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Bridging the Performance Gap: Transforming South African Refineries Through Global Best Practices

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Abstract

South Africa's ageing petroleum refineries face operational inefficiencies, high costs, and increasing pressure to meet stringent environmental regulations. This study investigates the performance gaps between local refineries and leading international counterparts, aiming to identify critical success factors (CSFs) for transformation. A mixed-methods approach was employed, combining quantitative survey analysis (n = 79) with qualitative thematic coding of expert insights. Findings reveal that South African refineries adopt compliance-driven, reactive strategies with limited investment in automation, advanced process control, and workforce development. Key improvement areas include technology upgrades, energy efficiency, environmental compliance, and skills enhancement. The research proposes a practical framework to guide modernisation, emphasising proactive, performance-driven strategies to improve reliability, sustainability, and competitiveness. These insights offer actionable recommendations for decision-makers and investors seeking to transform ageing refineries from the lower standard to global best-practice standards.

Keywords
Modernisation, sustainability, performance, technology advancement and energy efficiency.

1. Introduction
Petroleum refining played a critical role in the South African economy by producing essential fuels and supporting key industries such as power production, transport and mining. Over time, refineries have evolved from basic manual operations to complex, automated and efficient operations. Environmental regulations have become increasingly stringent to protect human health and the environment. However, South African refineries operate with ageing infrastructure, outdated technology, and operational inefficiencies that drive high costs, limiting their competitiveness and sustainability, as highlighted in (Kostov, Ivanov & Atanasov, 2023). The industry is faced with increasing pressure from the tightening of environmental regulations and the need to reduce emissions, while energy costs remain a significant portion of operational costs (Reuters, 2025). Although global leading refineries had adopted proactive strategies, South African refineries often lagged, relying on reactive approaches and minimal investment in technology (Olodun, 2024). The findings underscore the urgent need for South African refineries to transition from compliance-driven, reactive strategies to proactive modernisation initiatives. Prioritising technology upgrades, energy efficiency, and environmental compliance, alongside workforce development, is essential to close the gap with global best practices and ensure long-term sustainability and competitiveness.

Leading refineries are adopting automation, advanced process control systems, and digitalization to enhance operational efficiency, safety, and environmental compliance. One significant benefit of automation is the reduction of human intervention, which in turn decreases the likelihood of human error. Technologies such as Distributed Control Systems (DCS), Supervisory Control and Data Acquisition (SCADA), and digital twins facilitate real-time monitoring, predictive maintenance, and remote control. These innovations help minimise unplanned downtime, optimise maintenance schedules, and lower operational costs. Additionally, technologies like hydrogen upgrading and advanced cracking units ensure that refineries operate efficiently while maintaining emission control.

In contrast, South African refineries continue to operate with ageing infrastructure and insufficient technology investment, resulting in high operational costs and reduced competitiveness. These challenges underscore the urgent need for strategic transformation to enhance operational efficiency, reliability, and environmental compliance. This study aimed to address these issues by exploring the transformation of an ageing refinery from the lower quartile to the highest performance level. It sought to identify global best practices and critical success factors (CSFs) that could enhance refinery reliability, efficiency, and overall performance to ensure sustainability.

1.1 Research Objectives

In order to address the identified deficiencies and facilitate the transformation of South African refineries in alignment with global best practices, this study is underpinned by the following research objectives:

RO.1 To evaluate the level of adoption and perceived effectiveness of key technological advancements in South African refineries.
RO.2 To identify and rank the main investment drivers influencing modernisation decisions in South African refineries.
RO.3 To determine the most preferred energy efficiency strategies and assess consensus among refinery professionals.
RO.4 To analyse workforce development practices in South African refineries and identify gaps compared to global benchmarks.
RO.5 To extract actionable lessons from leading global refineries to inform a transformation framework for South Africa.

To achieve these objectives, the study employed a mixed-methods approach, combining quantitative survey analysis with qualitative thematic coding to ensure comprehensive insights. The remainder of this paper is organised as follows: Section 2 reviews relevant literature and identifies critical success factors; Section 3 outlines the research methodology; Section 4 presents data collection procedures; Section 5 discusses the results and their implications; and Section 6 concludes with recommendations for transforming South African refineries toward global best practices.

2. Literature Review

The existing scholarly and industry literature relevant to the refinery performance improvement and optimisation were examined. Reviews are focused on the challenges, successes and opportunities facing ageing refineries in South Africa. This chapter identified the critical success factors, key trends and gaps in the current South African knowledge and practices.

