Strategies for Sustainable Mobility: Urban Railways as Global Corporate Citizens

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Abstract

Urban rail does not fully exploit the strengths of rail's genetic technologies, yet ever more cities are implementing heavy- and light rail mobility solutions. The association of urban rail drivers and their outcomes thus still seems obscure. The authors sought to describe and to examine whole-industry adaptation from a behavioural perspective. They have presented a new, dedicated database, which supported global measurement of key urban rail variables, and statistical analysis of the data, which offered new insights into urban railways as global corporate citizens. They found eight factors representing objectives that could be on the agenda of urban railways as they develop their corporate citizenship, and ten clusters that demonstrated how urban rail solutions align to particular economic-, geographic-, political-, and social settings. Potential for implementation is discussed, leading to conclusions regarding establishing and developing urban rail's corporate citizenship.

1 Introduction to the research

1.1 Seeking to understand urban rail positioning

Three genetic technologies, namely Bearing (the ability to carry heavy axle loads), Guiding (the ability to run at high speeds), and Coupling (the ability to couple vehicles into trains), underpin the steel-wheel-on-steel-rail transport mode. They distinguish railways from all other transport modes, and give them distinctive competitive strengths. Representing these technologies as three mutually orthogonal axes, yields four archetypal market spaces, in which railways are inherently competitive. First, Bearing and Coupling support heavy haul railways. Second, Guiding and Coupling support high-speed intercity passenger railways. Third, Bearing, Guiding, and Coupling support heavy intermodal railways that convey double-stacked containers. Fourth, Coupling on its own supports urban railways, the subject of this paper.

The authors have previously examined relations among competitiveness, sustainability, and the abovementioned genetic technologies, in the context of railway globalization [1]. The findings from that research provided valuable insight into positioning railways for competitiveness and sustainability, a theme that they have developed further in a companion paper at WCRR 2008 [2]. However, they excluded urban rail from their previous research for two reasons. First, human beings as payload do not achieve high axle load, even in double deck coaches. Second, physical laws maximize line capacity at ± 80km/h maximum speed. Unlike line haul applications, urban rail thus cannot leverage the Bearing and Guiding genetic technologies. Notwithstanding that weakness, combining vehicles into trains does allow them to maintain shorter average headway than would be feasible between autonomous single vehicles. This facility enables urban rail to outclass the capacity of rival passenger transport modes.

Urban rail's competitive strength thus stems primarily from high capacity, by maximizing the throughput from every headway slot. Hence, despite limited exploitation of rail's potential strengths, ever more cities are implementing heavy- and light rail mobility solutions. Oddly, not all large cities have urban railways, yet many smaller cities do. Young cities might not be as densely developed as older cities that developed around urban rail, yet rail solutions are emerging even in urban sprawl. As highway congestion worsens, petroleum prices escalate, and the green movement gains momentum, ridership will increase [3]. However, the association of urban rail drivers and their outcomes still seems obscure. The authors therefore undertook the exploratory research reported here, with the objective of developing insight into positioning of urban railways, to complement the insight they have already developed into positioning of line-haul railways.

1.2 Corporate citizenship as an appropriate research paradigm

Corporate citizenship comprises the contribution an entity makes to society through its core business activities, its social investment, and its engagement in public policy. The manner, in which it manages economic, social, and environmental relationships, and the way it engages with stakeholders, affects its long-term success [4]. Hence, the authors argue that one should be able to represent the positioning of an urban railway, and its fit within its relevant environment, by its corporate citizenship.

The authors' research question was thus: *What insights can one gain into the positioning of urban rail by examining its corporate citizenship within a global setting*? To unlock those insights, the authors hypothesized the existence of a number of time-dependent relations among variables associated with urban railways' contributions to their societies. The variables would reflect the resources that urban railways deploy to adapt to relevant economic, political, social, and technical challenges and opportunities in their respective country- and local settings. The research reported in this paper explored the existence and nature of such relations.

2 Methodology

2.1 Research design

2.1.1 Railway corporate strategy descriptive research

Many aspects of railway strategy research are well grounded, but the railway corporate strategy field remains relatively new. A Google search for "railway corporate strategy" yielded only websites associated with the authors' business. In this paper, they report on further research in that field, using a methodology developed and described previously [1]. A brief recapitulation follows, to make this paper self-contained.

Global railway industry research should seamlessly compare settings with various degrees of economic development and -freedom, private- or public ownership, regulation and deregulation, and so on. While pre-global railways supported comprehensive national statistics, maintained by entities such as the International Union of Railways, the World Bank, and several others, their databases no longer appear to support the recent surge of disaggregated industry structures and new entrants, and the disparate data that accompanies them. Noting the similarity with human behaviour in general, the authors therefore described and examined whole-industry adaptation from a behavioural perspective. Scientific descriptive research requires a set of variables, usually the columns or fields, and a set of cases, usually the rows or instances, in a database: They concluded that rigorous railway corporate strategy research deserved a new, dedicated, urban railway database.

