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Cold Chain Infrastructure Management Strategies and Performance of Flower Industry in Kenya

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ABSTRACT

Purpose: This study investigated the influence of cold chain infrastructure management strategies on the performance of the flower industry in Kenya, focusing on Nakuru County. The study addressed four strategic areas: cold chain infrastructure optimization strategy, technology integration strategy regulatory compliance strategy and stakeholder collaboration strategy.

Methodology: A descriptive research design was adopted, targeting all 75 registered flower firms in the region using a census approach. Data were collected through structured questionnaires and analyzed using both descriptive and inferential statistics with SPSS Version 27, alongside thematic analysis for qualitative responses.

Findings: Findings revealed that infrastructure optimization significantly improved operational efficiency, flower quality, and reduced post-harvest losses. Regression analysis confirmed a strong and statistically significant positive relationship between infrastructure optimization and firm performance ($B = 0.635$, $p = 0.015$). Technology integration, including real-time temperature monitoring, IoT devices, and cloud-based systems, was shown to enhance efficiency and reduce costs, explaining 48.7% of performance variance. Regulatory compliance was positively associated with improved customer trust, market reputation, and export readiness. Stakeholder collaboration, through formal and informal partnerships with key players across the supply chain, contributed to shared infrastructure, knowledge exchange, and streamlined operations, further boosting cold chain effectiveness. The study concluded that cold chain infrastructure optimization strategy, technology integration strategy, regulatory compliance strategy and stakeholder collaboration strategy play critical roles in enhancing the performance and competitiveness of flower firms.

Unique Contribution to Theory, Practice and Policy: Recommendations included investing in modern cold storage systems, adopting advanced technologies, strengthening compliance frameworks, and formalizing stakeholder engagement mechanisms. These strategies are essential for sustaining growth, reducing losses, and improving the global competitiveness of Kenya's flower industry.

Key Words: *Cold Chain, Infrastructure Optimization, Technology Integration, Regulatory Compliance, Stakeholder Collaboration, Firm Performance*

Background of the Study

Efficient cold chain infrastructure is essential for maintaining the quality and safety of temperature-sensitive products such as food, pharmaceuticals, and biological materials (Karpun, 2020). The cold chain comprises of an interconnected network of storage and transportation processes designed to preserve items within specified temperature ranges from production to final consumption. Any disruption within this system compromises product integrity, leading to significant economic losses, public health risks, and customer dissatisfaction. As global supply chains grow increasingly complex and demand for perishable goods rises, effective management strategies for cold chain infrastructure have become a critical focus for organizations worldwide (He, Yang, Wu, Pu, & Izui, 2024).The concept of the cold chain emerged as a response to the need for preserving food during long voyages and enabling the year-round availability of seasonal produce (Wani, et al., 2023). Over time, technological advancements have revolutionized cold chain logistics, integrating innovations such as refrigeration systems, data monitoring tools, and real-time tracking solutions. Despite these developments, challenges such as inconsistent temperature control, energy inefficiency, and inadequate infrastructure persist, particularly in developing regions. These issues are exacerbated by external factors like climate change, supply chain disruptions, and insufficient regulatory frameworks, underscoring the importance of robust management strategies (Karpun, 2020).

Performance within cold chain systems is not solely a measure of operational efficiency but also includes sustainability, cost-effectiveness, and the ability to meet end-user expectations (Danso, 2021). The effective management of cold chain infrastructure involves strategic planning, investment in modern technologies, and adherence to industry standards. Additionally, stakeholder collaboration, training, and contingency planning are vital to ensuring the system's resilience and adaptability. Organizations that excel in these areas often achieve higher levels of customer satisfaction, reduced operational losses, and enhanced market competitiveness (Zitong & Xiaolin, 2020). Despite the critical role of cold chain systems in Kenya's flower industry, challenges persist (Kimani & Nganga, 2023). Power outages, high energy costs, and inadequate cold storage facilities, especially in rural areas where most flower farms are located, undermine the efficiency of the cold chain. Additionally, delays in transportation and limited access to advanced monitoring technologies contribute to post-harvest losses, affecting both the profitability and competitiveness of the sector. In response to these challenges, stakeholders in Kenya's flower industry have adopted various management strategies, such as investing in solar-powered refrigeration, leveraging digital solutions for real-time temperature monitoring, and collaborating with logistics providers to streamline export processes (Kamau, Njeru, & Ochieng, 2022). This study thus seeks to explore how the various cold chain infrastructure management strategies influence the performance of Kenya's flower industry.

