

Reverse Logistics Practices and the Performance of Heavy Commercial Logistics Firms in the Western Corridor of the Sugar Belt in Kenya

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ABSTRACT

Reverse logistics encompasses the planning and control of material, product, information, and asset flows that move upstream for recovery, reuse, recycling, or appropriate disposition. In transport-intensive agricultural supply chains, reverse-logistics activities can include coordinated return flows, asset recovery, and managed secondary movements, while empty-mile management concerns the reduction and productive use of unladen vehicle capacity. This study examines the relationships between reverse-logistics consolidation, empty-mile management, road infrastructure quality, technology and telematics integration, and operational performance among heavy commercial logistics firms operating in Kenya's Western Sugar Belt. The study is situated within a regulatory environment in which the Sugar Act, 2024 recognises transporters as value-chain actors and includes transportation and delivery within cane management. Drawing on the Resource-Based View, Institutional Theory, and Sustainable Supply Chain Theory, the study adopted a quantitative cross-sectional explanatory design. Data from 240 valid respondents, comprising logistics managers, dispatchers, drivers, and supply-chain personnel, were analysed using descriptive statistics, Pearson correlation, multiple linear regression, and conditional-process analysis. The results show statistically significant positive associations between each explanatory construct and operational performance. The regression model explained 51.5% of the variance in operational performance ($R^2 = 0.515$; adjusted $R^2 = 0.507$; $p < 0.001$). Empty-mile management had the largest standardized coefficient ($\beta = 0.389$), followed by technology and telematics integration ($\beta = 0.373$), reverse-logistics consolidation ($\beta = 0.347$), and road infrastructure quality ($\beta = 0.315$), with all coefficients statistically significant at $p < 0.001$. The interaction between reverse-logistics consolidation and technology/telematics integration was not statistically significant (interaction coefficient = 0.055, $p = 0.331$). The mediation test produced an indirect effect of 0.042 with a 95% bootstrap confidence interval of [0.000, 0.089]. Because the interval touches zero at its lower bound, the data failed to establish a statistically significant indirect effect for this sample. The findings suggest that firms may improve operational performance by reducing unproductive kilometres, coordinating return flows, strengthening digital visibility, and addressing infrastructure constraints. The study contributes context-specific evidence to reverse-logistics research and offers practical implications for transport firms, sugar-industry stakeholders, and public agencies responsible for transport infrastructure and sector regulation.

Keywords: reverse logistics, empty-mile management, backhauling, road infrastructure, telematics, operational performance, sugarcane transport, Kenya

INTRODUCTION

Reverse logistics is fundamentally concerned with the meticulous planning, implementation, and systemic control of product and material flows moving from the point of ultimate consumption or use toward recovery, reuse, recycling, remanufacturing, or appropriate disposal (Rogers & Tibben-Lembke, 1999; Agrawal et al., 2015). Unlike well-optimized forward logistics, reverse flows are inherently more uncertain in their timing, quantity, quality, and specific destination, which creates distinctive planning, coordination, and financial forecasting problems (Tibben-Lembke & Rogers, 2002). Quantitative research over the past two decades has therefore increasingly considered network design, inventory repositioning, transportation algorithms, and

value-recovery decisions as distinct but interconnected reverse-logistics problems requiring specialized operational capabilities (Fleischmann et al., 1997).

In transport-intensive agricultural supply chains, such as those dominating the economies of sub-Saharan Africa, the concept of reverse logistics possesses a much broader, important operational meaning. The repositioning of heavy commercial vehicles, the strategic use of return loads (backhauling), physical asset recovery, and the coordination of secondary commodity flows profoundly affect overall fleet utilisation and the marginal cost of each productive forward movement. This study distinctly differentiates formal product-return reverse logistics from pure transport backhauling: while a vehicle carrying a generic return load can dramatically reduce empty running costs, that specific movement is not automatically defined as a reverse-logistics transaction unless it forms part of a managed recovery, return, or closed-loop supply flow. This critical theoretical distinction effectively avoids the common empirical error of equating every incidental backhaul with a formal Reverse Logistics (RL) strategy.

