Railway Globalization and Heavy Haul

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Summary: The paper examines rapidly changing business models and their impact on heavy freight railways. It explores the diminishing returns of physical technologies vis-à-vis the increasing returns of networking economics. It interprets data-based research to demarcate the domain and technologies of heavy freight railways, to propose a high tech research agenda and concludes that double stack, the third mainline of the railway renaissance, could extend the application domain of heavy haul.

Index terms: heavy haul, intermodal, double stack, genetic technology, network economics.

1 INTRODUCTION

1.1 Business models and railway settings

Halfway through the first decade of the new century, fundamental change has shaken the business world. The forecast for most companies is chaos, with a chance of disaster [1]. Industrial Age icons are in disarray: General Motors is on the verge of bankruptcy [2], and the business model that sustained Ford Motor Company for decades is no longer sufficient to sustain profitability [1]. Even Information Age icon Microsoft is in crisis [3], and founder Bill Gates has cultivated new philanthropic interests. The Information Age has disrupted traditional competitive advantages, and Chinese and Indian manufacturing output has created new logistics axes in economic geography. The question is thus not whether railways, a founder member of the Industrial Age, will also change: The question is how a reputedly asset heavy, change resistant industry will adapt to contemporary drivers as it enters its third century.

1.2 Convergence of key drivers

Significant changes in strategic direction typically result from convergence of more than one driver, and are accompanied by disruptive rates of change in significant parameters. In railways, as in most mature industries, double-digit growth percentages are almost unknown. When they do occur, one should pay attention. The pace of railway development for the last four decades has been set by heavy haul, high-speed intercity, and heavy intermodal. Note, in this context, that the author distinguishes between *intermodal* and *heavy intermodal*. While intermodal has come to mean transferring freight from one transport mode to another, typically among maritime, rail, and road, it is useful to refine the meaning. Double-stack is a competitive railway market space that is growing disruptively, whereas intermodal, or simply transferring single-stack containers between rail and another mode, is usually neither competitive nor growing. Single stack containers on rail are generally not a resounding success in a free market. While the International Heavy Haul Association (IHHA) has ably rung the changes in heavy haul, heavy intermodal, which has grown at higher rates for several years, is of interest here. Three drivers have converged:

First, during the period that containerization took off in global trade, international trade in manufactured goods grew twice as fast as global manufacturing production, and two and a half times as fast as global economic output [4, p. 11]. Noting the extremely sharp drop in freight costs, Levinson [4, p. 12] argued that container shipping had a large effect in stimulating trade and economic development. Dramatic shifts in trade patterns and economic activity over the past half century suggested that the connection between containerization and changes in economic geography is extremely strong [4, p. 14].

Second, during the 1970s the economic advantages of heavy axle load and long trains became apparent, and coal, grain, and iron ore came to move in unit trains in several countries. The first International Heavy Haul Railway Conference in 1978 formally marked that significant development on the railway industry timeline, and the rest is familiar history to the target audience of this paper.

Third, the present era of railway economic and regulatory liberalization dawned. The United States' Staggers Rail Act of 1980 allowed railroads to set rates and service levels according to the transportation marketplace. Its effects were swift, testifying to the underlying economic- and techno-logical viability of rail transportation in a competitive economic environment [5, pp. 4, 102]. Containers double-stacked on dedicated wagons soon followed, in 1983, offering a dramatically lower capital and operating costs [4, pp. 261-262]. This finally rendered railways competitive in cost sensitive and service sensitive markets [6].

1.3 Research into railway globalization

Against that background, the author set out to examine the impact of globalization on heavy haul railways. This paper develops scientifically grounded insight into the drivers of heavy haul, and its offshoot, double stack or heavy intermodal. It is scoped to examine the underlying economic and technological drivers, and to relate them to extending the application domain of heavy intermodal.

The author's business created a database dedicated to global railway corporate strategy research, and introduced it, with multivariate statistical analysis thereof, at World Congress on Railway Research 2006 [7]. Cases

were defined by country, because railways are generally legitimized by national legislation. The global population of countries with line-haul railways is 114, so longitudinal analysis of four years' data was used to enhance statistical significance. By filtering out non-essential detail, around forty variables were sufficient to exhaustively describe essential distinctions among countries and their railways. The full operational definitions, scales, and database are voluminous: Interested readers may download them from www.railcorpstrat.com. Multivariate statistical procedures can extract mathematically rigorous, comprehensible factors from the complex issues captured in such a database. The researcher must nevertheless interpret their outcomes in the light of knowledge about the setting.

From those general findings, the author identified one factor, fundamental to heavy freight railways, and researched it further for this paper. The following variables loaded onto it, in descending order: Route Diversity, Double-stack Presence, Heavy-haul Presence, Distributed-power Presence, Relative Maximum Axle Load, Rolling Stock Ownership, and Country Size. The fact that several variables preceded axle load, heavy haul's renowned competitive advantage, suggested that its development trajectory may be approaching an inflection. The author develops the context within which to interpret factors in §2 and §3, and then examines it and two further factors pertinent to heavy haul's alter ego, heavy intermodal, in §4.

