Railway Globalization: Leveraging Insight from Developed- into Developing Regions

RD (Dave) van der Meulen, LC (Fienie) Möller

Railway Corporate Strategy Close Corporation, Pretoria, South Africa
E-mail: dave@railcorpstrat.com, Phone: +27-83-275-7004, Fax: +27-88-012-345-2017

Abstract

Globalization has stimulated incisive changes in the world's railways, some highly regarded, and others disappointing. The research reported here sought a scientifically rigorous understanding of railway competitiveness and sustainability, within a defined setting. Application of multivariate statistic techniques to a new database extracted ten factors, representing underlying railway drivers, and six clusters of countries, interpreting their outcomes. The findings demonstrated a scientific foundation for relations among railway competitiveness, freedom and sustainability: The insights may be freely leveraged from developed- into developing regions.

1 Introduction

1.1 An industry in revolution

Railways have been relegated from prime land transport mode to one of several. Trucking competes vigorously, while rail also attacks maritime traffic. Logistics- and mobility criteria currently dominate modal choices and traffic flows. Globalization has concentrated equipment suppliers, and dispersed infrastructure- and train operators. Railways now resemble the few-supplier/many-operator model of other transport modes. Systems are open, managements are accountable, restructuring is rampant, connectivity is advancing, stakeholders are innovative, and financial returns are expected.

1.2 Competitiveness and sustainability

Railway competitiveness is reasonably well understood. Three genetic technologies distinguish railways from other transport modes: *Bearing*, or carrying heavy axle loads; *Guiding*, or operating at high speed; and *Coupling*, concatenating vehicles for capacity. High axle load, high speed, and long trains, alone or in combination, stand invincible against other modes in the heavy-haul, double-stack or heavy intermodal, and high-speed intercity niches. Many examples exist, predominantly in countries that consistently advance genetic technology state-of-the-art, where application of rail's strengths has earned high regard for the industry.

Sustainability appears less well understood. Criteria range from mere survival, to earning cost of capital. Whether they are explicitly or implicitly stated is immaterial. Increasingly, railways are called to account for their contribution to their societal setting: Where they do not pass muster, governments are reluctant to countenance inefficiency and ineffectiveness. Remedial interventions, such as vertical separation and private participation, have shaken industry structures. In retrospect, some outcomes have satisfied stakeholders, while others have disappointed them. It would thus be valuable to understand relations between competitiveness and sustainability.

1.3 The research question

Whatever the criteria, some railways in the new global order are sustainable, others are not. Advanced and sustainable are not necessarily synonymous. Some sustainable railways reside in developed economies, while others reside in emerging economies. In Western Europe, economies and railways are advanced, but rail freight market share is small and threatened. Furthermore, expectations and criteria shift as stakeholders learn from interventions. Many theories in this field appear not to be scientifically grounded. The research question thus addressed a scientifically rigorous foundation for understanding railway competitiveness, and its relation to sustainability, within a country setting. The findings could leverage insight from railways in developed regions to uplift railways in developing regions.

1.4 Developing regions

As globalization impacts on developing countries, leveraging relations among competitiveness, sustainability, and context, could unlock the value of freight- and/or passenger railways. They could learn from one another, develop and implement solutions to build freight and passenger capacity, appreciate the limitations of sharing infrastructure between freight and passenger trains, identify possible fatal flaws in existing arrangements, and minimize further investment in unsustainable legacies. The following settings exemplify some opportunities:

Africa is aspiration-driven, seeking to transfer road traffic to rail, to conserve fragile roads. However, lack of connectivity and interoperability on its narrow-gauge railways thwart a continental strategic horizon.

China's economy is formidable. Its standard gauge supports three railway growth niches—heavy-haul, double-stacking, and high-speed intercity. It is set for a substantial contribution from railways.

India's economy is growing vigorously. Challenges attend its monolithic state railway in servicing high passenger demand while supporting a manufacturing economy, and in dealing with its broad gauge track.

Middle East-North Africa, at the emerging global railway crossroads, seeks high-speed passenger and heavy freight operations—an outcome feasible only in its accommodating topography.

South America has critical connectivity challenges, which impede competitiveness and sustainability. It has advocated concessioning, but some outcomes have proven unsustainable [7].

Southeast Asia has a connectivity hurdle. It is contiguous with China, yet its meter-gauge railways lack ability to support trade with the countries stretching to Indonesia, and on to Australia by container ship.

These examples illustrate the scope of insight that is needed to build durable capacity in developing regions. The authors set out to develop some scientifically-grounded understanding of the field.

1.5 Hypothesis formulation

To unlock the requisite understanding, the authors hypothesized the existence of mutually reinforcing relations among variables associated with railways' competitiveness and sustainability, and their economic and social settings. Based on exploratory research over several years [8], they had identified that such relations appeared to be rooted in the Competitiveness, Connectivity, Market, Ownership, Presence, Society, and Sustainability of railways. The research reported here examined the existence and makeup of such relations.