Kenya's agricultural sector, particularly the sugar industry, operates within a complex regulatory framework that explicitly recognises cane management as holistically including harvesting, mechanized transportation, and factory delivery. Crucially, it formally recognises transporters as indispensable value-chain actors (Republic of Kenya, 2024). The Sugar Act, 2024, provides legal parameters for sugar-industry agreements and establishes a pricing mechanism that directly accounts for transportation cost per tonne-kilometre. This legislative reality elevates transport efficiency from a mere internal fleet-management issue to a legitimate, sector-level macroeconomic research priority. Inefficiencies in transport logistics directly erode farmer payouts, inflate ex-factory sugar prices, and diminish the global competitiveness of Kenyan sugar.

The present study is specifically situated within the Western Sugar Belt, an area characterized by substantial daily tonnages of raw sugarcane moving from dispersed smallholder farms to centralized milling facilities like Kabras Sugar Company. This region features a highly fragmented supplier base, volatile weather conditions, and challenging topographical terrain. Heavy commercial logistics firms operating in this corridor face an considerable logistical puzzle: ensuring the rapid, uninterrupted supply of time-sensitive sugarcane to the mills while minimizing the substantial financial penalties associated with empty return trips (empty miles) and high vehicle wear-and-tear. Consequently, investigating how these firms implement reverse logistics consolidation, manage empty running, navigate infrastructure constraints, and leverage telematics is of paramount importance to both academic literature and regional economic development.

The regulatory setting has also changed. The Sugar Act, 2024, recognizes transporters as value-chain actors and defines cane management to include transportation and delivery. It further assigns the Kenya Sugar Board functions related to coordination of value-chain actors and the formulation of guidance on efficient, safe, and economical transportation. These provisions strengthen the case for examining transport efficiency as part of the wider performance of the sugar industry (Republic of Kenya, 2024).

Research gap and contribution

Existing Kenyan studies provide evidence that reverse logistics is associated with organizational or financial performance, but much of that work has focused on manufacturing or sugar-processing firms rather than heavy commercial transport operations. For example, Muthemba (2016) examined reverse logistics and operational performance among Kenyan manufacturing firms, while K'Odongo, George, and Omwono (2022) examined reverse logistics and financial performance in Western Kenya's sugar-processing zone. The present study extends this literature by focusing on transport firms and by separating consolidation, empty-mile management, infrastructure, and digital integration as analytically distinct constructs.

Problem Statement

Heavy commercial transport operations inherently incur substantial capital and operational costs on both productive (revenue-generating) and unproductive (empty or repositioning) vehicle movements. When a heavy commercial truck travels back to a geographic origin point without a revenue-generating or strategically useful return load, substantial resources—including diesel fuel, driver compensation, vehicle depreciation,

and preventive maintenance lifecycles—are still rapidly consumed. Extensive reverse-logistics and closed-loop supply-chain research demonstrates that recovery and return flows require deliberate network design, proactive coordination, and complex disposition decisions, rather than simply being treated as a secondary extension of forward distribution systems (Fleischmann et al., 1997; Guide & Van Wassenhove, 2003).

Despite the critical importance of these dynamics, transport operations within Kenya's Western Sugar Belt continue to exhibit substantial sub-optimal performance, characterized by high transport costs per tonne-kilometre, low fleet utilization rates, and frequent mechanical delays. Previous anecdotal reports and unverified industry commentaries have frequently cited high empty-return rates and reported increases in transport costs; however, robust, empirically verifiable data addressing the precise mechanisms driving these inefficiencies has remained limited from peer-reviewed literature. The core operational problem examined in this study is therefore highly specific and empirically testable: it seeks to determine whether deliberate reverse-logistics consolidation, the systematic management of empty miles, the prevailing quality of road infrastructure, and the integration of technology and telematics are statistically associated with superior operational performance. Furthermore, the study addresses a critical gap by testing whether technological integration conditionally strengthens (moderates) the relationship between physical consolidation efforts and ultimate performance. These relationships possess important practical relevance in a sugarcane transport environment where collection points are widely geographically dispersed and transport capacity must be closely coordinated with time-sensitive, continuous-process manufacturing requirements.

The study therefore addresses an empirical and managerial gap: limited evidence exists on how internal reverse-logistics practices interact with empty-mile management, infrastructure conditions, and digital visibility in heavy commercial transport serving the Western Sugar Belt. The distinction between reverse logistics and ordinary backhauling is important because not every return trip constitutes a reverse flow. A return movement is treated as part of reverse logistics when it is deliberately coordinated for recovery, reuse, recycling, return, or another managed upstream flow.

