

NAVIGATING UNCERTAINTIES IN THE PETROLEUM INDUSTRY: A MULTI-CRITERIA DECISION MAKING AND FORECASTING APPROACH FOR SUSTAINABLE PRODUCTION

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ABSTRACT

From 2019-2020, COVID-19 caused an uncertain situation in the petroleum industry that led to an imbalance in supply and demand and requires resilient solutions for the Pakistani industry's sustainability. The current research seeks to find these solutions in two stages, i.e., decision-modeling and forecasting-modeling. In the first step, a Multi-Criteria Decision Making (MCDM) method called the Analytical Hierarchy Process (AHP) was applied to rank the most preferred product in Pakistan's petroleum industry and concluded that Premium Motor Gasoline (PMG) of Attock Refinery Limited (ARL) is the most preferred alternative. This alternative was further confirmed by a sensitivity analysis, which proved the robustness of the results. Similarly, in the second step, the research analyzed PMG production and pricing effects on Attock Refinery Limited (ARL) sales using Multi Linear Regression (MLR), and found that production significantly boosts sales while price has minimal impact. Forecasting techniques, particularly ARIMA, effectively predicted petroleum demand, even reflecting COVID-19 disruptions. The research highlights the need for optimized PMG production and robust forecasting to ensure industry stability in Pakistan. Similarly, the research also leads to various policy formulations and will allow refineries to tackle uncertainties in the future. It provides an in-depth study of petroleum products that are preferred and in high demand so that the refineries can automate their production plans and schedule accordingly, to help maintain their sustainability.

Keywords: petroleum; AHP; ARIMA; PMG; MLR; sensitivity analysis; Pakistan

1. Introduction

The need for the utilization of fossil fuels is always on the rise as the world is transforming day by day and ever-growing advancements in wide ranging areas are being made. It is important to note with the global rise in population, the need for these resources increases and it's a daunting task to sustainably maintain the supply for longer periods of time (Kelkar, 2024). It is also important to mention that the stockpile of raw oil

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in terms of fossil fuels is limited and will eventually be used up. Therefore, it is necessary to maintain a sustainable supply of energy resources to meet the needs of society as a whole and to contribute effectively to the economy (Gandomi, et al., 2024).

In the global context, in 2018, there was a decline in oil consumption and variation in prices followed by the huge impact of COVID-19 in 2019 and 2020. The pandemic created a huge decrease in the general consumption level of consumers, and the oil refining industry is one of the core industries that suffered a huge loss (Maliszewska, et al., 2020). The lockdown situation decreased the consumption level of oil and dropped the price to \$2.175 per gallon (Khan, et al., 2020). Countries like Saudi Arabia managed to flood the market with oil on March 29, 2020, which resulted in crude oil prices dropping by more than 20% and the following effect was so shocking that it shattered the financial markets (Albulescu, 2020). This is an example of how instability in the demand for petroleum products and fluctuating prices of crude oil can badly affect markets, sectors, and industries (Younis et al., 2024). In summary, the uncertainty in the demand for petroleum products and their prices are important factors that need to be considered before making any decision, and therefore requires the utmost care in its assessment (Rao et al., 2024). It is important to note that companies usually determine their demand for factors of production through different sets of input factors that help them achieve higher market share by increasing the profit or minimizing their existing costs since production is more important and something that affects decisions further downstream (Pan et al., 2024).

Similarly, in the case of Pakistan, the petroleum products supply chain is divided into two major streams. One is upstream which consists of companies that discover crude oil and drill wells to extract, and the other is the downstream distribution which consists of refineries that turn crude oil into valuable usable products. The marketing companies are part of the downstream distribution as well. The downstream distribution is dependent on the refinery's production and its importance can be justified by the fact that it is not limited to the oil and gas industry but to other sectors and industries as well (Nazir et al., 2024). Furthermore, Pakistan is one of the countries that possesses a limited supply of fossil fuels and crude oil but has other enriched natural resources. Since Pakistan is an agricultural country, it can also produce energy through biomass and energy waste. Despite all of these resources, Pakistan is still facing the problem of not being able to meet the demand and lack of production of petroleum products (Chughtai et al., 2024).

1.1. Industrial expansion

Pakistan, previously the Indian subcontinent, was known as a petroleum hub and the first well was drilled in Kundai in 1866, which is located in the region of Indus Valley (Ahmad & Jha, 2008). The history of petroleum exploration of the Potwar Basin began in 1915 when large quantities of oil were discovered in Khaur, district Attock by the forerunner of The Attock Oil Company (AOC) (Zaidi, et al., 2013). Similarly, Pakistan Petroleum Limited (PPL) was also on the frontline of Pakistan's energy sector in the mid-1950s and found a giant gas field in Sui, Baluchistan (PPL, 2020). Years such as 1973 were shocking years for the world due to the unexpected oil price fluctuations. Oil price shocks were a result of geo-political crises, and various remarkable site discoveries were being made by the private sector and Oil and Gas Development Company Limited (OGDCL) during this time (Memon, 2018). The extensive demand for petroleum products is not only present in the transportation sector, but also in the power, agriculture,

industrial, and domestic sectors. The consumption level of petroleum products in Pakistan was around 15.28 million metric tons in 2023-2024, and the local crude oil only meets 15-20% of the overall demand, while the rest must be imported (Profit Report, 2025). Table 1 summarizes the main companies involved in exploration, production and refining crude oil in Pakistan.

Table 1
Major refineries and companies that produce crude oil

Major refineries of Pakistan	Major companies that produce crude oil in Pakistan
Attock Refinery Ltd (ARL)	Orient Petroleum Private Limited (OPPL)
BYCO Petroleum Pakistan Ltd (BPPL)	Pakistan Oilfields Limited (POL)
National Refinery Ltd (NRL)	MOL
Pak-Arab Refinery (PARCO)	Mari Petroleum Company Limited (MPCL)
Pakistan Refinery Ltd (PRL)	Oil & Gas Development Company Limited (OGDCL)
ENAR	United Energy Petroleum Limited (UEPL)
DHODAK	Pakistan Petroleum Limited (PPL)

As seen in Table 1, the ARL is considered the most important in the petroleum sector of Pakistan and is therefore considered of primary importance for the current study. ARL covers the northern region of Pakistan and is located in Rawalpindi which is in the north of Punjab. The purpose of the refinery is to refine crude oil and supply major petroleum products. It has a capacity of 53,400 barrels per day and by March 2024 it had produced about 1.266 million metric tons of petroleum products, operating at nearly 75% of its total capacity. This means it used three-fourths of its annual capacity of 2.5 million metric tons, which equals around 55,400 barrels per day (ARL, n.d.a). There are fifteen products currently being produced at ARL and some of them are listed in Table 2.

Table 2
ARL products

Liquefied Petroleum Gas (LPG)	High-Speed Diesel (HSD)
Unleaded Premium Motor Gasoline (PMG)	Light Diesel Oil (LDO)
Jet Petroleum -1 (JP-1)	Kerosene Oil
Jet Petroleum -8 (JP-8)	Residual Furnace Oil etc.

Source: (ARL, n.d.a)

The current research divides the assessment into two sections, i.e., decision-based and forecasting-based. The purpose of using this method was to formulate a complete picture that can help policymakers and stakeholders ensure that the industry remains sustainable and efficient. Similarly, it must be mentioned that the uncertainty in the petroleum sector manifests in two critical and interdependent dimensions, i.e., resilient decision-making under volatility and predictive uncertainty. This deliberate integration of decision analysis and forecasting mirrors the industry cycle, aligning decision parameters with forecasting objectives to enable truly informed decisions.