2 Method

2.1 Research design

2.1.1 Descriptive research

Research on many aspects of railway strategy is well grounded, but as a distinct field, railway corporate strategy is relatively new. A Google search for "railway corporate strategy" only finds sites associated with the authors' business. Scientific description of a research setting requires a set of variables, usually in columns, and a set of cases, usually in rows, with the caveat that one can exhaust all cases, as the authors have done, but practical constraints often preclude exhausting all variables. The authors have explored and described the emerging global railway industry over several years on this basis, among other identifying the variables listed in the next section.

Global railway industry research must seamlessly compare railways in command economies with those in free economies, open access with vertical integration, heavy haul with transnational operators, and so on. It must also compare monolithic national railways, which may publish comprehensive statistics, with entities whose data are consolidated at higher level, and with small operators whose data are confidential. The authors therefore adopted a behavioural approach, predicated on metric- and nonmetric data. More, or less, of a particular attribute is frequently measurable, whereas ratio measurement is

frequently inaccessible. They devised surrogate variables to measure attributes that were not readily available in the public domain, where necessary using ordinal variables. The remaining challenge was to extract measurements from public data.

With the fall of interoperability barriers and ownership constraints, structural changes in the global railway industry have created a new order. Pre-global railways supported comprehensive national statistics, captured in databases maintained by the Association of American Railroads, International Union of Railways, and World Bank. However, government interventions, such as open access and vertical separation, fragmented the industry in many countries. The databases mentioned did not accommodate new entrants, disaggregated structures, and opaque data, thereby hindering whole-industry research. The authors concluded that railway corporate strategy research needed a new, dedicated, data base.

2.1.2 Variables and their definitions

The authors developed the following variables to support their objective, cumulatively to variables the first author had used previously [11, 12]. They sub-divided them where applicable, e.g. freight/passenger; infrastructure/rolling stock; and narrow/standard/broad gauge. The 11-pages of operational definitions for all 45 variables plus their scales exceeds the length limit: It is available on the authors' website [13].

Competitiveness Group represents developing and exploiting railway genetic technologies, specifically Research and Development Level, Genetic Technology Leverage Level, Presence of Railway Growth Niches, Motive Power Type, and Attitude to Competition.

Connectivity Group represents the territorial domain within which a railway can position itself, specifically Own Network, Contiguous Network, and Strategic Horizon.

Market Group represents railway market attributes, specifically Route Diversity, Operator Diversity, and Existence of Customer/Stakeholder/User Non-governmental Organizations.

Ownership Group represents the extent of private participation, specifically Infrastructure-operations Separation, Ownership Locus, and Commitment Horizon.

Presence Group represents the railway footprint in a country, specifically Overall Size, Traffic Volume, and Human Resources.

Society Group represents the societal setting, specifically National Economic Freedom, National Population, National Income, National Physical Size, Initiative Source, and Determinism[1].

Sustainability Group represents ability to continue over time, specifically Asset Investment Capacity, Stakeholder Satisfaction, Service Reputation, Safety Reputation, and Subsidy Influence: It is a surrogate for financial data, which is not available consistently across all cases.

Time represents a necessary element of longitudinal research. Sustainability cannot be examined by cross-sectional research.

2.1.3 Cases and their population

National legislatures currently regulate most railways, whether single- or multiple operators; exceptions exist where substantial railway operations cross national boundaries, under agreements that render borders transparent. The North American Free Trade Agreement is an example, and the European Union is set to become another. The authors thus concluded that the only workable paradigm was to sample railways by country. They recognize that while this paradigm accommodates most countries at present, a time could come when another paradigm ascends.

Many railway attributes are independent of track gauge, but in an industry dominated by standard gauge, there is scant evidence that track gauge less than yard/meter/3'-6'' supports sustainability: The authors therefore excluded statistics for narrower track gauges, irrespective of gauge mix in a country.

[1] One could conceive of more societal variables: However, they are interrelated, and inclusion of too many such variables may obscure rather than clarify relations among railway variables.

Metropolitan railways exploit neither heavy-axle-load nor high-speed strengths of rail, but contribute in other ways, and therefore relate best to other transport arrangements within a metropolitan setting: The authors therefore excluded statistics for metropolitan railways. The analysis that follows subsumes the remaining subset, countries with yard-gauge-or-wider line-haul railways, which each represent one case. With measurements for each of four years for each country, the population (and sample) size is 114 x 4 = 456 cases.

2.1.4 Measurement scales

Multivariate statistical procedures require observations for all cases and all variables. They cannot process data that contains missing values; hence one must delete either the case or the variable in question, simultaneously deleting any other cases or variables in the respective row or column. Railway data frequently have missing values, so one risks trashing good data. The authors therefore constructed measurement scales for ordinal variables such that each had a natural default value, neutral with respect to the poles, which they applied absent data for a particular railway, variable, or year. Ratio variables generally do not suffer from missing values, and all required observations could be found. Ordinal measurements were treated as if they were interval measurements [5].