2.1.2 Selection of variables

Noting the strong and reciprocal linkage between urban public transport and the cities and regions that it serves, an article by Rat [6] implicitly suggested appropriate variables to describe and to measure the subject research field. The authors' previous research [1] suggested supplementary variables. They grouped them as follows, where applicable sub-dividing them to support detail distinctions, such as light rail/metro; infrastructure/rolling stock; and cars, buses and motorcycles.

Country Setting represents the environment that cities inherit from the countries in which they are set, specifically Country (Name), Population, Economic Freedom, Income, Income Inequality, Climate-change Position, and Motor Vehicle Population (Cars, Buses, and Motorcycles).

Local Setting represents distinctions that characterize individual cities, specifically City (Name), Population, Population Growth Rate, Area, Status, Coordination Level, Risk Locus, Train Operator Diversity, and Alignment with Standard Solutions.

Contribution Group represents the contribution of urban rail to a particular city, specifically Transport Task (Light Rail and Metro), Network Configuration, Network Growth[1], Value-added Service Potential, and Employment Created.
Light-rail Resources represents key attributes of the light rail solution(s) (if present) in a particular city, specifically Inaugural Year, Network Coverage, Rolling Stock Fleet, and City Track Gauge.

[1] Sustainability is vital to a railway's corporate citizenship. While this attribute was previously measured directly [1], urban rail settings frequently include support, by way of subsidy, or protection, by way of constraints on competition. It is thus difficult to define and to measure their sustainability using public domain data. Rolling stock decrease or increase was a candidate proxy for sustainability, but distinguishing between replacing older stock with more of the same, or a smaller quantity of contemporary multi-unit light rail vehicles, was impractical. Measurement of sustainability was therefore confined to changes in network size.

Metro-rail Resources represents key attributes of the heavy rail solution(s) (if present) in a particular city, specifically Inaugural Year, Network Coverage, Rolling Stock Fleet, and City Track Gauge.

Time represents a necessary element of time-dependent research, required to test the hypothesis by examining urban railway positioning and sustainability.

Practical constraints often preclude exhausting all pertinent variables. Furthermore, in examining relations between an industry and its setting, multivariate statistics may extract setting-centric factors if the research design admits too many setting-specific variables. The number of variables selected was thus a judgment call by the authors. The operational definitions for the variables selected, plus their scales, are too long to fit within this paper: They are available in file *WCRR2008 Urban Rail Operational Definitions.doc* on the authors' website [7]. The authors claim a new contribution to the field in respect of packaging the foregoing set of descriptive variables.

2.1.3 Cases and their population

The authors argued that it is natural to sample railways by city. They defined the population as the Railway Directory [5] *City Railways* section. However, some cities were too small to be recognized by supplemental data sources. They therefore defined a sample as the subset for which they could find sufficient data to measure the selected variables. It included all large cities, and reached as low as four towns of some 100000 people. Preliminary statistical analysis suggested that some cities belonged to other data sets: Those with monorails or rubber-tyred guided systems were therefore eliminated as being outside the set underpinned by rail's steel-wheel-on-steel-rail genetic technologies. Nevertheless, cities that used rubber tyred heavy metros, which closely resemble conventional rail, were retained to include significant cases such as Mexico City, Montréal, and Paris.

2.1.4 A new, dedicated, urban rail database

The present research is based on the natural affinity between corporate citizenship and public domain data. Railway data was extracted primarily from *Railway Directory*, supplemented by Internet-sourced historical- and setting data listed against the Operational Definitions in file *WCRR2008 Urban Rail Operational Definitions.doc*. The latter, together with the new 28-page Excel database, populated with 2002-2007 data[2], in file *WCRR2008 Urban Rail Database.xls*, is available on the authors' website [7].

2.2 Statistical analysis

Using the abovementioned database, the authors applied multivariate statistical analysis to examine relations among multiple variables and multiple cases. First, they selected Factor Analysis, to analyze relations among a large number of variables and then explain them in terms of a smaller number of common underlying factors. Second, they selected Cluster Analysis, to group a large number of cases by within-cluster homogeneity and between-cluster heterogeneity. Statistical analysis stops at the Factor Loading Matrix and Icicle Plot: Factor- and Cluster names, and the discussion that follows, reflect the authors' interpretation of their knowledge of the variables and cases in the research setting. Statistical rigour is addressed in Appendix 1.