Decision-making is always an integral part of daily life, ranging from the choice of cooking food to selecting the quality of petroleum to put in your automobiles. In the current research, since ARL produces various kinds of petroleum products, it is hard to predict which product is chosen the most by consumers based on distinct criteria. Therefore, MCDM, a mathematical and graphical tool, can be used with several criteria adopted from the literature and company experts for this complex decision scenario (Yousaf, et al., 2017). Some criteria utilized in the literature consist of production factors such as production cost, technical difficulty, and product extensibility (Roy & Abdul-Nour, 2024). In such a scenario, various MCDM techniques can help formulate a reasonable decision for the policymakers such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Full Consistency Method (FUCOM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), to mention a few. In the current research, the AHP is a perfect choice since it follows a hierarchical structure with the goal, criteria, and alternatives at different levels. The AHP is a decision-making tool that helps solve any unstructured problem and was introduced by T.L. Saaty (Saaty, 1980). The AHP works based on a rating method with values being provided by experts and helps convert these values into weights. Then, the alternatives are scored based on pairwise comparisons by the decision-makers. The process involves weighting and scoring results in a final total score for each alternative to generate a rank (Saaty, 2004). Many researchers around the world use the AHP as an MCDM technique due to its simplicity and the efficiency with which it produces accurate results (Khaira & Dwivedi, 2018). Similarly, the current study also employs the sensitivity analysis which is an indispensable component of the AHP methodology. The sensitivity analysis is necessary given the inherent subjectivity in the expert-driver pairwise comparisons, and the research rigorously incorporates the sensitivity analysis to validate the stability of the outcomes, fulfilling the first stage of the assessment (Dutta and Deka, 2024).

Furthermore, in the second stage, the research also utilizes various forecasting methods to ensure a proper assessment of the effects that the production and prices might have on the sales of various refineries in the case of a developing country like Pakistan, especially in the case of ARL, the main target refinery for the current study. Finally, it is necessary to evaluate the production and consumption of various refineries in the case of Pakistan. These steps are carried out to ensure that Pakistan's oil industry is sustainable and generates economic benefits for the economy.

1.2. Research aim

The aim of this article is divided into several parts. The first part uses the AHP, an MCDM method, to drive top petroleum products based on different criteria. Previous literature lacks applications on driving products of the petroleum industry possibly due to

the difference in demand inside various sectors based on different geographical locations. The second part of this research is to study ARL and the effects that the production and prices have on sales of refineries in Pakistan. The third part of the research aims to cover the forecasting aspect for all refineries based in Pakistan. This will help analyze the level of production and consumption inside Pakistan under uncertain situations.

2. Literature review

The global petroleum and fossil fuel situation depends on many dynamics, especially in the case where its utilization has increased over time and with the ever-growing population. Our growing dependence on petroleum has outstripped our ability to meet global demand, i.e., of the individual users, transportation sector, power generation, etc. (Dagar & Malik, 2023). Global economies have now started shifting towards renewable resources and away from non-renewable resources like petroleum and fossil fuels. Although petroleum products remain a cornerstone of global energy systems and economic stability, their markets are still vulnerable to uncertainties such as economic policy shifts, geopolitical shifts, and imbalances in supply and demand. These uncertainties are known to amplify the volatility of prices and also disrupt the supply chains, and are not limited to only a certain area or a country but rather transcend the borders on a global scale (Gamso, Inkpen & Ramaswamy, 2024).

Due to economic development, demand for petroleum products increased dramatically and production levels also increased. Every region of the world has different utilization rates; Asia consistently shows utilization rates higher than other regions like Africa and Latin America (Ruble, 2019). Geopolitical tensions such as the Russia-Ukraine conflict and the Middle Eastern conflicts have added more to these dramatic circumstances that impact supply-demand, make the economic situation more volatile, and also result in the spiking of oil prices. From 2022-2024, the prices of Brent crude fluctuated between \$74 and 90 USD per barrel due to the OPEC production cuts, followed by the sanctions on Russia (Carr et al., 2024). Moreover, the economies of scale that help the refining sector, are composed of some companies that are vertically integrated and involved in all streams of the supply chain in order to benefit by producing a wide range of products. The difficulty with extensive supply chains is to ensure the gain of benefit by producing a wide range of products. Similarly, the difficulty with such an extensive supply chain network in the oil industry sometimes leads to risks associated with designing and operating problems (Mohammad et al., 2025). The large average size of such a supply chain can be justified by the fact that after processing the crude oil, the refineries produce various energy products, i.e., 13.53 million tons in total. This is what makes it difficult to manage such an extensive supply chain, especially under unstable situations. The extensive production throughout the supply chain is depicted in Figure 1.

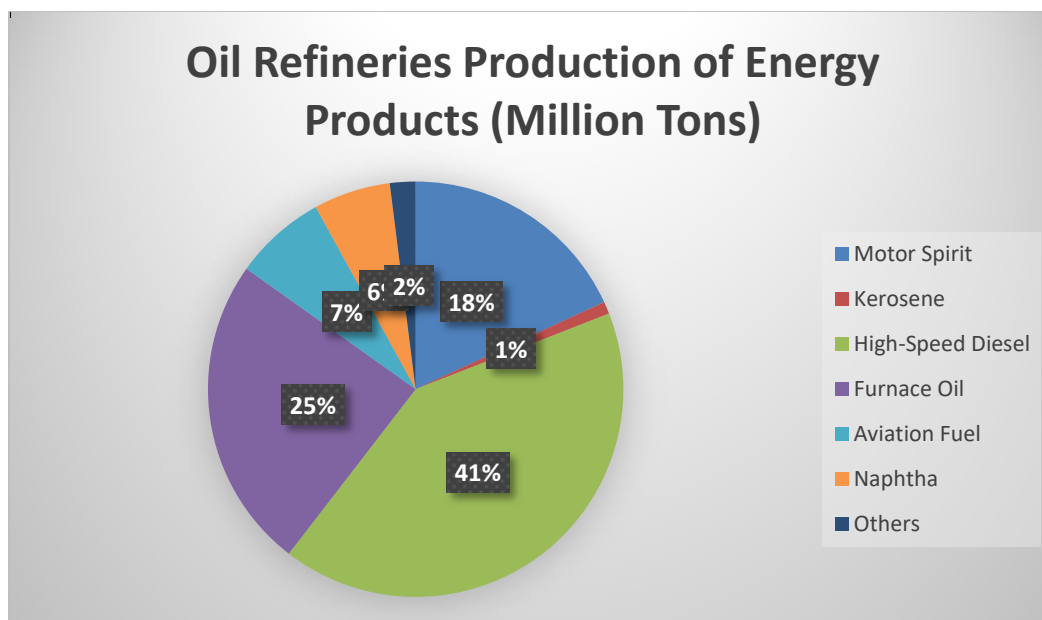


Figure 1 Energy products production in 2024-25
Source: Simonsky, 2025

Furthermore, the uncertainty within the petroleum industry lies in either price or demand since it is necessary to keep up with the ever-changing trends. Caldara and Iacoviello (2018) state that uncertainty shocks can weaken small currencies when the level of uncertainty increases. Previous literature also states that the influence of oil is so vast that it affects other factors like the CPI stock market, gold prices, and many other factors which can further result in the increase or decrease in prices of various commodities (Ozkan et al., 2024). Similarly, the rise in geopolitical uncertainty also causes oil prices to fluctuate and inversely impacts the countries that export oil in the long run (Akram, 2020). Depreciation of currency is another factor that further reduces the buying power which certainly affects the imports as the higher prices of oil squeeze demand, supply, and income (Bennett & Grabs, 2025). Diaz, Cunado, and De Gracia (2024) state that instead of supply shocks, demand shocks are the main factor behind the adjustment of prices globally. Another uncertain period occurred when OPEC changed their production quotas followed by the early 2000 recession, the 9/11 incident (2001), the political instability in Nigeria and Venezuela (2003), and the Iraq war (2003) (Filippidis, et al., 2020). Benk and Gillman (2020) note that inflation expectations rose after the 2008 monetary-base expansion, but oil prices driven by those expectations collapsed in 2014, further exacerbating the downturn. The latest uncertain situation, caused by COVID-19, resulted in lockdowns and lower petroleum demand, especially in the transportation sector and impacted the financial markets as well as the oil prices (Albulescu, 2020). It is important to mention that the energy transition policies also add to the uncertainty as firms like SLB and Baker Hughes are now transitioning into carbon capture and climate-related regulations are reshaping corporate strategies, which highlights a Fed rate cut of 150 basis points and thus adds to the uncertainty to petroleum supply chain (Kiley, 2025).

Furthermore, Asia is considered a global hub for the refining of oil and also hosts some of the biggest refining industries in regions such as South Korea, India, and China. The

refining capacity of these countries can be demonstrated by the fact that the Asia-Pacific regions have the highest values in terms of refining capacity of a thousand barrels per day (BP, 2025) as shown in Figure 2.