2.1.5 Database architecture

The authors undertook longitudinal analysis of the four-year period 2002-2005. For countries that did not already have private participation, it spanned the rollout (through concessioning, open access, public-private partnerships, and so on) in Europe and, to a lesser extent, elsewhere in the world. They looked-up ratio measurements in *Railway Directory* [9] and *Jane's World Railways* [4]; and extracted ordinal measurements by content-analyzing textual data embedded in *International Railway Journal* and *Railway Gazette International* articles, to provide global railway event coverage, source redundancy, and multiple perspectives. The authors then populated a new 39-page Excel database, available on their website [13].

2.2 Statistical procedure

2.2.1 Data extraction

The authors have cooperated in railway corporate strategy research for nine years, and have mutually agreed on the present operational definitions. To minimize data errors, and maximize inter-coder reliability, one measured variables by content analysis, and the other double checked by random sampling. Periods without data were filled by repeating the last available measurement, or failing that, the default, until a new measurement emerged. The methodology can exaggerate errors in infrequent observations: However, such periods only occur in less newsworthy railways, which fortuitously tend to be less significant. Rather than arbitrarily correct them, they were left until the cluster analysis was complete. No unexpected associations emerged, so the data were left untouched.

2.2.2 Statistical intervention

Multivariate analysis simultaneously examines relations among multiple variables and multiple cases in complex settings. Of several such techniques, the authors selected factor analysis and cluster analysis. Factor analysis is a technique for analyzing the relations among a large number of variables, and then explaining these variables in terms of their common underlying factors. Cluster analysis is a technique for grouping cases into clusters, such that cases in a cluster exhibit within-cluster homogeneity, and between-cluster heterogeneity. The data were analyzed using Statgraphics Centurion XV.

2.2.3 Statistical significance

The exploratory factor analysis arrayed 39 variables and 456 cases. For >11 cases per variable, eigenvalues >1 can be considered significant. Applying the latter criterion, the authors extracted ten factors. For >50 cases, factor loadings >0.3 are considered significant [3], a criterion achieved by all factors. Cluster analysis is more an art than a science [3], because researcher discretion determines the

number of clusters and their interpretation: Its significance is therefore not addressed, but employing the same database as the factor analysis assures methodological integrity.

3 Findings

3.1 Factor analysis

3.1.1 The factor loading matrix

Prior experience with railway industry factor analysis, and simply-structured variable scales that minimize error variance, suggested the principal components option to extract maximum insight from the available data, and the varimax rotation option to separate factors clearly. Factor analysis cannot process textual data, so the outcome is anonymous—cases (countries) cannot be identified. Table 1 shows the loading, in descending order, of each variable onto one of the ten underlying factors. Note that the loading indicates association, not causality. Note further that the scales for each variable were constructed such that positive values act in same direction: Negative loading thus indicates that a particular variable opposes other positive variables, either on the same factor, or on other factors. Lest there be suspicion that naming the scale directions reflected author bias, appreciate that while the poles could have been transposed, factor loadings would also have changed sign, to yield the same outcome.

Statistical analysis stops at the factor loading matrix. The factor names, and discussion that follow, reflect the authors' interpretation of what they know about the variables in the research setting. For convenience, the upper- and lower scale poles are mentioned below, while the complete scales are available on the authors' website [13].

3.1.2 Factor 1: Societal Orientation

The following variables loaded onto Factor 1, accounting for 25.5% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Employee Count	relatively high number	relatively low number
Route Kilometers	relatively high number	relatively low number
Passenger Traffic Volume	relatively high number	relatively low number
Freight Traffic Volume	relatively high number	relatively low number
Electric Traction	present	absent
Relative Maximum Speed	relatively high number	relatively low number
National Population	relatively high number	relatively low number
Stakeholder Sensitivity	concerned	complacent
High-speed Intercity (passenger trains)	present	absent

Change in large-scale socio-cultural systems, such as railways in a host country, can lead to more than one possible outcome [2]. Which particular outcome emerges depends on the process dynamics that produce it. This factor suggested a societal orientation (Employee Count, Passenger Traffic Volume, National Population, and Concerned Stakeholder Sensitivity); advanced economic- and technological development (Route Kilometers, Electric Traction, Relative Maximum Speed, and High-speed Intercity Presence): Freight Traffic Volume also loads onto it, suggesting that a modicum of freight came with a passenger-oriented railway. Factor 1 suggested Western Europe, where contention between freight- and passenger demands does indeed exist.

3.1.3 Factor 2: Territorial Orientation

The following variables loaded onto Factor 2, accounting for 10.1% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Route Diversity	parallel options	single only
Heavy Intermodal	present	absent
Heavy Haul	present	absent

Distributed Power	present	absent
Relative Maximum Axle Load	relatively high number	relatively low number
Rolling Stock Ownership Locus	private	public
Country Physical Size	relatively high number	relatively low number

Having noted that change in large-scale socio-cultural systems can lead to more than one possible outcome [2], Factor 2 suggested freight railways that deployed advanced technology (Heavy Intermodal Presence, Heavy Haul Presence, Distributed Power Presence, and Relative Maximum Axle Load). It also suggested equity-driven competition among railways (Route Diversity and Rolling Stock Ownership Locus). Long, heavy trains conveying bulk commodities and manufactured goods suggested a territorial orientation toward economic-, natural-, and spatial resources, as in North America.

