# Competitiveness and Sustainability of Railways

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## 1. Introduction

### 1.1 Failure and success: Competitiveness and sustainability

The world's railway population spans many outcome variations between failure and success. The study of differences is of course the foundation of scientific research: The ability to understand what drives such differences facilitates cognitive positioning of railways for success, or more specifically, competitiveness and sustainability. The authors have pioneered research that contributed some understanding, on a journey that commenced with research to describe the global railway setting, and ultimately applied multivariate statistical analysis to discover how railways adapted to their particular settings. The findings were published piecemeal as they emerged (e.g. International Heavy Haul Association 1997, 2007, and 2009; Railway Gazette International, 2006; Transport Research Arena 2012; and World Congress on Railway Research, 2003, 2006, and 2008), and have been integrated for the first time in this chapter to present a global overview of the railway industry. As put forward here, the research foundation is still evident, but only sufficient detail to support the storyline has been retained. The present objective is to emphasize interpretation and significance of the findings for future railway positioning, within the available page limit. Reference will of course be made to the underlying research where appropriate.

### 1.2 Building a foundation for research into railway positioning

The research stream originated in a need to redress South Africa's colonial railway heritage of narrow track gauge, light axle load, low speed, small vehicle profile, steep gradients, and monolithic state ownership, which attributes posed many challenges. Some were amenable to technological solution—for example it developed successful heavy haul operations—but others remained endemic. Solutions to similar challenges emerged around the world during railway renaissance and ensuing railway reform. However, the need to control for many differences among such solutions and their settings deterred research to understand which interventions work and which do not. It will become evident, for example, that debating the merits of vertical integration and vertical separation can miss the point that either can work if a railway is inherently competitive, while neither will work if it is inherently uncompetitive. Unlike other more or less homogeneous modes such as airlines, which are challenged to differentiate their offerings, rail's attributes are so heterogeneous that their variance boggles the unaided human mind. Gradually awareness dawned that only high-level numerate research would make progress.

The field of corporate strategy is a well established major in business administration and business leadership. It addresses the total enterprise and how various functions interact to achieve objectives. Thus while all enterprises encompass several common functions, e.g. human capital, information technology, and so on, they must also manage their distinct core business, whether that be banking, mining, whatever, or in the case of railways, moving goods and people to support their logistics and mobility needs. However, googling *railway corporate strategy* returned items dominated by the authors' enterprise and their publications. The unique contribution of the present research stream is therefore a grounded understanding of corporate strategy with respect to the core business of railways.

## 2. Railway positioning

### 2.1 Competitiveness fundamentals

To comprehend railway positioning, it is helpful to examine railway competitiveness vis-à-vis that of other transport modes by considering their degrees-of-freedom-of-movability. Three degrees-of-freedom-of-movability (e.g. aerial- and submarine transport) offer high, spatial movability, but at relatively high cost. Next, two degrees-of-freedom-of-movability (e.g. unguided surface transport) offer lower, surface movability at lower cost. Last, one degree-of-freedom–of-movability (e.g. guided surface transport) offers only limited, linear movability, back and forth on its guideway. To the extent that limited movability reduces the value of their offering, guided surface transport modes such as railways must offer compensating advantages to compete effectively against other modes that offer higher movability, including door-to-door transport.

Axiomatically, such compensating advantages should inhere in technologies that differentiate guided surface transport from other transport modes. A vehicle-guideway pair ensures precise application of vertical loads, and safe application of lateral loads: Wheel-rail contact mechanics develop vertical- and lateral force components, technologies named *Supporting* and *Guiding* by Vuchic (2007: 449), which can sustain respectively heavy axle load and high speed. One may leverage Supporting and Guiding by combining two or many vehicles, to scale capacity as required, a technology the authors named *Coupling*. Supporting, Guiding, and Coupling are the three *genetic technologies* that distinguish guided surface transport from all other transport modes: *Inherent competitiveness* is defined here, and is measurable as, the extent to which such modes exploit their genetic technologies.

Note that the preceding two paragraphs have been generalized to guided surface transport, of which railways is a subset. Other guided surface transport modes also exist, which do not use steel-wheel-on-steel rail. We shall return to them in the context of urban guided transit in §3.3 and §3.5. Until then, this chapter addresses railways.

Cross-breaking Bearing and Guiding, in Figure 1, yields four railway market spaces. For this purpose, speed in tens of km/h is low speed, speed in hundreds of km/h is high speed; axle load above 25 tonnes is heavy. Three market spaces feature high competitiveness, by exploiting two or more of rail's genetic technologies—namely Heavy Haul (Supporting and Coupling), High-speed Intercity (Guiding and Coupling), and Heavy Intermodal[1] or Double

[1]Heavy intermodal traffic has heavy axle load: It is distinct from light traffic that simply transfers from one mode to another.

Stack (Supporting, Guiding, and Coupling). All three have demonstrated robust sustainability in competition with other transport modes.

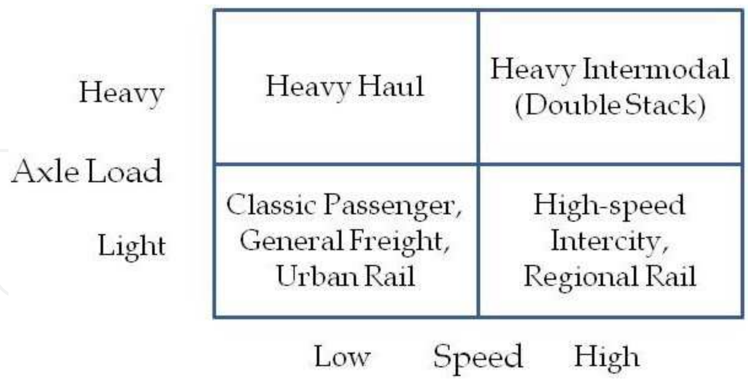


Fig. 1. Railway market spaces by Axle Load and Speed

The fourth market space is potentially weak—light axle load combined with low speed exploits neither Supporting nor Guiding genetic technology. Failure to exploit the remaining genetic technology, Coupling, in general freight- and classic long-distance passenger rail applications exacerbates their weakness, hence competitors erode their markets. Depending on whether economic-, political-, or social objectives determine their destiny, such railways are respectively eliminated, protected, or subsidized.

### 2.2 The special case of urban rail

Human passengers as payload do not achieve high axle load by railway standards, even in double deck vehicles. Furthermore, the comfort criteria and physical laws pertaining to acceleration, coasting, retardation, and station dwell time, maximize the capacity function at around 80km/h. Therefore urban rail cannot maximally exploit either the Supporting- or the Guiding genetic technology: It is confined to a potentially weak market space, in which it can exploit only the Coupling genetic technology. By forming vehicles into trains, it can achieve shorter mean headways than would be attainable by the same number of autonomous vehicles, thereby maximizing passenger capacity per direction per unit time. However, where urban rail does not exploit that one and only genetic technology to realize its capacity potential, it is vulnerable to competition from the rubber-tyred modes Automated Guided Transit, Bus Rapid Transit, and Monorail. The maximum speed of all urban guided transit modes is similar, so winners must leverage headway to maximize capacity. With no pretence at high axle load, rubber tyred modes exploit their consistent high adhesion to encroach on rail's eminent domain.

### 2.3 The railway renaissance

From bleak prospects in the first decade after World War II, railways in many countries have learned to exploit the competitive strengths that inhere in rail's genetic technologies. The following events mark the course of their learning:

In 1964, Japan introduced the world's first commercial high-speed intercity trains (Japanese Railway, 1964); they exploited the Guiding genetic technology to reach speeds of 210km/h, and leveraged high capacity by exploiting the Coupling genetic technology. Today, high-speed trains attain average speeds in excess of 300km/h, and move 20 000 passengers per hour per direction.

In 1972, a landmark article (Tracks to, 1972) recognized heavy haul as a distinct market space. By then, Supporting and Coupling technologies and equipment to Association of American Railroads specifications had spread abroad to dedicated railways conveying bulk-commodities. Today, heavy haul lines can move 400 million tonnes per year in trains of 300 cars or more.

In 1980, the United States' Staggers Act deregulated its railways: The ensuing wave of innovation among other triggered introduction of double stack container trains (Levinson, 2006). They enhanced inherent competitiveness through increasing axle load despite conveying low-density high-value freight in containers, and leveraged it further with the Guiding and Coupling genetic technologies.

In 1989, the fall of the Berlin Wall tipped the balance of power across the world toward those advocating democratic, consensual, free-market-oriented governance (Friedman, 2006), an ongoing process that stimulated economic globalization. In the railway supply industry, the resultant increased competition and trade rationalized many nationally-fragmented system integrators into fewer strong global brands. Concurrently, accelerating agglomeration in developing economies has expanded the urban rail market. The number of cities has proliferated by some seventy in the last decade.

Economic globalization has of course been transforming all four abovementioned railway market spaces: As examples, the *Global Rail Freight Conference 2007* in New Delhi reflected that transformation in its title, and World Congress on Railway Research 2008 reflected it in its theme *Towards a global railway.*

The foregoing four events revitalized railways in those countries that appreciated the imperative to enter as many of rail's inherently competitive market spaces as applied to them. Their accumulation across all railway countries has become known as the *railway renaissance*. It has precipitated a substantial body of data, able to support research into the modalities. However, even as the railway mode enters its third century as a strong competitor, many railways still have not integrated seamlessly into global logistics and intelligent mobility; they look different from one another, and even from many other global service industries. So how does one undertake research that will lead to some understanding of the differences among them?