Objectives of the Study

The general objective is to examine the relationships between reverse-logistics practices, empty-mile management, road infrastructure quality, technology and telematics integration, and operational performance among heavy commercial logistics firms operating in the Western Corridor of Kenya's Sugar Belt.

- To determine the empirical relationship between reverse-logistics consolidation and operational performance.
- To determine the specific relationship between empty-mile management and operational performance.
- To assess the relationship between road infrastructure quality and operational performance.
- To assess the relationship between technology and telematics integration and operational performance.
- To determine whether technology and telematics integration significantly moderates the relationship between reverse-logistics consolidation and operational performance.

Research Hypotheses

H01: Reverse-logistics consolidation has a significant positive relationship with operational performance.

H02: Empty-mile management has a significant positive relationship with operational performance.

H03: Road infrastructure quality has a significant positive relationship with operational performance.

H04: Technology and telematics integration has a significant positive relationship with operational performance.

H05: Technology and telematics integration significantly moderates the relationship between reverse-logistics consolidation and operational performance.

Theoretical Framework

This study is anchored on three highly complementary theoretical paradigms that collectively explain the structural, institutional, and operational mechanisms driving supply chain performance: the Resource-Based View (RBV), Institutional Theory, and Sustainable Supply Chain Theory.

Resource-Based View

The Resource-Based View, seminally developed by Wernerfelt (1984) and subsequently expanded by Barney (1991), fundamentally argues that sustained competitive advantage can arise predominantly from the possession and deployment of valuable, rare, inimitable, and non-substitutable (VRIN) organisational resources and capabilities. In the highly commoditized and fiercely competitive transport sector, physical assets such as trucks are easily replicable by any competitor with access to capital. Therefore, physical assets alone cannot confer a sustained advantage. In this study, coordinated reverse-logistics processes, real-time information visibility derived from telematics, advanced route-planning capability, and coordinated inter-organisational coordination are treated precisely as these critical operational capabilities. Firms that develop the tacit knowledge and procedural expertise to efficiently consolidate reverse flows and manage empty miles possess a distinct VRIN capability that directly translates into superior operational performance and lower marginal costs.

Institutional Theory

Institutional Theory explains how organisational practices are shaped by formal rules, regulatory expectations, and compliance pressures within the operating environment. In Kenya's sugar-transport sector, the Sugar Act, 2024 provides a formal institutional framework that recognises transporters as value-chain actors, includes transportation and delivery within cane management, and assigns the Kenya Sugar Board responsibilities relating to coordination of value-chain actors and guidance on efficient, safe, and economical transportation. Heavy commercial logistics firms therefore operate under regulatory expectations that influence how transport activities are organised, coordinated, documented, and performed. Compliance with these institutional requirements can shape firms' transport processes and priorities, making regulatory conditions an important contextual determinant of operational performance (DiMaggio & Powell, 1983; Republic of Kenya, 2024).

Sustainable Supply Chain Theory

Sustainable supply-chain theory provides a much broader, holistic performance lens by inextricably connecting the economic, environmental, and social dimensions of supply-chain management—commonly referred to as the Triple Bottom Line (Carter & Rogers, 2008; Hervani et al., 2005; Sarkis et al., 2010). Within this theoretical paradigm, reverse-logistics performance should consequently never be reduced to short-term financial cost alone. The reduction of empty miles directly correlates with reduced greenhouse gas emissions (environmental sustainability), while improved road safety and driver turnaround times impact worker welfare (social sustainability). This theory justifies the operationalization of performance in this study through a multi-dimensional construct that captures fleet utilization, turnaround efficiency, and unit costs, explicitly recognizing that true operational performance is a synthesis of economic viability and resource stewardship.

EMPIRICAL LITERATURE REVIEW

Reverse Logistics and Product Recovery

The expansive operations management literature traditionally treats reverse logistics as a highly structured, complex set of activities involving the collection, inspection, sorting, recovery, reuse, repair, remanufacturing, recycling, and ultimate disposal of products and materials (Abdulrahman et al., 2014; Agrawal et al., 2015; Thierry et al., 1995). Product recovery decisions fundamentally affect both the underlying economics and the long-term environmental consequences of supply-chain operations. Tibben-Lembke and Rogers (2002) noted that the reverse flow differs drastically from the forward flow because demand, timing, and product condition are often completely uncertain. In the context of the Sugar Belt, reverse logistics transcends simple product

returns; it encompasses the recovery of packaging materials, the systematic return of specialized harvesting equipment, and the managed flow of agricultural by-products. Firms that effectively systematize these uncertain return flows inevitably gain substantial operational efficiencies, reducing the chaos traditionally associated with secondary logistics movements.