2.1 Critical Success Factors

The literature highlights several critical success factors (CSFs) for refinery performance, including technological advancement, process optimisation, energy efficiency, environmental compliance, and workforce development, as highlighted by Khor and Varvarezos (2017) and Joly, Rocha, Sousa, Takahashi, Mendonça, Moraes and Quelhas (2015). International case studies demonstrate that leading refineries have adopted proactive strategies such as automation, advanced process control, and digitalisation to enhance reliability and sustainability. These practices are supported by continuous workforce training and strong governance frameworks. Below are some of the examples that demonstrate the benefit of adopting global best practices:

- **Automation**: Shell's Deer Park refinery in Texas has implemented extensive automation across its operations. By using advanced sensors and automated systems, the refinery has significantly improved its operational efficiency and reduced the potential for human error. This automation allows for real-time monitoring and quick adjustments, leading to continuous improvements in process reliability.

- **Advanced Process Control (APC):** The ExxonMobil refinery in Baton Rouge has successfully integrated advanced process control technologies to optimise its refining processes. APC utilises algorithms and machine learning to analyse process data, enabling the refinery to operate closer to its optimal performance.

This not only enhances product quality but also minimises energy consumption and emissions, contributing to sustainability goals.

- **Digitalisation**: A great example of digitalisation can be found at the BP Whiting Refinery in Indiana. BP has embraced digital technologies such as cloud computing, IoT (Internet of Things), and big data analytics to enhance decision-making and operational insights. By leveraging these technologies, the refinery can predict maintenance needs, optimise production schedules, and improve overall plant reliability.

- **Continuous Workforce Training**: Leading refineries often integrate continuous workforce training as part of their strategy. For instance, Chevron's El Segundo refinery emphasises the importance of upskilling its employees in new technologies and best practices. This commitment not only enhances individual skill sets but also fosters a culture of safety and operational excellence throughout the organisation.

- **Strong Governance Frameworks:** The Phillips 66 refinery in Sweeny, Texas, has implemented a robust governance framework that includes safety, environmental standards, and operational excellence policies. This framework ensures compliance with regulatory requirements and promotes sustainable practices within the facility. Their governance approach has been instrumental in maintaining a strong safety record while pursuing environmentally friendly initiatives.

The analysis of contemporary case studies reveals that the integration of automation, advanced process control, digitalization, continuous training, and robust governance frameworks significantly enhances reliability and sustainability within refinery operations. These proactive methodologies not only facilitate increased productivity but also fortify the overall resilience of the industry in response to the dynamic challenges it faces.

In contrast, South African refineries remain largely compliance-driven, with limited investment in modernisation and skills development (Olodun, 2024). While some studies acknowledge these challenges, there is limited empirical evidence on the extent of adoption of global best practices in South Africa, the barriers hindering modernisation, and the specific strategies that could close this performance gap. Furthermore, the literature does not adequately address how energy efficiency initiatives and workforce development can be integrated into a comprehensive transformation framework for South African refineries. This study addresses these gaps by benchmarking South African refineries against global leaders to identify adoption gaps in critical success factors (CSFs). It investigates the drivers and barriers influencing modernisation efforts within the industry. Additionally, the research proposes a practical framework aimed at transitioning from compliance-driven to performance-driven strategies. This framework emphasises important aspects such as technology upgrades, energy efficiency improvements, environmental compliance, and workforce development, all of which are essential for enhancing the overall performance and sustainability of South African refineries.

2.2 Comparative Analysis of Refinery from Global Case Studies

International case studies looking at Chevron-Richmond, Shell - Netherlands, Saudi Aramco-Saudi Arabia and Reliance - India as leading refineries in the world have demonstrated proactive investment in technology, energy efficiency, and workforce development. These refineries integrated energy recovery, feedstock diversification, and advanced training to maintain competitiveness. South African refineries often adopt compliance-driven, reactive strategies with limited investment in modernisation and workforce development, resulting in operational inefficiencies and challenges in meeting environmental standards. International refineries excel in energy efficiency, environmental compliance and technological advancement, while South African refineries lag due to historical, regulatory, and infrastructural constraints. The top four critical success factors – environmental compliance, technology advancement, process optimisation and energy efficiency are essential for sustainability and competitiveness (Table 1).

