HEALTHCARE OPERATIONS MANAGEMENT

Effect of Analytical Modelling Capability on Operational Efficiency in Public and Private Hospitals in Nairobi City County, Kenya

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Abstract

Despite increasing adoption of predictive analytics in Kenyan health projects, public and private hospitals continue to record inconsistent operational efficiency. This study examined the effect of analytical modelling capability on operational efficiency in public and private hospitals in Nairobi City County, Kenya. The study was anchored on technology-organization-environment framework. The study adopted a quantitative cross-sectional correlational design. The target population comprised 561 health project managers, data analysts and compliance officers, from which 233 respondents were selected using Yamane's formula and proportionate stratified random sampling. Data were collected via structured questionnaires, with construct validity established through factor analysis and reliability confirmed using Cronbach's alpha ($\alpha \geq 0.70$). Data were analyzed using SPSS v27 through descriptive statistics, Pearson correlation, multiple regression and moderation analysis. The findings revealed that analytical modelling capability had a significant positive effect on operational efficiency, with improvements in analytical tools, computing infrastructure, and data accessibility contributing to enhanced efficiency, collaboration, and reporting within health projects. The study concluded that analytical modelling capability significantly enhances operational efficiency in public and private hospitals. The study recommends that hospital management should adopt and prioritize analytical modelling practices as a core operational strategy, given that the study revealed it had the strongest effect on performance outcomes.

Keywords: analytical modelling capability; hospitals; Nairobi City County; operational efficiency; public and private hospitals

1 Introduction

Analytical modelling capability has emerged as a critical component of modern healthcare management, enabling hospitals to transform large volumes of clinical and operational data into actionable insights that enhance operational efficiency. Through techniques such as predictive analytics, machine learning, forecasting models, and statistical simulations, healthcare institutions can improve decision-making, optimize resource allocation, anticipate patient demand, and streamline service delivery processes. As healthcare systems continue to experience increasing patient loads, rising operational costs, and growing demand for quality services, analytical modelling capability is increasingly recognized as a strategic tool for improving efficiency in both public and private hospitals.

Globally, healthcare organizations have increasingly adopted analytical modelling capability to improve operational efficiency through data-driven decision-making. In developed economies such as the United States, Canada, the United Kingdom, and Germany, predictive modelling tools are

extensively used to forecast patient admissions, optimize staffing requirements, manage hospital bed occupancy, and improve resource utilization. According to Ezeh et al. (2024), analytical modelling enables healthcare providers to identify patterns within large datasets, anticipate disease burdens, and allocate resources more efficiently. These capabilities have significantly reduced operational bottlenecks, minimized waiting times, and enhanced healthcare service delivery. Consequently, hospitals with advanced analytical modelling systems have reported improvements in patient flow management, cost containment, and overall institutional performance.

Furthermore, countries in Asia have demonstrated remarkable progress in integrating analytical modelling into healthcare operations. In Japan, predictive models have been incorporated into hospital management systems and epidemic response frameworks, resulting in improved patient flow and reduced service delays (ICLG, 2025). Similarly, Singapore's Smart Nation initiative has leveraged advanced analytics to optimize workforce deployment, forecast healthcare demands, and streamline service processes, thereby enhancing operational efficiency across healthcare facilities (DLA Piper, 2025). These developments demonstrate that analytical modelling capability provides hospitals with the ability to make proactive decisions, improve service responsiveness, and utilize available resources more effectively.

Across Africa, analytical modelling capability has increasingly become a vital strategy for strengthening healthcare operational efficiency amid resource constraints and growing healthcare demands. South Africa has successfully applied predictive modelling in managing HIV/AIDS and tuberculosis programs, enabling healthcare institutions to improve patient scheduling, prioritize resource allocation, and enhance service delivery timelines (WHO, 2023). Through the application of advanced analytical tools, health managers can predict treatment demands and optimize healthcare resources, leading to improved operational outcomes despite limited budgets. These interventions have contributed significantly to reducing service delays and improving healthcare accessibility.