All railways use diesel traction, whereas only a subset uses electric traction: The presence of diesel traction is thus not variable, and cannot be statistically analyzed. Diesel traction nevertheless commonly associates with the train types that loaded onto this factor.

Variables that do not load onto factors are as significant as those that do. The fact that Freight Traffic Volume loaded onto Factor 1 and not onto Factor 2, suggests that Factor 2 relates to railways where traffic volume is a non-issue: Diesel traction and distributed power introduce a scalability that is absent in Factor 1 railways. Comparison of the variables that loaded onto Factor 1 and Factor 2 suggests that they represent two mutually exclusive railway archetypes.

3.1.4 Factor 3: Global Connectivity

The following variables loaded onto Factor 3, accounting for 7.2% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
–Narrow Gauge (kilometers)	relatively high number	relatively low number
Networkability	relatively high number	relatively low number

The negative loading of Narrow Gauge suggested that it diminished Networkability, which in turn impeded the continental- and intercontinental reach, or global connectivity, that drives Heavy Intermodal. This suggested that African, South American, and Southeast Asian railways will need to address connectivity and track gauge, to access freight rail's richest growth niche, from which they are currently excluded.

3.1.5 Factor 4: Rising Expectations

The following variables loaded onto Factor 4, accounting for 6.3% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Economic Freedom (Restated Index)[2]	relatively high number	relatively low number
Gross National Income	relatively high number	relatively low number
–Stakeholder Satisfaction Level	high satisfaction	no satisfaction

Loading of Economic Freedom and Gross National Income onto this factor suggested a developed, free, economy. Stakeholder Satisfaction Level loads negatively onto it, suggesting that logisticians and passengers in such economies expressed their dissatisfaction when service did not meet expectations, thus promoting a culture of rising expectations.

3.1.6 Factor 5: Competitive Freedom

The following variables loaded onto Factor 5, accounting for 4.6% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***

[2] The *Index of Economic Freedom* rates higher freedom as lower values on a 0-5 scale. For consistent factor loading sign, *Economic Freedom (Restated)* = 5–*Index*, so higher values represent higher freedom.

Infrastructure-operations Separation	separated	integrated
Operator Diversity	open access	monopolistic
Infrastructure Ownership Locus	private	public
Service Reputation	positive	negative
Strategic Horizon	intercontinental	national

The first three variables (Infrastructure-operations Separation, Operator Diversity, and Infrastructure Ownership Locus) signified moving from state ownership to private participation. The last two variables (Service Reputation and Strategic Horizon) signified excellent, long-haul, service. Their positive loading on this factor suggested a competitive freedom to choose business models with which to extend excellent service to continental- and intercontinental reach.

3.1.7 Factor 6: Continuous Improvement

The following variables loaded onto Factor 6, accounting for 4.2% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
–Rolling Stock Commitment Horizon	long term	medium term
–Infrastructure Commitment Horizon	long term	medium term

Negative loading of both variables onto this factor suggested that relatively short commitment horizons, to capital projects and/or public-private partnerships, maximized the objective function. Competitive markets change rapidly: Low-cost short-lived assets were more effective than long-lived assets that became commercial misfits before they wore out. Continuously increasing axle load and speed drive competitiveness, hence the need for continuous renewal and upgrading. Regarding rolling stock, the days of the thirty-year train are over [6]. Regarding infrastructure, many ingenious approaches have raised axle load and speed, but the need for high-axle-load and high-speed niche infrastructure, as well as the demise of non-competitive routes such as colonial railways and light branch lines, is self evident.

3.1.8 Factor 7: Inherent Sustainability

The following variables loaded onto Factor 7, accounting for 3.7% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Calendar Year	2005	2002
Infrastructure Investment Capacity	expansion	abandonment
Rolling Stock Investment Capacity	expansion	abandonment

The Infrastructure- and Rolling Stock Investment Capacity variables measured a country's ability to renew or expand its railways. Their loading onto the same factor as Calendar Year suggested inherent sustainability over time. Some railways are unable to renew, let alone expand—on the contrary, the authors found evidence of deterioration, withdrawal or abandonment: For them, time is running out.

3.1.9 Factor 8: Government Encouragement

The following variables loaded onto Factor 8, accounting for 3.2% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Subsidy Influence	toward receiver	toward provider
Attitude to Competition	enabling	protective
Research and Development Level	industry leader	base technology

The authors observed that, in addition to the conventional direction of influence, failing railways sometimes seek an increased subsidy from the provider [7]. The loading of Subsidy Influence, toward the receiver, with Attitude to Competition, through enabling competition, on this factor, was found to raise R&D Level to railway industry leadership. This factor suggested that government encouragement is valuable.

