

**A STUDY OF INDIAN RAILWAYS:
PERFORMANCE AND POLICY ANALYSIS**

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**DEPARTMENT OF MANAGEMENT STUDIES
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A STUDY OF INDIAN RAILWAYS: PERFORMANCE AND POLICY ANALYSIS

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by

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CERTIFICATE

This is to certify that the thesis titled **A Study of Indian Railways: Performance and Policy Analysis**, submitted by **Vinod Bhatia**, to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy (Ph.D.)**, is a bonafide record of the research work carried out by him under my supervision. He has fulfilled the requirements for a PhD degree of the institute. The content of this thesis, in whole or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

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ABSTRACT

India's vast transport system is catering to the ever-rising mobility demands of more than 1.3 billion population, but energy-intensive carbon fuel vehicles are increasing fast due to the dominance of the road transport sector. The unplanned infrastructure development, capacity constraints, poor efficiency levels and paucity of funds are not keeping the current transport infrastructure in sync with the mobility demands of users. The holistic strategy to bring a paradigm shift in transport infrastructure development may involve planned interventions, improved resource efficiency, and appropriate technological tools. The planned interventions may include incentives for modal shift, specific infrastructural development and efficiency improvements of the constituents.

This research identifies the distortion in the logistics market, analyses the government interventions in the transport sector, recommends suitable changes in modal mix, describes the application of efficiency analysis to reduce the transportation cost, demonstrates the use of data analytic techniques to reduce the production costs, increase the revenue and recommends investments in thorough infrastructure appraisals employing scientific techniques. This study explores the Indian road and rail transport sectors. The key trends in the road, rail, public transportation systems, and transport issues associated with current transport policies give insights into the policy and performance issues of the transport sector. The study performs the environmental impact analysis of road and rail transport systems. The study describes the available alternatives to establish sustainable transport systems and suggests a simple conceptual transport policy framework to implement the policies at the field level. In a quantitative analysis, the study assesses the environmental impact of

commodity transportation in bulk or container mode through both rail and road transport.

This thesis investigates the technical efficiency of sixteen railway zones of Indian Railways based on expenses incurred in administration, operation of services, maintenance and repair of rolling stock, and lines opened for traffic. The study uses high-quality panel data for 2008-09 to 2017-18, published in Indian Railways Annual Statistical Statements by the Ministry of Railways, Government of India. The study incorporates the existing operating and working expenses to calculate efficiency scores and suggests targeted operating and working expenses for inefficient railway zones. The empirical contribution is provided by assessing the relative performance of zonal railways calculating technical efficiency scores using CRS and VRS methods. By sensitivity analysis, outlier detection and calculation of the Malmquist index, the study reveals several factors that affect the output efficiency.

The study undertakes passenger demand forecasting to fork out a well-thought-out strategy for properly utilizing available rolling stock and optimally planning for rolling stock production. The results demonstrate that demand forecasting can be an appropriate approach to plan for various transport services, resulting in enhanced revenues for the organisation. The study identifies Auto-ARIMA model for demand forecasting and tests several other models, i.e., trigonometric regressors (TBATS), Holt-Winters Additive model, Holt-Winters Multiplicative model, Simple Exponential Smoothing and Simple Moving Average methods.

Finally, given the scarce financial resources, the study proposes an integrated group discussion-ARP model to rank the construction sequence of three capital intensive IR projects, i.e., East-West DFC, East Coast DFC and North-South DFC. The sensitivity analysis demonstrates the robustness of the obtained results.

This study has made several recommendations for policymakers, implementation agencies, researchers and governments in India and other countries. The results and findings of this research would help them redesign and investigate their transport infrastructure development strategies and efficiently provide transport services.

सारांश

भारत की विशाल परिवहन प्रणाली 1.3 बिलियन से अधिक आबादी की बढ़ती गतिशीलता मांगों को पूरा कर रही है, लेकिन सड़क परिवहन क्षेत्र के प्रभुत्व के कारण ऊर्जा गहन कार्बन ईंधन वाहन तेज गति से बढ़ रहे हैं। अनियोजित बुनियादी ढांचे का विकास, क्षमता की कमी, खराब दक्षता स्तर और धन की कमी मौजूदा परिवहन बुनियादी ढांचे को उपयोगकर्ताओं की गतिशीलता मांगों के अनुरूप नहीं रख रही है। परिवहन बुनियादी ढांचे के विकास में एक आदर्श बदलाव लाने की समग्र रणनीति में नियोजित हस्तक्षेप, बेहतर संसाधन दक्षता और उपयुक्त तकनीकी उपकरणों का उपयोग शामिल हो सकता है। नियोजित हस्तक्षेपों में मोडल शिफ्ट, विशिष्ट अवसंरचनात्मक विकास और घटकों की दक्षता में सुधार के लिए प्रोत्साहन शामिल हो सकते हैं।