## 3. Railway adaptation: A research paradigm

### 3.1 Background

When informally comparing railways, which had not joined the renaissance, to those that had, the latter seemed to have acquired a modicum of consistent identity, or *corporate citizenship*. The latter concerns an enterprise's profitability and sustainability; balancing stakeholder expectations, including those of customers, suppliers, and communities in which it operates; maintaining sustainable partnerships with all levels of government; and accepting its role in developing countries (World Economic, n.d.). Railways attain this standing when their corporate citizenship resembles that of other global service industries, such as airlines and logistics service providers. Corporate citizenship therefore provided a sensible perspective on which to found the research reported here. It supports a social sciences behavioural approach, because human behaviour drives enterprises.

### 3.2 Research in a dynamic, global setting

Railway countries have adapted themselves for competitiveness and sustainability to varying degrees in a globalized industry. Hence, in addition to rail's genetic technologies, which address their inherent competitiveness, it is necessary to control for setting variables, which influence their positioning. The research design 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 a higher level, and with small operators whose data are confidential.

Corporate citizenship is by definition an ongoing process that requires observations over time. Behaviour implicitly includes a time scale—snapshot data cannot observe it. A behavioural approach can naturally support the foregoing requirements. One of the authors developed a methodology for longitudinal railway corporate strategy research using large samples in a doctoral dissertation (Van der Meulen, 1994), which methodology underlies the research reported here.

Fortuitously, the global population of cities and countries with railways is sufficiently small to avoid sampling, yet, using longitudinal research, at the same time sufficiently large to support multivariate statistical analysis. It has been mentioned that line haul- and urban rail are positioned differently, i.e. in respectively inherently competitive- and inherently weak market spaces. They were therefore researched separately, first line haul and thereafter urban rail. The necessary methodological distinctions start immediately below, and have been maintained throughout the rest of this chapter as appropriate.

### 3.3 The research questions

The authors formulated their research questions within the context of an enterprise's corporate citizenship, as represented by its Contribution to Society, Core Business, Social Investment, and Engagement in Public Policy, as well as resources deployed to set about its task. In respect of the three market spaces that demarcate line-haul railways, they hypothesized the existence of some number of underlying longitudinal, or time-dependent, relations among variables associated with positioning line haul railways. The research question was therefore: *Can one identify archetypal railway corporate citizenships within the global setting*?

In respect of urban rail, the market space is somewhat different. A subsidy is generally present, so the responsible authority tends to deal directly with public policy aspects. Furthermore, multiple guided transit modes in a city are not unusual, so urban transit solutions tend to be more complex. The authors therefore hypothesized that positioning the various urban guided transit modes in particular cities reflected attributes of their ever changing economic- and social setting vis-à-vis attributes of the various transit modes. Their research question was therefore *Which country- and city green- and socio-economic attributes and relations fit guided transit solutions to particular cities?*

The two different research questions reflect the essential difference between positioning line haul rail in market spaces where rail can be inherently competitive, versus positioning urban rail in a market space where it may be inherently uncompetitive. Nevertheless, the research design was set up to examine positioning, the action, and fit, the outcome, over time in both situations.

### 3.4 Line haul railways

#### 3.4.1 Variables and their definitions

For the purpose of this chapter, line haul railways transport goods or persons over long distances or between cities. The authors measured the interaction between them and their settings by the following variables that reflected rail's corporate citizenship as well as its genetic technologies and their naturally competitive market spaces. Pending the outcome of statistical analysis, they were placed in the following groups for convenience:

Business Group represents the way in which railways deal with their task (Variables Infrastructure Operator Diversity, Train Operator Diversity, Information Technology Leverage, Total Road Network-, Motorways- and Paved Roads Percentage).

Competitiveness Group represents the way in which railways position themselves to compete in their chosen or allotted market spaces (Variables Research & Development Level, Relative Maximum Axle Load, Relative Maximum Speed, Distributed Power Presence, Heavy Haul Presence, High-speed Intercity Presence, Heavy Intermodal Presence, Motive Power Type, and Attitude to Competition).

Contribution Group describes the railways' contribution to their society (Variables Network Coverage, Transport Task—Freight- and Passenger Traffic Volume, Employment Created, and Initiative Source).

*Networkability Group* describes the extent and gauge of track, and the contiguous network beyond a country's borders (Variables *Narrow-, Standard-, and Broad Gauge; Networkability;* and *Strategic Horizon*).

Ownership Group describes industry structure (Infrastructure-operations Separation, Infrastructure- and Rolling Stock Ownership Locus, and Infrastructure- and Rolling Stock Commitment Horizon).

Society Group describes the railway setting (Variables Country (Name), Economic Freedom, Population, Gross National Income, Physical Size, Determinism, and Climate-change Position).

Sustainability Group describes adaptation and fit (Variables Infrastructure- and Rolling Stock Investment Capacity, Stakeholder Satisfaction Level, Service Reputation, Safety Reputation, Subsidy Influence).

**Time Group** represents passage of time, a prerequisite for longitudinal research (Variable *Calendar Year*).

The operational definitions of the foregoing forty-four variables, plus their measurement scales, exceed the space available in this chapter: Full details may be found at www.railcorpstrat.com/Downloads/feb2008/WCR2008%20Line%20Haul%20Operational%20Definitions.pdf.

### 3.4.2 Identification and selection of cases

Whatever the detail institutional arrangements, national governments typically either own railways, or regulate to varying degrees railways that they do not own, within their jurisdictions. Exceptions do of course exist where railway operations crisscross national boundaries by agreement or directive, as in the North American Free Trade Agreement and the European Union respectively. The authors therefore elected to examine railways by country.

Some railway attributes are independent of track gauge, but the latter does drive inherent competitiveness. There is no evidence that railways on track gauge of less than yard/meter/3′-6′′ are sustainable: The authors therefore excluded data for narrower track gauges, irrespective of the gauge mix in a country. They used the Railways/Train Operators section of Railway Directory to define the set of line haul railways. The above criteria yielded 113 countries. Some of them included suburban and regional passenger operations, which are strictly not line-haul. However, the complementary set of global railway data is the City Railways section of Railway Directory, which the authors used for urban railways: Together these two sections represent the entire global population of railways. On that scale, they were disinclined to niggle about classification of boundary cases.

### 3.4.3 Construction of a database

Observations were predicated on the natural affinity between corporate citizenship and public domain data. Metric data was extracted from Railway Directory (2002-2007), Jane's World Railways (2005-2006, 2007-2008), or the Internet, and non-metric data was extracted by content analysis from International Railway Journal and Railway Gazette International. The detail measurement methodology has been reported by Van der Meulen & Möller (2006, 2008b). The Internet was used liberally to verify data to ensure internal consistency. The longitudinal database, containing one hundred and thirteen line-haul railways by country, populated with data for the six years 2002-2007, for each railway, gave a population (and sample) size of 113 x 6 = 678 cases, and is available at www.railcorpstrat.com/Downloads/WCRR2008%20Line%20Haul%20Database.xls.

### 3.4.4 Statistical analysis

The authors applied multivariate statistical analysis to the database to examine simultaneously relations among multiple variables, and multiple cases. They selected Factor Analysis, to analyze relations among a large number of variables and then to explain them in terms of a smaller number of latent variables, and Cluster Analysis, to reduce a large number of cases to a smaller number of clusters. Statgraphics Centurion XV was used to analyze the data. They culled variables with low communalities that contributed noise rather than insight (i.e. those that appeared in the Operational Definitions file, but which are absent from Table 1), after which the data set arrayed thirty-seven variables and 678 cases, for a total of 25 086 observations. Statistical analysis stops at the Factor Loading Matrix in Table 1, and at the Icicle Plot available at www.railcorpstrat.com/Downloads/WCRR2008%

20Line%20Haul%20Icicle%20plot.xls . Deeper discussion on the statistical intervention is available in Van der Meulen & Möller (2008b). Latent variable- and cluster names, and the following discussion, reflect the authors' interpretation of their knowledge of the variables in the research setting.

### 3.5 Urban guided transit

#### 3.5.1 Enlarging the scope

The authors next applied broadly the same research methodology to urban rail. Although a previous paper (Van der Meulen & Möller, 2008a) passed peer review and revealed a constructive distinction between positioning urban rail in cities in developed countries and in developing countries, they were less than satisfied with its overall predictive validity. Importantly, the research did not address and therefore could not explain the ascent of the rubber-tyred competitors Automated Guided Transit (Vuchic, 2007, p.455), Bus Rapid Transit, and Monorail, against which heavy- and light rail must compete for investment funding. The authors therefore enlarged the scope of their research in the light-axle-load, low-speed market space from urban rail to urban guided transit, by including the modes mentioned below (Van der Meulen & Möller, 2012):

**Heavy Metro** maximally exploits rail's genetic technologies in urban settings. Included are the rubber-tyred systems found on some Paris Métro lines, and similar systems elsewhere: Despite rubber-tyred Supporting and Guiding, their gleaming running rails and wheel flanges indicate that these steel components are not redundant.

