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Integrating Water and Energy Usage in Airport Performance Management

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Abstract

Airports play a major role in the global transportation industry, and their performance is paramount to management. The purpose of this research was to identify the Key Performance Indicators (KPIs) used by airport management in different regions and explore which KPIs are integrated into water and energy management. Five Key Performance Areas (KPAs): passenger service, operations, financial perspective, safety and security and environmental, including their respective KPIs, were established from the literature. A systematic analysis was used to assess KPAs and KPIs for nine Airports Company of South Africa (ACSA) airports. The findings noted that implementing and prioritising KPAs and KPIs varies with region. In Europe, KPAs and KPIs are highly structured and focus strongly on environmental sustainability and regulatory compliance. Most airports in this region have implemented real-time tracking systems for environmental KPIs. African airports, although lagging in technology, are implementing KPAs and KPIs, particularly in water and energy management. There is, however, room for improvement as far as efficient water and waste management is concerned. It was noted that operational KPIs are mainly integrated with water KPIs. While African airports implement water and energy KPIs for management purposes, there remains significant potential for improved tracking and monitoring.

Keywords
Performance management, Airport Performance, Water and Energy Management.

1. Introduction
Airports play a fundamental part in the economy by connecting air and ground transportation (Wattanacharoensil et al., 2017). An airport system consists of numerous important aspects: subsystems and stakeholders, management as well as customers. All of these aspects contribute to the overall performance of the airport management (Chakraborty et al., 2020). It is critical for airport management to ensure high performance, and to adapt to challenging environments. Airport performance indicators are used to assess airport operations, implement development and evaluate management performance (Humphreys and Francis, 2000). Previous studies have found that overall airport performance is directly influenced by the efficiency of airport managers (Pacheco R.R. and Fernandes E., 2003). Globally it is projected that aviation passenger traffic will grow by 3.8% annually over the next 20 years. The highest growth is expected from the Middle East, Asia-Pacific and Africa (IATA, 2024). Each region experiences unique challenges and opportunities to in expanding its aviation market share. Africa for example, which accounts for 18% of the global population and with a median age of 18.8 years, presents a promising market (World-Bank). The young individuals are likely to become frequent flyers, making it an exceptional market for aviation. To remain competitive, it is crucial for African airports to benchmark against KPAs and KPIs. This must be done while also optimizing the use of environmental resources and improving infrastructure.

Day-to-day operations of all airport activities require both water and energy. As a result, airports are gradually moving their to focus environmental sustainability. Airports are continuously expanding, and therefore monitoring environmental resources such as water and energy becomes even more crucial in developing effective environmental management systems (Kılkış and Kılkış, 2016). These metrics must also be integrated into the airport's overall performance. Maintaining efficient operations and integrating water and energy management remains a challenge. If not resolved, this might lead to inefficient operations, which affects regional and economic development as well as sustainability. The objective of this paper is to investigate the KPAs and KPIs used across various regions and identify KPIs that should be integrated into airport performance for energy and water management.

The rest of the paper is organized as follows: Section 2 presents the literature review where general KPAs and KPIs were identified. Additionally, existing articles and case studies on KPIs in airport management and performance were explored, covering airports from different regions, ownership/operating models, and types. Section 3 outlines the methodology, which followed a systematic process. Section 4 covers the results and analysis, and Section 5 elaborates on the conclusions, recommendations for future research, and study limitations.

2. Literature Review

Understanding airport dynamics is essential to airport managers, as it directly impacts airport performance and managerial effectiveness in different KPAs. KPAs are broad categories of outcomes or results that must be achieved through the execution of specific roles or a combination of responsibilities (Dougall and Mmola, 2015). KPIs are used to measure the performance of KPAs; they serve as a subset of KPAs and provide a way to assess the overall effectiveness of each KPA (Dougall and Mmola, 2015). KPIs are quantifiable and qualitative measurements used to assess organizational performance to recommend future directions and project success measurements. KPIs are grouped into four main categories: financial, operational, social, and environmental (Bruzzone F. et al., 2023), (Cavallaro et al., 2020). KPIs have five properties, namely, suitability, measurability, realism, defensibility, and universality (Sinha and Labi, 2007).

Management uses KPIs to assess the company, create action plans, provide information for understanding business progress, communicate company developments and conduct decision-making (Martins de Andrade and Sadaoui, 2017). Effective KPI implementation can improve operational efficiency, higher passenger satisfaction, and better environmental stewardship. This in turn can boost the airport's reputation and financial performance. As far as KPAs are concerned, performance management becomes important as metrics by themselves lose their relevance in the absence of proper action and response (Dougall and Mmola, 2015). Transitioning from performance measurement to performance management is crucial as it allows corrective actions to align with strategic work directions (Kulatunga et al., 2010). This transition is especially critical in airport management as the operation of facilities and environmental management directly impact passenger experience and operational performance. This systematic evaluation of performance and effectiveness by utilizing a set of metrics ensures that organizations remain competitive and successful in the market (Neely et al., 2005),(Eshtaiwi et al., 2018) . KPIs essentially reflect whether the airport manager allocates available resources in various airport areas (Wang and Song, 2020), (Suárez-Alemán and Jiménez, 2016), (Asker and Battal, 2017). This makes it crucial to identify KPAs and their respective KPIs for airports.