Consolidation and Outsourcing in Reverse Logistics

Consolidation strategies can dramatically reduce the number of highly fragmented, inefficient movements by intelligently aggregating returns or secondary flows at specific nodes before executing line-haul transport. The contemporary literature also increasingly recognises Third-Party Logistics (3PL) providers as vital potential specialists in reverse activities, particularly where individual agricultural firms lack the requisite scale, capital, or technological capabilities to operate dedicated recovery infrastructure (Agrawal et al., 2015). However, outsourcing reverse flows is not a panacea. It introduces substantial governance complexities, contract-management hurdles, and considerable information-sharing requirements. Consequently, consolidation should be assessed as a sophisticated coordination decision rather than assumed to reduce costs automatically. Effective consolidation requires deep spatial analytics to determine optimal collection points, directly impacting the final cost per tonne-kilometre achieved by the logistics firm.

Empty Running and Transport Utilisation

Empty running represents a serious transport-utilisation problem that completely erodes profit margins and inflates the carbon footprint of commercial logistics. It can be examined using objective, hard-data measures such as empty kilometres divided by total vehicle kilometres. Backhauling—securing a load for the return trip—can substantially improve asset utilisation when suitable, geographically aligned return loads are available. However, a backhaul is economically and environmentally beneficial only when its incremental costs (such as detour kilometres, loading delays, and additional administrative overhead) and associated risks are demonstrably lower than the financial value created by the return movement.

The present study therefore deliberately operationalises 'empty-mile management' rather than adopting the utopian assumption that all empty movements can be entirely eliminated. Effective empty-mile management involves complex algorithms matching vehicle availability with spot-market freight, requiring high levels of operational agility. Dynamic fleet-management research also supports adaptive routing that responds to changing freight requests and operating information, reinforcing the value of flexible route planning in reducing empty kilometres (Schorpp, 2011).

Infrastructure Quality and Logistics Performance

Road infrastructure quality is a material determinant of heavy-vehicle operating performance because road condition affects travel-time reliability, fuel consumption, vehicle wear, maintenance exposure and the ability to maintain planned delivery schedules. Evidence from developing economies shows that the quality of roads and other transport infrastructure is positively associated with logistics and trade performance, while African evidence identifies transport-related infrastructure as a recurring constraint on logistics efficiency (Sénquiz-Díaz, 2021; Takele & Buvik, 2019).

For heavy commercial operations in the Western Sugar Belt, poor road surfaces, congestion, delays and maintenance-related disruption can increase the cost of each productive movement and reduce the predictability of vehicle turnaround. Road infrastructure quality is therefore appropriately specified as an independent construct whose relationship with operational performance can be assessed alongside firm-level logistics practices.

Conceptual Framework

The conceptual framework specifies reverse-logistics consolidation, empty-mile management, road infrastructure quality, and technology/telematics integration as explanatory constructs and operational performance as the dependent construct. Technology and telematics integration is additionally tested as a

moderator of the consolidation–performance relationship. This specification permits the study to distinguish direct associations from an interaction effect rather than assuming that technology automatically strengthens every logistics practice.