**Light Rail and trams** were merged, as neither attains fully controlled right of way. By definition, at 10-11 tonnes/axle, exploitation of rail's Supporting genetic technology is weak. Likewise the built environment constrains Guiding, and typically only a small number of vehicles are coupled: Technically, their inherent competitiveness is marginal.

**Light Metro** takes Light Rail to the next level with fully segregated right-of-way. Light axle load minimizes the cost of elevated structures, while small vehicle profiles minimize the cost of underground works. Driverless operation offers consistent performance and operational flexibility free from the labour issues that disturb manned systems.

**Automated Guided Transit** e.g. VAL and similar, offers consistently higher acceleration and higher retardation than steel-on-steel, although rubber tyres constrain axle load. As for automated Light Metro, light axle load and small vehicle profile minimize the cost of civil works. Automated operation offers consistent, precise high performance.

**Monorail** excels where pre-existing built environment admits only elevated structures with small physical footprint. Transit-grade monorails have converged on rubber-tyred straddle systems. Capacity and performance is comparable to Automated Guided Transit: Once again, automated operation offers consistent, precise high performance.

**Bus Rapid Transit** reputedly rolls out faster at lower cost than comparable rail systems. Its inclusion in guided transit is justified by its narrow concrete runway to support relatively heavy 12-13 tonne axle load, plus emerging virtual guidance by lane tracking systems. Bi-articulated buses even emulate rail's Coupling genetic technology.

| Variable | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | No factor | Factor 8 |
|---|---|---|---|---|---|---|---|---|---|
| Relative Maximum Speed | ***0.78*** | 0.34 | -0.02 | 0.26 | 0.13 | -0.01 | 0.02 | -0.03 | 0.21 |
| Gross National Income | ***0.76*** | 0.03 | 0.22 | 0.22 | 0.36 | -0.01 | 0.15 | -0.01 | 0.03 |
| Motorways | ***0.76*** | 0.10 | 0.14 | 0.15 | 0.12 | 0.01 | 0.01 | -0.26 | 0.11 |
| Information Technology Leverage | ***0.70*** | 0.18 | 0.24 | 0.07 | 0.24 | -0.01 | 0.20 | 0.06 | 0.10 |
| High-speed Intercity Presence | ***0.66*** | 0.28 | 0.03 | -0.02 | 0.08 | -0.10 | 0.04 | -0.14 | 0.35 |
| Country Economic Freedom | ***0.64*** | -0.22 | 0.31 | -0.15 | 0.30 | -0.11 | 0.18 | 0.21 | -0.12 |
| Paved Roads | ***0.63*** | 0.13 | -0.17 | 0.42 | -0.04 | -0.02 | -0.01 | 0.14 | 0.01 |
| Research and Development Level | ***0.56*** | 0.46 | 0.37 | -0.08 | 0.11 | -0.01 | 0.06 | -0.08 | 0.32 |
| Electric Traction | ***0.47*** | 0.42 | -0.19 | 0.33 | 0.24 | 0.03 | -0.02 | 0.27 | -0.04 |
| Network Coverage | 0.23 | ***0.85*** | 0.27 | 0.03 | 0.20 | 0.02 | 0.02 | 0.08 | 0.11 |
| Country Population | -0.05 | ***0.84*** | 0.12 | -0.31 | -0.10 | 0.00 | 0.04 | -0.14 | 0.03 |
| Employee Count | 0.31 | ***0.81*** | -0.02 | 0.28 | -0.02 | 0.04 | -0.02 | 0.18 | 0.08 |
| Total Road Network | 0.21 | ***0.80*** | 0.32 | -0.13 | 0.19 | 0.04 | 0.06 | 0.04 | 0.02 |
| Passenger Traffic Volume | 0.60 | ***0.69*** | 0.00 | 0.05 | 0.16 | -0.03 | 0.04 | 0.15 | 0.07 |
| Country Physical Size | -0.35 | ***0.62*** | 0.40 | -0.32 | -0.01 | 0.01 | -0.01 | 0.03 | 0.12 |
| Freight Traffic Volume | 0.39 | ***0.62*** | 0.35 | 0.27 | 0.16 | 0.01 | 0.02 | 0.24 | 0.15 |
| Heavy Intermodal Presence | 0.03 | 0.09 | ***0.82*** | 0.08 | -0.02 | 0.09 | 0.06 | -0.09 | 0.08 |
| Distributed Power Presence | 0.04 | 0.25 | ***0.76*** | -0.01 | 0.00 | 0.04 | 0.05 | 0.04 | 0.16 |
| Heavy Haul Presence | 0.03 | 0.36 | ***0.73*** | -0.03 | -0.04 | 0.12 | 0.03 | 0.07 | 0.22 |
| Infrastructure Ownership Locus | 0.04 | 0.05 | ***0.67*** | -0.29 | 0.31 | -0.13 | -0.03 | 0.01 | -0.16 |
| Relative Maximum Axle Load | 0.15 | 0.09 | ***0.65*** | 0.47 | 0.13 | 0.01 | -0.17 | 0.22 | 0.18 |
| Infrastructure Operator Diversity | 0.22 | 0.05 | ***0.62*** | 0.12 | -0.11 | 0.01 | 0.03 | -0.23 | -0.13 |
| Narrow Gauge | -0.09 | 0.20 | -0.04 | ***-0.84*** | 0.05 | -0.04 | 0.00 | -0.12 | 0.01 |
| Networkability | 0.29 | 0.04 | 0.00 | ***0.76*** | 0.22 | 0.04 | 0.00 | -0.07 | -0.03 |
| Standard Gauge | 0.33 | 0.30 | 0.24 | ***0.49*** | 0.27 | 0.01 | -0.01 | -0.47 | 0.08 |
| Infrastructure-operations Separation | 0.29 | 0.12 | -0.11 | 0.18 | ***0.81*** | -0.05 | 0.07 | 0.04 | 0.18 |
| Train Operator Diversity | 0.31 | 0.12 | -0.05 | 0.16 | ***0.80*** | -0.04 | 0.12 | -0.01 | 0.16 |
| Rolling Stock Ownership Locus | 0.17 | 0.09 | 0.47 | -0.16 | ***0.68*** | -0.16 | 0.12 | -0.06 | -0.03 |
| Rolling Stock Commitment Horizon | 0.00 | 0.00 | 0.09 | 0.01 | -0.08 | ***0.90*** | -0.01 | 0.02 | -0.02 |
| Infrastructure Commitment Horizon | -0.07 | 0.03 | 0.03 | 0.06 | -0.05 | ***0.90*** | 0.01 | 0.06 | -0.05 |
| Calendar Year | -0.03 | -0.04 | -0.02 | -0.01 | 0.07 | 0.05 | ***0.81*** | -0.03 | 0.05 |
| Climate-change Position | 0.26 | -0.04 | -0.03 | -0.20 | 0.17 | 0.03 | ***0.59*** | 0.23 | -0.08 |
| Rolling Stock Investment Capacity | 0.18 | 0.41 | 0.17 | 0.21 | -0.01 | -0.04 | ***0.48*** | -0.21 | 0.20 |
| Infrastructure Investment Capacity | 0.15 | 0.41 | 0.14 | 0.12 | 0.05 | -0.18 | ***0.46*** | -0.02 | 0.01 |
| Broad Gauge | -0.02 | 0.23 | 0.00 | 0.13 | 0.02 | 0.09 | 0.04 | ***0.88*** | 0.04 |
| Attitude to Competition | 0.16 | 0.13 | 0.05 | 0.13 | 0.07 | -0.17 | 0.14 | 0.03 | ***0.72*** |
| Subsidy Influence | 0.17 | 0.07 | 0.14 | -0.12 | 0.13 | 0.08 | -0.06 | 0.00 | ***0.67*** |

Table 1. The line haul factor loading matrix

### 3.5.2 Variables and their definitions

For the purpose of this chapter, urban guided transit offers mobility to persons within cities. The authors measured the fit between guided transit modes and their settings by the following variables that reflected their corporate citizenship. Pending the outcome of statistical analysis, they were placed in the following groups for convenience:

**Business Group** represents the amount of competition or support that urban guided transit faces in performing its task (variables Bus-, Car-, and Motorcycle Populations; Fuel Price; Motorways, Highways; and Secondary plus Other Roads Distance).

**City Group** describes the close urban setting (variables City Name; Surface Area; Metropolitan Population; Population Growth Rate; World Cities Score; Green Cities Score; and Smart Card Application).

**Contribution Group** describes guided transit's contribution to its society (variables Inaugural Year, Number of Operators, Status of Project, Network Coverage, Rolling Stock Fleet, Passenger Journeys, Number of Routes, Number of Stations, and Employee Count). They were measured separately for each of the urban guided transit modes, namely Heavy Metro, Light Rail and Trams, Light Metro, Automated Guided Transit, Monorail, and Bus Rapid Transit.

**Country group** describes the broad national setting (variables Country Name; Agricultural Land; Agriculture, Value Added; Alternative and Nuclear Energy; $CO_2$ Emissions; Electric Power Consumption; Energy Use; Exports of Goods and Services; Foreign Direct Investment; Forest Area; GDP; GNI per Capita; Gross Capital Formation; High-technology Exports; Imports of Goods and Services; Improved Sanitation Facilities, Urban; Improved Water Source, Urban; Industry, Value Added; Inflation, GDP Deflator; Internet Users; Life Expectancy at Birth; Merchandise Trade; Mobile Cellular Subscriptions; Out-of-pocket Health Expenditure; Population Growth; Population, Total; Public Spending on Education; Services, Value Added; and Surface Area). These variables were selected from World Bank Development Indicators: Themes identified by content analysis of Time magazine for the period July 2009 to June 2010 suggested the twenty-eight indicators actually used out of 298 available.