2 PHYSICAL TECHNOLOGY—DIMINISHING RETURNS

2.1 Railway competitiveness

It is useful to consider railway competitiveness from a perspective of degrees-of-freedom-of-movement of a transport mode. First, three degrees of freedom of movement, exemplified by aerial- and submarine transport, offer spatial mobility, at relatively high cost. Second, two degrees of freedom of movement, exemplified by unguided surface transport, offer reduced mobility at lower cost. Last, a single degree of freedom of movement, exemplified by guided surface transport, by itself offers limited mobility, back and forth on its guideway. To the extent that limited mobility reduces their value, such modes, for example railways, must offer compensating advantages to hold their own against competing transport modes.

Railways are predicated on a vehicle-guideway pair, in which the steel-wheel-on-steel-rail contact mechanism develops vertical and lateral force components: They ensure precise application of vertical loads, and secure application of lateral loads, hence they have the potential to support respectively heavy axle load and high speed. The author terms these technologies *Bearing* and *Guiding*. The complex heavy haul wheel-rail interaction field may blur the distinction between vertical and lateral components, but the fundamentals nevertheless remain. Singly or in combination, Bearing and Guiding yield three intensely competitive railway market spaces—Heavy Haul (Bearing only), High-speed Intercity (Guiding only), and Heavy Intermodal or Double Stack (Bearing and Guiding)—in which

railways have demonstrated inherent competitiveness. One may leverage all three market spaces by linking vehicles, to scale capacity as required, a technology that the author named *Coupling*. Bearing, Guiding, and Coupling are the three *genetic technologies* that distinguish railways from all other transport modes.

The following empirical boundaries map railways to the three market spaces. On a logarithmic scale, $10^{1.x}$km/h includes most low speed applications, and $10^{2.x}$km/h includes most high speed applications, where $0<x<1$. IHHA Bylaw 4.9 (3) admits permissible axle load of ≥25 tonnes as heavy haul: At the 8th Conference in 2005 in Rio de Janeiro, *aspiring to 30 tonnes* was floated. Many examples exist, among railways that consistently advance genetic technology state-of-the-art, where application of rail's strengths has earned high regard for the industry. However, the high-speed intercity market space is not relevant to this paper, and the low axle load, low speed market space is outside its scope: They are not mentioned again here.

2.2 Standard Economics 101

In standard economics, the Law of Diminishing Returns posits that, if the amount of any one factor of production is increased successively in equal increments, while the amounts of other factors of production remain the same, then successive increases in output will be obtained, up to some limit, but each will be smaller than its predecessors The Law of Diminishing Returns is not really a law, because there are exceptions [8], a major one being discussed in §3.2. Railways are large scale systems in which many constraints, among them the physical limitations of its three genetic technologies, Bearing (axle load), Guiding (speed), and Coupling (train length), determine the bounds of system optimization. People who have wrestled to advance the genetic technologies will attest that each one is governed by the law of diminishing returns. Where some natural limit exists, the law of diminishing returns dictates that development can approach it asymptotically, but never exceed it, until a breakthrough allows the industry to advance to a next higher level. If breakthrough proves elusive, as it often does, development resources will flow elsewhere, where less bounded returns can be had for the same input.

2.3 Where to, heavy haul?

Heavy Haul railways have customarily increased axle load to enhance competitiveness—the Bearing genetic technology has consistently delivered most bang for the buck. However, content analysis of paper titles in proceedings of the five most recent IHHA conferences, the period during which globalization left its mark on railways, revealed that emphasis has shifted to reducing or managing the stress state. Furthermore, papers on increasing axle load have declined, being offset by an increase in papers on extending heavy haul to a wider domain of railway applications. These findings are shown in Figure 1, heavier line weights being used for the linear trends mentioned.

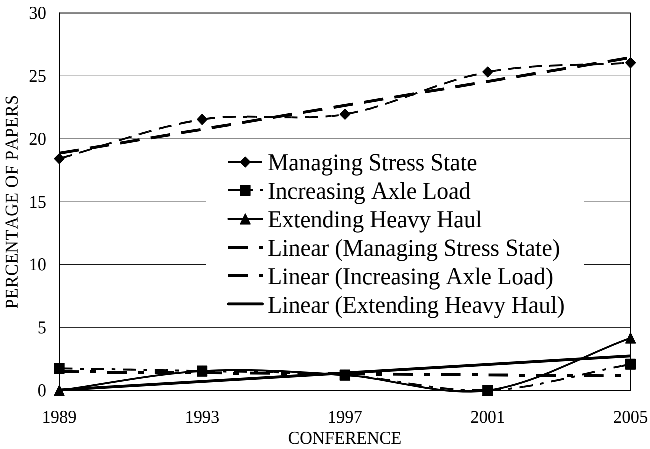

Figure 1 Selected trends in IHHA conference papers

Noting the caveats that conference themes could influence content of papers, and that content analysis should follow predetermined rules, it is nevertheless evident that extending heavy haul to a wider domain was more topical than raising maximum axle load. This paper does not address the underlying drivers, but merely applies the finding to support the research reported here. While economic and scientific reason no doubt encouraged this progression, the phenomenon may also indicate a sea-change in heavy haul competitiveness. Permissible axle load rests on physical laws hence, absent technological breakthrough, increasing permissible axle load must be governed by diminishing returns. Has the low-hanging fruit been picked, leaving future axle load increments to asymptotically approach the intrinsic potential of steel-wheel-on-steel-rail, whatever that might be?