3.1.10 Factor 9: Self Regulation

The following variables loaded onto Factor 9, accounting for 3.1% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Initiative Source	railway industry	society
Safety Reputation	positive	negative
–Determinism	authoritarian	laissez faire

This factor suggested that positive Safety Reputation associated with railway industry Initiative Source in a laissez faire society. The negative Determinism loading suggested that government and/or other significant stakeholders refrain from interfering in railways. Self regulation seems to work for railway operators who compete for custom and funding in liberal economies: They simply cannot afford the catastrophic accidents that occur in protected railways.

3.1.11 Factor 10: The Broad-gauge Conundrum

The following variables loaded onto Factor 10, accounting for 2.7% of total variance. Cumulatively, the first ten factors accounted for 70.7% of total variance: Factors that cannot support reliable interpretation made up the remainder.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
–Broad Gauge (kilometers)	relatively high number	relatively low number
Standard Gauge (kilometers)	relatively high number	relatively low number

Broad Gauge is technically as competent as Standard Gauge, even arguably superior, but its negative loading on Factor 10 suggested that it opposes the critical mass of standard gauge. In a replay of Betamax versus VHS, market dominance outweighed technological advantage. Spain has recognized the conundrum, and has dealt with it head-on [1]. Broad-gauge Kazakhstan has exploited its strategic location between European, Middle Eastern, and Chinese standard gauge networks, by constructing a standard gauge landbridge to link them [10]. In the longer term, one should expect tension over track gauge in Central Asia and the Indian Sub-continent.

3.2 Cluster analysis

3.2.1 The icicle plot

For straightforward interpretation, the authors performed a cluster analysis on the 114-country population for one year (2005) only, using the Nearest Neighbour (Single Linkage) method with Squared Euclidean distance metric. The authors chose to examine only six clusters, among other to respect the paper length constraint: The number of clusters could however range from few large, relatively heterogeneous clusters, to many small, relatively homogeneous clusters, at their discretion. The Icicle Plot[3], Figure 1, shows cases forming clusters: Adjacent cases are related, the shared length indicating the degree of homogeneity. The hatched vertical line through the icicles demarcates the chosen number of clusters.

The six clusters comprise two groups, namely 88 countries, predominantly developing ones, in one cluster, and 26 countries, predominantly the Group-of-Twenty countries, in another five clusters. Five statistically independent countries, which do not fit any cluster, separated them: They nevertheless shared attributes with one or both neighbours, and will be interpreted accordingly. Cluster analysis is not anonymous, but identifies countries by name. Clusters 3 to 5 essentially differ in degree and emphasis: Interpretation will therefore address key distinctions.

Although statistical outputs appear as ratio numbers, several variables were measured on ordinal scales. Such measurements should be interpreted by ranking them no better than ordinal: They are therefore qualified below by wording such as *relatively* high or -low.

[3] Contrary to nature, icicle plots show icicles in the same horizontal sense as the cases they represent.

3.2.2 Cluster 1: Constrained Railways

This broad cluster contains significant sub-clusters, primarily broad-or-standard-gauge railways and narrow-gauge railways, and within the latter, a homogeneous cluster of isolated narrow gauge railways of marginal sustainability. The cluster includes relatively developed countries, whose railways have not followed, while others are still developing, burdened perhaps by a railway legacy. Railway variables numerically dominated the statistics, so the position of any country reflects its railways more than the country itself. The following attributes characterized this cluster:

Low freight and/or passenger traffic volume; insignificant operator or route diversity; low connectivity with strategic horizon limited to national borders; low technology that does not exploit rail's competitive strengths; public ownership with long commitment horizons; low economic freedom and relatively low national income; and low sustainability.

Overall, Cluster 1 faced many constraints. Comparison with Clusters 2 to 6 will suggest significant constraints, and what to do to lift them.

3.2.3 Cluster 2: Railways under Intense Competition

Canada and the United States formed this cluster, while independent neighbours Australia and Mexico are closely related. The following attributes characterized it:

Freight traffic volume dominates output; high market diversity (Australia somewhat higher, Mexico somewhat lower); high connectivity and continental strategic horizons (except Australia, which cannot connect beyond itself); high technology and intense exploitation of rail's competitive strengths (high axle load, double stack trains, and distributed power); ownership oriented toward private sector, still with relatively long commitment horizons; relatively high economic freedom and relatively high national income (Mexico significantly lower income); and relatively high sustainability.

Cluster 2 showed that exposure to intense competition associates with innovative market- and technology solutions, which supports sustainability.

3.2.4 Cluster 3: Railways under Rising Private Participation

Austria, the Czech Republic, and Italy formed this cluster, while independent neighbour Sweden is rather distantly related. The following attributes characterized it:

Mixed freight and passenger traffic, with moderate volumes; moderate market diversity; high connectivity and regional strategic horizon (Sweden continental strategic horizon); moderate technology and relatively low exploitation of rail's competitive strengths; ownership moving toward private sector; relatively high economic freedom but national income lower than Cluster 4; and relatively low sustainability.