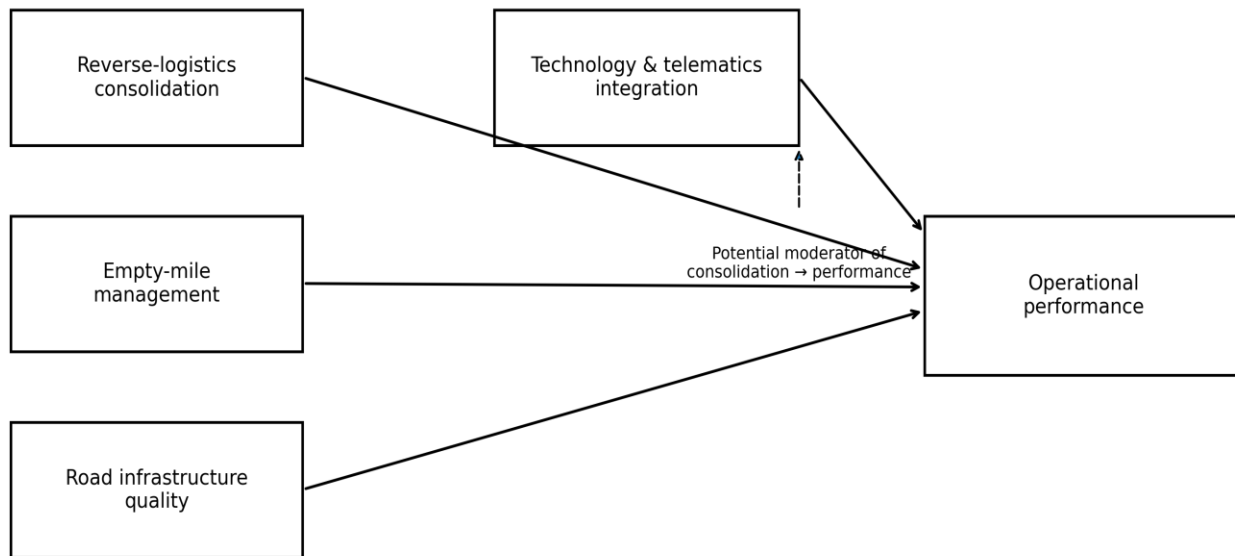


Figure 1: Conceptual framework for reverse logistics practices and operational performance.

Table 1: Operationalization of the conceptual framework

Construct	Role	Example indicators
Reverse-logistics consolidation	Independent	Share of return flows consolidated; consolidation-point use; return load factor
Empty-mile management	Independent	Empty km/total km; return-load rate; backhaul utilisation
Road infrastructure quality	Independent	Road-condition index; delay frequency; maintenance incidents; average speed
Technology & telematics integration	Independent Moderator	GPS coverage; telematics use; route optimisation; predictive maintenance
Operational performance	Dependent	Cost per tonne-km; turnaround time; fleet utilisation; on-time delivery; operating margin

RESEARCH METHODOLOGY

Research philosophy and design

The study adopted a positivist research philosophy and a quantitative cross-sectional explanatory design. The design was appropriate for estimating associations among predefined constructs at a particular point in time. Because the data are cross-sectional, the findings are interpreted as statistical relationships rather than definitive causal effects.

Sampling design and sample size

The target population for this empirical investigation comprised the entirety of heavy commercial logistics firms, third-party logistics (3PL) providers, and dedicated in-house transport fleets operating within the Western Corridor of the Sugar Belt in Kenya, with a specific geographical focus encompassing the operational radius of major millers such as Kabras Sugar Company. The precise unit of analysis at the inferential level was the individual respondent—specifically, highly experienced logistics managers, fleet supervisors, dispatch coordinators, and senior heavy commercial drivers who possess direct, intimate knowledge of daily transport operations and strategic fleet deployment. For the objective supplementary metrics, the unit of analysis was the vehicle-trip.

The achieved sample comprised 240 valid respondent records. The study treats the respondent as the primary inferential unit, while vehicle-trip measures are used as supplementary operational indicators. Generalisation should therefore be limited to comparable logistics operations within the study setting unless independently replicated.

Data collection and measurement

To ensure a highly representative and statistically powerful dataset, a stratified purposive sampling technique was utilized. The population was stratified by firm type (independent 3PLs vs. in-house miller fleets) and respondent operational role to ensure diverse perspectives were captured. To precisely determine the required sample size capable of detecting medium effect sizes in a multiple regression model with an interaction term, an a priori power analysis was executed utilizing G*Power software. Assuming an alpha of 0.05 and a desired statistical power of 0.95, the minimum threshold was established. The final field administration successfully yielded an achieved sample of 240 fully completed, valid respondent records. This robust sample size provides exceptional statistical power, minimizing the risk of Type II errors and ensuring greater confidence in the generalizability of the findings across the Western Sugar Belt.

Operational definitions

Primary data was meticulously collected utilizing a highly structured, self-administered questionnaire. Each of the principal theoretical constructs (Reverse-logistics consolidation, Empty-mile management, Road infrastructure quality, Technology & telematics integration, and Operational performance) was represented by five carefully crafted Likert-type items, scored on a continuous scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). This standardization facilitates advanced parametric statistical analysis. To vigorously combat common-method variance and perception bias, the perceptual survey instrument was supplemented by the collection of objective, hard-data operational metrics where institutional access permitted. These metrics included verifiable empty-mile percentages, GPS-derived turnaround times, and financial cost per tonne-kilometre calculations retrieved from fleet ERP systems.