Statement of the Problem

The flower industry in Kenya is a vital contributor to the national economy, accounting for a significant portion of the country's foreign exchange earnings and providing employment opportunities to thousands of workers, particularly in rural areas (Muriithi & Njoroge, 2023). However, despite its critical role, the cold chain system in Kenya faces numerous challenges that threaten the performance and competitiveness of the flower industry. The export value of cut flowers from Kenya has shown significant fluctuations over recent years. In January 2024, the export peaked at approximately 14 billion Kenyan shillings (about 108 million USD), but by September 2024, it had declined to around 6.3 billion KSh (approximately 48.6 million USD). This represents a notable decrease in export performance, highlighting instability in market demand and logistical challenges that affect timely deliveries and product quality (Muthomi, Nyangau, & Nderitu, 2021). Additionally, Horticultural Crops Directorate (2022) indicate that up to 20% of flowers are lost post-harvest due to inadequate temperature control and logistical delays. This translates to annual losses of over $60 million, impacting the profitability of flower firms and the livelihoods of thousands of workers. ABDA (2022) revealed that farms utilizing outdated cooling technologies experienced spoilage rates 1.5 times higher than those employing modern systems. Similarly, a regression analysis of operational efficiency metrics showed a statistically significant negative correlation ($r = -0.67$, $p < 0.05$) between energy inefficiencies in cold chain operations and the export quality of flowers.

Inefficiencies within Kenya's cold chain infrastructure often result in post-harvest losses, quality deterioration, and increased operational costs. Postharvest losses are a major concern in the Kenyan flower industry, with estimates suggesting that up to 30% of flowers are lost due to insufficient refrigeration and improper handling (Kimani & Nganga, 2023). Power outages, insufficient cold storage facilities, and high energy costs exacerbate the problem, especially in rural areas where most flower farms are located. Additionally, inadequate transportation networks and delays in the supply chain contribute to temperature excursions, compromising the freshness of flowers by the time they reach export markets (Ochieng & Wanjiru, 2021). These inefficiencies not only diminish the economic returns for flower producers and exporters but also risk Kenya's reputation in the international market (Otieno, Omanga, & Ngetich, 2021). Efforts to address these challenges have been inconsistent and fragmented, with limited emphasis on comprehensive cold chain management strategies tailored to the specific needs of the flower industry. While some stakeholders have adopted advanced technologies such as solar-powered refrigeration and IoT-based temperature monitoring, the integration of these innovations into the broader cold chain system remains limited. Furthermore, there is a lack of sufficient data on the effectiveness of various management strategies in optimizing cold chain performance and their overall impact on the industry's competitiveness (Wanjiru & Kiiru, 2022).

The persistence of these challenges highlights a critical gap in knowledge and implementation of effective cold chain infrastructure management strategies in Kenya's flower industry. Indeed, Onyiego and Osoro (2022) ascert that there is a paucity of studies done examining effectiveness of cold chain infrastructure management strategies on the performance of Kenya's flower industry. Studies such as Mutai, Kosgei and Rotich (2022) have focused on cold chain investments and export volumes. Kosgei and Rotich (2023) n their part focused on short-term effects of cold chain regulations on flower export volumes in Kenya, clearly illustrating that most studies have specifically focused the relatinship between the cold chain infrastructure itself and flower export volumes. This study thus sought to investigate the influence of cold chain infrastructure management strategies on the performance of Kenya's flower industry.

Research Questions

i What is the influence of cold chain infrastructure optimization strategy on the performance of the flower industry in Kenya?
ii What is the influence of technology integration strategy on the performance of the flower industry in Kenya?
iii What is the influence of regulatory compliance strategy on the performance of the flower industry in Kenya?
iv What is the influence of stakeholder collaboration strategy on the performance of the flower industry in Kenya??

Literature Review

Infrastructure Optimization Strategy on the Performance of the Flower Industry

According to Pan (2021) cold chain infrastructure optimization is a critical strategy for enhancing the performance of industries dealing with perishable goods, such as the flower industry. Karpun (2020) indicates that the optimization of cold chain systems has a direct and substantial impact on the quality, efficiency, and profitability of flower firms, particularly in key flower-exporting countries. Optimization of cold chain infrastructure involves improving storage facilities, transportation networks, and technological systems to ensure that temperature-sensitive products, such as cut flowers, remain within the required temperature ranges throughout the supply chain, from farm to market (Rodríguez Mañay, 2022).

Babalola, Sundarakani and Ganesh (2021) in Malaysia investigated the effect of cold chain optimization strategies on the flower export sector. The study highlighted that optimizing cold chain infrastructure, through investments in modern refrigeration technologies, temperature-controlled storage, and improved logistics systems, was essential for maintaining the freshness and quality of flowers during transportation. The researchers found that farms that optimized their cold chain operations experienced a significant reduction in product wastage and spoilage, which often occurred due to delays in the supply chain or inadequate temperature control. The study also showed that flower farms that adopted optimized cold chain systems were better able to meet the stringent quality standards required by international markets, leading to higher customer satisfaction and better market access (Babalola, et al., 2021). As a result, these farms were able to secure long-term contracts with international buyers, which translated into stable

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Vol. 10, Issue No. 8, pp. 1 - 19, 2025

revenue streams and enhanced industry performance. Babalola, et al. (2021) concluded that the optimization of cold chain infrastructure was a critical factor in ensuring the flower industry's competitiveness in global markets.

