

# Revisiting Parastatal Railway Performance in the 4IR: A Multi-Theoretical and Empirical Assessment of Maintenance, Leadership, and Policy Constraints at Zambia Railways Limited

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## ABSTRACT

This study examines the intersection of organizational theory and infrastructure reform in the context of parastatal railway performance, using Zambia Railways Limited (ZRL) as a case study within the Fourth Industrial Revolution (4IR) environment. Drawing on Total Productive Maintenance (TPM), Change Management, and Contingency Management Theory, the paper synthesizes contemporary scholarship on maintenance systems, leadership adaptation, and governance alignment to critically assess institutional performance constraints in state-owned railway enterprises. A structured review of peer-reviewed literature and institutional reports from 2010 to 2024 was conducted, with databases explored that included JSTOR, Scopus-indexed journals accessed via Google Scholar, and other indexed academic databases, complemented by contextual empirical insights from a survey on ZRL stakeholders (n = 109). The analysis identifies consistent patterns of institutional inefficiency linked to legacy maintenance systems, weak adaptive leadership, competitive pressure from road transport, and regulatory misalignment. Empirical evidence indicates that leadership effectiveness exerts the strongest influence on perceived performance, while funding adequacy alone does not independently predict improvement. These findings suggest that technological modernization under 4IR conditions is fundamentally mediated by governance capacity and organizational adaptation. The study contributes to infrastructure governance scholarship by reframing railway reform as an integrated institutional alignment process. It proposes a conceptual framework for repositioning ZRL and similar public transport enterprises in Sub-Saharan Africa.

**KEYWORDS:** *Parastatal performance, Zambia Railways Limited, maintenance effectiveness, 4IR, contingency management, infrastructure governance.*

## 1. Introduction

State-owned railway enterprises in developing economies continue to experience persistent operational inefficiencies, declining freight volumes, and chronic financial instability. While infrastructure deficits and funding constraints are frequently cited as primary causes, emerging evidence suggests that institutional and governance factors may exert a more profound influence on performance outcomes. The acceleration of the Fourth Industrial Revolution (4IR), characterized by digital integration, predictive analytics, automation, and data-driven asset management, further

intensifies the urgency for structural reform within public transport enterprises.

Despite extensive global scholarship on railway restructuring and public sector modernization, limited research integrates operational maintenance theory, leadership adaptation framework, and environmental contingency perspectives within a unified empirical model specific to sub-Saharan African railway institutions. Much of the existing literature remains either purely conceptual or focused on financial restructuring without examining the interplay between maintenance systems, governance quality, and market competition in technologically disruptive environments.

Zambia Railways Limited, a state-owned enterprise responsible for freight and passenger rail services in Zambia, provides an important case for examining these dynamics. Over the past decade, ZRL has experienced declining reliability, increased competition from road transport, and implementation challenges associated with regulatory reforms such as Statutory Instrument No. 7 of 2018. At the same time, the global transition toward digitalized logistics systems and predictive maintenance platforms places additional pressure on the organization to adapt within the 4IR landscape.

This study therefore revisits parastatal railway performance through a multi-theoretical and empirical assessment of ZRL. Drawing on Total Productive Maintenance (TPM), Change Management Theory, and Contingency Management Theory, the paper examines the combined influence of maintenance effectiveness, leadership quality, funding adequacy, competitive pressures, and regulatory support on perceived institutional performance. By integrating survey data (n=109) with theoretical synthesis, the study seeks to identify the dominant drivers of performance and evaluate ZRL's readiness for transformation in the 4IR era.

## 2. Thematic and Conceptual Framework

The performance of state-owned railway enterprises in the Fourth Industrial Revolution (4IR) cannot be explained by single-factor models. Rather, institutional outcomes emerge from the interaction between operational systems, leadership capacity, environmental pressures, and regulatory support. To capture these interdependencies, this study integrates three complementary theoretical perspectives: Total Productive Maintenance (TPM), Change Management Theory, and Contingency Management Theory.