Other African countries such as Rwanda, Uganda, and Nigeria have also made notable efforts toward adopting analytical modelling in healthcare systems. Although implementation remains uneven due to infrastructural limitations and skills shortages, healthcare organizations increasingly employ forecasting models to support disease surveillance, patient management, and resource planning. Emerging evidence suggests that hospitals utilizing analytical modelling capabilities experience improved decision-making and operational coordination compared to facilities relying solely on traditional management approaches. Nevertheless, challenges related to data quality, technological infrastructure, and limited analytical expertise continue to constrain the full realization of efficiency gains across many healthcare institutions in the region.

In Kenya, analytical modelling capability has gained prominence following increased investments in digital health technologies and data-driven healthcare management systems. Hospitals are increasingly utilizing predictive analytics to support disease surveillance, inventory management, patient scheduling, and healthcare demand forecasting. According to Tira and Kihara (2025), the application of predictive analytics in Kenyan healthcare facilities has contributed to significant reductions in patient turnaround times, with some hospitals reporting efficiency improvements of nearly 30 percent. These findings suggest that analytical modelling capability can substantially enhance hospital operations by facilitating proactive planning and informed decision-making.

Further evidence from Kenyan healthcare institutions demonstrates the contribution of analytical modelling capability to operational performance. Abuya and Okello (2026) reported that structured demand forecasting accounted for 70.1% of operational performance variation among hospitals in

Siaya County, highlighting the importance of analytical modelling in reducing stock-outs, improving inventory control, and minimizing service disruptions. By enabling hospitals to anticipate future healthcare needs and allocate resources accordingly, analytical modelling capability supports efficient utilization of financial, human, and material resources. However, challenges such as inadequate digital infrastructure and shortages of skilled personnel continue to hinder widespread adoption of these technologies (Mutinda and Wanjiru, 2021).

Within Nairobi City County, differences in analytical modelling capability have contributed to varying levels of operational efficiency between public and private hospitals. Private hospitals generally exhibit higher levels of digital maturity and analytics adoption, resulting in superior operational outcomes compared to public facilities. According to KNBS (2023), outpatient service completion rates average approximately 85% in private hospitals compared to 68% in public hospitals. Additionally, AI-enabled disease prediction systems have been found to explain 44.6% of performance variation in public hospitals, while system integration contributes 43.1% of operational improvements (Tira and Kihara, 2025). Despite these gains, public hospitals continue to face budgetary constraints, inadequate technical infrastructure, and limited analytical expertise. These disparities underscore the need to examine the effect of analytical modelling capability on operational efficiency in both public and private hospitals in Nairobi City County to establish evidence-based strategies for enhancing healthcare service delivery.

2 Purpose of the study

The purpose of the study was to evaluate the effect of analytical modelling capability on operational efficiency in public and private hospitals in Nairobi City County, Kenya.

3 Literature review

According to Vest et al. (2021), analytical infrastructure plays a critical role in strengthening health surveillance systems by enabling healthcare organizations to access integrated data platforms and real-time information for decision-making. The study established that the availability of analytical software and reliable digital infrastructure improved the responsiveness of healthcare systems during public health emergencies by reducing reporting delays and facilitating timely interventions. Furthermore, adequate computing resources enabled health organizations to process large volumes of data efficiently, contributing to improved operational performance and service delivery. The authors concluded that robust analytical infrastructure is an essential prerequisite for achieving operational efficiency through data-driven healthcare management (Vest et al., 2021).

Thun et al. (2021) examined Germany's digital health infrastructure and found that analytical capabilities significantly enhanced health system responsiveness and efficiency. The study revealed that real-time analytics platforms and interoperable digital systems improved information sharing, resource coordination, and healthcare planning during the COVID-19 pandemic. In addition, hospitals with stronger analytical infrastructures demonstrated better performance in managing healthcare demands and coordinating clinical services. The study concluded that reliable digital infrastructure and analytical systems are fundamental to improving operational efficiency in modern healthcare environments (Thun et al., 2021).