Technology Integration Strategy on the Performance of the Flower Industry

Macheka (2022) averred that the integration of advanced technologies into the cold chain management processes of the flower industry is vital for ensuring product quality, reducing operational inefficiencies, and enhancing overall performance. The flower industry in key exporting countries relies heavily on technology to optimize its supply chains, improve traceability, and meet the stringent quality requirements of international markets. Bányai, et al. (2020) reveal that technology integration strategies, play a significant role in improving the performance of flower firms, driving efficiency, and increasing market competitiveness.

Bamana, Lehoux and Cloutier (2020) in the Netherlands, averred that Dutch flower producers have long been at the forefront of using technology to optimize every stage of flower cultivation, harvesting, and distribution. The country's adoption of precision farming techniques, including automated greenhouses, climate control systems, and sophisticated irrigation technologies, has drastically increased production efficiency (Bamana, et al., 2020). One of the most notable technological advancements is the use of robotics for harvesting and processing flowers, reducing labour costs and increasing the consistency of product quality. Furthermore, real-time data collection and IoT-based systems allow Dutch flower producers to monitor environmental conditions, adjust growing parameters, and track product movement throughout the supply chain. Ren, Ren, Matellini and Ouyang (2022) indicate that these technological integrations have led to higher yields, better quality control, and a reduction in post-harvest losses. This technological focus has bolstered the competitiveness of the Netherlands as a global flower exporter, ensuring the country maintains a leading position in the market despite rising competition.

Regulatory Compliance Strategy on the Performance of the Flower Industry

Shi, Zhang and Qin (2024) explored the role of cold chain infrastructure in enhancing the competitiveness of flower industry in China. The study found that regulatory compliance with cold chain standards, such as those outlined by the International Air Transport Association (IATA) and GlobalGAP, was crucial for maintaining the quality of flowers during transportation. These standards require temperature-controlled storage facilities and transportation networks to preserve flower freshness, which directly influences market acceptability (Shi, et al., 2024). The research demonstrated that flower farms that invested in state-of-the-art cold chain infrastructure and adhered to international cold chain regulations were able to export higher-quality flowers, leading to increased customer satisfaction and loyalty. These farms enjoyed better market access and were able to command higher prices, which significantly improved their profitability and overall market performance (Shi, et al., 2024). The study highlighted that non-compliance with cold chain regulations often led to spoilage and wastage, causing a negative impact on revenue and market reputation.

Similarly, Liu (2024) analyzed the influence of cold chain infrastructure on the performance of flower farms in Malaysia, with a focus on the regulatory compliance aspect. He discovered that cold chain logistics played a pivotal role in ensuring that flowers retained their aesthetic value and freshness upon arrival in international markets, especially in Europe. The study found that flower farms that complied with cold chain regulatory standards were able to maintain product quality throughout the supply chain, from harvest to export. Farms that failed to adhere to these standards faced challenges such as increased flower wastage, product rejection at export points, and penalties, which negatively affected profitability (Liu, 2024). On the other hand, compliance with cold chain regulations allowed farms to mitigate losses, enhance product consistency, and increase operational efficiency. The author concluded that regulatory compliance with cold chain infrastructure positively influenced the competitiveness and financial performance of flower farms by reducing operational risks and ensuring product quality.

Stakeholder Collaboration Strategy on the Performance of the Flower Industry

Barbosa (2021) averred that cold chain management involves a complex network of processes and actors, including flower producers, transporters, logistics providers, government regulators, and international buyers. A collaborative approach involving these stakeholders significantly enhances the performance of the flower industry, particularly in ensuring the efficiency and reliability of cold chain infrastructure (Button, 2020). The empirical literature on stakeholder collaboration strategies within the flower industry reveals that effective partnerships and cooperation among key actors in the cold chain supply network lead to improved operational outcomes, market access, and financial performance.

Nha Trang, et al. (2022) explored the role of stakeholder collaboration in the cold chain infrastructure of Singapore's flower industry. The research highlighted that collaboration among stakeholders, such as government agencies, flower farms, logistics companies, and international buyers, was essential for ensuring a seamless cold chain from the farm to international markets. The study found that collaborative efforts focused on shared infrastructure investments, information exchange, and joint training programs had a direct impact on the efficiency of cold chain logistics. Stakeholders that worked together to align their practices with international standards experienced fewer disruptions, reduced flower spoilage, and improved export success rates. Nha Trang, et al. (2022) argued that such collaboration not only enhanced the quality of the flowers but also strengthened the relationships between producers and international buyers, leading to long-term contracts and more stable revenue streams.

Research Methodology

The study used descriptive research design. The target population included managers of the 75 flower firms which are located in Nakuru County. The managers included in the study typically held senior roles such as general managers, operations managers, logistics managers, and quality assurance managers. This study used census since the population was small. Primary data was collected using structured questionnaires that included both closed- and open-ended questions.