Table 1. Similarities and differences in the adoption of critical success factors

Critical Success Factors	Chevron Refinery	Shell refinery	Saudi Aramco	Reliance refinery	Natref refinery	Astron refinery	Number of Implemented CSF
Technology advancement	x		x	x		x	4
Energy efficiency	x	x	x	x			4
Environmental Compliance	x	x	x	x	x	x	6
Feedstock diversification		x		x	x		3
Process optimisation	x	x	x	x			4
Workforce development			x				1

The refining industry faces numerous challenges as companies strive to enhance operational efficiency and sustainability. Key among these are stringent environmental regulations that require significant investment in technologies and processes aimed at reducing emissions and minimising environmental impact, which can be both costly and technically demanding (Speight, 2020). Many refineries also operate with ageing infrastructure, leading to inefficiencies, safety concerns, and increased maintenance costs, making upgrades essential yet time-consuming and expensive (Shahbaz et al., 2023). The integration of advanced technologies such as process controls, data analytics, and automation presents additional hurdles, including compatibility with legacy systems and the need for workforce training (Fernández-González et al., 2023). Market volatility and geopolitical uncertainties further complicate investment decisions, while sustainability pressures demand the adoption of energy-efficient practices and carbon reduction initiatives. These challenges underscore the necessity for strategic modernisation and workforce development to ensure competitiveness and long-term viability.

2.3 Advantages and Risks of Refinery CFS

Critical success factors are the essential elements necessary for a refinery's success. Implementing these factors can enhance operational compliance and ensure long-term sustainability. In contrast, failing to implement them can increase safety risks and reduce competitiveness compared to other refineries. The advantages of implementing the top four critical success factors and the disadvantages of not doing so are outlined in Table 2.

Table 2. Pros of implementing and cons of not implementing the CSFs

CSF	Pros of Implementation	Cons of non-implementation
Environmental compliance	Avoidance of legal penalties and forced operational shutdowns due to non-compliance. Improved public image. Access to global markets where strict environmental regulations are required like an airport. Long-term sustainability through reduced emissions and waste.	Risk of regulatory fines and forced shutdown. Damage to company reputation. Not able to enter the international market.
Technology advancement	Enhanced operational efficiency and reliability. Reduced downtime and maintenance costs through automation, predictive condition-based maintenance strategies. Early problem detection through smart sensors. Prevent excessive damage during fire or a leak through the remote control. Improved safety and incident response through real-time monitoring and controls.	Higher risk of operational failures and accidents due to outdated systems. Inefficiency and loss of competitive edge in global markets. Increased long-term operational costs due to breakdown or reactive maintenance. A high number of employees are required to operate the refinery manually.
Process optimisation	Higher throughput. Efficient use of resources through better planning and scheduling.	Bottlenecks in production Running out of feedstock.

CSF	Pros of Implementation	Cons of non-implementation
	Reduced operational waste. Better alignment between units, improving overall refinery performance.	Suboptimal crude processing and blending, resulting in lower profitability. Increased operational unpredictability. Struggling to respond to changing market conditions.
Energy efficiency	Lower operational costs due to reduced energy consumption. Improved environmental performance and compliance. Increased resilience and competitiveness in places with energy costs. Longer equipment life due to optimised loads and process control. Optimised maintenance costs.	High energy bills impact profitability as about 50% of operational costs are energy. High operational costs. Strain on infrastructure, particularly during energy shortages or grid instability.

In conclusion, the prioritisation of critical success factors is paramount for achieving operational excellence and ensuring the long-term sustainability of a refinery within a dynamic market environment. This comprehension not only underscores the significance of these factors but also serves as a foundation for the subsequent section, where we will explore the research methodologies employed to analyse the influence of these factors on refinery performance.

3. Research Methodology

This study employed a mixed-methods research design to investigate the transformative processes within ageing South African refineries. By integrating both quantitative and qualitative methodologies, a comprehensive understanding of the research problem was achieved. The qualitative component focused on exploring the social meanings and organizational dynamics through in-depth interviews and document analysis, as outlined by Abuhamda, Ismail, and Bsharat (2021). In contrast, the quantitative component emphasized the quantification of data derived from surveys or experimental investigations (Abuhamda et al., 2021). This dual approach elucidates that while qualitative methods examine patterns, themes, and behaviors, quantitative methods seek to derive numerical and statistical insights.
To facilitate data collection, a structured questionnaire was meticulously developed and disseminated among South African refinery employees utilizing a snowball sampling technique. The questionnaire link, hosted on SurveyMonkey, was initially shared via email with the company's human resources department, who were then requested to distribute it among employees and encourage further sharing among their colleagues. This strategy effectively enabled the researcher to access a broad and pertinent sample. The questionnaire comprised both closed-ended and open-ended questions, allowing for statistical analysis and thematic coding. Closed-ended questions, defined by limited response options, provided quantitative data for swift analysis, while open-ended questions afforded participants the opportunity to articulate their insights without restrictions (Weller et al., 2018). The inclusion of both question types was essential in obtaining quantitative data rapidly while simultaneously capturing the nuanced perspectives of refinery experts.