**Society Group** describes governance and societal attributes of the setting (variables *Economic Freedom Index* and *Income Inequality*).

**Time Group** represents passage of time, a prerequisite for longitudinal research (variable *Calendar Year*).

Operational definitions, measurement scales, and source references, either documentary or uniform resource locator, for each of the abovementioned variables, are available at www.railcorpstrat.com/Downloads/Sep2011/TRA%202012%20Operational%20Definitions.pdf.

To emphasize the difference between the line-haul rail and urban guided transit datasets, note that the latter does not include the Competitiveness-, Networkability-, and Ownership groups of the former. Urban guided transit was researched separately because it occupies a potentially low competitiveness market space; it does not naturally network with other railways and frequently cannot; and it is generally vertically integrated under a public authority, so ownership aspects recede into the background. Furthermore, urban rail responds to authority initiative rather than market initiative as more generally applies to line haul rail: Subsidies are generally present so sustainability is inherently secure. It was therefore not considered necessary to describe and measure subsidy and sustainability.

#### 3.5.3 Identification and selection of cases

The research included the entire population of cities for which sufficient data could be found to populate the database in respect of the transit modes that served them. The City Railways section of Railway Directory (2009-2011) defined a minimum set of urban railways. Cities with one or more of automated guided transit, bus rapid transit, and monorail were added from websites listed under the applicable operational definitions at www.railcorpstrat.com/Downloads/Sep2011/TRA%202012%20Operational%20Definitions.pdf.

The longitudinal research design captured the adaptation dynamics of the global urban transit industry for the three consecutive years 2009-2011. To add a fourth, projected year, 2012, greenfields- and brownfields projects were also included, their various stages of progress measured on a five-point scale (Proposed 1, Feasibility Study 2, In Design 3, Under Construction 4, and Operational 5). The latter value of course also applied to all existing systems for the years 2009-2011.

Where necessary, raw data for agglomerations with more than one guided transit system were adjusted to match them to the population and area that they served. Details of the affected agglomerations accompany the applicable operational definitions.

#### 3.5.4 Construction of a database

The authors constructed a new, dedicated, urban guided transit database using the variables and cases mentioned above. The Microsoft Excel file comprises two complementary data subsets, namely Countries and Cities, and is available at www.railcorpstrat.com/ Downloads/Sep2011/TRA%202012%20Database%20and%20Factor%20Loading%20Matrices.xls. It gathered 330 cities with guided transit in sixty-eight countries, each with four years' data for the period 2009-2012, for a total of 1320 cases. The database thus contains (1320 cases) x (98 variables) = 129 360 observations.

#### 3.5.5 Statistical analysis

In previous research, Van der Meulen & Möller (2008a) had used factor analysis to reduce the initial variables to a smaller set of latent variables. However, the many variables required to describe country settings in sufficient detail tended to unduly dominate some of the latent variables. Therefore, reflecting the research question, exploratory factor analysis was first undertaken separately for Country- and for City descriptive variables, using Statgraphics Centurion XV software. From the initial 36 country variables, it found seven latent variables, namely *Country Stature*, *Economic Development Level*, *Energy Demand Level* and alter ego *Alternative Energy Acceptance*, *Services Contribution to GDP*; *Trade Contribution to GDP*, and *Societal Development Level*. From the initial 60 city variables, it also found seven latent variables, namely *Heavy Metro Position*, *Automated Guided Transit Position*, *Monorail Position*, *Light Metro Position*, *Light Rail Position*, and *Green City Impediments*. The authors named the latent variables in the light of the variables that loaded onto them, within the context of the urban rail industry setting: The separate factor loading matrices are available at www.railcorpstrat.com/ Downloads/Sep2011/TRA%202012%20Database%20and%20Factor%20Loading%20Matrices.xls, while a diagram showing which variables by name loaded onto each Country- and City latent variable is available at www.railcorpstrat.com/Downloads/Sep2011/TRA%202012%20Latent%20Variables%20Diagram.pdf. Thereafter, structural equation modeling using EQS 6.1 software found relations among these latent variables. The path diagram in Figure 2 shows the significant standardized regression coefficients as arrows pointing to the dependent latent variables. Positive correlations indicate support, negative correlations indicate opposition. Interpretation follows in §4.2.1. A detailed report on the structural equation modeling intervention is available on the authors' website at www.railcorpstrat.com/Downloads/ Sep2011/TRA%202012%20SEM% 20Report.pdf .

## 4. Findings

### 4.1 Line haul railways

#### 4.1.1 The factor loading matrix

Exploratory factor analysis extracted seven latent variables plus one single variable, shown in boldface italics in Table 1: They represent activities by which railways position their corporate citizenship in respect of their core business. Interpretation of the latent variables follows, with a reminder that §4.1 does not address urban rail: The latter will be addressed in §4.2.

### 4.1.2 Positioning passenger rail

The variables Relative Maximum Speed, Gross National Income, Motorways Percentage, Information Technology Leverage, High-speed Intercity Presence, Economic Freedom, Paved Roads Percentage, R&D Level, and Electric Traction, all loaded positively onto the latent variable Positioning Passenger Rail. Their effects are therefore mutually supportive. Relative Maximum Speed anchors Positioning Passenger Rail. Based on rail's Guiding genetic technology, it enabled the railway renaissance to meet passengers' high-speed expectations on dedicated high speed lines. It even created new markets, such as China's high-speed overnight electric multiple unit services, which extend their reach beyond the constraints of a working day. Such innovations facilitate rail's contribution beyond peak oil, when high fuel prices could curb air travel.

Significantly, high national income and economic freedom associate concurrently with motorways and paved roads, and with high-technology passenger railway attributes, i.e. high relative maximum speed, information technology leverage, high-speed intercity presence, electric traction, and high R&D level. Evidently road competition stimulates high-speed railways, which require high technology to remain competitive. It is therefore noteworthy that the R&D function has migrated from railway operators to industry: Emerging brand- and model competition among system integrators is comparable to that between Airbus and Boeing in the aircraft industry.

### 4.1.3 Exploiting opportunities

The variables Network Coverage, Country Population, Employment Creation, Total Road Network, Passenger Traffic Volume, Country Physical Size, and Freight Traffic Volume all loaded positively onto the latent variable Exploiting Opportunities. It suggested competitive and cooperative symbiotic relations among a country's transport infrastructure (Network Coverage and Total Road Network), its stature (Population and Physical Size), and rail's contribution to the economy (Employment Created, Passenger Traffic Volume, and Freight Traffic Volume). It demarcated the space in which Enlightened-, Progressive-, and Assertive Railways actualize their corporate citizenship as discussed in §4.1.10.

Large countries, or smaller countries with large contiguous networks beyond their borders, are prime railway locations. Notwithstanding that, the inherently competitive applications Heavy Haul, High-speed Intercity, and Heavy Intermodal, do not load on this latent variable: *Positioning Passenger Rail*, *Exploiting Opportunities*, and *Positioning Freight Rail*, therefore present mutually exclusive corporate citizenship positioning opportunities for railways.

Real world examples reflect both actualization and absence thereof. Large developing countries with high rail traffic volumes, such as Brazil, China, India and Russia are substantially redeveloping their railways to increase their contributions to their respective national transport tasks. Europe's high-speed railways, and North America's heavy freight railways, illustrate strong performance in particular market spaces. China's Freight- and Passenger Dedicated Lines, as well as India's Freight Dedicated Corridors and its emerging interest in high speed, illustrate ability to position railways in separate market spaces where opportunities are sufficient. By contrast, Europe has the population, area, and traffic to support substantial rail freight presence, yet substantial freight volume continues to move by road, for reasons that will become clear in the next section.

#### 4.1.4 Positioning freight rail

The variables Heavy Intermodal Presence, Distributed Power Presence, Heavy Haul Presence, Infrastructure Ownership Locus, Relative Maximum Axle Load, and Infrastructure Operator Diversity all loaded positively onto the latent variable Positioning Freight Rail. It suggested that competitive freight railways, manifested by heavy intermodal-, heavy haul-, and distributed power presence, associated with high relative maximum axle load, privately owned infrastructure, and competing infrastructure operators. Examples are preservation of competition among railways in the North American Free Trade Agreement (Canada, Mexico, and the United States), and competition among parallel iron ore railways in Australia's Pilbara and Québec's North Shore.

Highly competitive and sustainable positioning of freight railways is evident in the member countries of the International Heavy Haul Association (Australia, Brazil, Canada, China, India, Russia, South Africa, Sweden-Norway, and the United States); the double stack container trains of the North American Free Trade Agreement and Australia, China, India, and Saudi Arabia; and the emerging dedicated rail freight corridors in China and India (Dedicated Freight, 2010). By contrast, the constituents of *Positioning Freight Rail* are absent in Europe: Indeed the notion of a rail freight dedicated network has already been rejected (European Freight, 2008). It is therefore unsurprising that European rail freight struggles to compete with road freight (Heydenreich & Lehrmann, 2010), and it will be interesting to observe whether the evolving rail freight network (Jackson, 2011a) will turn the tide.