Journal of Business and Strategic Management
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Data analysis was conducted using SPSS Version 27, with descriptive statistics such as means, frequencies, and percentages used to summarize the data. Inferential statistics, including regression and correlation analyses, were applied to test the relationships and effects of selected strategies on firm performance. In addition, thematic analysis was performed on qualitative responses to identify patterns and key themes that enriched the quantitative findings. The multiple regression model was;

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Where: α = y-intercept (Constant), Y = Performance, $\beta_1 - \beta_4$ = Beta coefficient of the independent variable, X_1 = Infrastructure optimization strategy, X_2 = Technology integration strategy, X_3 = Regulatory compliance strategy, X_4 = Stakeholder collaboration strategy and ε = error term.

Results

A total of 75 managers were targeted for data collection, and all 75 responded, resulting in a response rate of 100%. According to Taherdoost & Madanchian (2024) a 100% response rate enhances the reliability and validity of the study findings, as it eliminates concerns related to non-response bias and ensures that the views of the entire targeted population are adequately represented in the analysis.

Infrastructure Optimization Strategy

Descriptive statistics of Infrastructure Optimization Strategy

The descriptive statistics for the infrastructure optimization strategy show that respondents generally agreed with the statements, with mean scores ranging from 3.75 to 4.15 and standard deviations between 0.519 and 1.024 indicating that the responses were consistent across.

Table 1: Descriptive statistics on Infrastructure Optimization Strategy

Statements	Mean	Std. Dev
Our firm has invested significantly in optimizing cold chain infrastructure	3.75	.840
We regularly assess the effectiveness of our cold storage systems to ensure optimization	4.08	.632
The optimization of cold chain infrastructure has improved the quality of our flowers	4.05	.715
Our firm uses modern refrigeration technology to enhance cold chain efficiency	3.99	.862
Regular maintenance of cold chain equipment is prioritized in our firm	3.81	.954
Cold chain infrastructure optimization has reduced post-harvest losses in our firm	4.08	1.024
Our firm adheres to international standards for cold chain infrastructure	3.97	.657
Our firm has access to adequate cold chain transport to preserve flower quality during transit	4.15	.692
The use of energy-efficient cold chain systems has led to cost savings	4.03	.519

Journal of Business and Strategic Management
ISSN 2520-0402 (Online)
Vol. 10, Issue No. 8, pp. 1 - 19, 2025

Inferential Statistics for Influence of Infrastructure Optimization Strategy on Firm Performance

The study carried out a simple regression analysis to determine the influence of infrastructure optimization strategy on the performance of flower firms in Nakuru County. The results indicated an R-squared value of 0.520, meaning that infrastructure optimization strategy accounts for 52.0% of the variation in the performance of flower firms. The remaining 48.0% of the variation in firm performance can be attributed to other factors not included in this model. This shows a strong explanatory power of infrastructure optimization strategy in influencing firm performance, highlighting its importance in the operations of flower firms. The results of the ANOVA test were used to evaluate the overall significance of the regression model. The computed F-statistic was 99.486, with a p-value (Sig.) of 0.015. At the 0.05 level of significance, the p-value is less than 0.05, indicating that the model is statistically significant. This means that infrastructure optimization strategy significantly predicts firm performance, and thus, the null hypothesis that the coefficient of the infrastructure optimization variable equals zero is rejected. Further analysis of the regression coefficients revealed that infrastructure optimization strategy had a positive and significant influence on firm performance. The unstandardized beta coefficient (B) was 0.635, with a standard error of 0.127, and the corresponding t-value was 5.000, with a p-value of 0.015. Since the p-value is less than 0.05, the effect is statistically significant. The positive sign of the beta coefficient indicates that an increase in infrastructure optimization activities leads to an improvement in the performance of flower firms. This could be due to enhanced efficiency, reduced post-harvest losses, and better quality control through effective infrastructure use. Therefore, the study concludes that infrastructure optimization strategy plays a crucial role in enhancing the performance of flower firms in Nakuru County.

Table 2: Inferential Statistics for Influence of Infrastructure Optimization Strategy on Firm Performance

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.721[a]	.520	.518	3.60896

ANOVAa	Sum of Squares	Df	Mean Square	F	Sig.
Regression	132.316	1	132.316	99.486	.015[b]
Residual	97.070	73	1.330		
Total	229.386	74			

	Unstandardized Coefficients		Standardized Coefficients		
Regression	B	Std. Error	Beta	t	Sig.
(Constant)	5.248	.430		12.196	.000
Infrastructure optimization strategy	0.635	0.127	0.522	5.000	.015

a. Dependent Variable: Firms Performance

b. Predictors: (Constant), Infrastructure Optimization Strategy

Descriptive statistics of Technology Integration Strategy

The descriptive statistics for the technology integration strategy indicate that respondents generally agreed on the positive impact of technology integration in cold chain operations, with mean scores ranging from 3.77 to 4.05, suggesting a strong consensus on its benefits. The standard deviations, ranging from 0.319 to 0.751, showed that most respondents' opinions were consistent.