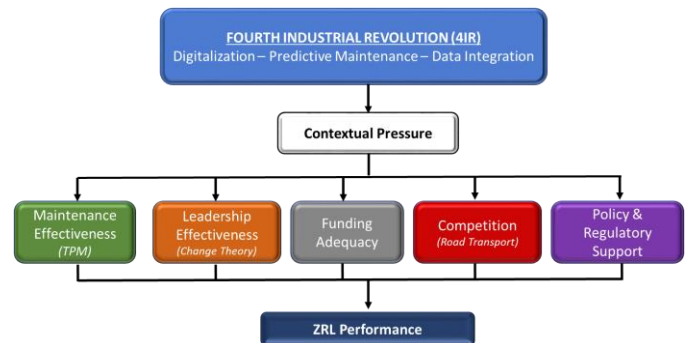
First, Total Productive Maintenance (TPM) provides the operational foundation. Originally advanced by Nakajima (1988), TPM emphasizes preventive maintenance, operator involvement, and system-wide reliability improvement. Within railway systems, TPM principles align with predictive diagnostics, asset monitoring, and lifecycle optimization, core components of 4IR-enabled infrastructure management. In the ZRL context, maintenance effectiveness represents the technical dimension of performance readiness.

Second, Change Management Theory highlights the role of leadership in driving institutional transformation. As organizations transition toward digital integration and data-driven operations, leadership effectiveness becomes critical in overcoming bureaucratic inertia, aligning stakeholders, and embedding innovation. In public sector settings, reform efforts

often fail not due to technical deficiencies, but due to resistance to change and weak managerial coordination. Leadership effectiveness thus represents the organizational transformation dimension of performance.

Third, Contingency Management Theory asserts that leadership and organizational structures must align with contextual realities. Railway enterprises in developing economies operate under regulatory constraints, fiscal limitations, and competitive pressures, particularly from road transport. Under 4IR conditions, technological adaptation requires strategic alignment between internal capabilities and external policy environments. Government policy and regulatory support, therefore, represent the institutional-environmental dimension influencing performance. By synthesizing these perspectives, the study conceptualizes ZRL performance as the outcome of interacting operational (maintenance), managerial (leadership), financial (funding), competitive (road transport), and regulatory (policy support) determinants within a technologically disruptive environment.

Figure 1: Integrated Framework for Parastatal Railway Performance in the 4IR Context.



Source: Generated by the Author (2026)

## 3. Methodology

The study adopts a structured qualitative approach to synthesize scholarly literature, industry reports, and policy documents addressing parastatal railway performance within the context of the 4IR. The review integrates theoretical perspectives with empirical insights drawn from Zambia and comparable Sub-Saharan African railway systems.

A thematic review design was employed to organize and interpret existing studies under three primary domains derived from the conceptual framework: (i) maintenance effectiveness and asset management system, (ii) leadership and organizational transformation, and (iii) governance and regulatory alignment. Literature was sourced from peer-

reviewed academic databases including JSTOR, Scopus-indexed journals accessed via Google Scholar, institutional reports from the World Bank and African Development Bank, and relevant transport policy publications.

Inclusion criteria focused on studies published between 2010 and 2024 addressing state-owned enterprise reform, railway restructuring, infrastructure governance, maintenance systems, and digital transformation in developing economies. Particular attention was given to literature examining predictive maintenance, institutional leadership adaptation, and regulatory framework under technologically disruptive conditions.

To contextualise the review within the ZRL environment, empirical findings from a structured survey of ZRL stakeholders ( $n = 109$ ) were selectively integrated to illustrate how the theoretical proposition manifests within a real-world institutional setting. The findings were analysed using non-parametric correlation and regression techniques to support and interrogate patterns identified in the literature, rather than to constitute a standalone empirical study. This integrated approach enables the study to bridge conceptual scholarship and applied institutional realities, positioning ZRL within broader debates on public sector transformation under 4IR pressures.

## 4. Literature Review and Synthesis

### 4.1 4IR and the Transformation of Infrastructure-Dependent Enterprises

The Fourth Industrial Revolution (4IR) represents a structural transformation in production systems, characterized by cyber-physical integration, artificial intelligence, predictive analytics, and digital connectivity (Schwab, 2016). Within infrastructure-dependent sectors such as rail transport, 4IR technologies are reshaping asset monitoring, logistics coordination, and performance management through digital twins, IoT-based diagnostics, and integrated enterprise resource planning systems (Ivanov & Dolgui, 2020).