यह शोध रसद बाजार में विकृति की पहचान करता है, परिवहन क्षेत्र में सरकारी हस्तक्षेप का विश्लेषण करता है, मोडल मिश्रण में उपयुक्त परिवर्तनों की सिफारिश करता है, परिवहन लागत को कम करने के लिए दक्षता विश्लेषण के अनुप्रयोग का वर्णन करता है, उत्पादन लागत को कम करने के लिए डेटा विश्लेषणात्मक तकनीकों के उपयोग को प्रदर्शित करता है, वृद्धि करता है। राजस्व और वैज्ञानिक तकनीकों को नियोजित करने वाले बुनियादी ढांचे में निवेश की सिफारिश करता है। यह अध्ययन भारतीय सड़क और रेल परिवहन क्षेत्रों की पड़ताल करता है। वर्तमान परिवहन नीतियों से जुड़े सड़क, रेल, सार्वजनिक परिवहन प्रणालियों और परिवहन मुद्दों में प्रमुख रुझान परिवहन क्षेत्र की नीति और प्रदर्शन के मुद्दों में अंतर्दृष्टि प्रदान करते हैं। अध्ययन सड़क और रेल परिवहन बुनियादी ढांचे की दक्षता का आकलन करता है और सड़क और रेल परिवहन प्रणालियों के पर्यावरणीय प्रभाव विश्लेषण करता है। अध्ययन स्थायी परिवहन प्रणालियों को स्थापित करने के लिए उपलब्ध विकल्पों का वर्णन करता है और क्षेत्रीय स्तर पर नीतियों को लागू करने के लिए एक सरल वैचारिक परिवहन नीति ढांचे का सुझाव देता है। मात्रात्मक विश्लेषण में, अध्ययन रेल और सड़क परिवहन दोनों के माध्यम से थोक या कंटेनर मोड में वस्तु परिवहन के पर्यावरणीय प्रभाव का आकलन करता है।

यह थीसिस प्रशासन, सेवाओं के संचालन, रोलिंग स्टॉक के रखरखाव और मरम्मत के साथ-साथ यातायात के लिए खोली गई लाइनों के आधार पर भारतीय रेलवे के सोलह रेलवे क्षेत्रों की तकनीकी दक्षता की जांच करती है। यह अध्ययन 2008-09 से 2017-18 की अवधि के लिए उच्च गुणवत्ता वाले पैनेल डेटा का उपयोग करता है, जिसे रेल मंत्रालय, भारत सरकार द्वारा भारतीय रेलवे के वार्षिक सांख्यिकीय विवरणों में प्रकाशित किया गया है। अध्ययन में दक्षता स्कोर की गणना के लिए मौजूदा परिचालन और कामकाजी खर्चों को शामिल किया गया है और अक्षम रेलवे क्षेत्रों के लिए लक्षित परिचालन के साथ-साथ काम करने वाले खर्चों का सुझाव दिया गया है। सीआरएस और वीआरएस विधियों का उपयोग करके तकनीकी दक्षता स्कोर की गणना करने वाले क्षेत्रीय रेलवे के सापेक्ष प्रदर्शन का आकलन करके अनुभवजन्य योगदान प्रदान किया जाता है। माल्मक्विस्ट इंडेक्स की संवेदनशीलता विश्लेषण, बाहरी पहचान और गणना से, अध्ययन कई कारकों को प्रकट करता है जो आउटपुट दक्षता को प्रभावित करते हैं।