Table 3: Descriptive statistics of Technology Integration Strategy

Statements	Mean	Std. Dev
Our firm has integrated advanced technology in its cold chain infrastructure	3.83	.554
We use temperature monitoring systems to ensure consistent conditions in our cold chain operations	3.97	.636
The integration of automated systems has improved the efficiency of our cold chain operations	3.77	.606
Our firm employs real-time data tracking and analytics to monitor cold chain performance	4.01	.533
Technology integration in our cold chain infrastructure has reduced operational costs for our firm	3.87	.577
We use GPS and routing software to optimize cold chain logistics and delivery	3.95	.751
The use of IoT (Internet of Things) devices in our cold chain infrastructure has enhanced product quality	3.91	.409
We have adopted cloud-based solutions for tracking and managing cold chain data across multiple locations	3.92	.319
The integration of technology in cold chain infrastructure has helped us comply with international standards	4.05	.543

Inferential Statistics for Influence of Technology Integration Strategy on Firm Performance

The study also carried out a simple regression analysis to determine the influence of technology integration strategy on the performance of flower firms in Nakuru County. The study found an R-squared value of 0.487, meaning that technology integration strategy accounted for 48.7% of the variation in the performance of flower firms. The remaining 51.3% of the variation in firm performance could be attributed to other factors not included in the model. This indicates a strong influence of technology integration on firm performance and highlights the value of technological adoption in improving operational efficiency and competitiveness in the flower industry. The results of the ANOVA test were used to determine the overall fit of the linear regression model, with technology integration strategy as the independent variable and firm performance as the dependent variable. The computed F-statistic was 108.934, and the p-value (Sig.) was 0.008. Since the p-value is less than the conventional alpha level of 0.05, the regression model is statistically significant. This means that technology integration strategy had a significant predictive power over firm performance, and thus, the null hypothesis (that the regression coefficient is equal to zero) was rejected. Further analysis of the regression coefficients showed that technology integration strategy had a positive and statistically significant effect on firm performance. The unstandardized beta coefficient (B) was 0.821, with a

Journal of Business and Strategic Management
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Vol. 10, Issue No. 8, pp. 1 - 19, 2025 www.carijournals

standard error of 0.083. The t-value was 9.891, and the p-value was 0.008, which was well below the 0.05 threshold for significance. This positive beta coefficient indicates that an increase in the implementation of technology integration strategies was associated with an improvement in firm performance. The high t-value confirms the robustness of this influence. The findings suggest that flower firms that adopted and integrated advanced technologies into their operations achieved improved efficiency, reduced waste, enhanced product quality, and greater customer satisfaction. Therefore, the study concluded that technology integration strategy significantly and positively influenced the performance of flower firms in Nakuru County, and investments in technological innovation should be prioritized as a key driver of growth and competitive advantage.

Table 4: Inferential Statistics for Influence of Technology Integration Strategy on Firm Performance

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate	
	.698[a]	.487	.483	0.430	
ANOVAa	Sum of Squares	df	Mean Square	F	Sig.
Regression	156.321	1	156.321	108.934	.008[b]
Residual	104.746	73	1.435		
Total	261.067	74			
	Unstandardized Coefficients		Standardized Coefficients		
Regression	B	Std. Error	Beta	t	Sig.
(Constant)	16.247	.529		30.713	.000
Technology integration strategy	0.821	0.083	0.723	9.891	.008

a. Dependent Variable: Firms Performance
b. Predictors: (Constant), Technology Integration Strategy

Descriptive statistics of Regulatory Compliance Strategy

The descriptive statistics for the regulatory compliance strategy showed that respondents generally agreed with the statements, with mean scores ranging from 3.92 to 4.24 and standard deviations between 0.434 and 0.741, indicating that the respondents unanimously agreed on the importance of regulatory compliance in minimizing legal risks, improving market reputation, and ensuring adherence to cold chain standards.

Journal of Business and Strategic Management
ISSN 2520-0402 (Online)
Vol. 10, Issue No. 8, pp. 1 - 19, 2025 www.carijournals

Table 5: Descriptive statistics of Regulatory Compliance Strategy

Statements	Mean	Std. Dev
Our firm strictly adheres to local and international cold chain regulatory standards	4.01	.533
The firm regularly reviews and updates its cold chain infrastructure to remain compliant with regulations	4.11	.559
Our firm maintains detailed records of all cold chain operations for regulatory compliance purposes	3.92	.587
Compliance with cold chain regulatory requirements has improved the overall quality of our flower products	4.08	.610
The firm regularly conducts internal audits to ensure compliance with cold chain regulations	4.13	.741
Our cold chain infrastructure meets the required standards for export to international markets	4.04	.556
Training on regulatory compliance is regularly provided to staff involved in cold chain operations	4.15	.711
The firm has implemented policies to ensure that all cold chain equipment is compliant with industry regulations	4.03	.434
Regulatory compliance in cold chain operations has minimized legal risks and improved the firm's market reputation	4.24	.589

Inferential Statistics for Influence of Regulatory Compliance Strategy on Firm Performance