To illustrate researcher discretion, clusters could have been cut such that Clusters 3, 4, and 5 were in one cluster. However, that larger cluster would also have annexed the emerging countries in the present Cluster 6, which are clearly distinct from the Europe-oriented countries. The authors therefore chose to work with three separate Europe-oriented clusters, and to interpret the subtle distinctions among them.

3.2.5 Cluster 4: Railways under Unreceptive Private Participation

Belgium, The Netherlands, Switzerland, Denmark, Norway, Finland, South Korea, and Luxembourg formed this cluster, characterized by:

Mixed freight and passenger traffic with moderate volumes; unreceptive to market diversity; High connectivity but conservative strategic horizon; marginally higher competitiveness than Cluster 3; clinging to public sector ownership with a longer commitment horizon; relatively high economic freedom with highest national income among Clusters 3, 4, and 5; and relatively low sustainability.

3.2.6 Cluster 5: Railways under Liberal Private Participation

Germany, the United Kingdom, and Japan formed this cluster, characterized by:

Moderate freight volume and high passenger volume; relatively high market diversity; high connectivity (except Japan, which is isolated) but conservative strategic horizon; high technology level and intense application of rail's competitive strengths; advancing private sector ownership with relatively short commitment horizon; high economic freedom and high national income; and relatively high sustainability.

Independent neighbour France relates to this cluster by virtue of high technology and intense application of rail's competitive strengths: However, it has relatively low economic freedom, is unreceptive to private participation, and has low sustainability, in which regard it relates to Cluster 4. The following attributes differentiate independent neighbour Spain from Cluster 5: low connectivity (but it has committed to standard gauge); relatively long commitment horizons, and relatively high sustainability. By comparison with Clusters 3 and 4, it is evident that competitiveness, freedom, and sustainability associated with one another.

3.2.7 Cluster 6: Railways in Emerging Economies

International Heavy Haul Association members Brazil, South Africa, China, India, and Russia formed this cluster, characterized by:

A substantial freight traffic base, together with significant passenger traffic: monopolistic markets; relatively low connectivity and conservative strategic horizon; relatively high technology with deployment of at least one rail strength by each member; public ownership with relatively short commitment horizon that reflects the emerging economies; low economic freedom and low national income, and relatively high sustainability.

Cluster 6 suggested that heavy haul railway strength is relatively insensitive to track gauge, rendering competitiveness reasonably accessible to any railway, without the relatively higher entry barriers that accompany High-speed Intercity and Heavy Intermodal.

4 Discussion

4.1 Factor analysis

Per the objective of factor analysis, the ten factors extracted a set of latent variables for positioning railways in the global industry. In the cryptic terms that the paper length can accommodate, they:

Reveal the mutually exclusive Societal- and Territorial Orientation.

Identify sound interventions (Rising Expectations, Competitive Freedom, and Continuous Improvement).

Measure outcomes (Inherent Sustainability, Government Encouragement, and Self Regulation).

Indicate no-go areas (Global Connectivity and the Broad-Gauge Conundrum).

Note that factor loading is sign-sensitive, therefore as parameters tend toward the lower scale pole, the interpretation may invert: Sustainability may become expiry.

4.2 Cluster analysis

The six clusters suggested relations among the competitiveness, freedom, and sustainability of railways. The relations appear to be influenced by structural differences among the countries.

Cluster 2 represents railways where free competition associates with sustainability.

Clusters 3, 4, and 5 represent railways where private participation associates with sustainability.

Cluster 6 represents railways where at least one strong railway genetic technology associates with sustainability.

All three clusters support higher sustainability than railways that are constrained. It is accepted that competition and private participation are turbulent: However, they do not associate with low sustainability.

4.3 Hypothesis support

The relations revealed by the cluster and factor analyses supported the hypothesis that they exist. They are important, because they provide conceptual tools by which to predict the outcomes of alternative interventions, to leverage insight from developed regions into developing regions.

4.4 Further research

Omitted variables threaten the predictive validity of multivariate analysis. Further research around the clusters and factors identified is recommended, to mitigate the threat by ensuring that all pertinent variables are identified.

This study examined the influence of subsidy, but not its quantum, which was not readily accessible. Further research on relations among direct- or cross subsidy and competitiveness, e.g. regarding high-speed technology developed in state railways, would deepen understanding of the risks attributable to, and value associated with, subsidies.

5 Conclusions

The findings demonstrated a scientific foundation for relations among railway competitiveness, freedom and sustainability: The insights may be freely leveraged from developed- into developing regions.

The competitiveness- and sustainability virtues of the heavy haul, high-speed intercity, and heavy intermodal niches are clearly evident. Railways that are burdened by general freight- and line-haul passenger services, may need to jettison them to ensure survival.