अध्ययन में उपलब्ध चल स्टॉक के उचित उपयोग के लिए एक सुविचारित रणनीति बनाने और चल स्टॉक उत्पादन के लिए इष्टतम योजना बनाने के लिए यात्री मांग पूर्वानुमान का कार्य किया गया है। परिणाम दर्शाते हैं कि मांग का पूर्वानुमान विभिन्न परिवहन सेवाओं की योजना के लिए एक उपयुक्त दृष्टिकोण हो सकता है, जिसके परिणामस्वरूप संगठन के लिए राजस्व में वृद्धि होती है। अध्ययन मांग के पूर्वानुमान के लिए ऑटो-एरिमा मॉडल की पहचान करता है और कई अन्य मॉडलों का परीक्षण करता है, जैसे कि त्रिकोणमितीय रजिस्टर (टीबीएटीएस), होल्ट-विंटर्स एडिटिव मॉडल, होल्ट-विंटर्स मल्टीप्लिकेटिव मॉडल, सिंपल एक्सपोनेंशियल स्मूथिंग और सिंपल मूविंग एवरेज मेथड्स।

अंत में, दुर्लभ वित्तीय संसाधनों को देखते हुए, अध्ययन एक एकीकृत समूह चर्चा-एआरपी मॉडल का प्रस्ताव करता है जो तीन पूंजी गहन विकल्पों के निर्माण अनुक्रम को रैंक करता है, अर्थात्, पूर्व-पश्चिम डीएफसी, पूर्वी तट डीएफसी और उत्तर-दक्षिण डीएफसी। संवेदनशीलता विश्लेषण प्राप्त परिणामों की मजबूती को दर्शाता है।

इस अध्ययन ने भारत और अन्य देशों में नीति निर्माताओं, कार्यान्वयन एजेंसियों, शोधकर्ताओं और सरकारों के लिए कई सिफारिशें की हैं। इस शोध के परिणाम

और निष्कर्ष उन्हें परिवहन बुनियादी ढांचे के विकास रणनीतियों को फिर से डिजाइन करने और जांच करने और कुशल तरीके से परिवहन सेवाएं प्रदान करने में मदद करेंगे।

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LIST OF ABBREVIATION

ACF: Autocorrelation Function

ADF: Augmented Dicky-Fuller

AHP: Analytical Hierarchy Process

AIC: Akaike Information Criterion

ANP: Analytical Network Process

AQI: Air Quality Index

ARIMA: Auto-Regressive Integrated Moving Averages

BIC: Bayesian Information Criterion

BTK: Billion Tones Kilometers

CAGR: Compounded Annual Growth Rate

CART: Classification and Regression Tree

CR: Consistency Ratio

CRS: Constant Return to Scale

DEA: Data Envelopment Analysis

DEAP: Data Envelopment Analysis Program

DFC: Dedicated Freight Corridor

DM: Diebold and Mariano Test

DMU: Decision-making Unit

DPR: Detailed Project Report

DRF: Distributed Random Forest

ELECTRE: ELimination and Choice Expressing Reality

EMU: Electric Motor Unit

ETS: Exponential Smoothing Methods

FDI: Foreign Direct Investment

FMCG: Fast Moving Consumer Goods

GBM: Gradient Boosting Machine

GDP: Gross Domestic Product

GHG: Green House Gas

GST: Goods and Services Tax

ICMS: Integrated Coach management System

IEA: International Energy Agency

IR: Indian Railways

IT: Information Technology

LPI: Logistics Performance Index

MAE: Mean Absolute Error

MAPE: Mean Absolute Percentage Error

MCA: Multi-Criterion Analysis

MCDM: Multiple Criteria Decision Making

ME: Mean Error

MI: Malmquist Productivity Index

MIS: Management Information System

MoRTH: Ministry of Road Transport and Highways

MSE: Mean Square Error

NHDP: National Highway Development Project

NRP: National Rail Plan

NTDPC: National Transport Development Policy Committee

NTKM: Net Tonne Kilometers

OD: Origin-Destination

PACF: Partial auto-correlation function

PKM: Passenger Kilometers

PNR: Passenger Name Report

PPP: Public-Private Partnership

PRS: Passenger Reservation System

RAE: Relative Absolute Error

RME: Relative Mean Error

RMSE: Root Mean Square Error

SRTU: State Road Transport Undertakings

TEU: Twenty equivalent Unit

TFC: Total Final Consumption

TFP: Total Factor Productivity

TOD: Transit-oriented Development

TTW: Tank-to-Wheels

VECM: Vector Error Correction Model

VRS: Variable Return to Scale

WHO: World Health Organization

WPM: Weighted Product Method

WSM: Weighted Sum Method

WTT: Well-to-Tank

WTW: Well-to-Wheels

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