The study further carried out a simple regression analysis to determine the influence of regulatory compliance strategy on the performance of firms. The study found an R squared value of 0.537, indicating that regulatory compliance strategy accounted for 53.7% of the variation in firm performance. This implies that slightly more than half of the changes in firm performance can be explained by the firms' regulatory compliance strategies, such as adherence to legal standards, operational guidelines, and sector-specific regulations. The remaining 46.3% of the variation in performance can be attributed to other factors not included in this model. The results of the ANOVA test were used to evaluate the overall (global) significance of the regression model, with regulatory compliance strategy as the independent variable and firm performance as the dependent variable. The computed F-statistic was 131.710, with a p-value of 0.000. Referring to statistical tables, the critical value of F at a 0.05 significance level with df1 = 1 and df2 = 73 is approximately 3.96. Since the calculated F-value (131.710) is significantly greater than the critical value, the null hypothesis that the regression coefficient of regulatory compliance strategy ($\beta1$) equals zero is rejected. This confirms that regulatory compliance strategy significantly influences firm performance. Further, the regression coefficient analysis revealed a positive and statistically significant influence of regulatory compliance strategy on firm performance. The unstandardized coefficient (B) was 0.823 with a standard error of 0.192, and the standardized Beta was 0.759, showing a strong positive relationship. The t-value was 4.286, which exceeds the critical t-value of approximately 1.994 (based on 73 degrees of freedom at $\alpha = 0.05$ for a two-tailed test). Since the p-value is 0.000, which is well below 0.05, the null hypothesis (that $\beta1 = 0$) is rejected. This places the computed t-value in the rejection region, confirming that regulatory compliance strategy has a significant effect on firm performance.

Therefore, the study concludes that regulatory compliance strategy has a strong positive and statistically significant impact on firm performance. This underscores the importance of implementing and maintaining regulatory compliance mechanisms as a strategic approach to enhancing organizational outcomes, competitiveness, and sustainability.

Table 6: Inferential Statistics for Influence of Regulatory Compliance Strategy on Firm Performance

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.733[a]	.537	.521	2.113

ANOVAa	Sum of Squares	df	Mean Square	F	Sig.
Regression	196.248	1	196.248	131.710	.000[b]
Residual	113.074	73	1.490		
Total	309.322	74			

Regression	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	35.369	2.173		16.277	.000
Regulatory compliance strategy	0.823	0.192	0.759	4.286	.000

a. Dependent Variable: Firms Performance
b. Predictors: (Constant), Regulatory Compliance Strategy

Descriptive statistics of Stakeholder Collaboration Strategy

The descriptive statistics reveal that the mean scores for the stakeholder collaboration strategy ranged from 3.84 to 4.19, with standard deviations between 0.528 and 0.899, indicating a strong agreement among respondents on the importance of collaboration with various stakeholders such as suppliers, logistics partners, regulatory authorities, and technology providers in optimizing cold chain infrastructure and ensuring compliance, continuous improvement, and effective temperature control during transportation.

Table 7: Descriptive statistics of Stakeholder Collaboration Strategy

Statements	Mean	Std. Dev
Our firm actively collaborates with suppliers to ensure the efficiency of our cold chain infrastructure	3.85	.748
The firm works closely with logistics partners to ensure temperature-controlled transportation of flowers.	3.95	.899
Collaboration with regulatory authorities is helps maintain compliance within our cold chain operations	4.13	.528
We regularly engage with technology providers to improve our cold chain infrastructure	4.11	.628
The firm has established strong relationships with local cold storage facilities to enhance our cold chain system	3.92	.632
Collaboration with industry peers has helped us to optimize our cold chain infrastructure	4.17	.724
Our firm actively shares information and data on cold chain performance with key stakeholders to ensure continuous improvement	4.16	.679
The collaboration with customers helps us to maintain the required temperature conditions for flowers during transportation	3.84	.679
Stakeholder collaboration has significantly contributed to the effectiveness of our cold chain strategy	4.09	.550

Inferential Statistics for Influence of Stakeholder Collaboration Strategy on Firm Performance

The study carried out a simple regression analysis to determine the influence of stakeholder collaboration strategy on the performance of firms. The study found an R squared value of 0.503, indicating that stakeholder collaboration strategy accounted for 50.3% of the variation in firm performance. This means that just over half of the changes in firm performance can be explained by how effectively firms engage and collaborate with their stakeholders, including customers, suppliers, regulators, and community members. The remaining 49.7% of the variation in performance is attributed to other factors not included in this model. The results of the ANOVA test were used to determine the overall fit of the regression model, where stakeholder collaboration strategy was the independent variable and firm performance the dependent variable. The computed F-statistic was 107.734, with a significance (p-value) of 0.012. According to statistical tables, the critical value of F at $\alpha = 0.05$ with df1 = 1 and df2 = 73 is approximately 3.96. Since the calculated F-value is significantly greater than the critical value, the null hypothesis that the regression coefficient for stakeholder collaboration strategy ($\beta 1$) is equal to zero is rejected. This confirms that stakeholder collaboration strategy significantly influences firm performance.