3 Findings

3.1 Factor analysis

3.1.1 The factor loading matrix and interpretation of factors

The Factor Analysis extracted the following eight factors. The Factor Loading Matrix, which is too large to include in this paper, is available in file *WCRR2008 Urban Rail Factor Loading Matrix.xls* on the authors' website [7]. It shows variables loading highly onto one of the underlying factors, and, ideally, negligibly onto the others. For convenience, the upper- and lower scale poles, as well as the unit of measurement, for each variable are repeated below.
Factor analysis cannot process textual data, so factors are anonymous—it is not possible to identify cities. Note also that factor loading indicates association only: It cannot indicate causality, so the

[2] The authors cannot control data published by others: Where they found that others had revalued data since their 2006 paper [1], they used current values for 2002-2007 to ensure internal consistency in this study. Some of the new data is thus not directly comparable with that of their 2006 paper.

interpretations are necessarily presented in tentative terms. The authors constructed the scales for each variable 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. Appreciate also that variables that load on a particular factor are as significant as those that do not.

3.1.2 Factor 1, Positioning Metro Rail

The following variables loaded onto Factor 1, accounting for 25.1% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Rolling Stock Fleet Metro Rail, number	6800	12
Network Coverage Metro Rail, km	660	6
Transport Task Metro Rail, million journeys per year	3200	3
–Inaugural Year Metro Rail	2004	1863
Employment Created, employee count	74000	10
City Population, million	35.3	0.1
Train Operator Diversity, number	6	1
City Area, square kilometers	8680	10
Network Configuration, complexity	Orbital routes	Single routes
City Status	National Capital	Other

This factor suggested that metro positioning, i.e. Resources (Rolling Stock Fleet, Network Coverage, and Inaugural Year), associated with its Setting (City Population, Train Operator Diversity, City Area, and City Status), and with its Contribution (Transport Task, Employment Created, and Network Configuration). The loadings are unsurprising—a metro system anchors mobility in many large cities. This factor therefore provided a credibility check for other factors that might contain loadings that are more surprising. The positive loading of all but one variable suggested that they work in unison. The exception, negative loading of Inaugural Year, suggested that older metros associate more strongly with contribution to their setting, presumably because their cities grew around them. The loading of Train Operator Diversity, Network Configuration, and City Status, suggested that policy makers and community administrators should consider a liberal approach when getting the transport task done, or when positioning new urban rail applications.

3.1.3 Factor 2, Positioning Light Rail

The following variables loaded onto Factor 2, accounting for 14.5% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Rolling Stock Fleet Light Rail, number	1900	5
Network Coverage Light Rail, km	690	2
Transport Task Light Rail, million journeys per year	1110	0.2
–Inaugural Year Light Rail	2007	1835

Like Factor 1, this factor suggested that light rail positioning, i.e. Resources (Rolling Stock Fleet and Inaugural Year), associated with Contribution (Network Coverage and Transport Task). Similarly, negative loading of Inaugural Year suggested that older light rail systems associate more strongly with contribution to their setting, presumably because their cities grew around them. However, recalling from §4.1.1 that variables that do not load on a factor are as significant as those that do, the Setting (as described by the variables City Population, Train Operator Diversity, City Area, and Status in the case of metro), and Contribution (as described by the variables Employment Created and Network Configuration in the case of metro), appear less significant for light rail than for metro rail. Factor 2 is thus the first finding that supported the assertion, in §1.1, that the association of urban rail drivers and their outcomes still seems obscure. Light rail is frequently the entrée to urban rail, but the findings unfortunately do not offer new insight into positioning at this time: They do however suggest that authorities and communities should approach new applications of light rail with due awareness that they are entering territory that is less well understood than metro rail.

3.1.4 Factor 3, Pitching Urban Rail at Developing Economies

The following variables loaded onto Factor 3, accounting for 9.0% of total variance.

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

Country Population, number	1319000000	1300000
Buses, number	2138000	4800
Motor Cycles, number	76000000	2500
Income Inequality, Gini coefficient	59.7	19.0

All four variables that loaded onto this factor reflected a Country Setting, but no railway variable loaded onto it. The positive loading of the variables Country Population, Buses, Motor Cycles, and Income Inequality suggested that countries with high human-, bus-, and motorcycle populations (the latter arguably rail's closest natural competitors) associated with higher income inequality, which in turn typically associated with rapid economic development. It seemed to present an opportunity for urban railways to project themselves as attractive corporate citizens, an alternative to low cost motor solutions—buses for masses, and motorcycles for individuals or families. However, it also suggested that urban rail might not be an early solution in the unsettled society that associates with high income inequality, but that policy makers could rather wait until the benefits of development have permeated throughout society.