In an understanding setting, the railway industry is sustainable. Like any other industry, it needs to exploit its competitive strengths, and needs the freedom to do so. Governments should encourage competition and development, and refrain from encumbering railways in ways that will emasculate any other industry.

One simple recommendation is to examine the development trajectory of railways in individual countries in the light of the findings, to ensure that their sustainability is boosted and not compromised. Railways in many countries are marginal: Appropriate intervention may position them for survival rather than oblivion.

6 Acknowledgements

The authors thank Mr. John Morgan and Dr. Antonie van Rensburg for their constructive comments.

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[13] www.railcorpstrat.com/perspectives.php; go to Page 2.

Variable	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*	*Factor 9*	*Factor 10*
Employee Count	**0.89**	0.12	0.13	0.13	0.08	0.06	0.07	0.10	0.04	0.12
Route Kilometers	**0.82**	0.42	0.10	0.03	0.11	0.09	0.10	0.12	0.02	0.02
Passenger Traffic Volume	**0.79**	0.12	0.03	0.20	0.11	0.01	0.09	0.04	0.11	0.09
Freight Traffic Volume	**0.68**	0.34	0.28	0.09	0.13	0.14	0.04	0.10	0.08	0.18
Electric Traction	**0.67**	0.16	0.33	0.24	0.03	0.08	0.07	0.00	0.05	0.10
Relative Maximum Speed	**0.65**	0.00	0.31	0.43	0.13	0.04	0.03	0.29	0.10	0.15
National Population	**0.61**	0.26	0.42	0.40	0.02	0.12	0.08	0.05	0.09	0.13
Concerned Stakeholder Sensitivity	**0.54**	0.27	0.05	0.37	0.23	0.20	0.02	0.14	0.11	0.15
High-speed Intercity Presence	**0.48**	0.04	0.06	0.37	0.12	0.19	0.02	0.39	0.14	0.24
Route Diversity	0.01	**0.90**	0.07	0.10	0.02	0.14	0.06	0.05	0.02	0.05
Heavy Intermodal Presence	0.06	**0.86**	0.11	0.06	0.03	0.06	0.07	0.04	0.07	0.06
Heavy Haul Presence	0.17	**0.84**	0.04	0.03	0.00	0.19	0.00	0.08	0.05	0.02
Distributed Power Presence	0.07	**0.82**	0.04	0.11	0.02	0.00	0.06	0.10	0.15	0.03
Relative Maximum Axle Load	0.14	**0.63**	0.53	0.13	0.03	0.19	0.06	0.08	0.02	0.18
Rolling Stock Ownership Locus	0.20	**0.58**	0.05	0.14	0.55	0.02	0.06	0.08	0.03	0.20
Country Physical Size	0.31	**0.54**	0.44	0.41	0.06	0.08	0.02	0.07	0.05	0.02
Narrow Gauge (kilometers)	0.04	0.06	**-0.86**	0.04	0.07	0.04	0.01	0.02	0.03	0.14
Networkability	0.28	0.02	**0.75**	0.16	0.14	0.02	0.05	0.01	0.11	0.14
Economic Freedom (Restated Index)	0.07	0.16	0.06	**0.84**	0.21	0.05	0.03	0.04	0.14	0.07
Gross National Income	0.29	0.15	0.20	**0.73**	0.13	0.05	0.10	0.17	0.11	0.23
Stakeholder Satisfaction Level	0.01	0.18	0.12	**-0.39**	0.18	0.35	0.15	0.25	0.18	0.02
Infrastructure-operations Separation	0.02	0.10	0.10	0.01	**0.75**	0.03	0.03	0.24	0.11	0.00
Operator Diversity	0.27	0.04	0.13	0.43	**0.54**	0.12	0.06	0.16	0.14	0.08
Infrastructure Ownership Locus	0.29	0.48	0.13	0.12	**0.53**	0.01	0.18	0.13	0.12	0.21
Service Reputation	0.12	0.04	0.06	0.14	**0.51**	0.09	0.08	0.14	0.06	0.23
Strategic Horizon	0.30	0.19	0.28	0.16	**0.36**	0.10	0.33	0.02	0.04	0.25
Rolling Stock Commitment Horizon	0.07	0.01	0.05	0.07	0.09	**-0.88**	0.05	0.01	0.07	0.08
Infrastructure Commitment Horizon	0.21	0.01	0.06	0.04	0.10	**-0.82**	0.09	0.03	0.17	0.05
Calendar Year	0.16	0.02	0.03	0.02	0.19	0.05	**0.70**	0.14	0.07	0.01
Infrastructure Investment Capacity	0.32	0.09	0.02	0.14	0.08	0.01	**0.65**	0.17	0.25	0.10
Rolling Stock Investment Capacity	0.32	0.17	0.14	0.02	0.09	0.11	**0.58**	0.10	0.23	0.17
Subsidy Influence	0.11	0.16	0.07	0.04	0.05	0.09	0.07	**0.71**	0.04	0.01
Attitude to Competition	0.13	0.02	0.17	0.03	0.17	0.22	0.33	**0.60**	0.11	0.08
Research and Development Level	0.32	0.35	0.08	0.20	0.14	0.14	0.16	**0.51**	0.17	0.01
Initiative Source	0.16	0.11	0.08	0.07	0.09	0.03	0.12	0.00	**0.77**	0.09
Safety Reputation	0.14	0.32	0.05	0.18	0.05	0.22	0.12	0.16	**0.65**	0.06
Determinism	0.26	0.17	0.03	0.16	0.21	0.23	0.36	0.17	**-0.44**	0.01
Broad Gauge (kilometers)	0.29	0.03	0.14	0.08	0.08	0.17	0.01	0.05	0.04	**-0.81**
Standard Gauge (kilometers)	0.37	0.25	0.49	0.12	0.07	0.02	0.09	0.02	0.05	**0.53**