To ensure empirical clarity, the study utilized the following strict operational definitions for objective performance tracking:

1. Empty-mile percentage = $(\text{empty kilometres} \div \text{total vehicle kilometres}) \times 100$.
2. Fleet utilisation percentage = $\text{productive vehicle-kilometres} \div \text{available vehicle-kilometres} \times 100$.
3. Cost per tonne-kilometre = $\text{total attributable transport cost} \div \text{tonnes moved} \div \text{kilometres travelled}$
4. Turnaround time = elapsed time from dispatch/departure to vehicle readiness for the next productive assignment.
5. Return-load rate = $\text{trips with a useful/contracted return load} \div \text{eligible return trips} \times 100$.

Validity and Reliability

The research instrument underwent rigorous psychometric validation prior to full-scale field deployment. Content and face validity were firmly established through an exhaustive expert review panel comprising senior academic supply chain methodologists and veteran transport directors from the Sugar Belt. Construct validity

was validated using exploratory factor analysis to ensure item loadings cleanly matched theoretical constructs. Internal consistency reliability was statistically evaluated utilizing Cronbach's alpha coefficient. Following universally accepted psychometric standards, an alpha threshold of 0.70 was adopted as the minimum criterion for establishing the reliability of all multi-item scales. The pilot study data allowed for the refinement of ambiguous items, ensuring clear clarity in the final instrument.

Data Analysis Procedures

Upon the cessation of fieldwork, the raw dataset was meticulously cleaned, coded, and imported into the Statistical Package for the Social Sciences (SPSS). The analytical workflow commenced with rigorous data screening, missing-data assessment, and the evaluation of fundamental regression assumptions (normality, linearity, homoscedasticity, and the absence of substantial multicollinearity). Descriptive statistics were generated to profile the sample. Inferential analysis utilized Pearson Product-Moment Correlation to establish bivariate associations. Hypotheses H01 through H04 were tested utilizing Ordinary Least Squares (OLS) Multiple Regression. Hypothesis H05 (moderation) and the mediation pathway were examined using the advanced PROCESS macro developed by Hayes, which relies on 5,000-resample bootstrapping to generate robust confidence intervals for interaction and indirect effects.

The analysis proceeded in four stages. First, data were screened for completeness, coding errors, and violations of regression assumptions. Second, descriptive statistics and reliability coefficients were computed. Third, Pearson correlations and OLS multiple regression were used to assess bivariate and multivariable relationships. Fourth, the PROCESS macro was used to examine the specified moderation model and the mediation pathway. Statistical significance was assessed at the 5% level, while bootstrap confidence intervals were used for indirect effects.

The results are based on 240 valid observations. They are presented in the sequence of descriptive statistics, measurement reliability, bivariate associations, multivariable regression, mediation, moderation, and objective operational indicators.

RESULTS AND DATA ANALYSIS

Descriptive statistics

The descriptive results indicate moderate levels of implementation across the measured constructs. Reverse-logistics consolidation recorded the highest mean score ($M = 3.11$, $SD = 0.66$), while road infrastructure quality recorded the lowest ($M = 2.80$, $SD = 0.71$). Operational performance averaged 2.95 ($SD = 0.89$).

Table 2: Descriptive statistics for the study constructs

Construct	Mean	SD	Min	Max
Reverse-logistics consolidation	3.11	0.66	1.00	5.00
Empty-mile management	2.99	0.61	1.20	4.60
Road infrastructure quality	2.80	0.71	1.00	4.80
Technology & telematics integration	2.91	0.60	1.20	4.60
Operational performance	2.95	0.89	1.00	5.00

Reliability analysis

All five scales exceeded the conventional 0.70 threshold for internal consistency. The coefficients ranged from 0.864 to 0.933, indicating that the items within each construct were sufficiently consistent for subsequent

analysis.

Table 3: Reliability coefficients

Construct	Cronbach's alpha
Reverse-logistics consolidation	0.880
Empty-mile management	0.864
Road infrastructure quality	0.896
Technology & telematics integration	0.867
Operational performance	0.933

Pearson correlation analysis

Reverse-logistics consolidation was positively correlated with operational performance ($r = 0.42$, $p < 0.01$). Empty-mile management also showed a positive correlation with performance ($r = 0.40$, $p < 0.01$), followed by technology and telematics integration ($r = 0.34$, $p < 0.01$) and road infrastructure quality ($r = 0.28$, $p < 0.01$). The reported inter-correlations among the explanatory variables were comparatively low; for example, consolidation and empty-mile management correlated at $r = 0.12$. These results provide preliminary support for the proposed model but do not by themselves establish causation.