3.1.5 Factor 4, Pitching Urban Rail at Developed Economies

The following variables loaded onto Factor 4, accounting for 8.7% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Country Income, US$ per capita	66530	174
Economic Freedom, Heritage Foundation Index	90.1	3.0
Cars, number	137633467	251961

The three variables that loaded onto this factor also reflected a Country Setting, and once more, no railway variable loaded onto it. The positive loading of the variables suggested that high Country Income, high Economic Freedom, and Passenger Cars associated to present another opportunity for urban railways to project themselves as attractive corporate citizens, an alternative to private cars. Absence of loading on Light Rail- or Metro Contribution suggested that a country's level of development, and its derivative, competition from cars, does not relate to urban rail. It is thus interesting to note the resurgence of light rail in North America, which could be considered typical of the variables that loaded onto this factor: Possibly the prevalence of urban rail applications in such economies is still too small to influence factor loading.

3.1.6 Factor 5, Positioning Railway Technology

The following variables loaded onto Factor 5, accounting for 5.2% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
City Track Gauge Light Rail, mm	1587	900
Alignment with Standard Solutions	Std. gauge present	Standard gauge absent

The positive loading of both variables suggested that light rail aligns with standard solutions. The emergence in recent years of proprietary light rail solutions from major system integrators underscores this factor. There is even activity evident in Europe to convert meter gauge track to standard gauge track, to extend and to network light rail (and sometimes even heavy rail) systems. While narrow gauge is arguably adequate for low speed and low axle load, authorities and communities should appreciate that the critical mass of standard products must eventually dominate.

3.1.7 Factor 6, Contributing Mobility

The following variables loaded onto Factor 6, accounting for 4.1% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
City Track Gauge Metro Rail, mm	1676	1000
Population Growth Rate, per cent	4.5	–1.3

One may not have considered track gauge a prima facie driver of urban railways, because their speed is relatively low. However, double deck coaches are gaining credence, because they allow urban railways to exploit rail's Bearing genetic technology by leveraging axle load to raise capacity. The authors therefore included city track gauge as a variable. Narrow track gauge generally precludes double decking, although the authors do recognize examples such as double deck trams in Hong Kong, and JR East 215 Series double deck trains in Japan, both on 1067mm gauge. This factor suggested that wider track gauge, as opposed to narrower track gauge, associated with high population growth rate in meeting the mobility challenges of rapidly growing cities. Communities with narrow gauge legacy systems should recognize a potential constraint on mobility as they develop.

3.1.8 Factor 7: Greening the Image

The following variables loaded onto Factor 7, accounting for 3.5% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Calendar Year	2007	2002
Climate-change Position, Kyoto Protocol	Signed, ratified	Not signed, not ratified

No railway-specific variable loaded onto this factor: Climate-change Position associated only with the passage of Time. Evidently, urban railways have not leveraged the potential of their eco-friendly contribution to society. This factor is another finding that supports the assertion, in §1.1, that the association of urban rail drivers and their outcomes still seems obscure. While railways claim energy efficiency and low emissions, and climate change is high on almost every strategic agenda, authorities and communities have not yet found a satisfactory nexus of urban railways and natural ecology.

3.1.9 Factor 8: Driving Intelligent Mobility

The following variables loaded onto Factor 8, accounting for 3.4% of total variance.

Variable	***Upper Scale Pole***	***Lower Scale Pole***
Network Growth, km per year	575	-90
Value-added Service Potential, smart cards	In use	Not in use

This factor associated network growth and the deployment of smart cards to add value to urban rail service. From inspection of the database, the authors noted that network growth was spotty. Indeed, network coverage in many cities remained unchanged over the period 2002-2007. Evidently, many urban railways have yet to add intelligence to mobility through information technology or smart cards. Many cities proclaim an aspiration to achieve modal shift from road to rail. However, they appear not to have harnessed the value of intelligent mobility to achieve their aspirations.

3.1.10 Simple and complex variables

After factor analysis, it was evident that some factor loadings were less than ideal. First, noting that a factor must consist of at least two variables, the variable Risk Locus, which did not load on any factor, proved to be simple—that is, within the set of variables selected, it measured what its operational definition stated, and only that,. Evidently, private participation does not yet relate to any other driver of urban railways. Second, despite selecting the Varimax rotation option, which maximizes the uniqueness of each factor, and minimizes the variance shared between factors, the variable Cars proved to be complex: Although it loaded highly on Factor 4, Pitching Urban Rail at Developed Economies, it also loaded significantly on Factor 3, Pitching Urban Rail at Developing Economies. This is no surprise—motor cars are a complex expression of several economic- and social drivers.