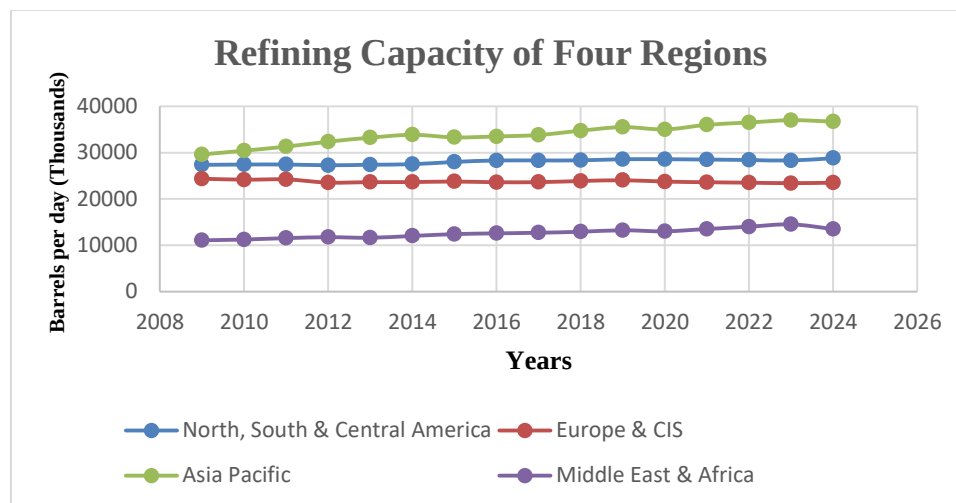


Figure 2 Refining capacity of regions
Source: BP, 2025

In comparison, for countries like Pakistan, the refining capabilities are still considered underdeveloped because of the outdated infrastructure and heavy reliance on crude oil, which the country is trying to accommodate in collaboration with China under the China-Pakistan Economic Corridor (CPEC) (Khan, Shi & Ali, 2024). Pakistan saw a record high consumption of oil in May 2024 which was 514 thousand barrels per day while the production was 62-64 thousand barrels per day in the same time period (EIA, 2025). Due to limited reserves of oil within Pakistan and the political nature of energy, along with such a huge difference in terms of consumption and production, the country has to import huge quantities of oil and other related products from the Middle East, especially from Saudi Arabia (Ahmad et al., 2024).

Furthermore, since 1992, petroleum products have been dominating the total energy demand across various sectors, especially the transportation sector, and with the ever-increasing demand, the uncertainty in the petroleum supply chain has reached a peak in Pakistan (Rehman, et al., 2019). The country's dependency on oil imports is due to higher consumption in various energy sectors which leads to higher prices (Raza & Lin, 2024). To overcome the shocks created by prices, the country needs to reexamine its production policy and develop better systems to overcome the uncertainty and losses (Imran Rafiq, 2024). Similarly, although Pakistan imports almost 85% of its petroleum needs, the government generates approximately 13 billion USD annually from petroleum-related taxes and duties, which are added to the national exchequer, and with the macroeconomic uncertainty, a certain increase in exports is negated by such a situation that further reduces the exports to a mere 0.7% (Khan et al., 2021). Figure 3 illustrates the gap between the consumption and production levels of Pakistan's energy products and also shows the biggest decline in consumption from 2020-2021 due to COVID-19 and its impact on the transportation sector.

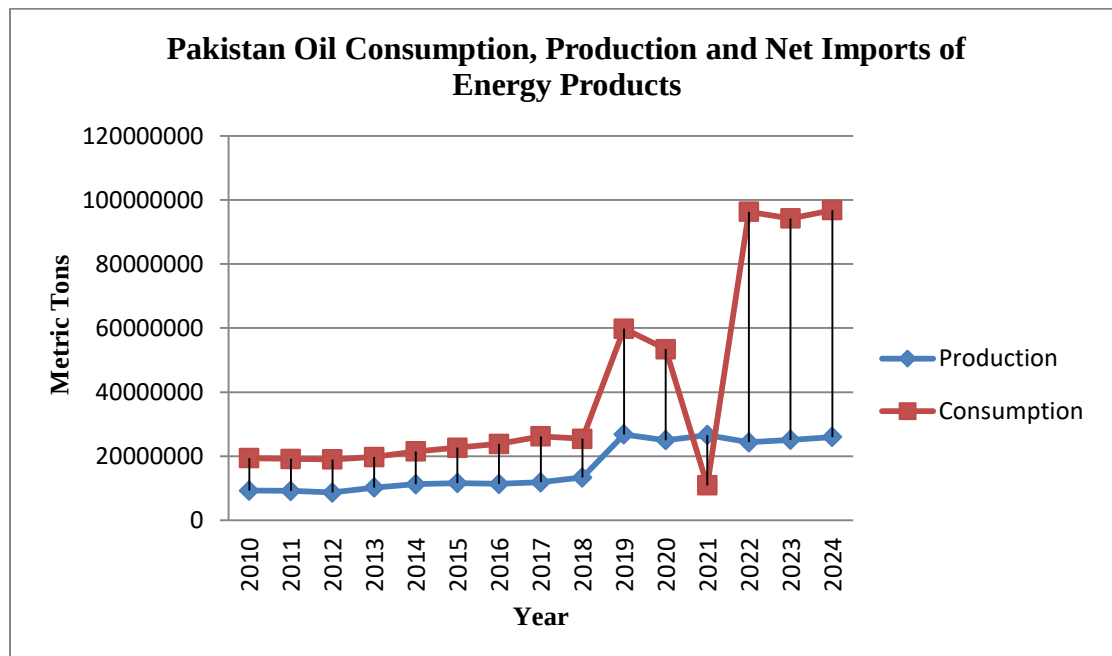


Figure 3 Pakistan's consumption, production and net imports of energy products
Source: Enerdata, 2024

Previous literature also links Pakistan's structural vulnerabilities to the uncertainties in economic policies and energy security. The country's fiscal deficits and political instability negatively affect the market, and therefore impact the stock exchange. Even the CPEC faces delays due to debt sustainability concerns and geopolitical tensions in the region, directly impacting the LNG projects, etc. (Mahmood, 2023). This demands a conclusive assessment of Pakistan's capability to ensure sustainability in the petroleum sector under uncertain conditions.

The current research adopts a bifurcated analytical framework to comprehensively address the research objectives using a two-stage evaluation assessment, i.e., decision-modeling and forecasting or predictive modeling (Shi et al., 2024). In such a scenario, a vigorous assessment is required and for this purpose, the current study adopts various research methods to evaluate the topic at hand. The first stage adopts a Multi-Criteria Decision-Making (MCDM) method, i.e., the AHP. MCDM techniques are useful when it comes to complex decision-making scenarios that require assessment of alternatives based on distinct criteria to help assist the policymakers (Ali et al., 2020). Various MCDM methods are adopted in numerous applications, i.e., FUCOM, ANP, VIKOR, and TOPSIS, etc., each possessing its applications over the past literature. The current study focuses on the AHP because of its hierarchical structure that comprises goals, criteria, and alternatives. The literature comprises various applications of the AHP methodology, either as a separate entity or as hybrid combinations with other techniques.

One such application in the Indian hotel industry involves the AHP in a fuzzy environment, highlighting the green behavior of the employees (Nadeem et al., 2025).

Evaluation of a lecturer's performance is another application of the AHP with a hybrid combination of fuzzy TOPSIS method in the country of Vietnam (Do, Tran & Tran, 2024). Forest management is another area that the AHP excels in enabling the sustainability of the environment and selecting the best possible European experts to ensure authenticity (Grošelj, Zandebasiri & Pezdevšek Malovrh, 2023). Similarly, the applications of MCDA tools such as the AHP and TOPSIS models have been very well studied in terms of their vast applications from 2000 to 2019 (Khan & Ali, 2020) and to 2023 (Chaube et al., 2024). The AHP and fuzzy entropy-TOPSIS also include applications in the area of petroleum upstream investment in the connected African basins, a study very much in line with the current research (Cui, Taiwo & Aaron, 2024). It is worthwhile to mention that on one hand, the AHP provides a structured framework for multi-criteria decision-making, and the sensitivity analysis approach proves to be its extended validation step. Previous research shows that AHP assessment can depict volatility in a few scenarios and in such cases it calls for additional validation (Vásquez, Escobar & Manotas, 2021). In some areas of AHP research, such as health-care related studies, only 55% report sensitivity analysis testing, which might prove inconsistent in some cases (Schmidt et al., 2015). The current research follows some of the recent literature that allows sensitivity testing to prove uncertainty management, transparency enhancement and group decision validation in some cases, thus proving to be an extended choice to be used alongside the already established methodology for the current study. One of the recent applications involves the evaluation of the public transportation business models via the implementation of the fuzzy AHP and sensitivity analysis (Buran & Erçek, 2022). Similarly, selection of the process mining technology is also a valid application of the AHP and the sensitivity analysis, adding robustness to the overall assessment (Dogan, 2021). Another application involves the selection of a natural fiber via sensitivity analysis and AHP-TOPSIS methodologies (Bhadra, Dhar & Abdus Salam, 2022), giving valid reasoning for its effective implementation in the recent applications and valid support for its implementation in the current research.