Airports worldwide are progressively focused on increasing passenger satisfaction to attract more airlines and respond to global demand for higher passenger service standards (Knoch et al., 2020). Neglecting passenger expectations in service quality assessment can cause airport management to overlook critical areas for improvement; this makes passenger service a crucial indicator (Lubbe et al., 2011). Airport business results are reflected in the number of passengers throughput, cargo throughput, and operating revenue (Cifuentes-Faura and Faura-Martínez, 2023). Another study states that the leading financial and operational outputs of an airport include passengers, cargo (freight and mail), and total revenue (Chakraborty S. et al., 2020). This makes operation and finance key performance areas in the airport. The airport needs to conduct safety and security measures to improve its performance. These essentially fall under risk management (Grabowski et al., 2007), (Enoma and Allen, 2007). Additionally, airports are large commercial sites with significant environmental impacts; this makes it important for airport management to focus on their environmental stewardship (Graham, 2023). Environmental aspects include water management, waste management, energy management, emissions management, noise management and wildlife management (Graham, 2023), (Sreenath et al., 2021), (Dimitriou and Karagkouni, 2022). Identified KPAs and their respective KPIs (Granberg and Munoz, 2013), (Baltazar et al., 2018),(Červinka and Štverková, 2014), (Wyman, 2012) are shown in Figure 1.

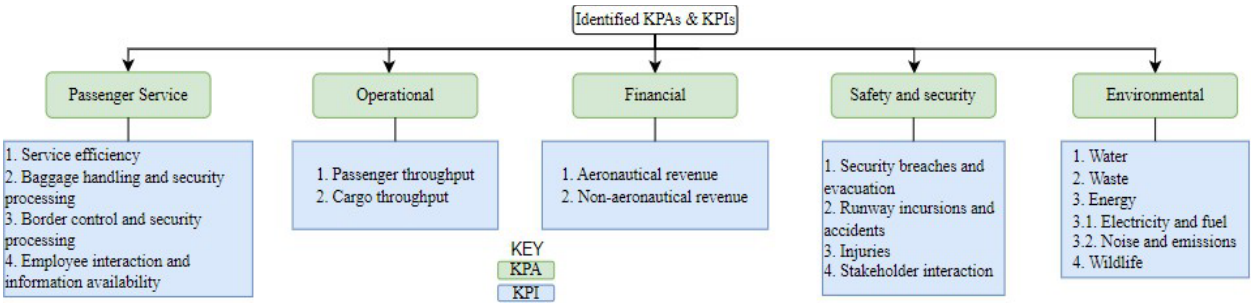


Figure 1. Identified KPAs and KPIs from the literature (author derived)

2.1 Additional KPAs and KPIs on airport performance and management from existing articles and case studies

An analysis was conducted on articles and case studies found in the literature to explore airport management and performance KPIs from different regions, continents, and various types of airports (Chakraborty et al., 2020), (Pacheco and Fernandes, 2003), (Eshtaiwi et al., 2018), (Wang and Song, 2020), (Cifuentes-Faura and Faura-Martínez, 2023), (Enoma and Allen, 2007), (Sreenath et al., 2021), (Pacheco et al., 2006), (Fernandes and Pacheco, 2018), (Paraschi et al., 2019), (Ripoll-Zarraga and Huderek-Glapska, 2021), (Leva et al., 2014), (Patunola and Bolarinde, 2022), (Bulatovic et al., 2023), (Daries-Ramon and Cristobal, 2017), (Park et al., 2023), (Budd et al., 2015), (Baxter et al., 2018c), (Baxter et al., 2018a), (Baxter et al., 2018b), (Boca Santa et al., 2020). The articles and case studies noted that airport operations, terminal building capacity, and financial KPA are crucial in airports globally. However, airports in Europe, America, and Asia prioritize environmental KPIs, specifically sustainable energy alternatives and water-saving initiatives (Sreenath et al., 2021), (Budd et al., 2015), (Baxter et al., 2018c), (Baxter et al., 2018a), (Baxter et al., 2018b). These airports invest more in energy, water, and waste-sustainable management systems from the environmental KPIs (Budd et al., 2015). Despite this, a worldwide gap is noted in tracking systems for environmental KPIs. Case studies from European, Asian, and Spanish airports highlighted the importance of revenue diversification, with some airports excelling in aeronautical revenues and others in non- aeronautical revenues (Wang and Song, 2020), (Daries-Ramon and Cristobal, 2017), (Park et al., 2023). An article on Skytrax ratings give emphasis to the fact that passenger satisfaction is another critical indicator. The article states that the airport's reputation and competitive edge are directly linked to how passengers perceive airport facilities, service quality, and overall experience (Bulatovic et al., 2023). International airports, for example Asia, Europe and Libya, emphasise KPIs related to global connectivity, passenger services, and security measures (Eshtaiwi et al., 2018), (Enoma and Allen, 2007). Additionally, the articles and case studies highlighted that regional and domestic airports focus mainly on cost-effectiveness and social impact, while smaller airports in undeveloped countries prioritise operational performance, service quality, reputation, and cost management (Leva et al., 2014), (Daries-Ramon and Cristobal, 2017).