Quantitative data were analyzed using explanatory data analysis and descriptive statistics, such as frequencies, percentages, weighted means, interquartile ranges, and the relative importance index. These statistical techniques facilitated the identification and ranking of critical success factors, as well as the evaluation of the internal consistency of the data. The reliability of the survey instrument was assessed using Cronbach's alpha, with a value exceeding 0.7 indicating acceptable internal consistency.

Qualitative data extracted from open-ended responses were subjected to thematic coding. This analytical process involved a systematic review of all responses, allowing for the identification and grouping of recurring themes and patterns within participant responses. Ethical considerations were rigorously adhered to throughout the study. Participation was voluntary, informed consent was obtained, and confidentiality was maintained in compliance with the Protection of Personal Information Act (POPIA). Additionally, the study addressed the ethical principles of autonomy, beneficence, non-maleficence, and justice to ensure fairness and safeguard the rights of participants.

4. Data Collection

Data is defined as a piece of information and can be categorised into two main types: primary data, which is collected directly from firsthand sources, and secondary data, which refers to information that has already been gathered and analysed (Mazhar, Anjum, Anwar & Khan, 2021). This study employed a structured and systematic methodology for data collection to ensure both the reliability and validity of the results obtained.

The data was gathered through a survey distributed to employees within the petroleum industry. The platform SurveyMonkey facilitated the generation of both open-ended questions designed to elicit qualitative insights and recommendations and closed-ended questions, which served to capture quantitative data. The survey link was disseminated via email to human resources personnel, as well as to individuals known to the researcher, who were subsequently requested to forward it to their colleagues. This approach, referred to as a sampling technique, was instrumental in broadening the reach and enhancing the diversity of the participant sample.

The survey was accessible for responses from August 27, 2025, to September 19, 2025. On September 20, 2025, the data collection concluded, yielding a total of 79 respondents who participated in the survey. Prior to participation, all individuals were informed of the study's purpose and their rights as participants, which included assurances of voluntary participation, anonymity, and the ability to withdraw from the study at any point without facing any adverse consequences.

5. Results and Discussion

The survey included 79 respondents, primarily managers, technicians, engineers, and supervisors with significant experience in the petroleum industry. Notably, 48% of the respondents had over ten years of experience, indicating a knowledgeable participant base. The purpose of the survey was to identify the gaps between South African refineries and their internationally best-performing counterparts. The key findings highlighted several areas for improvement: technology, automation, infrastructure upgrades, energy efficiency, environmental compliance, and workforce development.

5.1 Numerical Results

The distribution of the roles of respondents in percentages and frequency is tabulated below in Table 3 in descending order.

Table 3. Frequency and percentage for the roles and responsibilities of respondents

Roles and responsibilities		
Roles	**%**	**n**
Other	36	28
Managers	29	23
Technicians	14	11
Engineer	10	8
Totals	**100**	**79**

A survey of respondents revealed diverse levels of experience in the petroleum industry, with 48% reporting more than 10 years of experience, 27% having between 5 and 10 years, 16% with 3 to 5 years, and 9% with 0 to 3 years of experience. This indicates that a significant majority of the respondents possess considerable experience in the sector.

Furthermore, a substantial proportion of respondents reported the implementation of various technologies: 73% indicated the adoption of automation, 60% mentioned hydrogen plant upgrades, and 53% referenced advanced cracking units (Table 4). However, the reliability of these findings was assessed using Cronbach's alpha, which yielded a score of 0.606, suggesting questionable reliability. The perceived impact of these technological advancements varied; automation was rated as the most important with a Relative Importance Index (RII) of 72%, while hydrogen plant upgrades and advanced cracking units were assigned RII values of 61% and 57%, respectively. This suggests that, despite the adoption of some global best practices, the extent of these technological upgrades at South African refineries appears to be limited, as respondents do not consider hydrogen plant upgrades and advanced cracking units to be significant advancements at their facilities.