Furthermore, in the second predictive assessment stage, the current research also focuses on the forecasting of various dimensions connected to the petroleum sector of a developing country such as Pakistan. Different forecasting techniques are implemented such as moving average, weighted moving average, exponential smoothing factor, and Auto Regressive Integrated Moving Average (ARIMA). Such techniques include various applications in the literature such as the use of exponential smoothing along with weighted moving averages in the forecasting of sales as financial literacy (Saputra & Hariyana, 2024). Weighted moving average also includes applications in the areas of building statistical quality charts from the beta distribution (Hamasha, Shawaheen & Mayyas, 2024) and the forecasting of the streamlining inventory at various trading companies (Suryadana & Sarasvananda, 2024). Similarly, ARIMA involves various applications especially in the area of financial risk prediction, based on machine learning concepts (Dong et al., 2024). Forecasting of the railway industry's shares is another example of ARIMA's widely implemented applications (Toshaliyeva, 2024), along with the modeling of heart rate prediction in the health industry (Ni et al., 2024). Lastly, the prediction of the diesel and petrol prices in Ghana is also an example of ARIMA's widespread applications, especially in combination with SARIMA models (Agyare, Odoi & Wiah, 2024).

2.1. Research gap

The current research involves a multi-dimensional application in the evaluation of the petroleum sector in the case of a developing country such as Pakistan. The literature highlights various applications in terms of the studies being carried out regarding policies of different countries based on different methodologies; however, there are few studies that have been carried out in a developing country that highlight an application based on such a multi-dimensional perspective. The current study will assist policymakers in terms of complex decision-making along with the implementation of sensitivity analysis for robustness and validity, and also help with forecasting various areas such as the production and consumption of the petroleum industry in the case of Pakistan. It will help solve the issues related to the industry and answer any potential vulnerability that might arise. Similarly, it will also answer the following hypothesis related to the sales of refineries in Pakistan:

H1: Production of PMG (a product of ARL) has a positive impact on sales of refinery

H2: Price of PMG has a negative impact on sales of refinery

Based on these discussions, the research gaps in this area and the novelty of this study have been identified, and the proposed application of the current research is a first-of-its-kind study.

3. Methodology

The current research comprises both qualitative and quantitative methods (Ruble, 2019) and divides the assessment into two parts, i.e., decision-modeling and forecasting or predictive-modeling. In the first part of the collection of primary data, interviews were conducted with the employees of ARL, and the top four petroleum products were selected and used in a questionnaire to evaluate the priority of products. The questionnaire had 12 five-point Likert-scale questions including a question to assign preference over other products which is shown in the Appendix. The opinions obtained from the experts were then subjected to the AHP to assess the criteria and alternatives. The first stage concluded with a sensitivity analysis being applied to the highest rated criteria and its impact was observed on the final rankings of the alternatives.

3.1. AHP for selection of products made in refineries

The sources of the criteria considered for the current research are two-fold and include secondary and primary data, both of which include past literature and the expertise provided by employees of ARL. The literature containing the relevant criteria and their applications that led them to be chosen for the current research are depicted in Table 3. The AHP determines a preference and evaluates weights based on responses gathered through a questionnaire. The goal is to obtain the most preferred petroleum product by taking a sample of 134 responses. The profile of the experts involved in the pairwise comparisons is shown in Table 4. The goal, criteria under consideration and the alternatives that were chosen based on the recommendations of the experts that are to be evaluated using the AHP are shown in Figure 4. The entire process depicts the pathway of formulating the hierarchical structure for the assessment of the AHP.

Table 3
Criteria definitions and sources

Criteria	Definition	Reference citation
High-risk & safety concerns	Denotes the properties of the petroleum products that might result in catastrophic events such as explosions and the related hazards that might require administrative controls to prevent any potential injury or illness.	(Aydin, Seker & Şen, 2022)
High efficiency in terms of mileage	A mileage ratio of a real-world vehicle or car to an ideal break-loss equivalent.	(Patankar, Lin & Patankar, 2021)
High cost	An amplified price volatility as a result of low inventory levels and supply-demand imbalances that results in elevated costs.	(Ederington et al., 2019)
Causes highest amount of pollution	Factor that defines the ability of a petroleum product to generate great amounts of pollutants during combustion, extraction or refining.	(Tavella et al., 2025)

Table 4
Breakdown of expert profile

Expert profile	No. of respondents
Petroleum engineers	36
Refinery administrators	41
Petroleum analysts	25
Academics (students, professors)	32

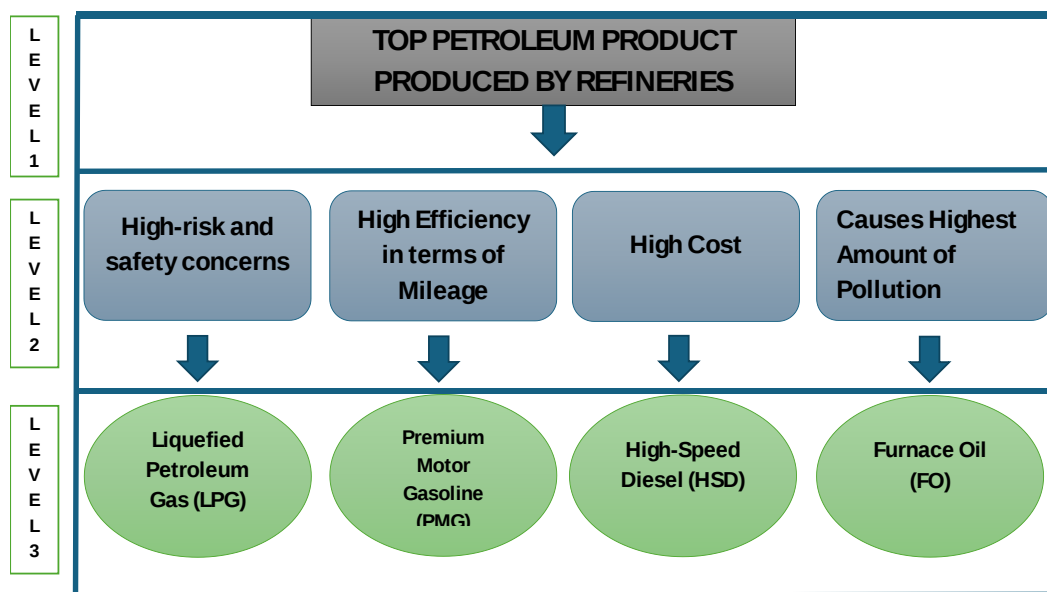


Figure 4 Three levels of AHP for decision-making

As shown in level 2 of Figure 4, the criteria under consideration include the highest risk and safety concern, higher efficiency in terms of mileage, cost and higher pollution. The four most popular petroleum products are the alternatives to be evaluated against each criterion. The scale used in the AHP was Saaty's scale which is shown in Table 5 (Saaty, 1980). First, a pairwise matrix for each criterion was constructed and then the criteria were rated with numbers used in Table 5. If a criterion/product was preferred over another, reciprocal values (e.g., 1/3, 1/5) were assigned to reflect this priority. These comparisons were organized into a priority vector using eigenvalue calculations. Each product was then assessed as an alternative against every criterion. A normalized matrix was generated to standardize the data, and final weights were determined by averaging rows. This approach ensured consistent, bias-free rankings across all criteria. Similarly, the Consistency Index (CI) was calculated using Equation 1, which helped find the Consistency Ratio (CR) which should always be less than 0.1, as depicted in Equation 2. CR was calculated using a random index scale shown in Table 6.