In order to influence performance in a positive manner, effective airport management requires exploring managerial human capital (Ripoll-Zarraga and Huderek-Glapska, 2021). Additionally, effective leadership and communication are vital, especially during change initiatives (Leva et al., 2014). Airport managers must encourage a workplace where employees can express concerns and reflect on their daily activities and the management's leadership. Airport KPAs are also affected by strategic management and leadership effectiveness (Leva et al., 2014). An airport requires robust movement frameworks and strategic decision-making to achieve long-term sustainability. Ownership and operational models also influence airport management and airport performance (Pacheco and Fernandes, 2003), (Pacheco et al., 2006, Fernandes and Pacheco, 2018). Publicly operated airports, such as those managed by Infraero in Brazil, were examined for their performance under government oversight and policy changes, impacting operational costs and service quality KPIs (Pacheco R.R. and Fernandes E., 2003). Policy transparency affects the effectiveness of KPIs in airport management, limiting management's flexibility. Additionally, unclear future planning also results in a decrease in airport performance (Pacheco and Fernandes, 2003), (Pacheco et al., 2006), (Fernandes and Pacheco, 2018). It was noted that privately owned airports usually perform better than government-owned ones, and transitioning from government to private ownership doesn't guarantee significant immediate improvements (Fernandes and Pacheco, 2018). An article on airports in Nigeria outlined that outsourcing airport operations and using contractual managers are strategic approaches to increase airport performance (Patunola and Bolarinde, 2022).

Other factors affecting airport performance and management included location and distance from the city centre (Chakraborty S. et al., 2020). Based on articles about Spanish airports, passenger demographics, the concentration of air traffic in hubs and regional airports, and overcapacity influence the operational and financial KPIs (Cifuentes-Faura and Faura-Martínez, 2023). For environmental KPIs, climate change and regional weather affect water and energy management. For instance, some dry regions face water scarcity, while others receive heavy rains, enabling rainwater harvesting. Conversely, sunny regions are ideal for implementing solar farms for renewable energy production. Figure 2 shows the additional KPAs and KPIs that were derived from the articles and case studies:

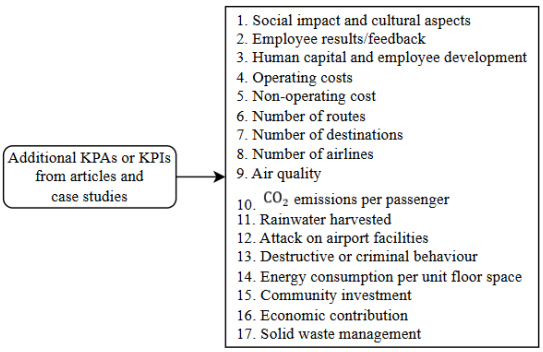


Figure 2. Additional KPAs and KPIs derived from articles and case studies (author derived)

The articles and case studies revealed a gap in the analysis of airport performance management for airports located in different regions of an African country, all operating under a hybrid private-government ownership model.

3. Methodology

In this study, quantitative secondary data was used; this is advantageous since collecting airport performance data can be time and resource consuming. The built environment is adopting qualitative research to supplement quantitative research (Amaratunga et al., 2002), (Galli, 2023), this is also the case with airport performance. Quantitative research was used, given the numerical data collected for various KPIs from airport annual reports. Quantitative research aided in establishing the development of the KPIs' and an explanation of the quantifiable data will be provided and supplemented by qualitative concepts. A systematic approach shown in Figure 3 was used. The ACSA airports in different regions were selected as the population sample. ACSA is a hybrid government and privately owned entity, with the government having a 74.6% share (ACSA). Integrated Annual Reports (IARs) from the years 2017,2019,2021,2022 and 2023 were used to obtain data (ACSA, 2017), (ACSA, 2019), (ACSA, 2021), (ACSA, 2022), (ACSA, 2023b). ACSA's IARs, Annual Financial Statements (AFS) and passenger statistics are available to the public as ACSA is a state-owned entity. A systematic approach with the steps shown in Figure 3 was used to answer the research question and aim.