3.2 Cluster analysis

3.2.1 The icicle plot and interpretation of clusters

In theory, the number of clusters could range from few large, relatively heterogeneous clusters, to many small, relatively homogeneous clusters: In practice, researcher discretion determines the number of clusters selected for interpretation. The authors selected the smallest number that seemed clearly interpretable, namely the following ten. Most of them gathered cases from several countries into the same cluster: This balanced within-cluster heterogeneity, in support of global comparisons, against a larger number of more homogeneous clusters, dominated by country-specific attributes. To preclude cities clustering differently for one or more of the years 2002-2007, and hence to support clear interpretation, the authors performed cluster analysis on the sample for one year (2007) only. The Icicle Plot, which is too large to include in this paper, is available in file *WCRR2008 Urban Rail Icicle Plot.xls* on the authors' website [7]. It shows cases forming clusters: Adjacent cases are related, their shared length indicating the degree of homogeneity. The differently coloured bands, cutting the icicles in Column E, demarcate the chosen clusters. For convenience, the following cluster descriptions list the cities in the same order: Appreciate that the order does not imply ranking.

For brevity, the following interpretations highlight only high- or low attributes: Those not mentioned are medium. *High* and *Low* ratings compared the average of a particular cluster to the average of the sample. A range between plus and minus half a sample standard deviation, considered to be medium, discriminated usefully among the clusters. Cluster averages outside that range were considered high or low. The authors described attributes using liberal meanings for words, for example *large* could mean *high*, *moderate* could mean *medium*, and *small* could mean *low*.

3.2.2 Cluster 1: Principal Cities

Thirteen large cities (Buenos Aires, **London**, Tokyo, Hong Kong, Osaka, Mexico City, Madrid, Cairo, Moskva, St Petersburg, Kolkota, Barcelona, and Yerevan), characterized by London, United Kingdom. A domain dominated by mature metro systems, with light rail presence; populous cities in populous countries; comparatively low average income; a positive position on climate-change; large area and high status; an appetite for private participation and operator diversity; delivering a substantial transport task through a complex network, supportive of intelligent mobility; a high employment contribution; and deploying substantial infrastructure and rolling stock resources. The name reflects their stature: A fully developed corporate citizenship to which growing communities could aspire.

3.2.3 Cluster 2: Mid-range Capital Cities

Nine mid-range capital cities (Baku, Minsk, Warszawa, **Kyiv**, Tashkent, Praha, Budapest, Tunis, and Bucuresti), characterized by Kyiv, Ukraine. A domain dominated by light rail with metro presence; low economic freedom, low per capita income, and low income inequality; low car and bus populations; delivering a high light rail transport task, a positive position on climate-change, high employment contribution; and deploying substantial light rail infrastructure and rolling stock resources. The association of low income inequality and high light rail transport task should interest communities in selecting and positioning their urban rail applications.

3.2.4 Cluster 3: Significant Cities

Twenty-five medium cities (Novosibirsk, Samara, **Dnipropetrovsk**, Kharkiv, Wien, München, Milano, Athens, Roma, Napoli, Toronto, Berlin, Frankfurt, Nürnberg, Hiroshima, Kyoto, Brussels, Amsterdam, Rotterdam, Oslo, Lisboa, Singapore, Stockholm, Lyon, and Marseille), characterized by Dnipropetrovsk, Ukraine. A mixed light rail and metro domain, a positive position on climate-change, high status; high train operator diversity; and complex network configuration. The name reflects a combination of stature and status—they are one or more of large, or national- or provincial capitals. The association of complex network configuration and mixed light rail and metro domains suggested that authorities and communities should consider the potential complementarity in the roles these two urban rail applications can play.

3.2.5 Cluster 4: Brazilian Metro-only Cities

Six large Brazilian cities (**Belo Horizonte**, Porto Alegre, Brasilia, Recife, Rio de Janeiro, and São Paulo), characterized by Belo Horizonte. A young metro-only domain; low economic freedom, low per capita income, and high income inequality; a positive position on climate-change; high bus population; high population, high population growth rate, and large area; and wide-gauge track. While the name speaks for itself, this cluster provides a role model for cities that might contemplate going directly to a metro rail solution. Nowadays rapidly growing cities are typically found in developing countries, where they have no city rail legacy.

3.2.6 Cluster 5: Global Metro-only Cities

Nineteen medium cities (Montréal, Hamburg, Vancouver, Newcastle upon Tyne, Busan, Taegu, Kobe, Nagoya, Yokohama, Glasgow, Fukuoka, Sendai, Santiago, Medellin, Tehran, Caracas, **Kuala Lumpur**, Bangkok, and Seoul), characterized by Kuala Lumpur, Malaysia. A metro-only domain, high income inequality; a positive position on climate-change; aligned with standard solutions; complex network configuration; and supportive of intelligent mobility. The name reflects the global diversity of the cities. Other than its positive position on climate change, which distinguishes it from Cluster 4, this cluster shows that medium cities may also go directly to metro rail. It is nevertheless a small cluster, suggesting that authorities and communities should contemplate this solution with due awareness.