Interestingly, while both freight- and passenger railways use information technology, the latent variable *Information Technology Leverage* loaded only onto *Positioning Passenger Rail*, but is absent from *Positioning Freight Rail*. This suggested that freight rail's ideal corporate citizenship is that of competent carrier, and that logistics management belongs elsewhere. It supports the assertion that few railways have had the management capability to integrate acquired logistics companies efficiently and effectively (Reinhold & Gasparic, 2009).

#### 4.1.5 Exploring horizons

The variables *Narrow Gauge* (negative), *Networkability*, and *Standard Gauge* loaded onto *Exploring Horizons*. The signs indicated that Narrow Gauge opposed networkability, while Standard Gauge reinforced it. Standard gauge track allows network- and train operators to explore ever-wider horizons. This is evident in several initiatives to connect the standard gauge networks of China, Europe and the Middle East. Note from Table 1 that Broad Gauge did not load onto any latent variable: From a networkability perspective it is an independent variable, like the real world examples.

By contrast, many narrow gauge railways must forego participation in long-haul business. While they have achieved modest success in heavy haul, arguably the only viable post-renaissance narrow gauge application, heavy haul railways are usually short, and do not naturally network with one another. Queensland's are interesting—approximately parallel systems from multiple coalmines to several ports. South Africa's are on opposite sides of the continent. Brazil's Estrada de Ferro Vitória a Minas is essentially a single purpose operation. None of them establish a basis for continental scale networkability.

### 4.1.6 Pursuing competition

The variables *Infrastructure-operations Separation*, *Train Operator Diversity*, and *Rolling Stock Ownership Locus* all loaded positively onto the latent variable *Pursuing Competition*. Vertical separation, multiple train operators, and private rolling stock ownership constitute the basis of liberal on-rail competition with open access to infrastructure, which has emerged notably in the European Union and Australia. Latent variables are mutually exclusive: *Pursuing Competition* introduces competition in the market in settings that are physically unable or politically unwilling to support competition for the market among multiple infrastructure operators as in *Positioning Freight Rail*. Whether vertical separation benefits the railway industry and its stakeholders has been debated since Sweden first implemented it in 1987: There are many arguments for and against (Jackson, 2011b). However, *Pursuing Competition* is only one of a suite of applicable corporate citizenship latent variables. It is evident that in instances where vertical separation has not worked as expected, that inherent competitiveness has also fallen short. Consider, for example, that open access has met EU expectations for passenger operators, but missed them for freight, while the freight-oriented Australian Rail Track Corporation network has met expectations: In Europe, passenger rail positioning is inherently competitive, but not so freight, while in Australia freight rail positioning is inherently competitive.

### 4.1.7 Aligning assets

The variables *Rolling Stock Commitment Horizon* and *Infrastructure Commitment Horizon* both loaded positively onto the latent variable *Aligning Assets*. It suggested aligning infrastructure and rolling stock investment for appropriate periods, to avoid competitiveness being eroded by obsolescence. Without competition to demand ever-increasing performance, railways are not incentivized to replace existing assets with higher performing assets. If they do not routinely raise the bar of their genetic technologies by increasing axle load, speed, and/or train length, it becomes difficult to justify new- or upgraded assets. Railways then contemplate refurbishment and rehabilitation, often leading indicators of unsustainability. Sometimes they deploy new rolling stock on existing infrastructure—a palliative that may fail to realize the new trains' full performance potential. The countervailing value of private ownership emerged in *Positioning Freight Rail* and *Pursuing Competition*. Sustainable private enterprise works assets hard or works them out.

### 4.1.8 Greening the image

The variables Calendar Year, Climate-change Position, Rolling Stock Investment Capacity, and Infrastructure Investment Capacity all loaded positively onto the latent variable Greening the Image. The anchor roles of Calendar Year and Climate-change Position suggested that actors outside rather than inside the railway industry were actually setting the pace of greening.

*Greening the Image* reinforces *Positioning Passenger Rail* and *Positioning Freight Rail*, but the benefits of a greener but uncompetitive mode are insignificant: The real challenge is to increase rail's competitiveness and thereby shift traffic to a greener mode by ecological adaptation. Rail's green credentials are undisputed: High speed railways accept steeper gradients that minimize environmental impact; heavy axle load attracts traffic from road to rail. State-of-the-art high-speed trains, and hybrid diesel locomotives with intelligent driving aids, reduce energy consumption per passenger journey and per ton-km. However, high speed and heavy axle load are uncomfortable bedfellows: Hence, in principle and to the extent that it is viable, physically separate dedicated freight- and passenger infrastructure promotes greening.

Passenger trains tend to be lighter and more frequent, so recovery of their regenerated braking energy poses the lesser challenge. However, *Positioning Freight Rail* promotes longer and heavier trains, so recovery of their regenerated braking energy poses the greater challenge. In particular, many heavy haul railways descend from mine to port, and several are potentially net energy generators over the empty-loaded round trip (Van der Meulen, 2010). Maximum regenerative braking should be the point of departure. However, while on-board battery storage on hybrid diesel locomotives might be worthwhile, such systems cannot deal with a net surplus. Furthermore, regenerating all instantaneously surplus energy requires locomotives to control the same load on downgrades that they haul on upgrades. While this requires symmetrical up- and downgrades, many heavy haul routes have asymmetrical grades that oblige loaded trains to dissipate potential energy through dynamic or friction braking on descending grades, which reduces sustainability. Even if gradients supported full regenerative braking, matching a three phase supply grid to single phase overhead traction supply is the next challenge. This introduces the concept of smart grids and open systems, which one hears about, but not yet in railway traction.

### 4.1.9 Constraining downside

The variables *Attitude to Competition* and *Subsidy Influence* both loaded positively onto the latent variable *Constraining Downside*. It suggested that encouraging competition, while applying subsidy to influence the beneficiary, could constrain downside in adverse situations. A country's railway industry is only as competitive as government will allow or encourage. Where appropriate, governments traditionally subsidized railways directly, but their role is changing. Instead of simply assuming responsibility for runaway expenses, they now tend to recognize railways as worthy corporate citizens that they influence through instruments such as investing to raise competitiveness, public-private partnerships, tax incentives, and so on. Two examples are the United States' Passenger Rail Improvement and Investment Act of 2008 and its American Recovery and Reinvestment Act of 2009, which provided seed investment for high speed rail, to be matched by state funding for operational support (Boardman, 2010).

### 4.1.10 Cluster analysis

Whereas factor analysis finds relations among the variables in a database, the multivariate procedure cluster analysis finds relations among the cases in a database, countries in this instance. Applying cluster analysis, to the 2007 data only, reduced the 113 countries in the population to five clusters, which the authors named Fortuitous Railways, Insecure Railways, Enlightened Railways, Progressive Railways, and the quasi-cluster Assertive Railways. The procedure maximizes within-cluster homogeneity and maximizes between-cluster heterogeneity. Mentioning cluster members by name is restricted here, because some ups and downs have occurred over time. Full details are nevertheless available in Van der Meulen & Möller (2008a), while discussion of key issues follows.

**Fortuitous Railways** clustered twenty medium-sized countries. Their *Relative Maximum Axle Load* was the only high attribute, the rest rating either moderate or low. They were standard- or broad gauge state railways, redeemed by axle load that happened to be sufficiently heavy to support basic competitiveness. The authors named them *Fortuitous Railways* because they lacked attributes with which to project a distinctive corporate citizenship. Demonstrating that railway renaissance is advancing, several Middle Eastern countries, which are making substantial railway investment, have probably moved from the Fortuitous cluster to one of the Enlightened-, Progressive-, or Assertive clusters.

**Insecure Railways** clustered fifty-four medium-sized countries. It had no high attributes, had generally moderate attributes, and had low competitiveness, i.e. low maximum axle load and -speed; no distributed power-, heavy haul-, or heavy intermodal presence; predominantly narrow track gauge and low networkability. The authors named them *Insecure Railways* because they failed to exploit any of rail's strengths, and hence could be vulnerable to external threats or withdrawal of political support. Many have colonial origins, which possibly denied them wherewithal to actualize the positioning latent variables detailed in §4.1.2 to §4.1.9: In countries where line haul railways are justified at all, rebalancing of global power from developed- to developing countries could well redress this legacy, one way or another.

New Zealand, which returned full circle during the present research, characterizes the Insecure Railways cluster. Privatized in 1995, it soon fell short of expectations, running down assets along the way (New Zealand, 2008). The government repurchased the infrastructure in 2004, and the operations in 2008, thereby re-nationalizing railways. The events are unsurprising: Narrow track gauge on an island, and other handicaps, precluded it from *Positioning Passenger Rail*, *Exploiting Opportunities*, *Positioning Freight Rail*, or *Exploring Horizons*, not to mention the other positioning latent variables. Government's skepticism regarding the role of rail (KiwiRail debates, 2009) appeared justified.

**Enlightened Railways** clustered twenty small countries, mainly European Union members, -candidates, or -applicants, plus South Korea. They rated high on relative maximum axle load and -maximum speed, electric traction, networkability, information technology leverage; paved roads, economic freedom, and gross national income. All other variables were moderate, while freight technology was low—no distributed power-, heavy haul-, or heavy intermodal presence. The name reflected their enlightened approach to rail reform by encouraging competitive railway positioning per the latent variable *Pursuing Competition*.