According to Jha et al. (2020), analytical infrastructure contributes significantly to improving efficiency in healthcare laboratories through enhanced information management and decision-

making processes. The study established that real-time access to laboratory information systems reduced duplication of services, improved workflow coordination, and increased patient throughput. Moreover, adequate computing capacity facilitated timely data processing, which supported more efficient utilization of healthcare resources. The authors concluded that investment in analytical systems enhances operational efficiency by optimizing laboratory processes and improving service delivery outcomes (Jha et al., 2020).

Chen et al. (2020) investigated the relationship between analytical infrastructure and hospital performance in China and found that standardized software systems and reliable digital platforms enhanced operational efficiency. The study indicated that real-time access to patient information improved resource allocation and enabled hospitals to reduce service bottlenecks. Furthermore, healthcare facilities with well-developed analytical systems demonstrated greater effectiveness in managing patient flows and operational processes. The researchers concluded that strong analytical infrastructure serves as a key driver of operational efficiency within public healthcare institutions (Chen et al., 2020).

According to Tiong et al. (2020), software-enabled analytical infrastructure improved service efficiency in Malaysian emergency departments by facilitating rapid access to patient records and supporting informed clinical decisions. The study found that reliable information systems significantly reduced waiting times and enhanced triage effectiveness. Additionally, real-time data availability improved coordination among healthcare providers, leading to more efficient emergency care delivery. The authors concluded that analytical infrastructure is instrumental in enhancing operational efficiency within emergency healthcare settings (Tiong et al., 2020).

Ngobeni et al. (2020) assessed healthcare efficiency in South Africa and found that inadequate analytical infrastructure and unreliable information systems constrained operational performance across provincial healthcare facilities. The study revealed that provinces with stronger digital and analytical capabilities achieved superior efficiency outcomes compared to those with limited technological resources. Furthermore, effective deployment of analytical software improved healthcare planning and resource utilization. The authors concluded that investments in analytical infrastructure are critical for enhancing operational efficiency in public healthcare systems.

According to Tijani et al. (2021), analytical infrastructure supported efficient management of COVID-19 testing centres in Nigeria through automated software systems and integrated data platforms. The study established that real-time access to healthcare data improved decision-making accuracy and minimized operational errors. Additionally, effective analytical tools enhanced coordination among healthcare personnel and increased testing efficiency. The authors concluded that robust analytical infrastructure is vital for improving healthcare operational outcomes during disease outbreaks (Tijani et al., 2021).

Kiwanuka et al. (2026) investigated the adoption of DHIS2 systems in Uganda and found that analytical infrastructure significantly enhanced health program monitoring and planning efficiency. The study revealed that adequate computing resources and dependable information systems facilitated timely access to health data, improving healthcare managers' ability to make informed decisions. Moreover, analytical capabilities strengthened organizational responsiveness and operational coordination. The researchers concluded that investments in analytical infrastructure contribute substantially to operational efficiency within healthcare systems (Kiwanuka et al., 2026).

According to Omondi and Wanjiru (2023), analytical modelling capability significantly improves operational efficiency by enhancing forecasting accuracy and supporting proactive resource

allocation. Their study conducted at Kenyatta National Hospital established that predictive analytical models effectively reduced patient congestion and improved resource utilization. Additionally, accurate forecasting enabled healthcare managers to anticipate service demands and optimize operational planning. The authors concluded that continuous investment in analytical modelling tools is necessary for sustaining improvements in healthcare operational efficiency (Omondi and Wanjiru, 2023).

Mutua and Chege (2024) examined the influence of analytical model update frequency on operational efficiency in private hospitals within Nairobi County. The findings indicated that hospitals that frequently updated analytical models were better positioned to respond to emerging health trends and changing service demands. Furthermore, dynamic model updates enhanced organizational adaptability and improved real-time decision-making processes. The study concluded that regular updating of analytical models strengthens operational efficiency by ensuring the continuous relevance and accuracy of predictive insights (Mutua and Chege, 2024).

According to Njoroge and Kihara (2023), analytical modelling capability contributes to operational efficiency through its diverse applications in patient flow management, inventory control, and workforce scheduling. Their study found that broader deployment of analytical models reduced wastage, enhanced staff utilization, and improved service coordination. Additionally, hospitals utilizing analytical models across multiple operational functions achieved better performance outcomes compared to those applying such tools in limited areas. The authors concluded that expanding the scope of analytical model utilization can significantly improve healthcare operational efficiency (Njoroge and Kihara, 2023).