3.2.7 Cluster 6: Heavyweight Cities

Fourteen large cities (**Beijing**, Shanghai, Guangzhou, Tianjin, Atlanta, Washington DC, Chicago, Miami, New York, Baltimore, Cleveland, Philadelphia, Boston, and Los Angeles), characterized by Beijing, China. A metro-dominated domain with light rail contribution; populous cities in populous countries with high population growth; high economic freedom and high income inequality; ambivalent about climate-change, high motor vehicle populations (car, bus and motorcycle); absence of private participation; supportive of intelligent mobility; high employment contribution; substantial metro network coverage and rolling stock fleet; small light rail transport task and network coverage. The name reflects the heavyweight rating of these cities on many of the variables. The cluster is similar in many respects to Cluster 1. Authorities and communities should note the contending association of population growth and private participation: It appears that high growth might call for a more authoritarian touch.

3.2.8 Cluster 7: Ordinary Cities

Eighty medium cities (Buffalo, Denver, San Diego, Sacramento, Salt Lake City, St Louis, Dallas, Portland, Houston, Pittsburgh, New Orleans, San Jose, Memphis, Tampa, Adelaide, Sydney, Calgary, Edmonton, Göteborg, Dublin, Porto, Christchurch, Graz, Liberec, Olomouc, Plzen, Kosice, Brno, Ostrava, Debrecen, Miscolc, Utrecht, Den Haag, Krakow, Poznan, Wroclaw, Timisoara, Grenoble, Nantes, Strasbourg, Montpellier, Orleans, Rouen, St Etienne, Linz, Zürich, Helsinki, Antwerpen, Charleroi, Gent, Bilbao, Valencia, Vitebsk, Szeged, Riga, Tallinn, Bratislava, Sarajevo, Zagreb, Beograd, Sofia, Lodz, Augsburg, Heidelberg, Ludwigshafen, Bielefeld, Cottbus, Würzburg, **Braunschweig**, Freiburg, Halle, Oberhausen, Mülheim/Ruhr, Bochum-Gelsenkirchen, Erfurt, Mainz, Gera, Ulm, Zwikau, and Takaoka), characterized by Braunschweig, Germany. A light rail domain with small metro contribution; most variables moderate; relatively narrow light rail track gauge; and young metros with small network coverage. The name reflects a dearth of distinctive attributes: The largest cluster of all, its size appears to reinforce the assertion, in §1.1, that the association of urban rail drivers and their outcomes still seems obscure. This finding contrasts with the clear clustering of line haul railways found by the authors [2].

3.2.9 Cluster 8: Light Rail Cities in Economically Free Countries

Thirty-one medium cities (Bonn, Bremen, Karlsruhe, Leipzig, Köln, Chemnitz, Duisburg, **Kassel**, Rostock, Krefeld, Dortmund, Dresden, Hannover, Stuttgart, Düsseldorf, Essen, Magdeburg, Potsdam, Schwerin, Saarbrucken, Genova, Kumamoto, Birmingham, Manchester, Croydon, Sheffield, Hakodate, Kochi, Okayama, Kagoshima, and Nagasaki), characterized by Kassel, Germany. A light rail-only domain; high economic freedom, high income, and low income inequality; a positive position on climate-change; low population growth and low city status; and an appetite for private participation. The name reflects the high economic freedom, high income, and low income inequality that typically associate with economically free countries. Authorities and communities should pay attention to the association of private participation in public transport with the attractions of private transport in such societies.

3.2.10 Cluster 9: Light Rail Cities in Economically Restrained Countries

Thirty-four medium cities (Mozyr, Achinsk, Cherepovets, Yenakiyevo, Lviv, Vinnitsa, Zhitomir, Astrakhan, Oryol, Kemerovo, Magnitogorsk, Ul'yanovsk, Irkutsk, Barnaul, Izhevsk, Kursk, Lipetsk, **Ulan-Ude**, Vladikavkaz, Tomsk, Omsk, Yaroslavl, Ufa, Yekaterinburg, Tula, Volgograd, Donetsk, Zaporozhye, Odesa, Lugansk, Changchun, Alexandria, Guadalajara, and Monterrey), characterized by Ulan-Ude, Russia. A light-rail-only domain; low economic freedom and low per capita income; a positive position on climate change; high bus population; no private participation; and wide track gauge. The name reflects the low economic freedom and low per capita income that typically associated with economically restrained countries. Authorities and communities should note that lack of private participation associated with public transport and an absence of attractive alternatives.

3.2.11 Cluster 10: Turkish Cities

Five Turkish cities (Ankara, Istanbul, **Bursa**, Konya, and Izmir), characterized by Bursa. A mixed light rail/metro domain; low economic freedom, low per capita income and high income inequality; an ambivalent position on climate change; low car- and high bus populations; high population growth rate; low network complexity; young light rail and metro systems, with low light rail network coverage. One or more of the foregoing clusters could have accommodated all the cities in this cluster. However, a consistent ambivalence to climate change uniquely distinguished it from all other clusters.