**Progressive Railways** clustered France, Italy, Spain, Japan, Germany, and the United Kingdom. They rated high on R&D level, relative maximum speed, high-speed intercity presence, electric traction, attitude to competition, standard gauge, train operator diversity, information technology leverage, total road network, motorways, network coverage, freight traffic volume, passenger traffic volume, employee count, economic freedom, population, gross national income, infrastructure investment capacity, and rolling stock investment capacity. These attributes supported competitive high-speed passenger services in developed economies, while freight technology rated low—distributed power, heavy haul, and heavy intermodal were absent. All other attributes rated moderate. However, state involvement was still present, and infrastructure operator diversity was essentially absent, hence actualization of the full spectrum of positioning latent variables was circumscribed. The name speaks for itself.

The Enlightened- and Progressive clusters needed to position their rail freight for competitiveness. Setting aside Japan and South Korea, where respectively geography and present politics constrain networkability, this reduces to a European matter. The uncertain outlook of Europe's rail freight (Reinhold & Gasparic, 2009) is not unexpected. The latent variables *Positioning Passenger Rail* and *Positioning Freight Rail* indicate that positioning freight- and passenger rail are distinct corporate citizenship activities: To date, these clusters have hardly actualized *Positioning Freight Rail*. The prospect of heavy freight that will predominantly run on a dedicated Trans-European Freight Network (European Rail, 2007) is therefore encouraging. If successful, the notion of general freight transport increasingly being undertaken by relatively light containerized trains that resemble passenger trains in terms of loads exerted on the infrastructure, average speed, reliability and performance, should be expected to rearrange the latent variable *Positioning Freight Rail*, and possibly other latent variables too.

**Assertive Railways** formed a quasi-cluster, i.e. statistically independent railways that are icicle plot neighbours but did not actually cluster. They are not insignificant railways, as the following two selected above-the-median examples illustrate.

*The United States* rated high on research and development level, relative maximum axle load and -speed; distributed power-, high-speed intercity-, and heavy intermodal presence; attitude to competition; standard gauge; infrastructure operator diversity; information technology leverage; total road network; infrastructure- and rolling stock ownership locus; network coverage; freight traffic volume; economic freedom; gross national income; physical size; infrastructure investment capacity; and subsidy influence. The US' competitive private enterprise and technology leadership have established a formidable freight railway corporate citizenship. Trucking is both a tough competitor and a symbiotic supporter, mainly in the intermodal market space. However, its comparatively high rail freight market share, one of the highest in the world, has moved shippers to seek increased competition and strengthened federal oversight (Kimes, 2011). Comparing European and US outcomes to freight and passenger separation challenges in terms of *Positioning Passenger Rail* and *Positioning Freight Rail*, note that Europe's is generally a *minus freight* outcome; the US' is generally a *minus passenger* outcome. Both actively seek to introduce the missing positioning latent variable. However, as mentioned under *Progressive Railways* above, Europe's rail freight still needs to demonstrate turnaround. Noting that the US is the only country with strong underpinning for the latent variable *Constraining Downside*, its recent modest stimulus funding (High speed, 2009) was on cue, but the quantum seemed unlikely to create dedicated passenger corridors, while admission of 145km/h intercity trains on conventional mixed-traffic routes might have diluted its potential impact. Subsequent progress has been ambivalent (Six-year high, 2011; Governor halts, 2011), with only California committing to commence construction of a 350km/h system in 2012 (California High, 2011). Evidently the latent variables *Positioning Passenger Rail* and *Positioning Freight Rail* are so robustly rooted in rail's genetic technologies that they do not readily yield to political expediency.

*China* rated high on R&D level, relative maximum speed; distributed power-, high-speed intercity-, and heavy intermodal presence; electric traction; attitude to competition; motorways; paved roads; freight traffic volume; employee count; population; physical size; and infrastructure- and rolling stock investment capacity. Its rapid network growth and technological development, and its immense railway corporate citizenship, have drawn global admiration. Initially, it mixed high-speed passenger and freight on an upgraded, network: For a country eagerly actualizing the latent variable *Exploiting Opportunities*, that outcome aligned uneasily with the latent variables *Positioning Passenger Rail* and *Positioning Freight Rail*. However, in recent times it has vindicated the research findings by rapid expansion actualizing *Positioning Passenger Rail* through the emerging Passenger Dedicated Line (PDL) network (Li-ren & Li, 2010), and *Positioning Freight Rail* through a second heavy haul line to augment the 400 million-tonnes-per-year Daqin line (Second heavy, 2009) with an ultimate objective of a 10000km heavy haul network. Heavy axle load is absent from the variables listed above, but is set to increase to 30 tonnes on heavy haul lines (Seizing the, 2009). China's actualization of *Positioning Passenger Rail* and *Positioning Freight Rail* has positioned it as world's busiest heavy haul railway, and operates the first trains in the world timetabled to run at an average of over 300km/h (China's star, 2010).

To do justice to members of the Assertive Railways cluster requires more space than the page limit of this chapter. Because they are a quasi-cluster and not a true cluster, it is not possible to discuss them in generic terms as has been done for the Fortuitous-, Insecure-, Enlightened-, and Progressive Railways clusters. Instead each one requires discussion of its individual attributes. Further examples may be therefore be found in Van der Meulen & Möller (2008b).

### 4.2 Urban guided transit

#### 4.2.1 The path diagram

Section 4.1 has interpreted the statistical findings of rail's three inherently competitive market spaces. Next, in urban transit language, §4.2.2 to §4.2.10 will interpret the path diagram in Fig. 2 with respect to rail's inherently weak market space. More detail is available in Van der Meulen & Möller (2012).

#### 4.2.2 Green city impediments

The latent variable *Green City Impediments* mediated between the country setting and urban rail solutions in particular cities. Noting carefully the relative directions of their signs, and that double negative is positive, the latent variables *Societal Development Level* (-0.389), *Alternative Energy Acceptance* (-0.256), *Economic Development Level* (-0.150), and *Services Contribution to GDP* (-0.149), opposed it, while *Country Stature* (0.075) supported it. From the perspective of populous, large countries that feature urban guided transit, larger is evidently not greener: Rather, positive societal development, minus alternative energy acceptance, minus economic development, and minus services contribution, associate with green cities.

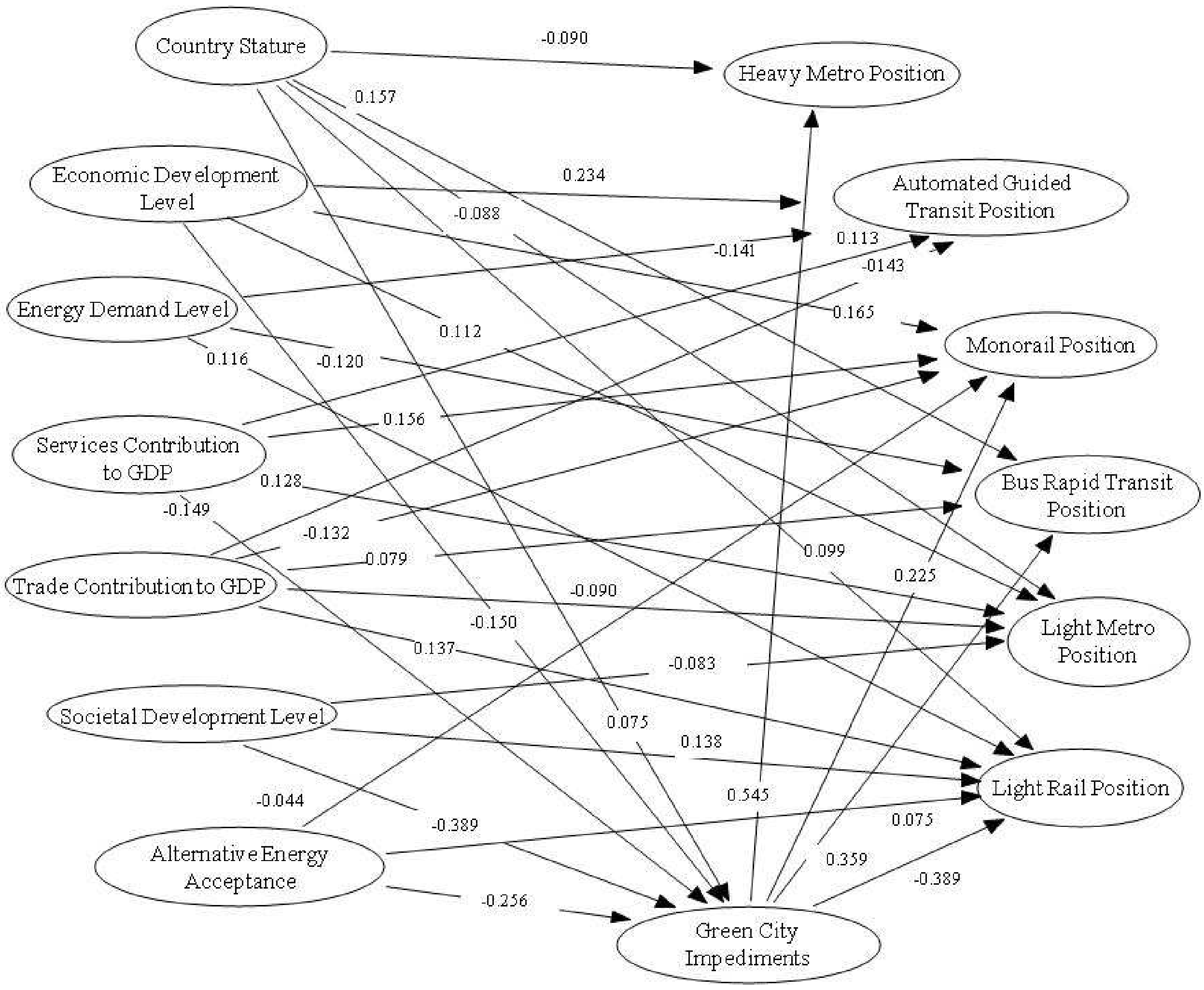


Fig. 2. Path Diagram showing standardized regression coefficients as arrows pointing to dependent latent variables