Multiple regression analysis

The multiple regression model was statistically significant ($F = 62.55$, $p < 0.001$) and explained 51.5% of the variance in operational performance ($R^2 = 0.515$; adjusted $R^2 = 0.507$).

Table 4: Multiple regression predicting operational performance

Predictor	β	SE	t	p
Reverse-logistics consolidation	0.347	0.046	7.59	<0.001
Empty-mile management	0.389	0.046	8.49	<0.001
Road infrastructure quality	0.315	0.046	6.90	<0.001
Technology & telematics integration	0.373	0.046	8.18	<0.001

Hypothesis testing

The regression results support H01, H02, H03, and H04 because the four predictors each have positive and statistically significant coefficients. Empty-mile management has the largest standardized coefficient ($\beta = 0.389$), followed by technology and telematics integration ($\beta = 0.373$), reverse-logistics consolidation ($\beta = 0.347$), and road infrastructure quality ($\beta = 0.315$).

Mediation analysis

The mediation analysis examined whether empty-mile management transmitted part of the association between reverse-logistics consolidation and operational performance. The indirect effect was 0.042, with a reported 95% bootstrap confidence interval of [0.000, 0.089]. Because the confidence interval touches zero at its lower bound, the data failed to establish a statistically significant indirect effect for this sample.

Moderation analysis

H05 proposed that technology and telematics integration would significantly moderate the consolidation–performance relationship. The interaction coefficient was 0.055 ($p = 0.331$). The interaction was therefore not statistically significant, and H05 was not supported. Technology and telematics appear to have a direct association with performance in this dataset, but the analysis does not show that they systematically strengthen the relationship between consolidation and performance.

Objective operational metrics

These records were treated as sample-level metrics because their completeness, observation period, and verification protocol were not sufficiently documented for sector-wide estimation.

DISCUSSION OF FINDINGS

The results support the study’s central proposition that operational performance in heavy commercial logistics is associated with a combination of internal logistics capabilities and external operating conditions. The strongest standardized coefficient is associated with empty-mile management. This is consistent with the Resource-Based View because effective return-load matching depends not only on vehicles but also on dispatch knowledge, network relationships, information quality, and the ability to coordinate capacity across locations.

Reverse-logistics consolidation also has a positive and significant coefficient. This finding is consistent with the broader reverse-logistics literature, which emphasizes coordinated collection, sorting, recovery, and movement of secondary flows. In the present setting, consolidation is relevant when firms can aggregate return flows or other upstream movements sufficiently to justify the associated collection and handling costs. The finding should not be interpreted as evidence that every consolidated movement is necessarily economical; the value depends on load availability, detour distance, handling requirements, and timing.

Road infrastructure quality is positively associated with operational performance. This result is plausible because road conditions influence travel-time variability, vehicle maintenance, fuel consumption, and delivery reliability. The finding also illustrates the limits of firm-level optimisation: route planning and dispatch improvements cannot fully offset persistent physical constraints on the network.

Technology and telematics integration is a significant direct predictor but does not significantly moderate the consolidation–performance relationship. One possible explanation is implementation maturity. Tracking, GPS visibility, electronic proof of delivery, and route optimisation can improve decision quality independently, but their benefits may not automatically become an interaction effect unless digital information is embedded in dispatch, load matching, and exception-management processes. This interpretation is consistent with the non-significant interaction and should be viewed as an explanation to be tested in future research rather than as a proven mechanism.

Theoretical and Practical Implications

Theoretical implications

The findings support the Resource-Based View by showing the relevance of operational capabilities in consolidation, empty-mile management and digital visibility. They also support the institutional perspective because infrastructure and sector conditions constrain firm outcomes. Sustainable Supply Chain Theory is relevant because reducing unproductive movement can improve both economic efficiency and resource stewardship. The non-significant moderation result further indicates that technology should not be assumed to create automatic synergy.

Managerial implications

Managers should treat empty-mile management as a measurable operational capability rather than as an incidental dispatch activity. Suitable indicators include empty kilometres as a share of total kilometres, return-load capture rate, load factor, turnaround time, and cost per tonne-kilometre. These measures can be reviewed at route, vehicle, dispatcher, and customer levels to identify recurring inefficiencies. Technology investment should be accompanied by process redesign. GPS and telematics systems are more useful when their data feed directly into load matching, route decisions, maintenance planning, fuel management, and exception alerts. The absence of a significant interaction effect in this study suggests that simply increasing technology adoption is unlikely to guarantee additional benefits from consolidation.