4 Discussion regarding potential implementation

The authors extracted the factors from time-dependent data, and hence interpreted them as functions of time, or activities, that revealed facets of corporate citizenship. The factors thus represented objectives that could be on the agenda of urban railways as they set about developing their corporate citizenship through their contribution to society.

Although several cities featured both light rail and metro rail systems, the separate existence of Factor 1, Positioning Metro Rail, and Factor 2, Positioning Light Rail, suggested that their positioning is independent of one another. This observation seems to be supported by the existence of Cluster 8: Light Rail Cities in Economically Free Countries, in which the impact of urban decentralization and competition from private cars could be key determinants of railway ridership. The respective corporate citizenships of Factor 1 and Factor 2 appear thus to relate to two distinctly different settings, which seems to indicate that the variables that drive light rail positioning belong to a different set from those that drive metro positioning. If such variables do exist, the authors may have omitted them from this study simply because they were not aware of them. This possible omission is potentially a subject for further research into light rail positioning.

Absent the loading of any rail-specific variable on Factor 3, Pitching Urban Rail at Developing Economies, and Factor 4, Pitching Urban Rail at Developed Economies, it appears that the economies mentioned are external to urban railways. In the case of developing economies, one might argue that urban rail takes for granted its existence: In developed economies, one might argue that urban rail is out of touch with the market. Either way, good corporate citizenship would require that urban railway administrators establish intimate relationships with relevant environments. The remaining factors revealed areas where urban railways could assert and polish their corporate citizenship.

Factor 5, Positioning Railway Technology: Recall that urban rail does not leverage rail's Bearing and Guiding genetic technologies. It thus appears that these railway genetic technologies are less vital to urban rail's corporate citizenship than to other archetypal railway applications. Nevertheless, it remains important to secure the economic benefits of globalization: In this respect, alignment with standard solutions through intraoperability, rather than the customary objective of interoperability, to minimize the cost of equipment through global sourcing, is a key opportunity for urban rail.

Factor 6, Contributing Mobility: The association of population growth rate and metro track gauge suggested that standard- or wide gauge is indicated to rise to the challenging transport task that faces fast growing cities. Cluster 4, Brazilian Metro-only Cities, well illustrates the distinctive corporate citizenship of metro rail in rising to that challenge, by clustering independently of all other countries.

Factor 7, Greening the Image: Urban rail does not fare well by this factor, because no rail-specific variable loaded on it. Despite the topical climate change agenda, which raises green issues ever more frequently and more loudly, the present findings showed no association between the undisputed energy efficiency of railways, and a benefit to their society. Instead, the variable Time, which loaded onto Factor 7, suggested that organized society is setting the pace: The opportunity cost of urban rail's lost corporate citizenship reputation should be self-evident to policy makers.

Factor 8, Driving Intelligent Mobility: The association of network growth and value-added service potential is intuitively satisfying. However, during the period 2002-2007, few urban railways grew their networks significantly, and few implemented smart cards. Intelligent mobility is a logical extension of the Information Age to railways, and topical within the context of personal mobility. However, the findings suggested that this is still a development area for urban railway corporate citizenship.

The ten clusters demonstrated that urban rail solutions align to particular economic-, geographic-, political-, and social settings. The different clusters reflected significant nuances, rather than fundamental differences, in their positioning. To illustrate by grouping the clusters, five of them revealed different types of cities, namely Cluster 1, Principal Cities; Cluster 2, Mid-range Capitals; Cluster 3, Significant Cities; Cluster 6, Heavyweight Cities; and Cluster 7, Ordinary Cities. Of these, Clusters 1 and 6 are similar, differing essentially in the economies in which they are set.

Cluster 4, Brazilian Metro-only Cities, and Cluster 5, Global Metro-only Cities, exhibited interesting metro-only positioning. They are similar regarding many attributes, the essential distinction being that the Brazilian cities are larger, growing faster, and have younger metros than their counterparts have elsewhere in the world. Cluster 10, Turkish Cities, has salutary implications for corporate citizenship, regarding both the gravity of its climate change position, and its ability to form a cluster that draws attention to a critical issue by virtue of a single out-of-line variable.

5 Conclusions on urban rail's corporate citizenship

The authors have presented a new, dedicated database, which supports global measurement of essential urban rail variables, together with statistical analysis of the data, which offers several new, though not yet adequate, insights into urban railways as global corporate citizens, as follows.

The contributions of rail and road in urban context appear to be on autonomous, non-competing, trajectories. Thus, while there should always be opportunities for integration and synergy between these transport modes, they do not appear to intrude materially on one another's market spaces. This finding suggested a strategic opportunity for urban rail to position its corporate citizenship independently of that of its competitors, with due regard for the societal setting.

