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Risk Assessment of Railway Infrastructure Investment along the "Belt and Road" Based on BWM-WASPAS

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Research Background & Motivation

The Strategic Context

- BRI is a crucial tool for China's global economic integration strategy
- Railway infrastructure represents high-stakes, long-term investments spanning multiple decades
- Critical challenge: Projects face political volatility, economic instability, social unrest, and challenging natural environments

The Research Gap

- Existing studies rely heavily on subjective expert judgment (AHP, ANP, expert surveys)
- No comprehensive study covering all 60 BRI countries from a continental perspective
- Natural environment risks assessed qualitatively without GIS-driven quantification
- Lack of unified, data-driven methodology for cross-country comparison

Research Objectives

- Develop a data-geographic information driven risk assessment index system
- Determine indicator weights using Best-Worst Method to reduce subjectivity
- Apply WASPAS method for comprehensive risk ranking
- Provide decision support for Chinese railway enterprises

Two Real-World Cases from the Paper:

- Nigeria Modernization Railway Project (2006): Halted in 2008 after government transition
- Ethiopia-Djibouti Railway: Faced regional conflicts, terrorism, and currency instability

Literature Review & Existing Research

Risk Classification Research:

Bai Feibiao (2015): Political, economic, financial, environmental, legal, and force majeure risks;Shen Fuke (2017): Political, economic, social, technical, natural, financial, and managerial factors using factor analysis and fuzzy evaluation;Liu Yuming (2019): Identified 15 critical success factors through surveys, highlighting political environment and China relations as foundational;Yang Dingying (2015): Six-module risk management system for railway projects;Dong Suocheng (2018): Economic, social, and ecological risk model for China-Mongolia-Russia high-speed railway

Assessment Methodology Research:

Sun Jianjun (2020): Principal component analysis for six countries;hen Chaofeng (2017): Entropy weight method combined with matter-element extension model;Jin Jing (2019): Double-layer risk index system using PCA and grey-fuzzy AHP;Fikri Yucelazi (2018): ANP model for large-scale transport infrastructure projects

Critical Gaps Identified in the Paper:

- ◆ High subjectivity in expert-based assessments
- ◆ No continental-level analysis covering all 60 BRI countries
- ◆ Lack of GIS-based quantitative natural environment risk measurement
- ◆ Absence of integrated MCDM and geospatial analysis

Paper's Innovation: First study to combine BWM-WASPAS with GIS for BRI railway investment risk assessment

Methodological Framework

Three-Stage Integrated Approach

Stage 1: BWM (Best-Worst Method) for Weight Determination

- Published in Omega in 2015 by Rezaei
- Advantages over AHP: Only 2n-3 comparisons required instead of n(n-1)/2
- Reduces expert inconsistency and cognitive burden
- Linear optimization model: min ζ subject to constraints
- Provides unique optimal weights even in inconsistent systems

Stage 2: WASPAS (Weighted Aggregated Sum Product Assessment)

- Combines Weighted Sum Model (WSM) and Weighted Product Model (WPM)
- Formula: $Q_i = 0.5\sum_{j=1}^{n} \overline{x_{ij}} w_j + 0.5\prod_{j=1}^{n} (\overline{x_{ij}})^{w_j}$
- λ=0.5 determined as optimal through empirical testing
- More accurate than individual WSM or WPM methods

Stage 3: GIS-Based Natural Environment Risk Quantification

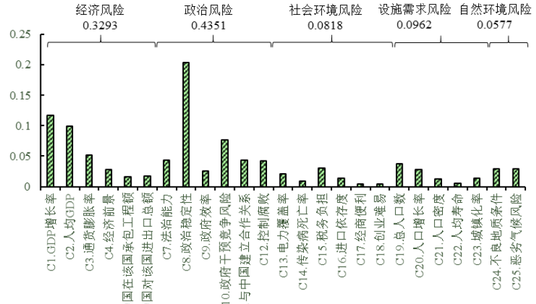
- Data: Global DEM (Digital Elevation Model)
- Three analyses in ArcGIS: slope grading, elevation difference, landform classification
- Complex terrain unit criteria: slope >30°, relative height difference >100m, plateau/mountain units
- Metric: Ratio of complex terrain units to total terrain units per country