Table 4. Descriptive statistics of Technology advancement

Items	α	M	min	max	RII	IQR
Hydrogen plant upgrades	0.606	3.025	1	5	61%	3
Automation and control systems		3.615	1	5	72%	0
Advanced cracking units		2.846	1	5	57%	3

The investment drivers identified for South African refineries included environmental goals (Relative Importance Index [RII] = 79%), operational efficiency (RII = 75%), and regulatory compliance (RII = 76%) (Table 5). The results indicated acceptable internal consistency, with a Cronbach's alpha of 0.703, suggesting reliability in the findings. Participants expressed similar views regarding regulatory compliance (Interquartile Range [IQR] = 0), operational efficiency (IQR = 0.75), and environmental goals (IQR = 1) as significant investment drivers. While there is a notable opportunity for South African refineries to explore cost reduction investments, this factor is perceived as less important (RII = 60%).

Table 5. Descriptive statistics of investment drivers

Items	α	M	Min	Max	RII	IQR
Regulatory compliance	0.703	3.782	1	5	76%	0
Cost reduction		2.987	1	5	60%	3
Operational efficiency		3.769	1	5	75%	0.75
Environmental goals		3.974	1	5	79%	1

Energy efficiency strategies that were seen to be more valuable to be adopted are ranked as the highest to the lowest energy audits (RII=86%), on-site power generation (RII=83%), equipment upgrades (RII=80%) and use of renewable energy (RII = 80%) (Table 6). The Cronbach's alpha is 0.779, indicating an acceptable internal consistency. All the energy strategies have an interquartile range of 1 or 0, indicating significant agreement amongst the participants on their views about the energy efficiency strategies that can be adopted and benefit their refinery.

Table 6. Descriptive statistics of energy efficiency

Items	α	M	Min	Max	RII	IQR
Equipment upgrades	0.779	4.320	1	5	86%	1
Energy Audits and Monitoring		4.166	1	5	83%	1
On-site power generation		4.000	1	5	80%	0
Use of renewable energy		3.987	1	5	80%	1

In conclusion, the data reflect a proactive industry stance towards modernisation and sustainability, with a clear prioritisation of longstanding investment drivers and energy efficiency. However, the limited perceived significance of certain technological advancements may highlight a need for further exploration of innovative practices and their tangible benefits to enhance operational effectiveness at South African refineries.

5.2 Graphical Results

In this section, participant responses were systematically categorised into distinct thematic groups. In response to the question, "What do you consider to be the most critical success factors for refinery performance in your region?", the most frequently identified critical success factors included workforce development (23%, n=18), asset reliability (21%, n=16), and technology (18%, n=14) (see Figure 1). These factors emerged as essential areas necessitating enhancement within South African refineries. Additionally, sustainability and energy efficiency accounted for 14%

(n=11) of the responses, closely followed by safety and risk management at 13% (n=10). Governance and strategic alignment were identified as the least frequently mentioned factors, representing 10% (n=8).

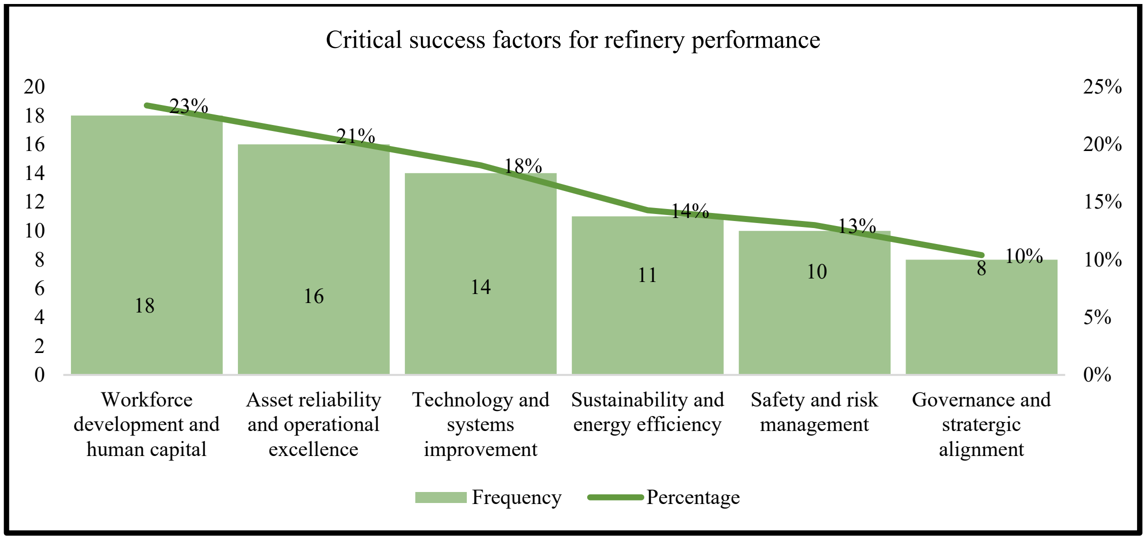

Figure 1. Critical success factors for refinery performance

In response to the question "What lessons can South African refineries learn from their international counterparts?", thematic analysis revealed that workforce development and culture were ranked highest 24% (n = 16), followed by technology and digitalisation 19% (n =13). Infrastructure and asset management were next 18% (n=12), with policy, benchmarking, and governance at 16% (n=11). Sustainability and energy transition 13% (n=9) and operational excellence 10% (n=7) were identified as lower priorities (see Figure 2).