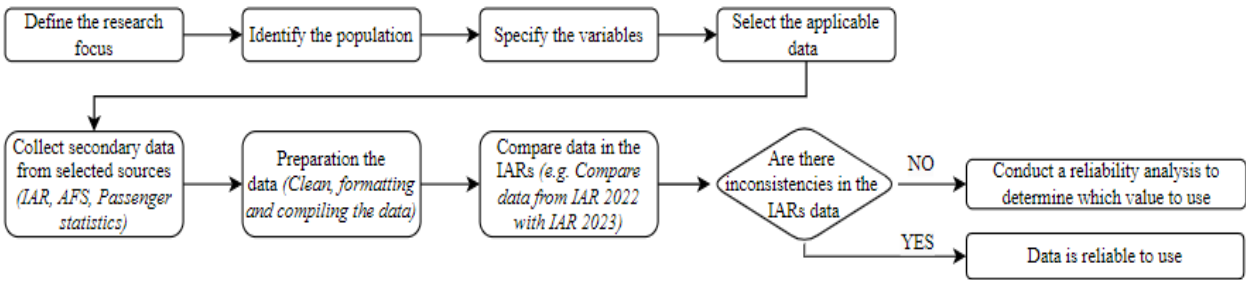


Figure 3. Systematic approach (Gray, 2014), (Subasi, 2020), (Zhang et al., 2003)

The nine ACSA airports shown in Table 1 accommodate international and domestic travel, ranging from small to large and mega airports. Using the ACSA airports as a population sample granted the ability to assess nine airports from

different regions managed by a hybrid-private-government-owned entity. Additionally, it allowed the ability to fulfil the research question and objective in assessing the KPIs integrated into airport performance to manage water and energy sustainably.

Table 1. ACSA airports and their respective IATA codes

Airport Name	IATA Code
Upington International Airport	UTN
Kimberley Airport	KIM
Bram Fischer International Airport	BFN
George Airport	GRJ
King Phalo Airport	ELS
Chief Dawid Stuurman International Airport	PLZ
King Shaka International Airport	DUR
Cape Town International Airport	CPT
O.R. Tambo International Airport	JNB

3.1 Research variables and data collection

The KPIs listed in Figure 1 were used as variables. However, the passenger service KPA was used to represent the weighted average of all its KPIs. The obtained data had to be prepared for analysis to ensure that it was reliable to use. The IAR for each year contains data from previous years; for example, 2022 data is available in the 2022 IAR report and the 2023 IAR report and this data must be the same in both reports. The data in IAR reports was compared; this is because inconsistencies can arise from errors or a correction of values in the subsequent versions of a published series of reports (Olabode et al., 2019), (Flintermann, 2014). The 2017, 2019, 2021, 2022, and 2023 IARs were compared, revealing only inconsistencies in the reported water consumption and waste recycled values for 2021/2022 in IAR 2022 and IAR 2023 as shown in the table below.

Table 2. Water consumption and waste recycled inconsistent values for the year 2021/2022

	Data source and reference		**Difference %**
	IAR 2022 [51]	**IAR 2023 [52]**	
Water consumption (kL)	103590	40655406	3825%
Waste recycled (‘000 tonnes)	673377	943567	40%

An analysis was conducted by plotting recycled water consumption and waste from 2015/2016 to 2022/2023 as shown in Table 2. The goal was to identify whether the values from IAR 2022 or IAR 2023 for 2021/2022 were outliers and to determine which value fits the trend better for further analysis. The water consumption value from IAR 2022 and the waste recycled value from IAR 2022 were chosen.

4. Results and Analysis

The nine ACSA airports were evaluated based on the identified general KPAs and KPIs and the additional KPAs and KPIs established from articles and case studies. It was noted that ACSA airports implement all the general KPAs and KPIs in Figure 1 and some of the KPIs and KPAs in Figure 2. Each KPA and KPI in Figure 1 were further evaluated from 2015/2016 till 2022/2023 to identify patterns and development in the performance of ACSA airports.