Final Output: Risk rankings and GIS visualization maps

Risk Assessment Indicator System

Five-Dimensional Framework with 25 Indicators

B1 Economic Risk (Weight: 0.329)	C1: GDP Growth Rate C2: Per Capita GDP C3: Inflation Rate C4: Economic Outlook C5: Chinese Contract Value in Country C6: China Trade Volume with Country	**B3 Construction Environment Risk (Weight: 0.082)**	C13: Electricity Coverage C14: Infectious Disease Mortality C15: Tax Burden C16: Import Dependency C17: Ease of Doing Business C18: Entrepreneurship Ease
B2 Political Risk (Weight: 0.435)	C7: Rule of Law C8: Political Stability C9: Government Efficiency C10: Government Intervention in Competition C11: China Partnership Relations C12: Corruption Control	**B4 Infrastructure Demand Risk (Weight: 0.096)**	C19: Total Population C20: Population Growth Rate C21: Population Density C22: Life Expectancy C23: Urbanization Rate
		B5 Natural Environment Risk (Weight: 0.058)	C24: Topographic Risk (GIS-derived) C25: Natural Disaster Risk



Critical Finding: Political stability has the highest single indicator weight at 20.4%, followed by GDP growth rate at 11.7%

Sub-theme: Risk Control and Management

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GIS-Based Topographic Risk Quantification

Innovative Geographic Data Processing

Data Source:

Global Digital Elevation Model (DEM) from Global Map Data

GIS Processing Pipeline:

Slope Analysis: Calculate gradient for each grid cell; identify cells >30°

Elevation Difference Analysis: Compute relative height differences >100m

Landform Classification: Categorize terrain into plains, hills, plateaus, mountains

Band Composite Synthesis: Merge three layers in ArcGIS

Zonal Statistics: Calculate complex terrain ratio per country boundary

Complex Terrain Unit Definition:

Slope >30° OR

Relative elevation difference >100m OR

Landform type: plateau or mountain

Risk Calculation:

Topographic Risk Value = (Number of Complex Terrain Units) / (Total Terrain Units)

Example Results from Paper:

Pakistan: 0.391 (High complexity)

India: 0.286 (High complexity)

Yemen: 0.421 (Very high complexity)

Latvia: 0.119 (Low complexity)

Belarus: 0.118 (Low complexity)

Integration: This GIS-derived metric is combined with political and economic data for comprehensive assessment

Weight Determination Results

BWM-Derived Indicator Weights

Primary Dimension Weights:

- B2 Political Risk: 0.435 (43.5%)
- B1 Economic Risk: 0.329 (32.9%)
- B3 Construction Environment Risk: 0.082 (8.2%)
- B4 Infrastructure Demand Risk: 0.096 (9.6%)
- B5 Natural Environment Risk: 0.058 (5.8%)

Top Secondary Indicators (Selected):

- C8 Political Stability: 0.204 (Highest single weight)
- C1 GDP Growth Rate: 0.117 (Second highest)
- C9 Government Efficiency: 0.085
- C12 Corruption Control: 0.041
- C4 Economic Outlook: 0.040

Key Insight from Paper:

Political and economic factors dominate, accounting for 76.4% of total weight, confirming that macro-level stability is most critical for investment success.