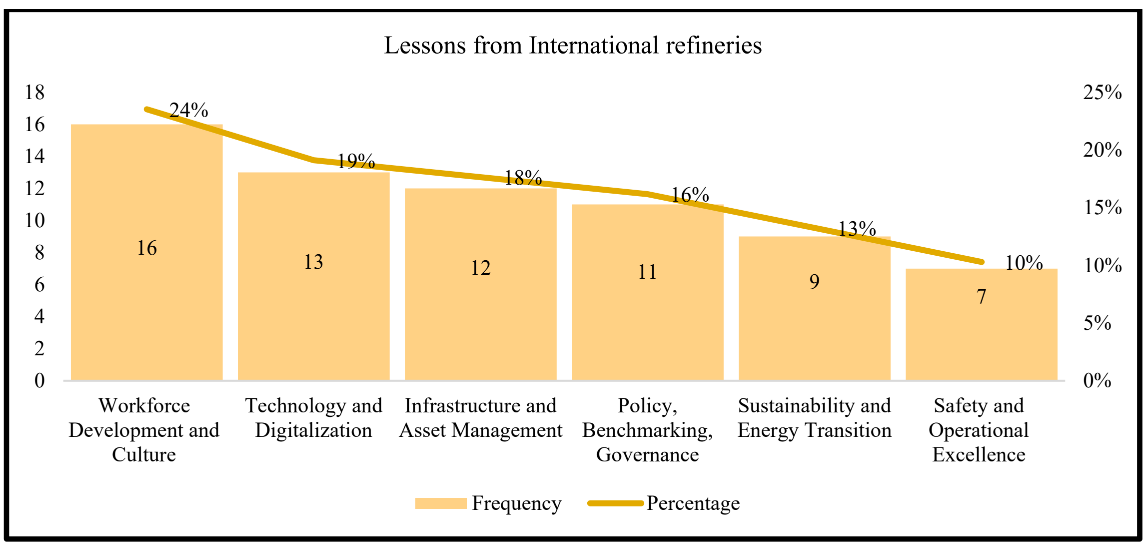

Figure 2. Themes of lessons learnt from international refineries

Figure 3 presents the results for the question, "What policy or infrastructure changes would most benefit your refinery?". Thematic coding indicated that policy and governance were the most frequently mentioned 23% (n =21), followed by infrastructure modernisation, 22% (n=20). Technology and automation 20% (n=20) and workforce development 19% (n=17) were also prominent themes. Environmental sustainability was cited least frequent, at 16% (n=15).