4.1 Main Results and Discussions

ACSA airports have sustained high performance in passenger satisfaction, with an average rate of 4.043 out of 5 pre-COVID-19. This is shown in its numerous achievements and awards for its airports. During COVID-19, performance satisfaction ratings were not recorded due to low passenger numbers. However, the ratings have rebounded in the years after COVID-19, with actual ratings surpassing the targets. Growth was also noted in the passenger throughput of the operational KPA, as shown in Figure 4. In 2017/2018, UTN, KIM, and BFN airports had a higher passenger throughput than the other years. However, GRJ airport experienced its highest passenger volumes in 2018/2019, with ELS and PLZ airports in 2019/2020. Between 2017/2018 and 2019/2020, CPT and JNB airports experienced a marginal increase of less than 1% in passenger traffic from 2017/2018 to 2018/2019, followed by a slight decrease of less than 2% from 2018/2019 to 2019/2020. Major international sports events and conferences greatly impacted the

recovery of passenger numbers after the COVID-19 pandemic (ACSA, 2023b). Cargo, on the other hand, still lags in its development. Additionally, major external factors, such as the war in Ukraine and the floods in the KZN, have impacted the passenger and cargo throughput (ACSA, 2023b).

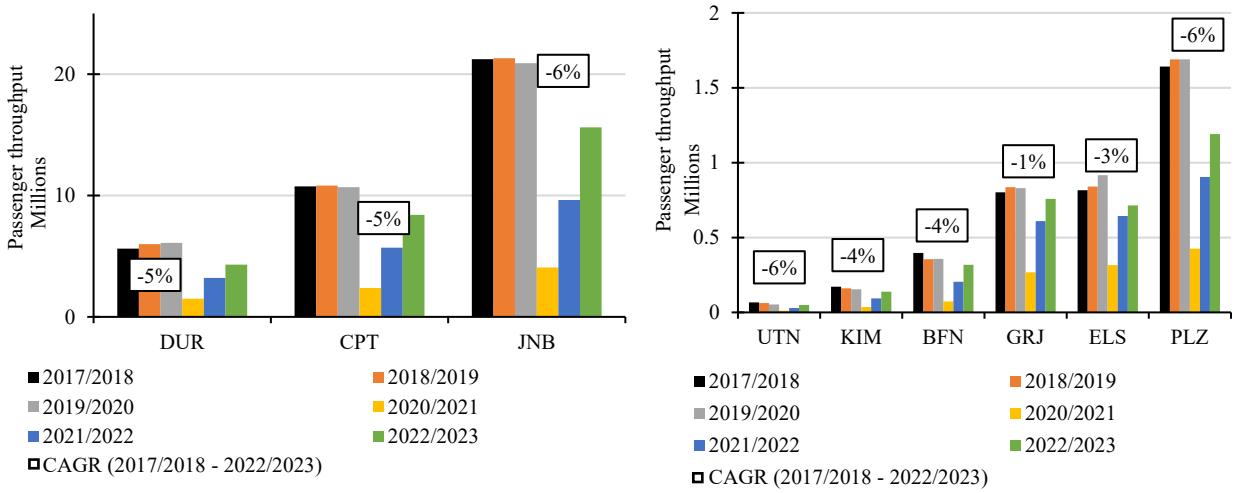
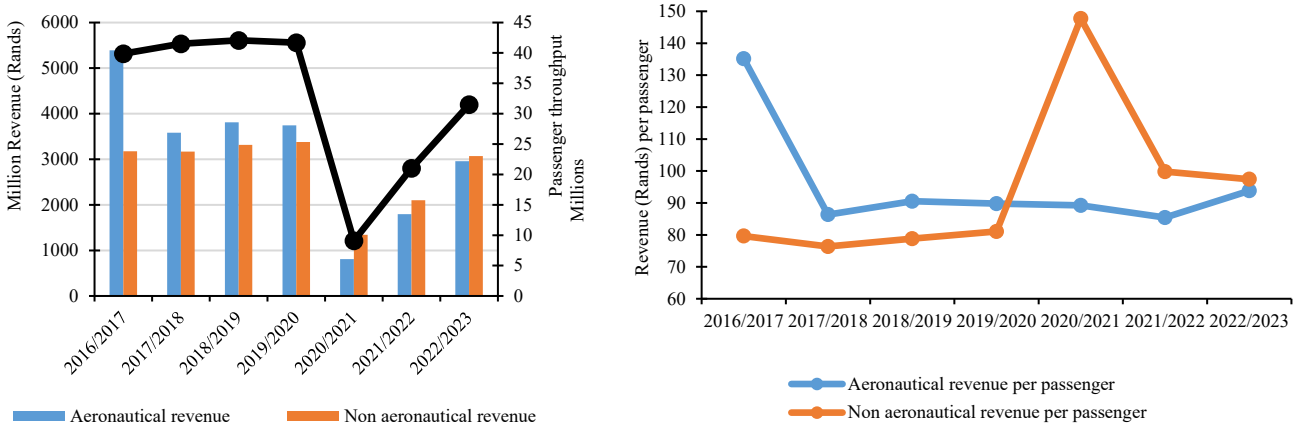


Figure 4. Passenger throughput of ACSA airports (data derived from (ACSA1), (ACSA2),(ACSA3), (ACSA4), (ACSA5), (ACSA6)

The financial area performance is shown in Figure 5. In the 2016/2017 financial year, ACSA airports peaked in aeronautical revenue, marking it as the highest among the observed years; this was followed by a sharp 34% decline in aeronautical revenue from 2016/2017 to 2017/2018. Non-aeronautical revenue has shown resilience and was higher than aeronautical revenue during COVID-19, reflecting revenue diversification's importance. Overall, the average aeronautical revenue generated per passenger across the years was 95.76 rands, while the average non- aeronautical revenue per passenger was 94.41 rands, which shows the importance of both revenue streams in the airports' financial sustainability.