Comprehensive Risk Ranking Results

Risk Score Range: 0.086 (Highest Risk) to 0.645 (Lowest Risk)

Five Risk Levels:

- Extremely High Risk (0.0-0.2): Syria (0.086), Yemen (0.090), Afghanistan (0.153), Nepal (0.191), Lebanon (0.193)
- High Risk (0.2-0.3): Tajikistan (0.199), Kyrgyzstan (0.214), Bosnia (0.223), Moldova (0.232), India (0.236)
- General Risk (0.3-0.4): Oman (0.305), Iraq (0.307), Azerbaijan (0.334), Bangladesh (0.345), Myanmar (0.347)
- Low Risk (0.4-0.5): Laos (0.401), Serbia (0.401), Philippines (0.403), Turkey (0.420), Kazakhstan (0.439)
- Extremely Low Risk (0.5-0.7): Israel (0.508), Saudi Arabia (0.517), Czech Republic (0.539), Malaysia (0.545), Poland (0.559), South Korea (0.593), UAE (0.621), Qatar (0.645)

Spatial Pattern:

Southeast Asia and Eastern Europe show generally low risk; Middle East and Central Asia show higher risk clustering.

Spatial Distribution & Regional Analysis

Regional Risk Patterns

Southeast Asia:

- Overall Assessment: Low risk levels dominate
- Key Countries: Singapore (0.394), Thailand (0.440), Vietnam (0.455), Malaysia (0.545), Indonesia (0.450)
- Characteristics: Relatively stable political systems, sustained economic growth, moderate terrain
- Strategic Context: RCEP agreement signed in November 2020 facilitates regional investment

Eastern Europe:

- Overall Assessment: Low to moderate risk
- Key Countries: Poland (0.559), Czech Republic (0.539), Hungary (0.488), Latvia (0.464)
- Exception: Ukraine (0.289) - High risk due to geopolitical conflict and slow economic development
- Characteristics: EU institutional frameworks provide stability

Central Asia:

- Overall Assessment: Moderate to high risk
- Key Countries: Kazakhstan (0.439), Uzbekistan (0.350), Kyrgyzstan (0.214), Tajikistan (0.199)
- Characteristics: Terrain challenges, governance variations, landlocked geography

Middle East:

- Overall Assessment: Highly variable risk levels
- High Risk: Yemen (0.090), Syria (0.086), Iraq (0.307)
- Low Risk: UAE (0.621), Qatar (0.645), Saudi Arabia (0.517)
- Driver: Sharp divergence in political stability and economic structure

Disaggregated Risk Analysis by Dimension

How Different Risk Dimensions Contribute

Political & Economic Risk Dominance:

- Countries with extreme political risk (Syria, Yemen, Afghanistan) also show extreme economic risk
- Paper notes these factors have "close relationship with national stability"
- Combined weight of 76.4% confirms their decisive importance

Natural Environment Risk Hotspots:

- Topographic Complexity: India (0.286), Pakistan (0.391), Yemen (0.421) show high values
- Historical Disasters: India experienced 725 natural disasters from 1920-2020, affecting 245 million people and causing $111 million in losses
- Paper's Finding: "High natural environmental risks will increase the technical difficulty of railway infrastructure construction, thereby affecting the cost of investment"

Construction Environment Risk:

- Paper states "overall, the construction environment risk and natural environment risk of countries along the route are at a relatively low level"
- Exceptions noted: Some countries show higher values due to specific local factors

Infrastructure Demand Risk Pattern:

- Paper observes "countries with larger populations and lower urbanization levels have higher infrastructure demand"
- India, Bangladesh, Indonesia show high demand but also face implementation challenges
- Inverse Relationship: High demand countries often have higher overall risk scores

Policy Implications & Strategic Recommendations

Key Conclusions from the Research Paper

For Chinese Railway Enterprises:

- Prioritize Low-Risk Regions: Southeast Asia and Eastern Europe show generally low risk and should be prioritized for investment
- Country Selection: Qatar, UAE, South Korea, and Malaysia are identified as lowest-risk countries
- Risk Factors to Monitor: Political stability and economic growth are the most critical factors affecting investment success
- Natural Environment Considerations: Despite lower weight, terrain complexity significantly impacts costs in countries like India and Nepal
- Demand-Risk Balance: High-demand countries often have higher overall risk, requiring careful evaluation