Nationally oriented corporate citizenships are still evident in many cities, particularly in the form of sub-clusters within the ten clusters selected for interpretation. Given the longevity of railway assets, that finding should come as no surprise. However, outside the Brazilian and Turkish clusters, the remaining clusters each had at least a modicum of global membership. Thus, despite their local roots, urban railways appear set to benefit from whatever global open systems or standard solutions emerge in the industry.

Although urban railways undoubtedly contribute value to their societies, they do not yet give the overall impression of being prominent global corporate citizens. Among other, the bureaucracy that still administered many of them might well have blurred some of their intrinsic value. While the study period contained few examples of distancing public authorities from urban railways, such liberalization as did occur in the urban rail industry has raised its contribution to society—consider the robust positioning of the Principal Cities in Cluster 1. Several clusters and factors have suggested strategic development opportunities for liberalizing urban rail, thereby leveraging its strengths across a broader application base.

Some of the factors also suggested that urban rail was aloof from its surroundings, the findings not providing substantial evidence of relations built on engagement and interaction between urban rail and its relevant environment. This may reflect the nature of urban rail, because once a system has been rolled out, it will be with a society for a long time, whether or not interaction takes place. It may also reflect the preponderance of public ownership at this time. Nevertheless, good corporate citizenship would preempt the rejection or revolt that sometimes happens when urban rail fails to meet a community's expectations.

Noting that new urban railways have to find a right of way—either underground at high cost, or above ground in contention with existing built environment, the results suggested an opportunity for urban rail stakeholders to devise appealing offerings by promoting a smaller set of solution clusters. It is conceivable that two basic offerings, namely standard gauge light rail and standard- or wide gauge metro, with support for intelligent mobility, could meet the requirements of most cities while leveraging prices down through aggressively pursuing intraoperability at sub-system level. This opportunity is already being visibly exploited in the sample—examples exist where standard gauge is used for urban rail, where city track gauge is either narrower or wider than the national network, or even differs within the same city.

This study set out to explore a new field, and has demonstrated the value of data-driven research in mapping it. The eight factors and ten clusters now provide useful high-level insight into the positioning of urban railways, while some gray areas have also been revealed. It has also suggested two aspects for further research, in particular with respect to those that were deliberately excluded. First, systems outside the current mainstream should be recognized, for example monorails, and rubber-tyred light metros such as the VAL system. The latter provides an interesting counterpoint to the present study, because it bypasses urban rail's inability to exploit the Bearing and Guiding genetic technologies, but goes on to exploit the Coupling genetic technology. Such systems are less amenable to data-driven research, due to their limited applications, while the alternative case study methodology is less rigorous due to the difficulty of comparing small samples by means of diverse variables. Second, cities without railways need to be recognized. Clearly, substantial insight remains to be extracted by comparing cities that have railways with those that do not. Such research would also require a new paradigm, because railway-specific variables are not measurable in cities without railways. To address that question would thus entail a new database. There clearly remains substantial work before the positioning of urban railways can be adequately understood.

6 References

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Appendix 1: Statistical rigour

Missing values

Multivariate statistical procedures require observations for all cases and all variables. They cannot process missing values. Unfortunately, railway data frequently have missing values, so one risks trashing a substantial amount of good data by deleting cases or variables, in turn threatening construct validity and statistical significance. The authors therefore filled missing values by one of the following procedures. First, they constructed measurement scales with natural default values, either neutral with respect to the poles, or far-removed from typical values, to substitute for missing values. Second, they estimated isolated missing values from comparable or neighbouring cases. Third, they calculated missing time series values using Microsoft Excel's *Forecast* function where observations were not available for all years. Fourth, where only a few intermittent time series observations were available, and estimated trends could be misleading, particularly if the observations were close together, they considered observations unchanged, until a new observation became available.

Significance

The data set arrayed 36 variables. Of the original 415-city population, a sample of 245 cases remained. With measurements for each city for each year 2002-2007, except Dublin, Houston and Yerevan, which materially changed status during that period and for which fewer years were used, the number of cases reduced to 245x6–7 = 1463. For factor analysis, >11 cases per variable, amply exceeded in this study, eigenvalues > unity can be considered significant. Application of this criterion yielded eight factors. For >50 cases, factor loadings >0.3 are considered significant, a criterion achieved by all factors. For cluster analysis, which is more an art than a science, because researcher discretion determines the number of clusters and their interpretation, the authors did not address significance. However, significance inheres in the data set, and using the same data for both cluster- and factor analysis assured consistency of significance.

Independence

For n clusters, there will be n–1 statistically independent cases, which are more individual than any of the clusters. Tbilisi, Pyongyang, Paris, Delhi, Taipei, San Francisco, Trondheim, Mannheim, and Manila, are statistically independent in this study, respectively separating Clusters 1 and 2, 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7, 7and 8, 8 and 9, and 9 and 10.