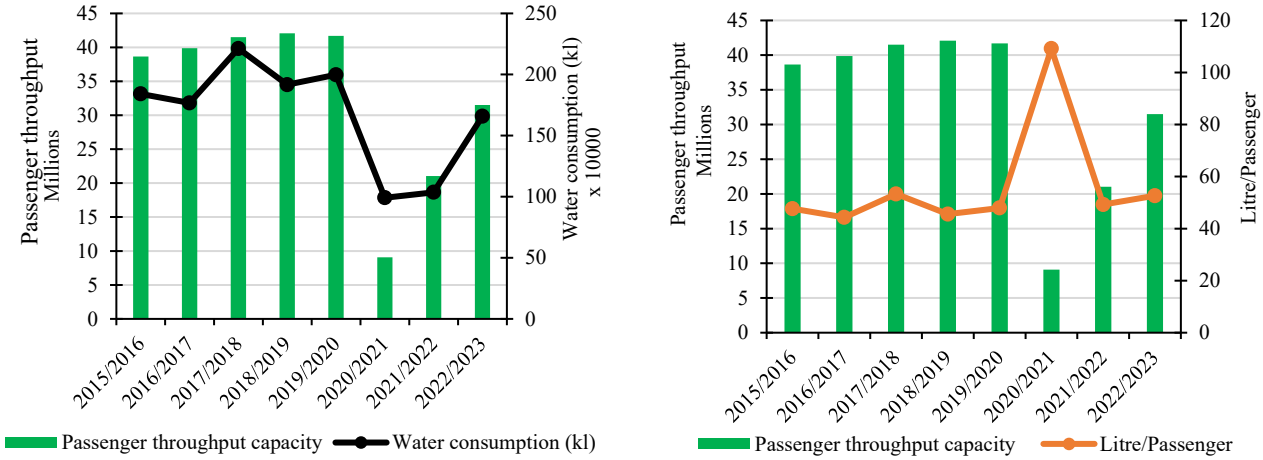


(a) (b)

Figure 5. a) Annual revenue generated vs passenger throughput b) Annual revenue generated per passenger (data derived from (ACSA, 2017), (ACSA, 2019), (ACSA, 2021), (ACSA, 2022), (ACSA1, ACSA2), (ACSA3), (ACSA4), (ACSA5), (ACSA6), (ACSA, 2023a), (ACSA7), (ACSA8), (ACSA, ACSA9)

As far as safety and security are concerned, there was a reduction in incidents. Work-related severe injuries remained consistent between 2020/2021 and 2021/2022. This suggests that there might be consistent, ongoing risks in operational safety that require attention. This decrease in incidents shows ACSA's continuous efforts to refine and

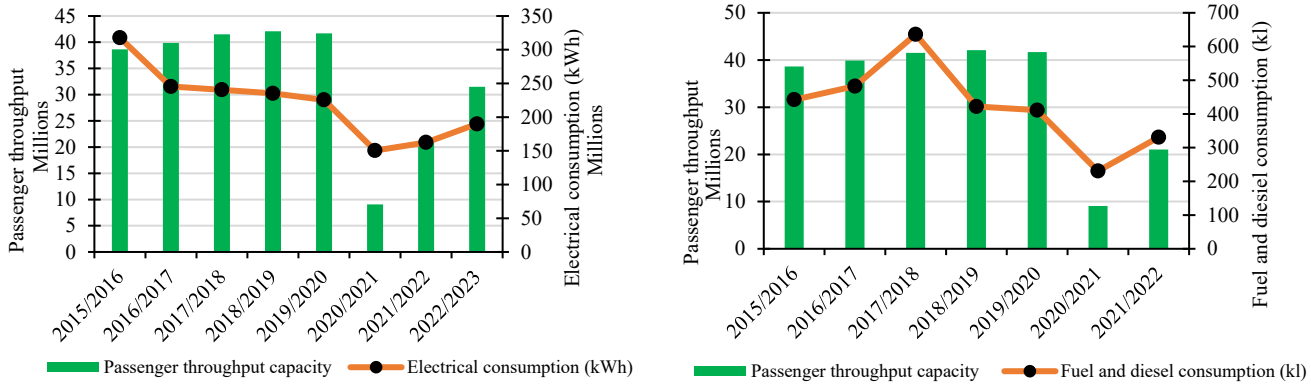
enhance safety and security measures to ensure its airports remain safe for its employees and customers. The total water consumption and water consumption per passenger shown in Figure 6 display a varying trend.