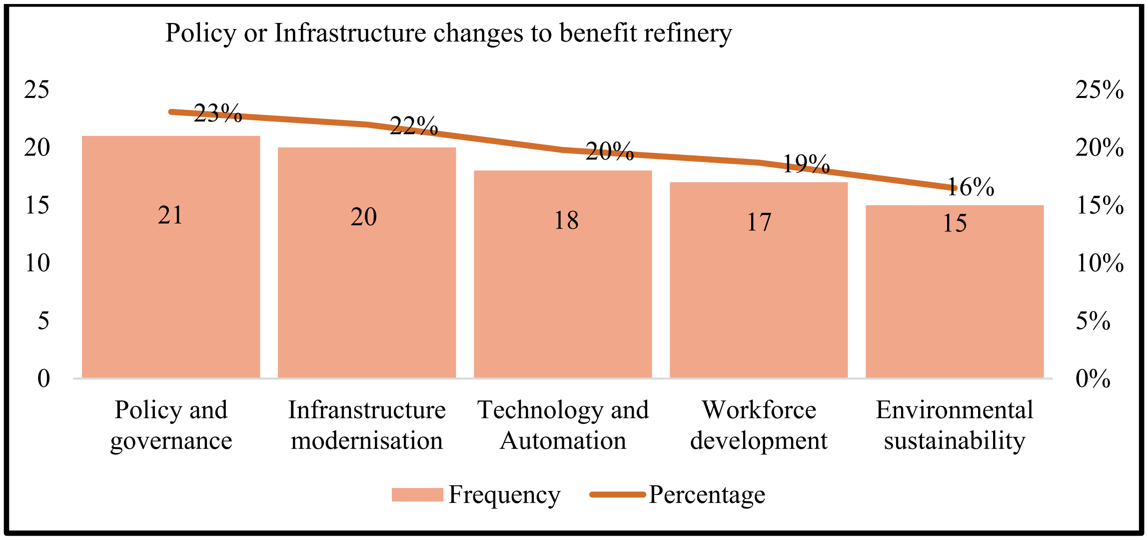

Figure 3. Themes of policy or infrastructure changes to benefit the refinery

This section summarises participant responses on critical success factors for refinery performance in South Africa. Key factors identified include workforce development (23%), asset reliability (21%), and technology (18%). Sustainability and energy efficiency followed at 14%. In lessons from international refineries, workforce development and culture were prioritised (24%), with technology and digitalisation at 19%. Policy and governance changes were deemed most beneficial (23%), alongside infrastructure modernisation (22%). Technology and automation received 20%, and workforce development 19%, while environmental sustainability was the least mentioned at 16%.

5.3 Proposed Improvements

Based on the findings of the study, the following improvements are proposed to enhance the performance and sustainability of South African refineries (see Figure 4):

- **Technology Upgrades:** Invest in modern automation technologies such as Distributed Control Systems (DCS) and Supervisory Control and Data Acquisition (SCADA) systems. These systems can provide real-time monitoring and control, reducing human error and improving operational safety. Incorporate advanced process control systems and digital twins to facilitate predictive maintenance, optimise maintenance schedules, and minimise unplanned downtime.

- **Energy Efficiency Initiatives:** Implement energy management systems that identify potential energy-saving opportunities and promote practices that reduce energy consumption. Explore the use of renewable energy sources, such as solar or wind, to supplement energy needs and decrease reliance on traditional energy sources.

- **Environmental Compliance:** Upgrade facilities with technologies that enhance emission control, such as hydrogen upgrading and advanced cracking units, which can ensure compliance with stringent environmental regulations. Invest in cleaner production technologies to reduce overall environmental impact, leading both to compliance and to improved public perception.

- **Workforce Development:** Foster a culture of continuous learning and skill enhancement among employees through targeted training programs that focus on new technologies and operational best practices. Encourage cross-functional teams to gain diverse perspectives and innovative approaches to problem-solving within the refinery operations

- **Proactive Operational Strategies:** Shift from compliance-driven approaches to more proactive, performance-driven strategies. This can include setting benchmarks based on global best practices and continuously assessing performance against these targets. Establish an innovation framework that encourages the exploration of new technologies and methodologies, enabling quick adaptation to emerging trends within the refining industry.