Table 5
Saaty's scale

Numerical representation	Linguistic representation
1	Equal Importance
3	Somewhat more important
5	Much more important
7	Very much more important
9	Extremely more important

Source: (Saaty, 1980)

Table 6
Random Index scale

Number of alternatives	Random Index (RI)
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41

$$\text{Consistency Index} = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

$$\text{Consistency Ratio} = \frac{CI}{\text{Random Index (RI)}} \quad (2)$$

3.2. Sensitivity analysis

The steps involved in the sensitivity analysis are:

- Identify the highest rated criterion, i.e., the weight obtained for the highest-rated criterion after the AHP analysis.
- Adjust the perturbation value, i.e., a change of +0.10 is being applied and the new weights are being calculated via Equation 3.

$$\text{New Weight}_i = \text{Original Weight}_i \times \frac{\sum \text{Original Weights}_{\text{other}}}{1 - \text{New Weight}_{\text{target}}} \quad (3)$$

- Recalculate the global priorities to compute new priorities, as depicted in Equation 4.

$$\text{Global Priority} = \sum (\text{Local Priority} \times \text{Adjusted Criterion Weight}) \quad (4)$$

- Compare the results.

3.3. Use of Multiple Linear Regression to forecast sales of ARL's PMG

Multiple linear regression (MLR) is a technique used to display the correlation between the dependent variable and more than one independent variable. In the second phase of this study, ARL's product PMG is chosen for further analysis and to forecast its sales. The data was gathered from ARL, which contained the production of PMG and price as an independent variable and sales of PMG as a dependent variable. Hypotheses were tested by keeping in view the P value, as depicted in Equation 5.

$$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \varepsilon \quad (5)$$

Equation 3 was utilized to run Multi Linear Regression (MLR) to evaluate results in the context of Pakistan.

3.4. Forecasting comparison of petroleum products consumption

In the next phase, the consumption data was collected from secondary sources, and therefore, moving average, weighted moving average, and exponential smoothing factor techniques were used to determine the best forecasting method with the lowest mean square error. The best forecasting technique with the lowest square error was the exponential smoothing factor. The smoothing factor was taken as $\alpha = 0.90$. The exponential smoothing is applied using Equation 6.

$$F_{t+1} = \alpha A_t + (1 - \alpha) F_t \quad (6)$$

After implementing the previous forecasting techniques, another comparison was made on the same data set with the ARIMA technique and it proved to be the best fit among all other techniques. The results produced by ARIMA were very close to the actual consumption level.

3.5. ARIMA forecasting for production of refineries

In the last phase, the production of all concerned refineries was forecasted until 2027 through integrating AR (Auto-Regressive) and MA (Moving Average), i.e., ARIMA. This technique was founded in 1976 (Box, et al., 1976), and is a statistical method applied when analyzing a single variable, classifying it as a univariate model. AR consists of the p model while MA consists of the q model. The future value of the variable is supposed to be a linear combination of past observations and random error. It can be stated as follows in Equation 7.

$$y_t = C + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \dots - \theta_q \varepsilon_{t-q} \quad (7)$$

4. Results and discussion

4.1. AHP

The current research carries out the evaluation based on various methods and in the first step, the AHP method was implemented using the ratings obtained from the experts. To do so, the normalized weights were calculated by assigning Saaty's scale to the criteria by making a comparison matrix. More weight was allocated to efficiency as the experts agreed that they look for a product with more potential for mileage. The second accepted criterion was cost. Cost matters when a petroleum product is being purchased, especially for an economically weaker country, but it does not matter more than efficiency. The normalized weights obtained for the criteria are depicted in Figure 5, which clearly shows that efficiency has a greater weight more than other criteria in the initial stages. The Consistency Ratio (CR) obtained for this criterion is well below the acceptable threshold of 0.1, and therefore the judgments are consistent and the criterion is accepted. Specifically, the CR for 'efficiency' (0.063) and 'cost' (0.069) are both below 0.1, confirming their consistency and acceptance. In contrast, 'risk & safety' (0.531) and 'pollution' (0.101) exceed the 0.1 threshold and are thus rejected, as depicted in Table 7.

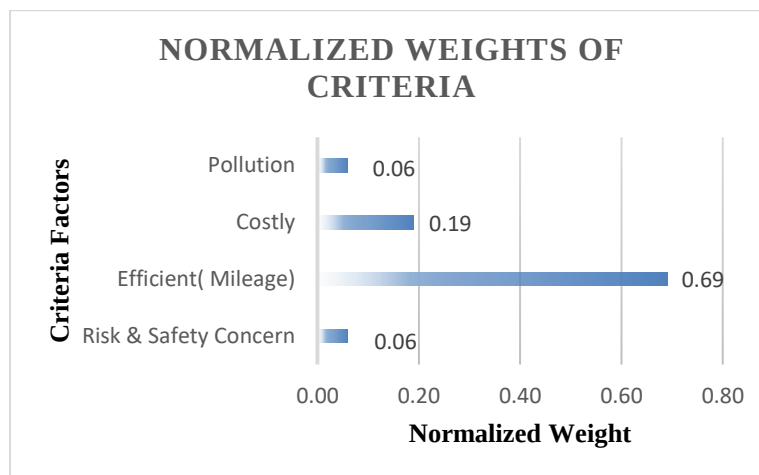


Figure 5 Normalized weights obtained for criteria

Table 7
CR values for the criteria (significant criteria <0.1)

Criteria	Consistency ratio
Risk & safety concerns	0.53104
Efficient in terms of mileage	0.063041
Costly	0.06943
Pollution	0.100606

After concluding the AHP assessment, the final ranking was obtained based on the highest normalized weight. The most popular and preferred product was PMG due to its ability to give more mileage and quality measures. People find PMG increases the efficiency of work and leads to fewer concerns as compared to other products. Although it still has risk and safety concerns, it is considered safer in comparison to LPG, and this is the reason that LPG is currently banned in public transport inside Pakistan. The rest of the rankings included diesel, LPG, and furnace oil as the second and third-ranked alternatives, respectively, and the outcomes are shown in Figure 6. PMG is regarded as a perfect choice by the experts because of its alignment with national and international fuel standards, production capabilities, and technical specifications. It is a premium-grade gasoline and the company has also introduced the production of 91 RON (Research Octane Number) PMG to extend its capacity for the production of Euro-V-complaint gasoline (ARL, 2024). Similarly, ARL is also investing \$500 million for an upgrade to boost PMG production by 25% and to reduce the reliance on imported fuels. The reason behind this venture is that PMG has been shown to be the source of a significant portion of ARL's profit accounting for the 56% of its total sales (Chase Securities, 2023). It should also be noted that PMG is an environmentally friendly fuel alternative, contributing to the reduction of air pollution and an answer to the ever-increasing smog in the region (Khan et al., 2025). Based on this, it is a probable choice for experts and policymakers to ensure its implementation and production capacity to meet Pakistan's sustainability needs.