#### 4.2.3 Positioning heavy metro

*Green City Impediments* (0.545) supported the latent variable *Heavy Metro Positioning*; *Country Stature* (-0.090) opposed it. The authors interpreted these relations to mean that the variables that impede green cities, namely *Area*, *Population*, and *Population Growth*, also drive the Heavy Metro mode, rather than that Heavy Metro is not green. The road network- and vehicle population variables loaded onto *Country Stature*: Its negative sign thus suggests that countries that enjoy advanced development might ultimately come to oppose Heavy Metro. Alternatively, one could interpret the relation to mean that large cities with large populations and high population growth might find Heavy Metro out of reach, and opt for Bus Rapid Transit instead. To emphasize its pre-eminence among other urban guided transit modes, note that *Heavy Metro Position* attracted loading by the variables *World Cities Score* and *Smart Card Application*. It appears that, until the present, leading cities considered Heavy Metro to be a must have feature.

### 4.2.4 Positioning automated guided transit

Economic Development Level (0.234) and Services Contribution to GDP (0.113) supported the latent variable Automated Guided Transit Positioning; Trade Contribution to GDP (-0.143) and Energy Demand Level (-0.141) opposed it. The authors interpreted this to mean that Automated Guided Transit fitted into developed, service economies, together with Monorail and Light Metro. See also §4.2.9 and §4.2.10 for additional interpretation.

### 4.2.5 Positioning monorail

Green City Impediments (0.225), Economic Development Level (0.165), and Services Contribution to GDP (0.156) supported the latent variable Monorail Positioning; Trade Contribution to GDP (-0.132) and Alternative Energy Acceptance (-0.044) opposed it. As for the Heavy Metro mode, the variables that impede green cities also drive the Monorail mode. Like Automated Guided Transit and Light Metro, Monorail fitted into developed, service economies. See also §4.2.9 and §4.2.10 for additional interpretation.

### 4.2.6 Positioning bus rapid transit

*Green City Impediments* (0.359), *Country Stature* (0.157), and *Trade Contribution to GDP* (0.079) supported the latent variable *Bus Rapid Transit Positioning*; *Energy Demand Level* (-0.120) opposed it. As for the Heavy Metro- and Monorail modes, the variables that impede green cities also drive Bus Rapid Transit. However, noting that *Country Stature* supports Bus Rapid Transit, one would naturally expect to find Bus Rapid Transit in large, rapidly growing cities, such as Jinan in China. See also §4.2.9 and §4.2.10 for additional interpretation.

### 4.2.7 Positioning light metro

Services Contribution to GDP (0.128) and Economic Development Level (0.112) supported the latent variable Light Metro Positioning; Trade Contribution to GDP (-0.090), Country Stature (-0.088), and Societal Development Level (-0.083) opposed it. Like Automated Guided Transit and Monorail, the Light Metro mode fits into developed, service economies, although not yet assertively due to its comparatively recent emergence. Opposition by Country Stature suggested that it fits well into smallish, more intimate cities. Opposition by Societal Developmental Level appeared counter intuitive, but it might indicate that high-capacity public transport is unwanted in such cities. See also §4.2.10 for additional interpretation.

### 4.2.8 Positioning light rail

Societal Development Level (0.138), Trade Contribution to GDP (0.137), Energy Demand Level (0.116), Country Stature (0.099), and Alternative Energy Acceptance (0.075) supported the latent variable Light Rail Positioning; Green City Impediments (-0.389) opposed it. The double negative (minus impediments) indicated that Light Rail actually supported green cities: It was the only urban guided transit mode for which all correlation coefficients that pointed to it were found to mutually reinforce its fit in a city.

#### 4.2.9 Energy awareness

Either *Energy Demand Level* or *Alternative Energy Acceptance* opposed each of the three rubber-tyred modes, Automated Guided Transit, Monorail, and Bus Rapid Transit. They have higher rolling resistance than steel tyred modes, and all things being equal, also higher energy consumption. Evidently, countries that already had high energy demand, and those that accepted alternative energy, were sensitive to unduly increasing their energy demand. By contrast, *Energy Demand Level* and *Alternative Energy Acceptance* both supported Light Rail: Its greenness therefore offsets its marginal inherent competitiveness.

#### 4.2.10 Trade awareness

The latent variable *Trade Contribution to GDP* opposed the higher technology automated modes, i.e. Automated Guided Transit, Monorail, and Light Metro; whereas it supported the lower-technology Bus Rapid Transit and Light Rail. Evidently there was an inverse relationship between technology and trade, which would manifest itself as the conservative tactic of initially deploying advanced technology close to its origin or support base.

## 5. Discussion

### 5.1 Positioning passenger rail

The latent variable *Positioning Passenger Rail* has become a prominent function of railway corporate citizenship. High speed rail has established itself as a formidable competitor against airlines in most developed countries. It is also considered to stimulate developing countries, and has become an aspirational objective in newly industrialized countries. Countries such as Brazil, India, Iran, Morocco, Russia, Thailand, and Turkey, already have, or are committed to acquiring high speed rail systems. China sees it as an environmentally responsible mode for journeys up to six hours. Dedicated passenger corridors have become the norm. China's 2010 High Speed Rail Conference sealed high speed as the way to do long-haul passenger rail for the future. *Positioning Passenger Rail* is a useful indicator of which variables should be within the high speed rail frame of reference.

### 5.2 Positioning freight rail

The latent variable *Positioning Freight Rail* has also become a prominent function of railway corporate citizenship. Heavy Haul is the prime solution for moving high volumes of bulk commodities, as is Heavy Intermodal for moving high volumes of containers long distances overland. Dedicated freight corridors have emerged in countries such as China and India, which have the traffic volumes to justify them. Aside from the essential technical attributes of heavy freight railways, the latent variable has highlighted the fundamental role of competition in freight transport, getting right down to private infrastructure ownership and then pitting competing railways against each other. Freight transport is generally a ruthless, low margin, and very competitive market, not well suited to a government player. It is therefore difficult to see why some governments continue to see freight transport as a core government function (Amos, 2006). Looking ahead to §5.4, it is evident that not all rail reforms have faced this issue.

### 5.3 Positioning urban rail

The findings on urban rail positioning have provided interesting insights into ecological adaptation in the light-axle-load low-speed market space. While Heavy Metro remains unchallenged at the highest capacity level, it appears that rubber-tyred guided transit modes have breached rail's pre-eminent status. One would therefore expect Light Rail, and by extension Light Metro, to be more vulnerable to competition from rubber-tyred systems by virtue of their low axle load. Notwithstanding that potential weakness, their good green credentials are attractive to smaller cities that value inherent environmental friendliness over the expediency of simply moving people under the weight of popular demand. Automated Guided Transit, Monorail, and Bus Rapid Transit do however seem well positioned to drive a wedge between the heavy- and light poles of urban rail. From there, one should expect them to win in medium cities such as Automated Guided Transit in Lille in France, and Bus Rapid Transit in Jinan in China.

### 5.4 The role of rail reform

This chapter commenced with observing differences among railways. In the context of this Section, variables in the Ownership Group and the Society Group were particularly relevant. Having researched and explained the modalities of railway positioning, and finding that renaissance is an achievable aspiration, it is now apposite to return to the original differences. Why do the Fortuitous and Insecure clusters still exist? Note that countries that have advanced have in many instances liberalized their institutional arrangements, or are in process of doing so. There are of course exceptions, such as China and India, but the weight of evidence from the Fortuitous and Insecure clusters, the majority of whose members are state-owned, suggests that unless state ownership results in operational efficiency and capital investment that positions railways for competitiveness and sustainability, it is an impediment rather than a facilitator.

Vertical integration versus vertical separation and open access has been another persistent reform issue. It is helpful to benchmark positions against the United States industry model. Interoperability is near seamless, and continental-scale haul distances transcend geographically-defined railroad franchises. Extensive leasing separates rolling stock ownership from liveries and reporting marks. Symbiotic trackage rights give access to infrastructure of others. Unrestricted interchange of 32.4 tonne-per-axle vehicles give the lie to assertions that heavy haul and vertical separation cannot co-exist. All told, US railroads are effectively infrastructure managers, not unlike those in Europe, and for purpose of this argument its actual vertical integration is less than what the name suggests. Note nevertheless critical differences regarding private infrastructure ownership, and extensive though not ubiquitous competition between parallel railroads. While shippers will attest that it is not a perfect market, it does suggest that anything less free is more constraining than it need be.