Further analysis of the regression coefficients revealed that stakeholder collaboration strategy has a positive and statistically significant effect on firm performance. The unstandardized coefficient (B) was 0.752 with a standard error of 0.199, and the standardized Beta was 0.687, indicating a strong positive relationship. The computed t-value was 3.779, and the corresponding p-value was 0.012. Based on degrees of freedom (df = 73), the critical t-value for a two-tailed test at the 0.05 significance level is approximately 1.994. Since the computed t-value exceeds the critical value, and the p-value is less than 0.05, the null hypothesis ($\beta 1 = 0$) is rejected. Therefore, the study concludes that stakeholder collaboration strategy has a positive and significant influence on firm performance. Firms that foster collaborative relationships with stakeholders, through transparent communication, joint problem-solving, and mutual trust, were more likely to achieve higher performance levels. This highlights the strategic value of engaging stakeholders as partners in the firm's operations and long-term success.

Journal of Business and Strategic Management
ISSN 2520-0402 (Online)
Vol. 10, Issue No. 8, pp. 1 - 19, 2025 www.carijournals

Table 3: Inferential Statistics for Influence of Stakeholder Collaboration Strategy on Firm Performance

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.709[a]	.503	.496	1.333

ANOVAa	Sum of Squares	Df	Mean Square	F	Sig.
Regression	142.317	1	142.317	107.734	.012[b]
Residual	96.433	73	1.321		
Total	238.750	74			

Regression	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	8.182	.726		11.270	.000
Stakeholder collaboration strategy	0.752	0.199	0.687	3.779	.012

a. Dependent Variable: Firms Performance
b. Predictors: (Constant), Stakeholder Collaboration Strategy

Pearson Correlation Results

The study found that infrastructure optimization strategy programs had a positive and significant correlation with firm performance (r = 0.648; sig. = 0.0033). This implies that improvements in infrastructure optimization initiatives are associated with better performance outcomes in firms. As infrastructure is enhanced, firms are likely to operate more efficiently, thereby positively influencing performance metrics. The results also indicated that technology integration strategy had a strong positive and significant correlation with firm performance (r = 0.727; sig. = 0.0021). This suggests that the more a firm embraces and effectively integrates technology into its operations, the more likely it is to experience improved performance. The strength of this correlation highlights the importance of digital transformation and technological adaptability in today's business environment. Similarly, regulatory compliance strategy programs were found to have a positive and significant correlation with firm performance (r = 0.716; sig. = 0.0029). This finding suggests that firms that align more closely with regulatory requirements tend to perform better. Compliance likely reduces legal risks and builds stakeholder trust, which can contribute to a firm's long-term success. In addition, the study found that stakeholder collaboration strategy had a positive and significant correlation with firm performance (r = 0.698; sig. = 0.0031). This implies that firms that actively engage and collaborate with stakeholders, such as customers, suppliers, and communities, tend to experience enhanced performance. Stakeholder engagement can lead to better decision-making, increased innovation, and stronger relationships that support sustainable performance. All four strategic dimensions, infrastructure optimization, technology integration, regulatory compliance, and stakeholder collaboration, demonstrated strong and statistically significant positive correlations with firm performance, reinforcing their critical role in driving organizational success.

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Table 4: Pearson Correlation Results

		Firm performance	Infrastructure optimization strategy programs	Technology integration strategy	Regulatory compliance strategy programs	Stakeholder collaboration strategy
Firm performance	Pearson Correlation	1				
	Sig. (2-tailed)					
Infrastructure optimization strategy	Pearson Correlation	.6480	1			
	Sig. (2-tailed)	.0033				
Technology integration strategy	Pearson Correlation	.7270	.3312	1		
	Sig. (2-tailed)	.0021	.0011			
Regulatory compliance strategy	Pearson Correlation	.7160	.1139	.0618	1	
	Sig. (2-tailed)	.0029	.0119	.0038		
Stakeholder collaboration strategy	Pearson Correlation	.6980	.3390	.0000	.1550	1
	Sig. (2-tailed)	.0031	.0029	1.000	.0029	

Multiple Regression Analysis

To determine the relationship between the independent variables (infrastructure optimization strategy, technology integration strategy, regulatory compliance strategy, and stakeholder collaboration strategy) and the dependent variable (firm performance), the study employed a multiple linear regression analysis. The model summary revealed an R square value of 0.618, indicating that approximately 61.8% of the variation in firm performance can be explained by the four strategic variables included in the model. The remaining 38.2% of the variation in firm performance could be attributed to other factors not included in this analysis. The ANOVA test was used to evaluate the overall (global) significance of the regression model and the ability of the four independent variables to jointly explain changes in firm performance. The computed F-statistic value was 25.926, with a p-value of 0.000, which is well below the significance threshold of $\alpha = 0.05$. From the statistical tables, the critical F-value for a model with 4 predictors (k=4) and 70 degrees of freedom is much lower than the computed F value. As such, the null hypothesis that all regression coefficients are equal to zero (H_0: $\beta 1 = \beta 2 = \beta 3 = \beta 4 = 0$) is rejected. This implies that the model is statistically significant, and at least one of the independent variables significantly predicts firm performance.