In railway systems, digitalization enables predictive maintenance, real-time traffic optimization, and integrated freight management, improving reliability and cost efficiency (European Union Agency for Railways, 2020). However, technological adoption alone does not guarantee performance improvements. Studies in public sector modernization consistently demonstrate that institutional readiness, governance capacity, and leadership alignment determine whether digital transformation yields measurable outcomes (OECD, 2019; World Bank, 2020). For state-owned

enterprises (SOEs) in developing economies, 4IR introduces both opportunity and structural strain. Limited capital investment, legacy infrastructure, bureaucratic rigidity, and policy fragmentation constrain technological adaptation (Foster & Briceno-Garmendia, 2010; AfDB, 2020). Consequently, digital transformation in railway systems must be examined not merely as a technological shift, but as an institutional reform process.

### 4.2 Predictive Maintenance and Operational Reliability

Maintenance systems represent a foundational pillar of railway performance. Total Productive Maintenance (TPM), originally articulated by Nakajima (1988), emphasizes preventive scheduling, cross-functional responsibility, and lifecycle asset optimization. Subsequent empirical studies confirm that TPM implementation significantly enhances equipment reliability and reduces downtime when organizational support structures are present (Ahuja & Khamba, 2008).

Under 4IR conditions, TPM evolves into predictive maintenance systems driven by sensor data, machine learning algorithms, and real-time performance diagnostics (Lee, Bagheri & Kao, 2015). In advanced railway networks, predictive asset monitoring reduces derailments, improves safety, and lowers operational costs (UIC, 2021). However, research across Sub-Saharan Africa shows that railway maintenance challenges persist due to aging rolling stock, spare part shortages, and weak preventive planning systems (World Bank, 2019; AfDB, 2020). Technological upgrades without institutional maintenance culture often fail to deliver sustained gains. This suggests that operational modernization must be embedded within broader organizational transformation frameworks.

### 4.3 Leadership and Organizational Adaptation under Technological Disruption

While maintenance modernization addresses operational reliability, leadership effectiveness determines whether institutional change is successfully implemented. Change Management Theory underscores the importance of structured transformation processes in overcoming resistance and embedding innovation (Kotter, 1996). Empirical studies in public administration reveal that reform outcomes are significantly influenced by leadership vision, communication clarity, and stakeholder coordination (Fernandez & Rainey, 2006).

Digital transformation demands cross-departmental collaboration, data-driven decision-making, and strategic

flexibility (Vial, 2019). Research in SOE governance indicates that leadership deficits, rather than capital shortages alone, often impede performance recovery (OECD, 2015). Contingency Theory further suggests that leadership effectiveness is context-dependent (Fiedler, 1967; Donaldson, 2001). In highly regulated environments such as state-owned railways, leadership must align internal capabilities with external policy frameworks and competitive pressures. Without such alignment, technological investments may fail to translate into performance improvement.

#### 4.4 Governance, Market Competition, and Regulatory Alignment

The governance architecture of railway SOEs significantly shapes performance trajectories. OECD (2015) corporate governance guidelines emphasize accountability, board independence, and financial transparency as critical determinants of SOE effectiveness. In developing economies, weak enforcement mechanisms and fragmented ministerial coordination often undermine reform efforts (World Bank, 2020).

Market competition further intensifies reform pressures. Road transport expansion across Sub-Saharan Africa has eroded rail freight market share due to flexibility, lower regulatory barriers, and private sector dynamism (World Bank, 2019). Studies show that underfunded railways lacking operational efficiency struggle to compete against more agile road logistics systems. Policy interventions such as freight allocation mandates can theoretically rebalance modal share; however, their effectiveness depends on enforcement capacity and institutional coordination (AfDB, 2020). Regulatory support without operational modernization risks producing compliance distortions rather than sustainable performance gains.

#### 4.5 Synthesis Towards an Integrated 4IR Institutional Framework

The reviewed literature converges on a central insight: technological transformation in railway enterprises is inseparable from governance reform and leadership adaptation. Predictive maintenance systems, digital logistics platforms, and regulatory restructuring must operate within an aligned institutional architecture. Within this integrated perspective, railway performance under 4IR conditions is shaped by five interacting domains: operational reliability (maintenance), managerial effectiveness (leadership), financial sustainability (funding), competitive positioning (road transport), and regulatory coherence (policy support). The interplay among these domains determines whether

technological modernization yields measurable institutional performance improvement. By situating Zambia Railways Limited within this broader 4IR reform landscape, the study advances a contextualized understanding of parastatal railway performance that moves beyond single-factor explanations.