Note that this Section applies to line haul railways only. Urban rail is generally a local government responsibility, which institutional arrangements are appropriate.

## 6. Future research

The research journey has revealed complex relations that underlie railway positioning. As the renaissance progresses, railways migrate to clusters that exhibit more advanced corporate citizenship. However, the adaptation process has fragmented the industry into more competing entities, whose data become less accessible due to commercial sensitivities, in many instances providing no more than minimum legal requirements. The present research was fortunately conducted in a window of opportunity that has all but closed in countries whose line-haul railways have advanced the furthest. Due to the public nature of urban rail, that has not yet happened to its data. It would therefore be difficult to replicate the line haul research with current data. It might even be pointless because, having identified the Fortuitous and Insecure clusters and the determinants of their position, there is arguably no more insight to extract. It would be more productive to learn from the Enlightened, Progressive, and Assertive railways. However, that would reduce the population size by 65%, which would require a new research design.

## 7. Conclusions

The research stream described in this chapter has developed a statistical research approach to global railway positioning, both line haul- and urban, from a corporate citizenship perspective.

In supporting the hypothesized existence of some number of underlying longitudinal, or time-dependent, relations among variables associated with positioning line haul railways, the research has found the eight latent variables *Positioning Passenger Rail*, *Exploiting Opportunities*, *Positioning Freight Rail*, *Exploring Horizons*, *Pursuing Competition*, *Aligning Assets*, *Greening the Image*, and *Constraining Downside*. These latent variables represent actualization of a railway's corporate citizenship with respect to its core business.

In supporting the hypothesis that positioning the various urban guided transit modes in particular cities reflected attributes of their ever changing socio-economic setting vis-à-vis attributes of the various transit modes, the research found the seven country-related latent variables *Country Stature*, *Economic Development Level*, *Energy Demand Level, Services Contribution to GDP*; *Trade Contribution to GDP*, *Societal Development Level*, and *Alternative Energy Acceptance*, and the seven city-related latent variables *Heavy Metro Position*, *Automated Guided Transit Position*, *Monorail Position*, *Light Metro Position*, *Light Rail Position*, and *Green City Impediments*. The relations found between country- and city latent variables were presented in a path diagram that shows regression coefficients from the socio-economic setting to particular guided transit solutions. It represents the positioning of those solutions with respect to their country and city settings.

The foregoing outcome has developed grounded understanding of railway positioning in all four of rail's market spaces, the three in which it is inherently competitive, namely

Heavy Haul, High-speed Intercity, and Heavy Intermodal, as well as the market space in which it is potentially weak, namely Urban Rail. This has made it possible to understand and to predict with reasonable certainty what will be the outcome of a particular railway positioning intervention, or to analyse a situation and design appropriate remedial intervention.

Like the top-down research design, its application is primarily top down. As examples, the authors have used it as a framework for national rail development strategy, national railway economic regulation, national railway policy, rail's contribution to national transport planning, national passenger commuter rail technology, development of strategic rail plans at provincial- and regional levels, high level positioning of major rail corridors, and conceptual design of a regional rail corridor. In short, it provides high-level insight with which to assess the viability of policy options.

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## 9. References

Amos, P. (2006). *Railway reform: Vertical integration and separation*, World Bank, Accessed 2011-10-16, Available from: www.euromedtransport.org/En/image.php?id=1129

Boardman, J. (2010). Fast-tracking the future, *Railway Gazette International*, Vol.166, No.7, pp.44-47

California High-speed Rail Authority (2011). *Chairman issues statement*, Accessed 2011-10-16, Available from: www.cahighspeedrail.ca.gov/10102011-leg.aspx

Dedicated Freight Corridor loan (2010). *Railway Gazette International*, Vol.166, No.9, p.7

European Freight and Logistics Leaders Forum (2008). *NEWOPERA The rail freight dedicated lines concept final report*, Author, ISBN 978-3-00-0275700-1, Brussels, Belgium, p.157

European Rail Research Advisory Council (2007). *Strategic Rail Research Agenda 2020*, Brussels, Belgium, p.13

Friedman, T.L. (2006). *The world is flat*, Penguin, ISBN 978-0-141-03489-8, London, England

Governor halts Florida high speed project (2011). *Railway Gazette International*, Vol.167, No.3, p.10

Heydenreich, T. & Lehrmann, M. (2010). How to save wagonload freight, *Railway Gazette International*, Vol.166, No.9. pp.126, 128, 130

High speed scramble (2009). *Railway Gazette International*, Vol.165, No.8, p.19

Jackson, C. (2010). China's star blazes a high speed trail, *Railway Gazette International*, Vol.166, No.2, p.3

Jackson, C. (2011a), Rail freight network starts to evolve, *Railway Gazette International*, Vol.167, No.3, pp.48-52

Jackson, C. (2011b). Does separation really work? *Railway Gazette International*, Vol.167, No.6, p.3

Jane's World Railways (2005-2006, 2007-2008). Englewood, Colorado, United States of America, IHS

Japanese Railway Engineering (1964). *Special Issue – New Tokaido Line*, Vol.5, No.4, pp.1-56

Kimes, M (2011). Showdown on the railroad, *Fortune*, Vol.164, No. 5. pp.81-88

KiwiRail debates the way forward (2009). *Railway Gazette International*, Vol.165, No.11, pp39-42

Levinson, M. (2006). *The box*, pp. 261-262, Princeton University, ISBN 978-0-691-12324-0, Princeton, New Jersey, United States of America

Li-ren, D. & Li, D. (2010). Planning the world's biggest high speed network, *Railway Gazette International*, Vol.166, No.12, pp.41-46

New Zealand nationalizes (2008). *Railway Gazette International*, Vol.164, No.6, p.344

Railway Directory (2002-2007, 2009-2012). Hamburg, Germany, DVV Media Group

Reinhold, T. & Gasparic, C. (2009). Facing the moment of truth, *Railway Gazette International*, Vol.165, No.12, pp. 24-27

Second heavy haul line gears up to handle more coal (2009). *Railway Gazette International*, Vol.165, No.9, p.40

Seizing the opportunity (2009). *Railway Gazette International*, Vol.165, No.9, pp.31-36

Six-year high speed plan announced (2011). *Railway Gazette International*, Vol.167, No.3, p.10

Tracks to carry the big mineral hauls (1972). *Railway Gazette International*, Vol.128, No.2, pp.49-53

Van der Meulen, R.D. (1994). Some relations of corporate strategy content to organizational environment by comparing a capital-intensive service industry across selected societies, Doctoral dissertation, University of Pretoria, *Dissertation Abstracts International*, Vol.55, No.5, p.1336-A.

Van der Meulen, R.D. (2010). Heavy haul railway electrification—experiences and prospects, *Proceedings of the Joint Rail Conference*, JRC2010-36151 [CD-ROM]. Urbana, Illinois, United States of America, ASME, IEEE, ASCE, TRB, AREMA, and University of Illinois.

Van der Meulen, R.D. & Möller, L.C. (2006). Railway globalization: Leveraging insight from developed- into developing regions. *Proceedings of the 7th World Congress on Railway Research* [CD-ROM], Montréal, Québec, Canada

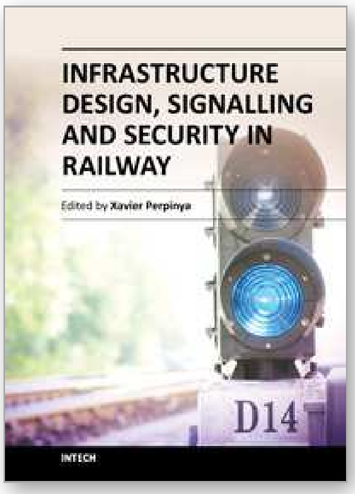
Van der Meulen, R.D. & Möller, L.C. (2008a). Strategies for sustainable mobility: Urban railways as global corporate citizens, *Proceedings of the 8th World Congress on Railway Research*, G.2.2.2.1 [CD-ROM], Seoul, Korea

Van der Meulen, R.D. & Möller, L.C. (2008b). Ultimate interoperability: Line-haul railways as global corporate citizens, *Proceedings of the 8th World Congress on Railway Research*, PN.1.2 [CD-ROM], Seoul, Korea

Van der Meulen, R.D. & Möller, L.C. (2012). European- and global urban guided transit: Green- and socio-economic fit, *Transport Research Arena,* Athens, Greece

Vuchic, V.R. (2007). *Urban transit systems and technology*, Wiley, ISBN 978-0-471-75823-5, Hoboken, New Jersey, United States of America

World Economic Forum (n.d). *Corporate global citizenship,* Accessed 2011-10-05*,* Available from*:* www.weforum.org/issues/corporate-global-citizenship




**Infrastructure Design, Signalling and Security in Railway**

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Railway transportation has become one of the main technological advances of our society. Since the first railway used to carry coal from a mine in Shropshire (England, 1600), a lot of efforts have been made to improve this transportation concept. One of its milestones was the invention and development of the steam locomotive, but commercial rail travels became practical two hundred years later. From these first attempts, railway infrastructures, signalling and security have evolved and become more complex than those performed in its earlier stages. This book will provide readers a comprehensive technical guide, covering these topics and presenting a brief overview of selected railway systems in the world. The objective of the book is to serve as a valuable reference for students, educators, scientists, faculty members, researchers, and engineers.



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