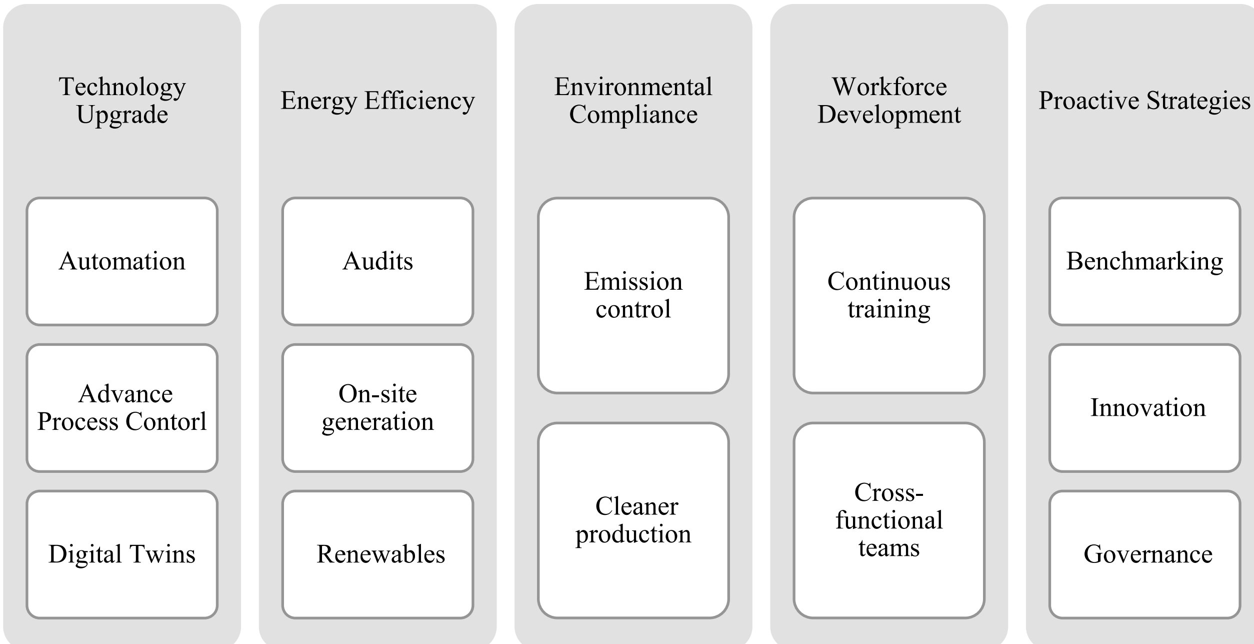

Figure 4. Transformational framework for modernising ageing refineries to meet global standards.

- **Investment Drivers Alignment:** Align investment priorities with identified critical success factors that reflect global best practices, focusing on technologies that drive efficiency and sustainability. Engage stakeholders, including government and private investors, to work collaboratively on funding initiatives that support refinery modernisation and improvement.

- **Collaborative Partnerships**: Create partnerships with technology providers, academic institutions, and industry leaders to facilitate knowledge sharing and access to cutting-edge technologies and practices. Participate in industry forums and networks that focus on performance improvement and innovation within the refining sector.

- **Monitoring and Assessment:** Implement a robust performance monitoring system that regularly evaluates operational efficiency, environmental compliance, and overall performance against both national and international benchmarks. Adjust strategies based on data-driven insights to continuously improve and modernize refinery operations.

5.4 Validation and Reliability

The validity of this study is grounded in the mixed-methods approach used to thoroughly assess the performance gaps between South African refineries and their global counterparts. The combination of quantitative survey analysis and qualitative expert insights enhances content validity, ensuring that the research captures a comprehensive view of the challenges and opportunities faced by the South African refinery sector. To establish construct validity, the study utilised established frameworks and theories related to operational efficiency, technology adoption, and environmental compliance. This alignment with existing literature reinforces the study's findings and provides a solid foundation for the proposed practical framework. Additionally, the formulation of research questions directly addresses critical areas of concern within the local refining industry, ensuring that the study is both relevant and meaningful.

Furthermore, face validity was improved by involving industry experts in the qualitative phase. Their insights and feedback on the survey instrument helped refine the questions, ensuring that they accurately reflect the constructs being investigated. This collaboration contributed to a more nuanced understanding of the factors influencing refinery performance and modernisation strategies. Reliability in this study was ensured through several key measures. The quantitative survey, administered to 79 participants, underwent a pilot test to identify any ambiguities or inconsistencies in the questions. This preliminary step allowed for refinements that improved the clarity and precision of the survey instrument, thereby enhancing the reliability of the data collected.

The consistency of the qualitative data analysis was maintained through thematic coding, where a systematic approach was employed to identify and interpret themes from expert insights. Multiple researchers independently coded the qualitative data to minimise biases and ensure that the findings reflected the collective input from respondents. Any discrepancies in coding were addressed through discussions and consensus-building, enhancing inter-coder reliability. Additionally, the study employed triangulation by comparing and contrasting the results from the quantitative surveys with qualitative insights. This method not only enhanced the reliability of the findings but also allowed for a richer understanding of the research questions, as patterns and themes were corroborated across different data sources.

In conclusion, the validity and reliability of this study are demonstrated through a carefully designed research methodology that combines robust quantitative and qualitative analyses, ensuring credible and actionable insights into the transformation of South African refineries.

6. Conclusion

In conclusion, the transformation of South African refineries is imperative for enhancing operational efficiency, sustainability, and competitiveness in an increasingly demanding market. This study highlights significant performance gaps compared to global best practices, chiefly due to outdated infrastructure, minimal technological investments, and reactive operational strategies. By adopting proactive measures such as advanced automation, energy efficiency initiatives, and workforce development, South African refineries can bridge these gaps effectively. The proposed framework serves as a roadmap for decision-makers and investors to initiate the much-needed modernization processes. Prioritizing critical success factors will not only boost reliability and operational performance but also ensure compliance with stringent environmental regulations. Ultimately, embracing these global best practices is essential for safeguarding the future viability of the South African refining sector, fostering economic growth, and contributing to a more sustainable energy landscape.

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Biographies

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