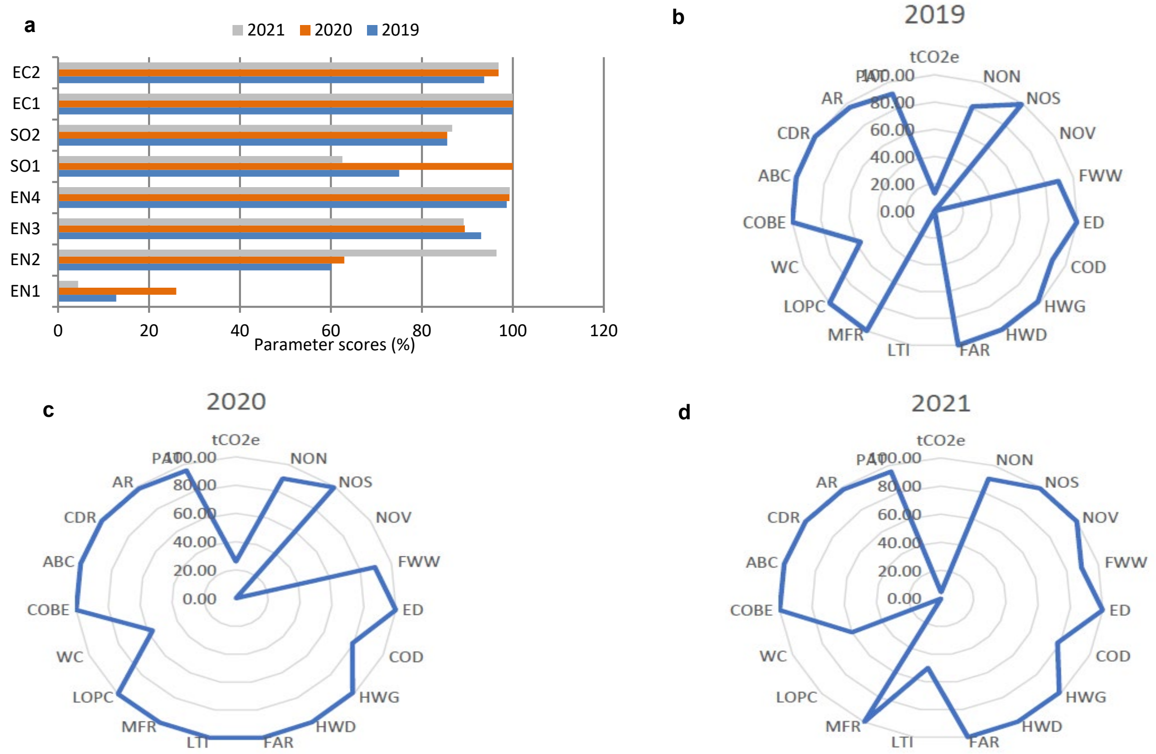

Figure 2: Illustration of (a) Parameter score for year 2019, 2020 and 2021; (b) PTT for each of the indicator in 2019; (c) PTT for each of the indicator in 2020; (d) PTT for each of the indicator in 2021

Figure 2b shows the indicators in 2019. GPK and GPS boosted their output in response to the high demand, which resulted in the highest value of total CO_2 equivalent (t CO_2-eq) in comparison to the years 2020 (Figure 2c) and 2021 (Figure 2d). The pandemic epidemic is partly to blame for the low level of production demand, but in 2021, t CO_2-eq will rise. The year 2019 has the highest chemical oxygen demand (COD) levels. The rising production rate has an impact on this. Higher COD readings signify the presence of more oxidizable organic material, which reduces the amount of dissolved oxygen (DO) in the sample. A drop in dissolved oxygen can cause anaerobic conditions, which are hazardous to higher aquatic life forms.
When compared to the years 2020 (Figure 2c) and 2021, GPK and GPS produced the largest amount of total CO_2 equivalent (t CO_2-eq) (Figure 2d). This is because of government rules and MCO being lifted, which permitted the increase in demand for the items.

5. Conclusion and recommendation

According to the established rules and laws, a sustainability framework and assessment were created for this study. The people' understanding of the industry's sustainable practices will be improved via sustainability frameworks and evaluation reports. Based on how the industry is currently performing in regard to the current global issue, the index score is calculated. The 2020 index underperformed because to the COVID-19 developing pandemic's effects on industrial activity. Due to increased production demand brought on by the revival of industrial activity, the index score increased in 2021. Future research can build on the sustainability evaluation and framework to solve the limitations of the current one.

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