Table 1: Factor Loading Matrix.

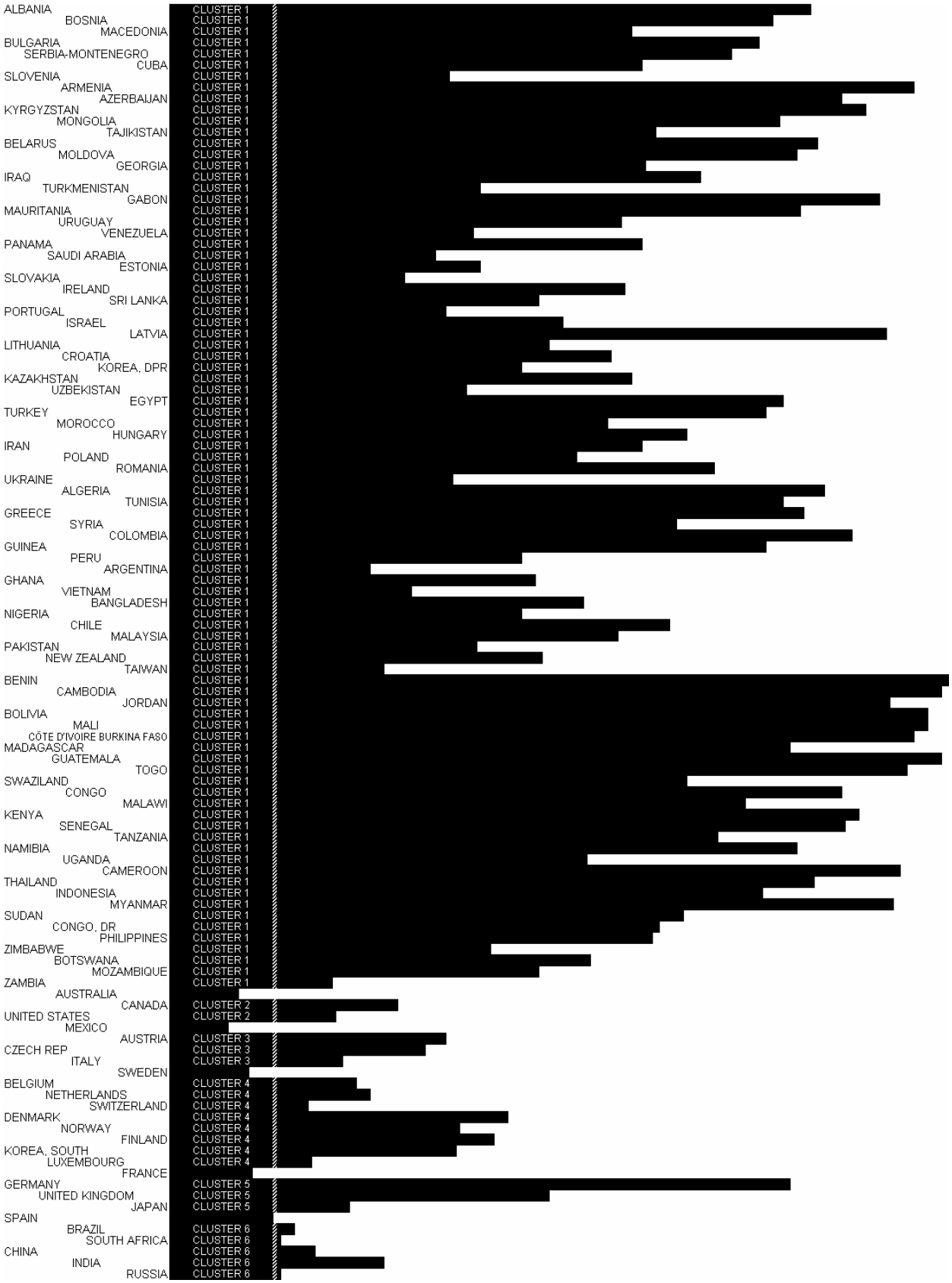

Figure 1: Icicle Plot, Ward's Method