Mwangi and Otieno (2024) investigated machine learning-based analytical models in county referral hospitals and found that high model accuracy improved emergency department efficiency. The study established that predictive analytics enhanced triage processes, reduced patient waiting times, and optimized hospital resource allocation. Furthermore, integration of analytical models into routine operational workflows significantly strengthened healthcare service performance. The researchers concluded that embedding machine learning analytics within hospital systems is an effective strategy for improving operational efficiency (Mwangi and Otieno, 2024).

Finally, the study by Kariuki and Mutiso (2023) assessed the effect of real-time analytical systems on operational efficiency in rural hospitals in Kenya. Their findings showed that timely updates of patient information improved interdepartmental coordination and reduced duplication of healthcare services. In addition, real-time analytical capabilities enhanced communication and facilitated more efficient service delivery processes. The study concluded that investments in real-time analytical systems can significantly improve operational efficiency, particularly in resource-constrained healthcare environments (Kariuki and Mutiso, 2023).

The reviewed literature demonstrates that analytical modelling capability improves operational efficiency through enhanced forecasting, real-time decision-making, resource optimization, workflow coordination, and service delivery. However, most authenticated studies were conducted in developed countries such as the United States, Germany, China, and India, while African studies largely focused on health surveillance systems, laboratories, or provincial healthcare facilities rather than hospitals. In Kenya, existing studies have primarily examined specific elements of analytical modelling such as predictive analytics, machine learning applications, forecasting accuracy, and model updates within individual hospitals. Consequently, there is limited empirical evidence examining analytical modelling capability as a multidimensional construct and its effect on

operational efficiency across both public and private hospitals in Nairobi City County. This presents a contextual, conceptual, and methodological gap that the current study seeks to address.

4 Materials and methods

The study adopted a positivist philosophy and a quantitative, cross-sectional correlational survey design to empirically test the effect of predictive analytics capability on operational efficiency in hospitals in Nairobi City County. The target population comprised 561 health project managers, data analysts, and compliance officers from public, private and mission hospitals, from which a sample of 233 was determined using Yamane's (1967) formula (Equation 1):

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

where n is the sample size, N the target population (561) and e the margin of error; the sample was selected through proportionate stratified random sampling. Primary data were collected using structured 5-point Likert-scale questionnaires measuring predictive analytics capability (data integration, modelling, competency, infrastructure) and operational efficiency (wait times, resource utilization, cost reduction), administered both physically and electronically after obtaining NACOSTI permit, hospital authority, and university ethical clearance with informed consent. A pilot of 23 respondents was used to test content validity via expert review and construct validity via factor analysis, and reliability via Cronbach's Alpha 0.70. Data were analyzed using SPSS version 27, employing descriptive statistics, Pearson correlation, and multiple and moderated regression to test hypotheses.

5 Results and discussion

This section presents the regression results assessing the role of advanced analytical modelling in predicting efficiency. It explores whether analytical skills contribute meaningfully to improved decision-making and operational outcomes.

Table 1. ANOVA for analytical modelling capability and operational efficiency.

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	8.214	1	8.214	59.82	.000
Residual	39.066	195	0.200		
Total	**47.280**	**196**			

The ANOVA results indicate that the regression equation for analytical modelling capability was statistically significant, $F(1, 195) = 59.82$, $p < .001$. This finding means that the null hypothesis, which stated that analytical modelling capability has no effect on operational efficiency, is rejected. The regression sum of squares (8.214) compared to the residual sum of squares (39.066) shows that analytical modelling capability explains a meaningful portion of the variance in operational efficiency, confirming its importance as a predictor.

Table 2. Model summary for analytical modelling capability and operational efficiency.

