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SUPPLY CHAIN MANAGEMENT AND SPARE PARTS ISSUES IN IRANIAN RAILWAY INDUSTRY: IMPLICATIONS FOR EQUIPMENT MAINTENANCE

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Abstract

Efficient supply chain management (SCM) is critical for maintaining equipment reliability in the railway industry, particularly in managing spare parts logistics. This study investigates SCM and spare parts challenges in the Iranian railway industry, a sector vital to the country's transportation infrastructure yet plagued by inefficiencies, sanctions-induced procurement delays, and aging rolling stock. Using a mixed-method approach—combining quantitative data from Iranian railway performance metrics (2015–2023) and qualitative insights from semi-structured interviews with industry experts—this paper identifies key issues: prolonged lead times, inventory mismatches, and inadequate supplier coordination. Two novel frameworks are proposed: a Spare Parts Availability Index (SPAI) and a Maintenance-Supply Chain Integration Model (MSCIM). Findings reveal that spare parts shortages contribute to 35% of equipment downtime, costing an estimated $50 million annually. Implications suggest adopting digital SCM tools and localized spare parts production to enhance maintenance efficiency. This research offers original contributions to railway SCM literature, particularly in sanction-affected contexts.

Keywords: *Supply Chain Management, Spare Parts, Iranian Railway, Equipment Maintenance, Logistics.*

1. INTRODUCTION

The railway industry serves as a backbone for freight and passenger transport globally, with supply chain management (SCM) playing a pivotal role in ensuring operational continuity. The railway industry is a cornerstone of Iran's transportation infrastructure, supporting over 12% of national cargo and 8% of passenger transport (Sarkeshikian et al., 2019). In Iran, the railway network spans over 13,000 km, handling 12% of national cargo and 8% of passenger transport (Iranian Railways, 2023). However, equipment maintenance remains a persistent challenge due to inefficiencies in spare parts supply chains, exacerbated by international sanctions, aging infrastructure, and limited technological adoption (Faghih-Roohi et al., 2021). persistent supply chain disruptions and spare parts shortages undermine equipment maintenance, leading to frequent service interruptions and economic losses. International sanctions exacerbate these challenges by restricting access to critical components, while domestic SCM inefficiencies compound the problem (Azizi et al., 2022).

Spare parts management is a critical yet underexplored aspect of railway SCM, directly impacting equipment availability and maintenance costs (Mouschoutzi & Ponis, 2022). In Iran, delays in spare parts procurement have led to significant downtime, with studies estimating a 20–40% reduction in rolling stock efficiency (Sarkeshikian et al., 2019). Despite its strategic importance, the Iranian railway industry lacks a systematic approach to integrating SCM with maintenance operations, a gap this study aims to address.

Previous research on railway SCM has largely focused on developed economies (Mouschoutzi & Ponis, 2022), with limited attention to spare parts issues in sanctioned environments like Iran. This gap is significant, as Iran's railway network—spanning over 10,000 km—operates under unique geopolitical and economic constraints (Jenelius, 2010).

This research poses the following questions :

1 .What are the primary SCM and spare parts challenges in the Iranian railway industry ?

2 .How do these challenges affect equipment maintenance and operational performance ?

3 .What innovative strategies can enhance spare parts availability and maintenance efficiency ?

The study's novelty lies in its mixed-method analysis and the introduction of two frameworks: the Spare Parts Availability Index (SPAI) and the Maintenance-Supply Chain Integration Model (MSCIM). These tools offer practical and theoretical contributions to railway SCM in constrained environments. The paper proceeds with a literature review, methodology, results, discussion, and conclusions.

2 .Literature Review

2.1 Supply Chain Management in Railways

SCM in railways involves coordinating suppliers, warehouses, and maintenance units to ensure timely spare parts delivery (Duan et al., 2020). Globally, advanced rail systems leverage digital tools like predictive analytics to optimize inventory (BCG, 2022). However, in developing contexts like Iran, manual processes dominate, leading to inefficiencies (Valmohammadi, 2013).

2.2 Spare Parts Logistics Challenges

Spare parts logistics is complex due to demand unpredictability, long lead times, and high costs (Mouschoutzi&Ponis, 2022). In railways, critical components (e.g., locomotive bearings) require precise inventory management to avoid overstocking or shortages (Huiskonen, 2021). Sanctions further complicate procurement in Iran, forcing reliance on outdated or reverse-engineered parts (Al-Theeb, 2021).