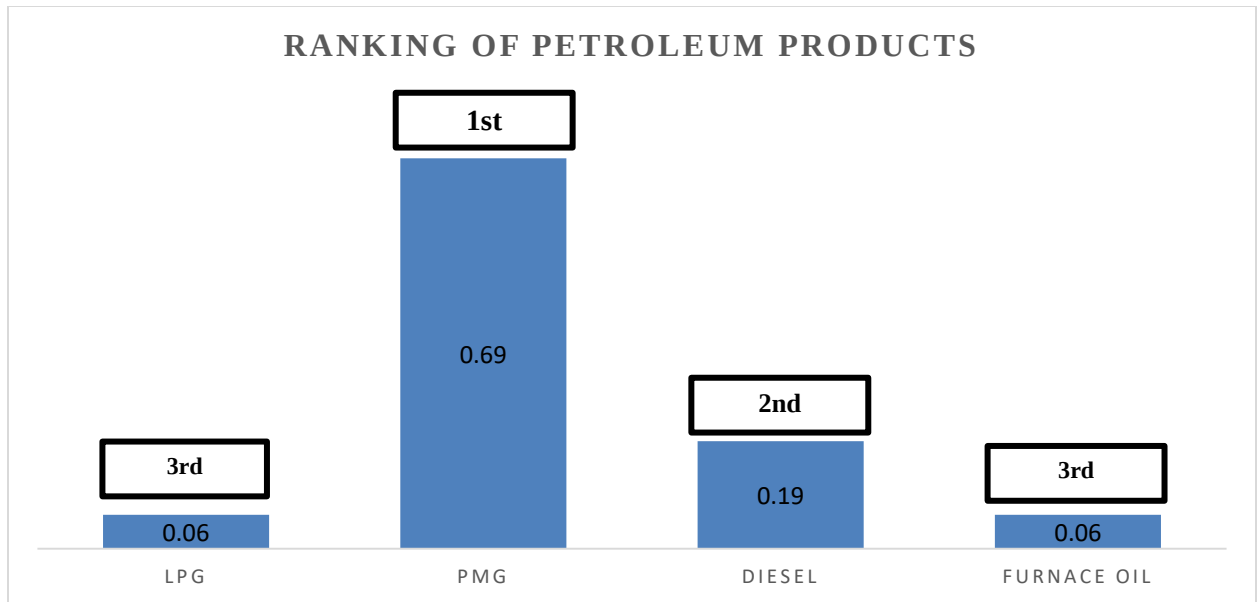


Figure 6 Ranking of AHP assessment-petroleum products

4.2. Sensitivity analysis

The next step involves the sensitivity analysis being applied to the highest-rated criterion after the AHP assessment. For this purpose, a change of 0.10 was made to the 'efficient in terms of mileage' criterion and new weights for the criteria were generated as shown in Table 8.

Table 8
New criteria weights post-sensitivity analysis

Criterion	New weight
Risk & safety concern	$0.06 \times 0.6774 = 0.0406$
Efficient in terms of mileage	0.790 (adjusted)
Costly	$0.19 \times 0.6774 = 0.1287$
Pollution	$0.06 \times 0.6774 = 0.0406$

Similarly, the next step involved the assessment of new global priorities to reevaluate the alternatives for any potential changes, as shown in Table 9.

Table 9
New priority values for the alternatives post-sensitivity analysis

Alternative	Global priority	Change from original
LPG	0.0864	-0.0198 (-18.6%)
PMG	0.6413	+0.0241 (+3.9%)
Diesel	0.2237	-0.0033 (-1.5%)
Furnace Oil	0.0484	-0.0012 (-2.4%)

As seen in the sensitivity analysis, the PMG ranking seems to have further extended its lead by approximately 3.9%. This is because PMG has the highest local priority mileage and increasing or adjusting the criterion further amplified its advantage. Similarly, diesel remained stable with a slight decrease of 1.5%. LPG and furnace oil were the most weakened with LPG dropping by 18.6%. The overall outcome shows that ranking depicts the overall robustness despite a significant increase of 10% in the weight of the highest rated criterion. It can be safely said that the overall dominance of the PMG petroleum product under the uncertain conditions promises a better future. These results provide a better understanding and support better policy formulations when adopting fuels for efficient transportation or logistics. PMG is a clear winner with better mileage. In such a scenario, the government should work closely with ARL to boost the production of PMG for better margins and effective solutions. Diesel can remain a second option in terms of cost-driven cases but it shouldn't be prioritized especially when it comes to environmental safety.

4.3. Sales forecasting of PMG - Multi Linear Regression (MLR)

To see the trend of sales that ARL has for all of their refined products in total, first, a comparison was made to see the behavior of the data. The assessment was carried out on the most recent available public data. The uncertainty is shown in Figure 7 as there is no proper trend.

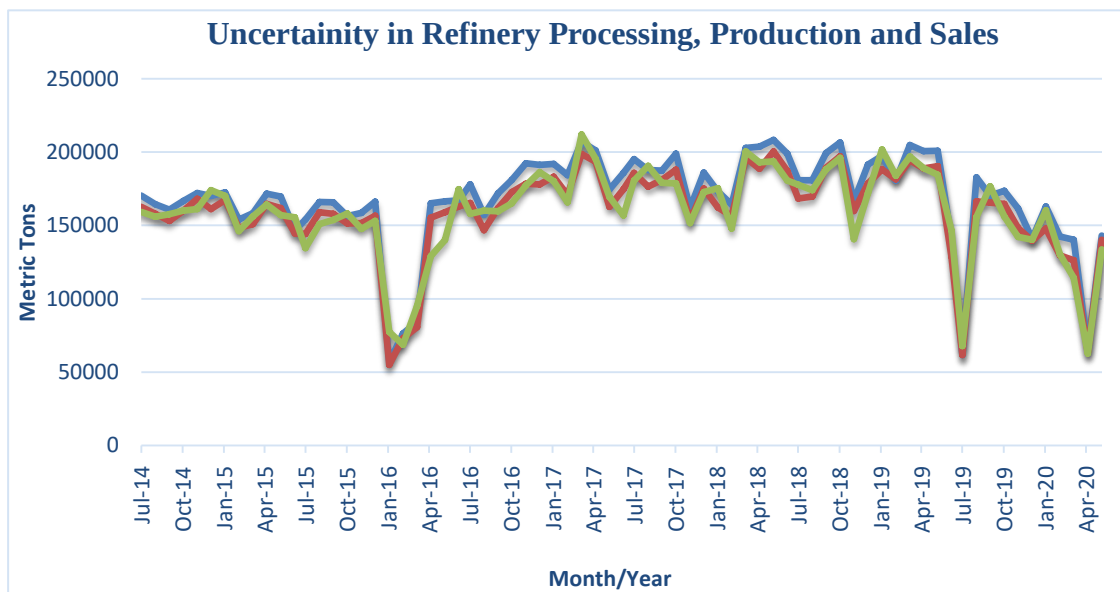


Figure 7 Uncertainty observed in ARL via MLR

As can be from Figure 7, ARL produced fewer amounts of products in January, February, and March of 2016. The production level of PMG was set as zero in these three months as shown in the residual plot in Figure 8. The latest uncertainty caused by the recent COVID-19 pandemic and the decline in the operations of ARL is visible as the processing of crude oil, production of petroleum products, and sales of ARL declined simultaneously. Saudi Arabia cut down production due to the effect on prices as the COVID-19 timeline extended. Therefore, lower prices resulting from less demand due to the pandemic forced the current operating refineries to limit their level of production. MLR was used to specifically target PMG sales by considering the latest available production and price data. The R-square value was 0.956 which is approaching 1 as shown in Table 6. This certainly shows that there is a strong positive correlation with independent and dependent variables as shown in Figure 9. The P value for production is lower than the level of significance which is 0.05 in our case. Therefore, our hypothesis stating that if the production of PMG goes up, sales will increase was accepted. The second hypothesis regarding price was rejected because the P value is greater than the required level of significance which leads to the conclusion that in the Pakistani context, the price won't have any significant role. This is likely because the use of PMG is a necessity and people will use it for their purposes regardless of price.

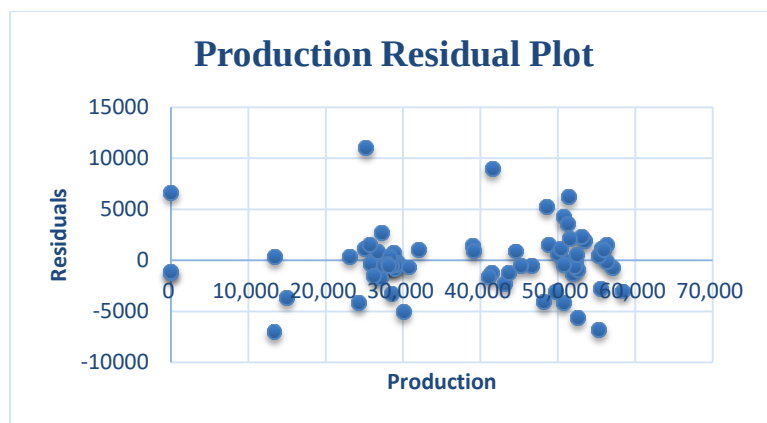


Figure 8 Residual plot

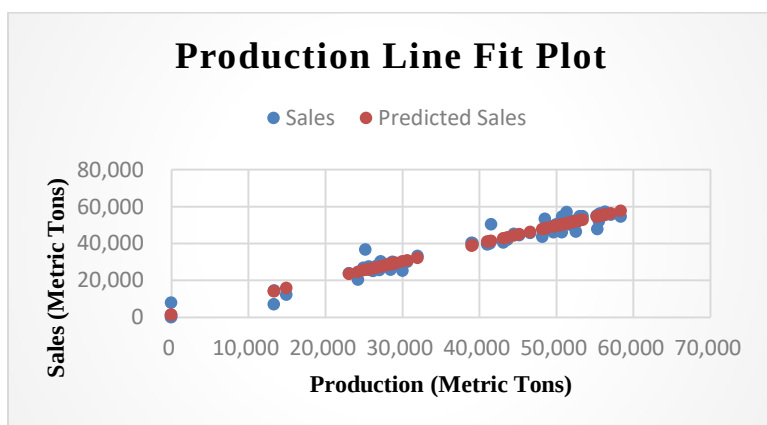


Figure 9 Correlation production line fit plot

Table 6
Multi Linear Regression (MLR)