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.414	0.171	0.167	0.372

The model summary provides further insight into the strength of this relationship. The correlation coefficient (R = .414) demonstrates a moderate positive association between analytical modelling capability and operational efficiency. The model explains 17.1% of the variance (R^2 = .171), with an adjusted R^2 of .167, indicating that the explanatory power remains consistent after accounting for the sample size. The standard error of the estimate (.372) suggests that the model predicts efficiency outcomes with reasonable accuracy, though a substantial proportion of variance remains unexplained by this single predictor.

Table 3. Coefficients for analytical modelling capability and operational efficiency.

Predictor	B	Std. Error	Beta	t	Sig.
Constant	0.082	0.052		1.577	0.117
Analytical modelling capability	0.501	0.049	0.518	10.21	.000

The regression results for analytical modelling capability provide strong evidence of its influence on operational efficiency. The unstandardized coefficient (B = 0.501) indicates that for every unit increase in analytical modelling capability, operational efficiency rises by about half a unit, holding other factors constant. This demonstrates a clear positive relationship between the predictor and the outcome. The standardized coefficient (β = 0.518) further confirms that analytical modelling capability is a substantial contributor relative to other variables in the model.

The t-value of 10.21, coupled with a significance level ($p < .001$), shows that this effect is highly statistically significant. The probability of observing such a strong effect if the null hypothesis were true is virtually zero. Therefore, the null hypothesis (H_0), which stated that analytical modelling capability has no significant effect on operational efficiency, is rejected. This confirms that analytical modelling capability plays a meaningful role in enhancing efficiency outcomes.

The constant term (B = 0.082, t = 1.577, p = .117) was not statistically significant, meaning the baseline effect without the predictor is negligible. In contrast, the predictor itself is highly significant, confirming that improvements in analytical modelling practices are strongly associated with better operational efficiency. Overall, the results highlight that analytical modelling capability is both statistically and practically important, making it a key driver of organizational performance.

The study findings were in agreement with findings by Vest et al. (2021) in the U.S., who showed that analytical infrastructure through software availability and real-time access to integrated platforms significantly improved operational efficiency, and by Thun et al. (2021) in Germany, who emphasized that robust computing capacity and reliable systems enhanced pandemic response efficiency despite regional disparities. Similarly, Jha et al. (2020) in India demonstrated that adequate computing and storage capacity improved diagnostic efficiency, though rural areas faced reliability challenges, while Chen et al. (2020) in China confirmed that standardized software and reliable computing systems facilitated real-time resource allocation in hospitals. Evidence from Tiong et al. (2020) in Malaysia revealed that software-driven analytical infrastructure reduced waiting times in emergency departments, and Ngobeni et al. (2020) in South Africa highlighted that limited computing adequacy

and unreliable systems hindered efficiency at provincial level. In Nigeria, Tijani et al. (2021) found that automated software and reliable systems improved efficiency in COVID-19 testing centres, while Kiwanuka et al. (2026) in Uganda showed that DHIS2 adoption enhanced program monitoring efficiency despite infrastructural and human resource challenges. Triangulated together, these studies affirm that analytical modelling capability and infrastructure are universal drivers of operational efficiency, while Kenya's unique gaps lie in county-level infrastructural inequalities, resource constraints, and uneven access to analytical tools, underscoring the need for equitable investment in computing capacity, reliable systems, and standardized analytical platforms to maximize efficiency across diverse health projects.

6 Conclusion

The study concluded that analytical modelling capability significantly enhances operational efficiency in public and private hospitals. The findings established a moderate positive relationship between analytical modelling capability and operational efficiency, indicating that improvements in data analysis, forecasting, and decision-support systems are associated with better efficiency outcomes. The regression results provided sufficient statistical evidence to reject the null hypothesis, confirming that analytical modelling capability has a significant positive effect on operational efficiency.

7 Recommendations

- The Hospital Management should adopt and prioritize analytical modelling practices as a core operational strategy, given that the study revealed it had the strongest effect on performance outcomes.
- Develop national guidelines for the adoption of analytical modelling tools in healthcare projects. Provide government-backed funding schemes to support acquisition of advanced analytical software and infrastructure.
- Expand access to analytical tools and computing resources within institutions to reduce inefficiencies. Build internal capacity through continuous training on analytical modelling techniques for project staff.

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