## 5. Discussion

The literature on railway modernization under the Fourth Industrial Revolution (4IR) emphasizes technological adoption, predictive maintenance, digital freight platforms, and real-time asset monitoring, as critical drivers of operational efficiency (Lee et al., 2015; UIC, 2021). However, the integration of empirical evidence from Zambia Railways Limited suggests that technological capability alone does not determine institutional performance. Rather, governance and leadership dynamics appear to exert more decisive influence.

Consistent with Change Management Theory (Kotter, 1996) and public sector reform scholarship (Fernandez & Rainey, 2006), leadership effectiveness emerged as the strongest predictor of perceived institutional performance in the ZRL context ( $\beta = -0.285$ ,  $p < 0.01$ ). This finding reinforces the argument that transformation in state-owned enterprises is primarily organizational before it is technological. In environments characterized by bureaucratic rigidity and constrained autonomy, adaptive leadership becomes the mechanism through which reform initiatives, digital or otherwise, are translated into measurable outcomes.

Maintenance effectiveness, grounded in Total Productive Maintenance (TPM) principles (Nakajima, 1988; Ahuja & Khamba, 2008), demonstrated a statistically significant but comparatively weaker influence on performance ( $\beta = -0.176$ ,  $p < 0.05$ ). While predictive maintenance and asset optimization are widely promoted within 4IR discourse, the findings suggest that operational improvements yield limited returns when not embedded within coherent leadership and governance structures. This aligns with broader infrastructure studies indicating that maintenance modernization without managerial alignment produces incremental rather than transformative gains (World Bank, 2019).

Interestingly, funding adequacy did not exhibit a statistically significant independent effect on performance. This result challenges conventional narratives that attribute parastatal underperformance primarily to financial constraints. Instead, it suggests that resource allocation without governance reform may fail to translate into efficiency improvements. OECD (2015) guidelines on SOE governance similarly argue that

capital injections absent structural accountability rarely produce sustained institutional change.

Competition from road transport and government regulatory support both demonstrated significant associations with performance, reflecting the contingency-based argument that institutional outcomes are shaped by external alignment (Donaldson, 2001). In the Zambian context, modal competition intensifies performance pressures, while policy enforcement capacity conditions reform effectiveness. Under 4IR conditions, this external alignment becomes even more critical, as digital logistics ecosystems increasingly demand interoperability, regulatory coherence, and market responsiveness.

Taken together, these findings support a governance-centred interpretation of railway modernization. Technological transformation under 4IR does not operate in isolation; it is mediated by leadership capability, institutional coordination, and regulatory consistency. For parastatal railway enterprises, digitalization initiatives must therefore be accompanied by leadership strengthening, accountability reforms, and strategic policy enforcement to yield sustainable performance gains.

## 6. Research Gaps and Future Directions

Despite the growing body of scholarship on railway restructuring and public sector modernization, several critical gaps remain in understanding parastatal railway performance under 4IR conditions. First, empirical research on digital readiness within African state-owned railway enterprises remains limited. While predictive maintenance, IoT-enabled monitoring, and data-driven logistics are widely discussed in global transport literature (Lee et al., 2015; UIC, 2021), few studies evaluate the institutional preconditions necessary for their successful implementation in resource-constrained public systems. Future research should develop measurable digital maturity or readiness indices tailored to railway SOEs in developing economies.

Second, the intersection between adaptive leadership and digital transformation in parastatal contexts remains underexplored. Existing change management frameworks (Kotter, 1996; Fernandez & Rainey, 2006) were largely developed in Western administrative settings. There is a need for context-sensitive models that account for political oversight structures, regulatory rigidity, and public accountability mechanisms typical of African SOEs.

Third, governance-policy interaction under technological disruption warrants further investigation. While regulatory instruments such as freight allocation mandates may seek to rebalance modal competition, their performance effects depend on enforcement capacity, institutional coordination, and stakeholder compliance. Quantitative impact assessments examining the effectiveness of policy interventions in shifting freight volumes toward rail would significantly advance current knowledge.