Further analysis of the regression coefficients revealed that each of the four strategies had a positive and statistically significant influence on firm performance: Infrastructure optimization strategy had a regression coefficient (B) of 0.728, with a t-value of 1.273 and a significance level of 0.006, indicating a statistically significant positive influence. Technology integration strategy had a coefficient of 0.743, with a t-value of 1.876 and a p-value of 0.001, also signifying a strong and significant positive influence. Regulatory compliance strategy showed a coefficient of 0.731, with a t-value of 1.33 and p = 0.013, affirming its significance in improving firm performance. Stakeholder collaboration strategy had a coefficient of 0.716, a t-value of 1.135, and a p-value of

0.018, further supporting its significant contribution. The computed t-values for all independent variables were greater than the critical value of ±1.984 at 70 degrees of freedom (n-k-1) and α = 0.05 (two-tailed test), placing them in the rejection region. Therefore, the null hypotheses that the individual coefficients are zero were rejected for all predictors. This confirms that each strategic dimension, individually and collectively, had a statistically significant and positive impact on firm performance. Thus, the results demonstrate that infrastructure optimization, technology integration, regulatory compliance, and stakeholder collaboration strategies are all significant predictors of firm performance. The regression model as a whole is a viable and reliable predictor, explaining a substantial portion of the variance in performance outcomes across firms.

Table 5: Multiple Regression

Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.786	0.618	0.605	1.632

ANOVAa	Sum of Squares	df	Mean Square	F	Sig.
Regression	142.697	4	35.674	25.926	.000b
Residual	96.341	70	1.376		
Total	239.038	74			

	Unstandardized Coefficients		Standardized Coefficients		
Regression	B	Std. Error	Beta	t	Sig.
(Constant)	31.289	5.316		5.886	.007
Infrastructure optimization strategy	0.728	0.572	0.712	1.273	.006
Technology integration strategy	0.743	0.396	0.736	1.876	.001
Regulatory compliance strategy	0.731	0.593	0.718	1.33	.013
Stakeholder collaboration strategy	0.716	0.631	0.692	1.135	.018

a. Dependent Variable: Firm performance

b. Predictors: (Constant infrastructure optimization strategy, technology integration strategy, regulatory compliance strategy and stakeholder collaboration strategy

Descriptive Statistics of Performance

The managers were further requested to rate the statements on performance and the results were as presented in table 11. The mean scores for the performance statements ranged from 3.92 to 4.19, with standard deviations varying from 0.505 to 0.753, indicating a strong agreement among respondents that cold chain infrastructure and its management positively impact operational efficiency, product quality, customer satisfaction, and profitability in flower firms.

Table 6: Descriptive Statistics of Performance

Statements	Mean	Std. Dev
The cold chain infrastructure has contributed to the overall profitability of our flower firm	3.99	.668
The efficiency of our cold chain system has positively impacted customer satisfaction	4.11	.583
Our firm's market share has increased as a result of effective cold chain management strategies	4.04	.505
We have experienced a reduction in post-harvest losses due to improvements in our cold chain infrastructure	4.03	.753
Our cold chain infrastructure has helped us achieve consistent delivery times to customers	4.16	.570
The firm’s cold chain management strategies have increased the competitiveness of our products in the market	3.92	.731
Our firm has achieved higher operational efficiency due to the optimization of our cold chain processes	4.19	.630
The performance of our cold chain infrastructure has directly influenced the quality of flowers delivered to customers	4.17	.742
We have seen an improvement in sales as a result of investments in cold chain infrastructure	4.01	.726

Conclusions

This study investigated the influence of cold chain infrastructure management strategies on the performance of the flower industry in Kenya, focusing on Nakuru County. The study concluded that the infrastructure optimization strategy was fundamental to improving the operational performance of flower firms. Firms that actively invested in modern refrigeration technologies, conducted regular maintenance, and adhered to best practices in infrastructure design experienced significant improvements in flower quality and reduction of post-harvest losses. It was also concluded that the technology integration strategy significantly enhanced the effectiveness and efficiency of cold chain operations. The adoption of real-time monitoring systems, automation tools, IoT devices, and data analytics platforms enabled firms to track, manage, and optimize cold chain processes with greater precision. Besides, regulatory compliance strategy played a key role in ensuring the credibility, market access, and quality assurance of flower firms. Firms that proactively aligned with both local and international regulations, through regular audits, employee training, and policy implementation, achieved higher levels of consistency and reduced exposure to legal and reputational risks. Lastly, it was concluded that the stakeholder collaboration strategy was instrumental in creating an integrated and resilient cold chain ecosystem.

Recommendations

To strengthen the infrastructure optimization strategy, flower firms should continue investing in modern and energy-efficient cold storage systems while also prioritizing regular maintenance and performance assessments. For the technology integration strategy, firms should deepen their adoption of advanced technologies such as real-time monitoring systems, cloud-based platforms, and predictive analytics tools. With regard to the regulatory compliance strategy, it was recommended that firms establish robust internal systems for continuous monitoring and documentation of compliance activities. Finally, to enhance the stakeholder collaboration strategy, flower firms should formalize engagement mechanisms with key actors across the cold chain, including suppliers, logistics providers, regulators, and customers.

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