Multiple R	0.978090998
R Square	0.956662
Adjusted R Square	0.955387353
Observations	71
Coefficients Intercept	819.2850889
Coefficients Production	0.964566559
Coefficients Price	4.594800285

4.4. Consumption level of Pakistan-forecasting comparison

The current analysis was made based on comparing various forecasting techniques, i.e., simple moving average, weighted moving average, and exponential smoothing. The

observations were made using the latest data available and forecasted to the required dataset. The value obtained for α was 0.9. Out of all the techniques, the lowest Mean Square Error (MSE) was observed from the exponential smoothing factor as shown in Table 7. Figure 10 shows the past data trend and how consumption of petroleum products has increased since the independence of Pakistan. Apart from that, the exponential smoothing forecasted line is observed to be the nearest to the actual line of consumption which makes it an accurate measure and technique to forecast such available data.

Table 7
MSE obtained for comparative forecasting methods.

Forecasting method	Mean Square Error
Simple Moving Average	1701584.563417
Weighted Moving Average	1196710.362636
Exponential Smoothing	770629.671178

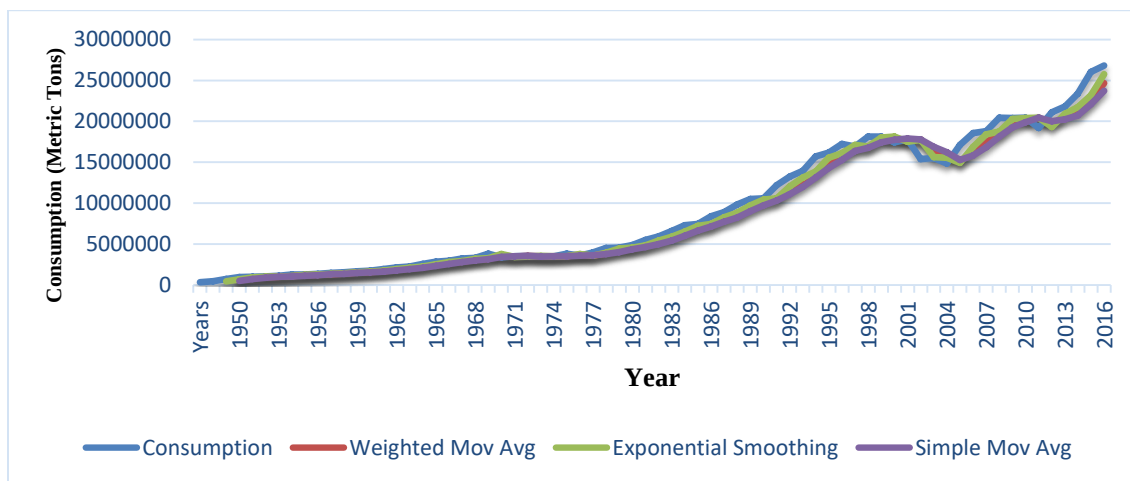


Figure 10 Comparative forecasting techniques-petroleum consumption

Similarly, the empirical results of ARIMA for the consumption of oil in Pakistan are shown in Table 8. The table consists of an R-square, Augmented Dickey-Fuller (ADF) test for trend analysis. Furthermore, since the ARIMA predicted much better results, generating the lowest MSE as shown in Table 8, the data was forecasted until 2027 for a better illustration as shown in Figure 11 and Table 9. This forecasting technique is very accurate considering the COVID-19 situation. The actual values for 69 observations were available until 2017, based on this information (in metric tons), forecasting was being carried out for the next 10 years for full-fledged assessment and policy formulation. Forecasted values in the year 2019 show a small decline which is accurate, keeping in view the pandemic situation.

Table 8
Summary for ARIMA-petroleum consumption

No of observations	69
Mean Square Error	356398.973
R - Square	0.994563

Table 9
Forecasted values of petroleum consumption through ARIMA till 2027 in metric tons

Year	Metric tons
2018	28564516.97
2019	27941010.7
2020	28174230.5
2021	28432671.5
2022	28004186
2023	28838918.6
2024	28823252.5
2025	28637942
2026	28527665.2
2027	28418191.2

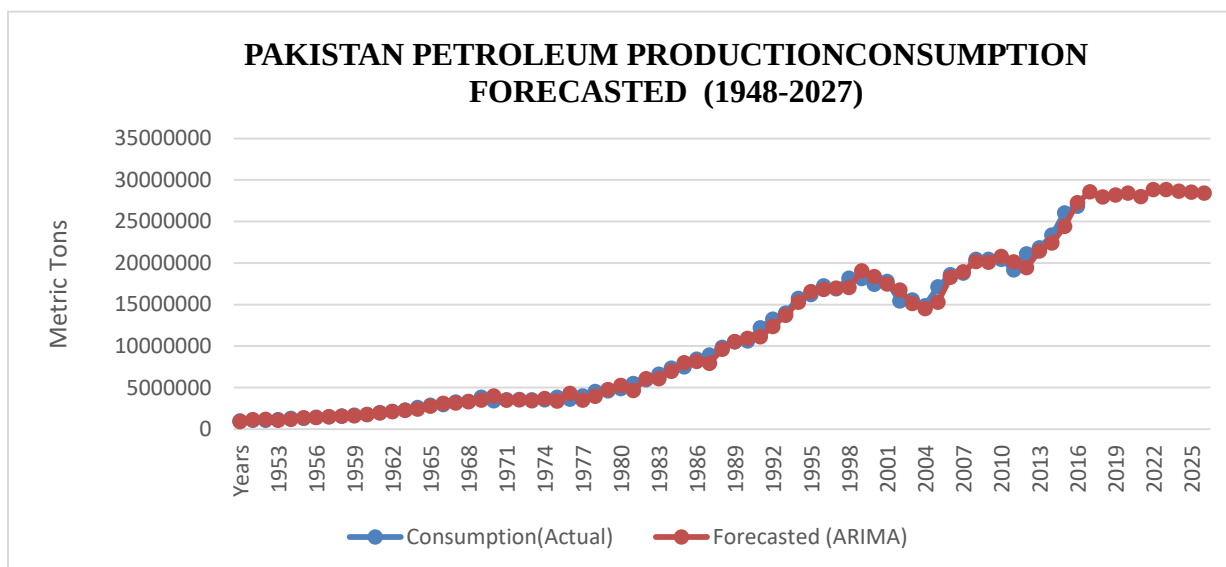


Figure 11 Forecasted values of consumption in Pakistan through ARIMA until 2027

4.5. Forecasting production of refineries in Pakistan

To forecast the potential production expected for years using the latest data available, ARIMA was used. Production data from refineries until 2026 was used. ARIMA was the choice for this step since it ensured better results when compared with other techniques. Pakistan's petroleum products industry has been uncertain which has resulted in various issues over time. Due to the dependency on imports and fewer reserves to store oil, all of the refineries work at their full potential and capacity to meet demand inside Pakistan. ARIMA proved to be highly efficient among other forecasting techniques, and therefore the data from this method was evaluated to obtain the results. The forecasted values shown in Figure 12 and Table 10 show a slight decline in the production of refineries followed by an unstable rise and fall resulting from the uncertain geopolitical and regional situations near Pakistan. This trend also confirms the findings of the consumption sector as consumption has declined as well. Pakistan, similar to other countries, faced the outbreak of COVID-19 which made this industry vulnerable to external threats due to the lockdown, bans on the majority of transportation sectors, shutting down of businesses, and the closing of factories and industries which resulted in the demand for petroleum products declining and forcing refineries to lower slow down the pace of their production.