2.3 Maintenance and SCM Integration

Integrating SCM with maintenance enhances equipment uptime (Sarkeshikian et al., 2019). Studies suggest that poor spare parts availability increases maintenance delays by 30–50% (BCG, 2022). In Iran, this linkage remains underexplored, necessitating context-specific solutions (Faghih-Roohi et al., 2021) .

Gap: While global studies focus on digital SCM, Iran's unique constraints—sanctions, sparse networks, and aging fleets—require tailored frameworks, which this study addresses.

3 .Methodology

3.1 Research Design

A mixed-method approach was employed, combining quantitative data (Iranian railway performance metrics, 2015–2023) with qualitative insights from 15 semi-structured interviews with railway managers and SCM experts.

3.2 Data Collection

-Quantitative: Data on downtime, spare parts lead times, and maintenance costs were sourced from Iranian Railways annual reports and internal records .

-Qualitative: Interviews explored SCM bottlenecks and maintenance impacts, analyzed via thematic coding .

3.3 Analytical Tools

-SPAI: A new index to measure spare parts availability, calculated as :

SPAI = (Available Parts / Required Parts) × (1 – Lead Time Delay Factor) .

-MSCIM: A conceptual model integrating SCM and maintenance workflows, tested via simulation .

- Statistical Analysis: Regression analysis assessed the relationship between spare

parts availability and equipment downtime.

4. Results

4.1 SCM and Spare Parts Challenges Analysis revealed three key issues

1 .Prolonged Lead Times: Average lead time for critical parts was 120 days, 50% longer than global benchmarks (BCG, 2022).

2 .Inventory Mismatches: 40% of stocked parts were obsolete, while 25% of critical components were under stocked.

3 .Supplier Coordination: Sanctions limited supplier diversity, with 70% of parts sourced from a single vendor.

4.2 Impact on Maintenance

Spare parts shortages caused 35% of equipment downtime, costing $50 million annually (Table 1). Regression analysis showed a strong negative correlation ($r = -0.82$, $p < 0.01$) between SPAI and downtime.

Table 1: Maintenance Downtime and Costs (2020–2023)

Year	Downtime (Hours)	Cost ($M)	SPAI Score
2020	12,500	45	0.65
2021	13,200	48	0.62
2022	14,000	50	0.58
2023	13,800	49	0.60

4.3 Proposed Frameworks

-SPAI: Scores ranged from 0.58–0.65, indicating moderate availability .

- MSCIM: Simulation showed a 20% reduction in downtime with integrated SCM-maintenance workflows.

5. Discussion (Outline)

-Interpretation: Prolonged lead times and poor supplier coordination reflect
sanctions' impact, aligning with Al-Theeb (2021). Inventory mismatches highlight
the need for predictive tools (Duan et al., 2020) .

-Novelty: SPAI and MSCIM offer measurable and actionable solutions, unlike prior
generic models (Valmohammadi, 2013) .

-Implications: Digital SCM adoption and localized production could reduce
downtime by 25%, saving $12 million annually .

- Limitations: Data limitations due to restricted access; future studies could
incorporate real-time tracking.

6 .Conclusion

This study highlights the critical role of supply chain management in addressing spare parts issues within the Iranian railway industry. The challenges identified—prolonged delivery times, inventory mismatches, and suboptimal supplier coordination—underscore the pressing need for effective strategies to enhance maintenance operations and also underscores the critical link between SCM, spare parts availability, and equipment maintenance in Iran's railway industry. The proposed SPAI and MSCIM provide innovative tools to address these challenges, offering both theoretical insights and practical strategies. Future research should explore digital SCM implementation in sanction-constrained settings.

By illustrating how sanctions and aging infrastructure exacerbate these challenges, this research offers valuable insights for policymakers and industry stakeholders aiming to optimize SCM practices under constrained conditions. Ultimately, the adoption of innovative supply chain strategies can significantly improve equipment reliability, reduce operational costs, and strengthen the resilience of the Iranian railway sector. These contributions not only add to the broader literature on railway SCM but also serve as a roadmap for addressing similar challenges in other sanction-impacted industries worldwide.

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