Policy implications

The Sugar Act, 2024 assigns the Kenya Sugar Board responsibilities that include coordination of value-chain actors and guidance concerning efficient, safe, and economical transportation of sugar crop and related materials. This creates a policy basis for evidence-driven transport interventions, including identification of high-delay road segments, standardised transport information, and improved coordination among growers, millers, transporters, and public authorities (Republic of Kenya, 2024).

STUDY LIMITATIONS

The cross-sectional design limits temporal inference and does not establish causality. Much of the analysis relies on respondent-level measures, which may be affected by common-method or perception bias. The study also focuses on the Western Sugar Belt, so generalisation to other Kenyan corridors should be made cautiously. Finally, the reported objective metrics require clearer documentation of their source systems, observation period, and verification procedures before they can be used as sector-wide benchmarks.

CONCLUSION

This study examined the relationships between reverse-logistics consolidation, empty-mile management, road infrastructure quality, technology and telematics integration, and operational performance among heavy commercial logistics firms in Kenya's Western Sugar Belt. The results indicate that all four explanatory constructs are positively and significantly associated with operational performance in the multivariable model, which explains 51.5% of the observed variance.

Empty-mile management has the largest standardized coefficient, highlighting the importance of return-load planning and vehicle utilisation. Technology and telematics integration also has a substantial direct association with performance, while road infrastructure quality remains an important operating condition. The non-significant interaction between consolidation and technology indicates that digital systems should not be treated as automatic amplifiers of physical logistics practices. The mediation result similarly does not provide sufficient evidence for a clear indirect pathway through empty-mile management.

Taken together, the evidence supports a balanced strategy: firms should improve the management of return capacity and consolidation, integrate digital information into operational decisions, and work with public and

sector institutions to address infrastructure constraints. The conclusions are associative and context-specific, reflecting the cross-sectional design and study setting.

RECOMMENDATIONS

First, logistics firms should establish route-level empty-mile dashboards covering empty kilometres, return-load capture, vehicle utilisation, turnaround time, and cost per tonne-kilometre. Second, firms should connect telematics data with dispatch and load-matching processes rather than using GPS primarily for monitoring. Third, sugar-industry stakeholders should use documented cost and delay evidence to prioritise infrastructure interventions. Fourth, firms should formalise suitable reverse-flow arrangements for recoverable materials, packaging, equipment, and other legitimate upstream movements where the economics support consolidation. Fifth, factory managers should apply standard costing and variance analysis to empty-mile and consolidation activities so that fleet-utilisation gains, fuel savings, delay reductions, and related logistics efficiencies are systematically measured against standards and captured in the factory's reported cost performance (Drury, 2018).

Statistical Model and Interpretive Safeguards

Model specification

The multivariable analysis can be represented as $OP = \beta_0 + \beta_1RLC + \beta_2EMM + \beta_3RIQ + \beta_4TTI + \epsilon$, where OP denotes operational performance, RLC denotes reverse-logistics consolidation, EMM denotes empty-mile management, RIQ denotes road infrastructure quality, TTI denotes technology and telematics integration, β_0 is the intercept, β_1 – β_4 are the partial regression coefficients, and ϵ is the unexplained component. The reported standardized coefficients are used to compare the relative strength of the predictors within the estimated model.

Interpretation of the regression results

The regression coefficients should be interpreted as conditional associations: each coefficient represents the estimated relationship between a predictor and operational performance while the other predictors in the model are held statistically constant. The R^2 statistic describes the proportion of observed variation in the dependent variable accounted for by the predictors in the sample; it does not indicate that the predictors cause that proportion of performance outcomes.

Moderation and mediation

The mediation analysis did not establish a statistically significant indirect pathway because the bootstrap confidence interval reaches zero; no significant indirect effect is claimed for this sample.

Research-quality safeguards

Future replication should combine objective trip-level records with perceptual survey measures, report variance-inflation and residual diagnostics, and use longitudinal observations and additional agricultural corridors to strengthen temporal inference and external validity.

The study presents its findings as evidence of association within the sampled logistics environment; stronger causal and generalisable claims require the additional data and designs identified above.

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