(a) (b)

Figure 6. a) Annual water consumption b) Annual litre per passenger (data derived from (ACSA, 2017), (ACSA, 2019), (ACSA, 2021), (ACSA, 2022), (ACSA, 2023b), (ACSA1), (ACSA2), (ACSA3), (ACSA4), (ACSA5), (ACSA6), (ACSA7), (ACSA8), (ACSA9))

From Figure 6 water consumption declined from 2015/2016 to 2016/2017, followed by a significant increase in 2017/2018. This may be attributed to the increase in airport operations and the expansion of commercial activities during that period. Interestingly, the Litre per passenger (L/passenger) index, a metric commonly used in airport annual reports (Carvalho et al., 2013), mirrors the overall water consumption trend except during the COVID-19 year. Although low water consumption during the pandemic was noted, the L/passenger index was higher compared to previous years. This suggests that while total water usage decreased, the reduced passenger numbers led to a higher per capita water consumption. This in turn indicates that fixed water needs may have remained constant even as passenger throughput declined. A study of 10 Brazilian airports noted that smaller Brazilian airports with 2 million annual passengers had the second-highest L/passenger index of 82, while airports handling between 5 and 6 million passengers annually had a L/passenger index below 30 (Carvalho et al., 2013). Smaller airports with fewer passengers may have higher L/passenger values, possibly due to less efficiency or higher fixed water usage per passenger. This shows the importance of tailored water management strategies to optimize water use per passenger, especially as passenger numbers fluctuate. The electricity consumption usage in Figure 7 showed a different trendline compared to water consumption.



(a) (b)

Figure 7. a) Annual electricity consumption b) Annual fuel and diesel consumption vs passenger throughput (data derived from (ACSA, 2017), (ACSA, 2019), (ACSA, 2021), (ACSA, 2022), (ACSA, 2023b), (ACSA1), (ACSA2), (ACSA3), (ACSA4), (ACSA5), (ACSA6), (ACSA7), (ACSA8), (ACSA9))

The graph shows there was a decline from 2015/2016 to 2016/2017 by 23%. This declining trend continued gradually even though there was an increase in passenger numbers. This inverse relationship between passenger growth and electricity consumption suggests that ACSA's implementation of solar farms and other energy-saving initiatives across airports was crucial in reducing energy usage (ACSA, 2023b). Electricity consumption decreased by 33.32% during COVID-19 compared to the previous year. While it is noted that energy efficiency measures have had a positive impact on reducing overall electricity consumption, passenger operations do not appear to have a direct proportional effect on electricity usage. The fuel consumption decreased after 2017/2018, indicating that the fuel-saving measures had a sustained impact (ACSA, 2017), (ACSA, 2019). Effective management practices and fuel-saving initiatives can stabilise fuel consumption, allowing for a clearer assessment of the direct impact of passenger operations on fuel usage.

The results show that waste recycled had a fluctuating trend similar to water consumption. From 2015/2016, 2016/2017, and 2017/2018, waste recycled per passenger was 88, 75, and 92 thousand kg, respectively. This was possibly due to increased airport operations, commercial activities, and upgrading projects. In 2021/2022, less than 1% of the waste ended up in landfills, and above 99% was recycled. In 2022/2023, there a significant shift was noted; waste recycling efforts continued fluctuating, with 68% of waste being sent to landfills and 32% being recycled. This analysis indicates that while passenger operations impact waste recycling, the relationship is influenced by various factors, including upgrading construction projects, operational capacity of recycling facilities, and broader waste management strategies used by the airport.

Noise complaints have decreased over the years, showing the successful implementation of noise abatement measures (ACSA, 2023b). OR Tambo International, Cape Town International, King Shaka International, and Chief Dawid Stuurman International Airports have received Level 2 ACI Carbon Accreditation Certification, indicating ACSAs aim to reduce emissions (ACSA, 2023b). The Airport Carbon Accreditation is a five-level program designed to support airports in progressively managing and reducing their greenhouse gas emissions (ACI, 2023). For wildlife, bird strike numbers were evaluated. In the pre-COVID-19 years, the number of bird strikes increased tremendously from the previous year in 2017/2018. However, the numbers have declined till 2020/2021. In addition to wildlife management, the airports have also shown their commitment to broader biodiversity initiatives (ACSA, 2023b).