Strategic Recommendations from Paper:

- "Reasonably arrange investment priorities and sequence"
- "Scientifically avoid risks" for Chinese railway "going out" strategy
- Use GIS and multi-criteria assessment to understand geographic limitations
- Focus on countries with stable political environments and sound economic systems

Investment Priority Matrix:

- Immediate Priority: Southeast Asian countries with stable political and economic conditions
- Secondary Focus: Central and Eastern European countries with EU institutional support
- Caution Required: Countries with active conflicts or extreme terrain challenges
- Avoid: Countries ranked in top 5 highest risk levels (Syria, Yemen, Afghanistan, Nepal, Lebanon)

Methodological Advantages

Why BWM-WASPAS-GIS is Effective

BWM Advantages :

- ◆ Requires only 2n-3 pairwise comparisons instead of n(n-1)/2
- ◆ "Operation is more convenient and results are more reasonable"
- ◆ "Can obtain unique optimal solution for indicator weights through linear solving"
- ◆ Reduces workload and inconsistency compared to traditional methods

WASPAS Advantages:

- ◆ Combines advantages of Weighted Sum Model and Weighted Product Model
- ◆ "Proven to be more accurate than single methods"
- ◆ λ=0.5 determined as optimal through multiple calculations and empirical evidence
- ◆ Minimizes error and improves decision accuracy

GIS Integration Advantages:

- ◆ "Innovatively uses GIS to obtain natural geographic characteristic risk data"
- ◆ Transforms qualitative terrain assessment into quantitative metrics
- ◆ Enables "overall grasp of geographic limitations of overseas investment"
- ◆ Provides visual representation of risk distribution patterns

Overall Framework:

- ◆ Reduces subjectivity through data-driven approach
- ◆ Enables continental-level analysis of 60 countries
- ◆ Provides practical decision support for enterprises

Study Limitations & Future Directions

Limitations Acknowledged in the Research

Data Limitations:

- Uses five-year averages (2014-2018 data) which may not capture recent shocks
- Some countries have missing data requiring interpolation
- GIS data processing limited by computational constraints

Scope Limitations:

- Macro-level country assessment does not address project-specific risks
- Static snapshot does not capture evolving risk profiles over time
- Focuses on railway infrastructure; other infrastructure types not examined

Methodological Boundaries:

- Expert-determined weights reflect current perspectives and may evolve
- Linear normalization may not capture non-linear risk interactions
- Does not incorporate financial market indicators or real-time political events

Future Research Directions from Paper:

- Extend model to dynamic risk tracking with regular updates
- Incorporate financial market volatility indicators
- Develop project-level corridor risk assessments
- Apply to other infrastructure sectors (ports, highways, energy)
- Enhance with real-time political and economic monitoring

Final Conclusions & Strategic Message

Core Research Findings

- Political and Economic Primacy: Political stability (20.4% weight) and GDP growth rate (11.7% weight) are the most critical risk factors
- Geographic Clustering: Risk levels show clear spatial patterns—Southeast Asia and Eastern Europe are low-risk zones; Middle East and Central Asia show higher risk concentrations
- GIS Innovation: First study to quantitatively integrate topographic complexity into BRI risk assessment using DEM data and ArcGIS processing
- Country Prioritization: Qatar, UAE, South Korea, and Malaysia rank as lowest-risk; Syria, Yemen, Afghanistan as highest-risk
- Demand-Risk Paradox: Countries with highest infrastructure demand (India, Bangladesh) often face higher overall implementation risks

Strategic Imperative for Chinese Railway Enterprises:

- "Comprehensively grasp investment risks of all countries along the route"
- "Reasonably arrange investment priorities and sequence"
- "Scientifically avoid risks" to ensure positive benefits from railway "going out" strategy
- Use data-geographic driven frameworks for decision support

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