The overall results obtained highlight the fact that Pakistan's petroleum industry is vulnerable to various external and internal issues but if it implements and invests in the selected product, it can enhance its sustainability and ensure the industry's stability in the long run. Similarly, the government needs to step in to assist these refineries and help them set up world-class refining systems to meet the supply and demand needs of the country.

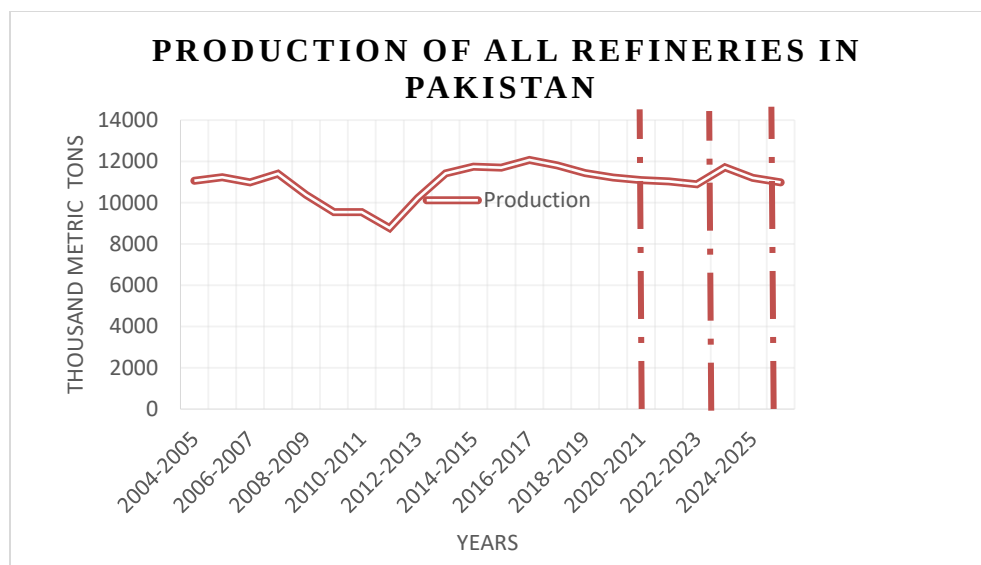


Figure 12 Forecasting of production inside all refineries in Pakistan until 2025-2026

Table 10

Forecasted values (in metric tons) of production in refineries for petroleum products

Year	Metric tons
2018-2019	11434.57
2019-2020	11222.51
2020-2021	11100.45
2021-2022	11030.2
2022-2023	10890
2023-2024	11720
2024-2025	11210
2025-2026	10980

4.6 Research implications and future recommendations

Research contributions of the current research are manifold as the study highlights the most recent scenario in which the global economies faced hurdles and disruptions because of uncertain events that affected the petroleum sector. The research studied the case of a developing country, Pakistan, which is vulnerable to external and internal threats resulting in a negative impact on its petroleum production and consumption. Because of this, the research introduced a multi-dimensional assessment model to assess sustainable products, as well as to compare and recommend the best forecasting techniques for future research. The study was able to draw comparisons based on the results obtained as well as draft necessary recommendations, thus highlighting the importance of the study in the current scenario. Similarly, it opens the door for future research in terms of its applications in other countries and also by introducing multiple hybrid methodologies to ensure authenticity in the results obtained.

5. Conclusion

The research carried out a multi-dimensional assessment of the petroleum sector of Pakistan and applied the MCDM method and various forecasting techniques to see the most suitable option for forecasting production and consumption in Pakistan. The AHP, a MCDM technique, was applied in the first stage and resulted in choosing Premium Motor Gasoline (PMG) as the most preferred product in the petroleum industry. People are more conscious about the efficiency of the product in Pakistan. Similarly, the sensitivity analysis also ranked PMG as a better and effective option, thus opening the door for effective and robust assessment as well as an authentic decision-making platform for the stakeholders to make this product a top priority to sustain especially under uncertain conditions. Furthermore, with the help of secondary data, a hypothesis was created to see the effect of the production and price of PMG on the sales of ARL through the MLR model. The results of the first hypothesis proved that production has a positive effect on sales and the price of PMG has no significant effect on sales of the refinery due to its nature of use and niche as a product used for transportation purposes. LPG is banned in Pakistan for public transportation purposes; therefore, PMG was shown to be an efficient product which was ranked and preferred regardless of price in refinery sales. The results suggest that among the available petroleum products, more attention needs to be given to PMG production to take care of consumer demands and deal with the shortage of PMG in the Pakistani market, especially in the case of uncertain situations. Furthermore, changes in the demand for petroleum products and uncertainty can cause disruption in the whole industry all over the world. In this case, the consumption level of petroleum products was measured through different forecasting techniques including moving average, weighted moving average, and exponential smoothing. Among these, exponential smoothing predicted the closest values to the actual value of consumption in Pakistan. ARIMA stood out among all the other forecasting techniques with the lowest MSE, and forecasted consumption level until 2027. Keeping the COVID-19 pandemic under consideration, the forecasting proved that this research was accurate in its outcome as the values assessed, decreased in 2019 and 2020 as compared to 2018. To meet the future consumption level, ARIMA was used to further forecast the production of refineries in Pakistan, as it proved to be the best technique when compared to others. The forecasted values produced significant results and confirmed the ongoing scenarios in the vicinity of Pakistan, keeping external and internal issues under consideration. The study concludes that effective forecasting and meeting customers' demands for preferred products in the petroleum industry will lead to less variability and uncertainty in the production and sales of petroleum products, thus making the industry sustainable and effective.

5.1. Limitations

The research covers almost every aspect required to assess sustainability in the case of the petroleum industry but it also has certain limitations. The first and foremost limitation is the data availability as much of the data is not publicly available and the authors heavily relied on the forecasted data. Furthermore, the time limitation and the limited number of experts available were other issues that can be addressed by future research.

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Appendix
Questionnaire

1. Your Age
(Open-ended response)
2. Your Gender
(Open-ended response)
3. Can you please tell the perception about each of the following product on these parameters? [Have risk and safety concerns]
(Options: Likert scale or product-specific responses)
4. Can you please tell the perception about each of the following product on these parameters? [Is Efficient in terms of Mileage]
(Options: Likert scale or product-specific responses)
5. Can you please tell the perception about each of the following product on these parameters? [Is Costly]
(Options: Likert scale or product-specific responses)
6. Can you please tell the perception about each of the following product on these parameters? [Causes Pollution]
(Options: Likert scale or product-specific responses)
7. How important quality and good mileage is for you?
(Likert scale: 1–5)
8. How likely is that good quality of petroleum products can increase the sales of refineries?
(Likert scale: 1–5)
9. How important price of petroleum product is for you?
(Likert scale: 1–5)
10. How likely is that price of petroleum products effects sales of refineries?
(Likert scale: 1–5)
11. Do you consider Risk and Safety factors before buying a petroleum product?
(Likert scale: 1–5)
12. How likely is that good transportation system in refineries can reduce risk concerns?
(Likert scale: 1–5)
13. How often you keep in mind the impact a petroleum product leaves on environment?
(Likert scale: 1–5)
14. How likely is that refineries concerns and efforts to help environment if made public, can increase their sales?
(Likert scale: 1–5)
15. How likely would it be for you to switch from a petroleum product if alternative product provides better mileage?
(Likert scale: 1–5)
16. How likely would it be for you to switch from a petroleum product if alternative product is cheaper?
(Likert scale: 1–5)
17. How likely would it be for you to switch from a petroleum product if alternative product provides less safety concerns?
(Likert scale: 1–5)

18. How likely would it be for you to switch from a petroleum product if alternative product causes lesser harm to environment?
(Likert scale: 1–5)

Notes:

- Likert-scale questions range from 1 (e.g., "Not important") to 5 (e.g., "Very important").
- Questions involve evaluating multiple petroleum products (e.g., LPG, PMG, Diesel, Furnace Oil).