5. Conclusion

This research aimed to investigate the KPAs and KPIs used across regions, identifying which KPIs should be integrated into airport performance for energy and water management. Five KPAs were identified: passenger service, operational, financial, safety and security and environmental. The implementation of these KPAs and KPIs differs globally. In Europe, KPAs and KPIs are highly structured, strongly focusing on environmental sustainability and regulatory compliance in and outside the continent. Most airports in this region have implemented real-time tracking systems for environmental KPIs. Sustainable alternative energy fuels are also increasing, with hydrogen, solar, and sustainable aviation fuels being adopted in various airports. Although lagging in technology, African airports are implementing KPAs and KPIs, particularly in water and energy management. However, there is still room for efficient water and waste management. Figure 8 shows the identified KPAs and KPIs used across regions and KPIs that are integrated into airport performance for water and energy management.

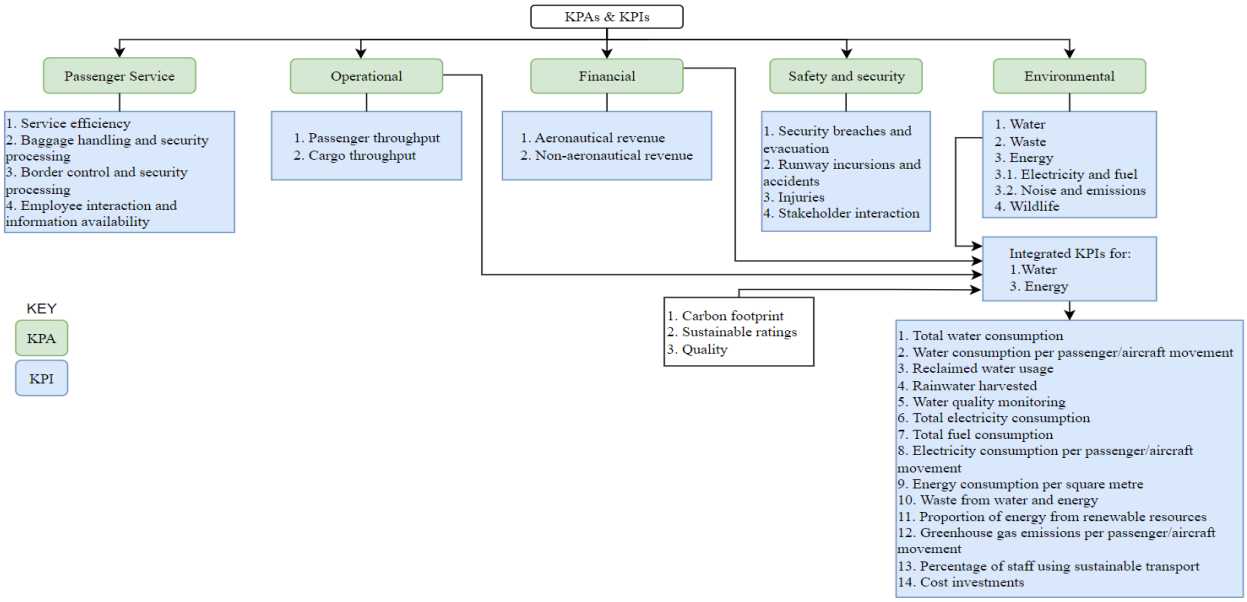


Figure 8. Identified KPAs and KPIs (author derived)

It is recommended that airports across regions use a set of general KPAs and KPIs to align with global standards and facilitate benchmarking with other airports. While many KPIs can be used, only general KPIs were established. Airports should also customise their KPIs to address their specific needs and challenges. As the industry moves towards green airports, airports must focus on environmental management practices to minimise environmental impact.

The ACSA case study illustrates how water and energy can be effectively integrated with the airport management framework. This integration highlights the interdependencies between resource consumption and operational efficiency especially in a water scarce and energy constrained country such as South Africa. Furthermore, the study also demonstrated the applicability of KPAs and KPIs across airports of varying sizes in a public-private model. It also shows how infrastructure investment, passenger service delivery and environmental performance are managed within a state influenced entity. ACSA data sources indicated KPI data as a combination for all nine airports.

The availability of individual airport data could help identify which airports are lagging and require urgent attention. This was also represented in the ACSA case study, showing practical challenges relating to data availability and reporting inconsistencies. The research was limited by the number of articles and case studies used, which may have restricted the broad analysis of KPIs in other regions. Additionally, differences in regulatory requirements and airport models across regions pose a limitation, as a one- size-fits-all approach may not be appropriate.

Future research could focus on assessing the impact of environmental regulatory changes applied to reduce carbon footprints on KPIs. This will guide the development of sustainable practices in airport performance. The research was limited by the number of articles and case studies used, which may have restricted the broad analysis of KPIs in other regions. Additionally, given the inconsistencies in the annual reports for KPI data, future work could explore the development of standardised frameworks for reporting KPIs.

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