Finally, longitudinal studies assessing the sequencing of reform, leadership strengthening, maintenance modernization, regulatory enforcement, and digital adoption, could provide practical roadmaps for staged transformation. Such work would contribute to bridging the gap between conceptual reform frameworks and implementable institutional strategies.

## 7. Conclusion

This study revisited parastatal railway performance through an integrated 4IR-oriented framework combining Total Productive Maintenance, Change Management Theory, and Contingency Management Theory. By synthesizing contemporary literature and contextual empirical evidence from Zambia Railways Limited, the analysis demonstrates that institutional performance under 4IR pressures is fundamentally governance-mediated.

While operational modernization and predictive maintenance systems are central to railway reliability, leadership effectiveness emerged as the most influential determinant of perceived performance within the ZRL context. This finding challenges purely resource-based explanations of parastatal underperformance and underscores the centrality of organizational adaptation in technological transformation.

The study contributes to infrastructure governance scholarship by reframing 4IR adoption not as a purely technological shift, but as an institutional alignment process involving operational systems, managerial capacity, competitive positioning, and regulatory coherence. For policymakers and railway administrators, the implication is clear: digital transformation initiatives must be accompanied by leadership strengthening and governance reform to yield sustainable performance improvements. By situating ZRL within broader debates on public sector modernization and technological disruption, the paper advances a context-sensitive understanding of railway reform in developing economies and provides a foundation for future empirical and policy-oriented inquiry.

## Conflict of Interest Declaration

The authors declare that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest. The institutional affiliations of the co-authors with ZCAS University are acknowledged and disclosed.

## References

- AfDB (African Development Bank). (2020). *African infrastructure development index report 2020*. African Development Bank Group.
- Ahuja, I. P. S., & Khamba, J. S. (2008). Total productive maintenance: Literature review and directions. *Journal of Quality in Maintenance Engineering*, 14(3), 224–243. <https://doi.org/10.1108/13552510810899425>
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage Publications.
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage Publications.
- Donaldson, L. (2001). *The contingency theory of organizations*. Sage Publications.
- European Union Agency for Railways. (2020). *Railway safety and interoperability in the EU*. Publications Office of the European Union.
- Fernandez, S., & Rainey, H. G. (2006). Managing successful organizational change in the public sector. *Public Administration Review*, 66(2), 168–176. <https://doi.org/10.1111/j.1540-6210.2006.00570.x>
- Fiedler, F. E. (1967). *A theory of leadership effectiveness*. McGraw-Hill.
- Foster, V., & Briceno-Garmendia, C. (Eds.). (2010). *Africa's infrastructure: A time for transformation*. <https://doi.org/10.1596/978-0-8213-8041-3>
- Ivanov, D., & Dolgui, A. (2020). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *International Journal of Production Research*, 58(7), 2184–2203. <https://doi.org/10.1080/00207543.2019.1629670>
- Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. *Social Sciences*, 8(9), 255. <https://doi.org/10.3390/socsci8090255>
- Kotter, J. P. (1996). *Leading change*. Harvard Business School Press.
- Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners* (5th ed.). Sage Publications.
- Lee, J., Bagheri, B., & Kao, H.-A. (2015). A cyber-physical systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters*, 3, 18–23. <https://doi.org/10.1016/j.mfglet.2014.12.001>
- Nakajima, S. (1988). *Introduction to TPM: Total productive maintenance*. Productivity Press.
- OECD. (2015). *OECD guidelines on corporate governance of state-owned enterprises*. OECD Publishing. <https://doi.org/10.1787/9789264244160-en>
- OECD. (2019). *The path to becoming a data-driven public sector*. OECD Publishing. <https://doi.org/10.1787/059814a7-en>
- Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson.
- Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768. <https://doi.org/10.1213/ANE.0000000000002864>
- Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.
- UIC (International Union of Railways). (2021). *Digital railways: Transforming the rail sector through innovation*. UIC Publications.
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>
- World Bank. (2019). *Railway reform: Toolkit for improving rail sector performance*. World Bank Group.
- World Bank. (2020). *Enhancing government effectiveness and transparency: The fight against corruption*. World Bank Group.
- Yukl, G. (2013). *Leadership in organizations* (8th ed.). Pearson.