3 NETWORKING TECHNOLOGY—INCREASING RETURNS

3.1 The double-stack phenomenon

From their origins in the United States, where they are set to contribute half Class 1 railroad revenues, double-stack container trains have become an aspiration or force on all continents that have standard- or broad-gauge railways, that is all except Africa and South America. The phenomenon

indicates that containers conveying manufactured goods, whose relatively high value justifies movement over long distances, have insufficient density to naturally achieve competitive axle load: Railways therefore double-stack containers to enter the heavy haul domain, where they are naturally competitive against other transport modes.

The double-stack phenomenon has however been addressed only cursorily in IHHA Proceedings thus far, specifically Curtis [9], who noted that double-stack container shipment throughout the United States had shown tremendous growth and success; Khan [10], who examined heavy haul technology transfer to intermodal transportation; and Lai et al. [11] who examined energy consumption of intermodal trains. While the increase in axle loads has been gradual but steady for decades [12], the rate of network and trade development has outstripped the rate of Bearing genetic technology development. As mentioned in §2.3, the record reveals an extension of heavy haul application, e.g. to general traffic routes, rather than raising the axle-load bar. Although Heavy Haul and Heavy Intermodal share genetic technologies, their applications are so different that they seem to be on different development trajectories.

3.2 Network Economics 101

Above a critical transport linkage density, isolated markets fuse into a large market, causing growth to accelerate [13]. The double-stack phenomenon well illustrates network economics at work—an exception to standard economics, at the frontier of economic theory [14]. Network businesses are exempt from normal forces of economic competition [15]: The benefit one user gets depends on the number of other users. Networks fascinate economic theorists because they do not fit neatly into the standard model of how markets work [14]. To paraphrase standard economics, and in contrast thereto, emerging network economics posits that if network linkages are increased successively in equal increments, then successive increases in output will be obtained, up to some possibly unbounded limit, and each increase will be larger than its predecessors. The Internet is bringing about changes as profound as previous milestones in the evolution of society, like the Renaissance and the Industrial Revolution [16]. The global logistics industry is changing the way supply chains work, and inescapably also where

their railway partners are headed. Progressive railways are no longer bound by their national roots, but face unbounded opportunities with global horizons.

3.3 The emerging global railway network

Heavy Haul runs out of competitive steam at distances greater than 1000km. So does high-speed intercity passenger, albeit for different reasons. That leaves suitably positioned railways to exploit the traffic growth potential of heavy intermodal, rail's only other inherently competitive market space. It is therefore axiomatic that container consignments must eventually move over the networks of two or more railway infrastructure operators as haul distances increase. Hence a global railway network, which reflects the network economics theory that drives other network industries, is rising in the Northern Hemisphere.

New paradigms are emerging, because rail freight is generally faster than sea cargo [17, p. 222]. The Tornio 1435-1520mm gauge-changing facility in Finland, near the IHHA 2007 Specialist Technical Session, exemplifies a technology that is likely to spread to many more sites. The Northern East-West Freight Corridor indeed includes this site. The European Commission's New Opera project envisions a fully dedicated pan-European rail freight network, introducing double stack where possible, heavier loads, long trains, distributed power, and wisely, necessary hubs and intelligent applications for management of information.. A feasibility study is underway to assess the economic viability of a 2000km railway between British Columbia, Yukon Territory, and Alaska [17, p. 223]. Kazakhstan has proposed a standard gauge link between the Chinese and European standard gauge networks: It could open parallel competition with the Trans-Siberian corridor. The Arab Mashreq network will link Arabian Peninsula and Middle Eastern countries to each other and to the standard gauge network to its north. South Korea is punting Seoul to London by rail. The network's reach into Southeast Asia remains enigmatic. Network businesses are governed by increasing returns, and significant breakthrough is thus likely to emanate from technologies that support large-scale railway networking. Has the leading edge of heavy haul research aspirations shifted to ultra-long hauls?

4 A HEAVY-HAUL INTERPRETATION

4.1 An introduction to multivariate statistics

Returning now to the train of thought developed in §1.3, multivariate statistical analysis simultaneously examines relations among multiple variables and multiple cases in complex settings. The procedure selected, factor analysis, reduces the relations among a large number of variables, typically the fields in a database, by explaining them in terms of their common underlying factors, sometimes called latent variables. However, statistical software can only go as far as outputting a factor loading matrix. The factor names, and a researcher's interpretation of factor loadings, necessarily reflect what he or she knows about the variables in the research setting.
As previously reported [7], the research project compared countries and their railways, and found a factor named Territorial Orientation to be a key driver of freight railways. Having broadly demarcated the landscape within which railways must position their heavy haul and heavy intermodal offerings, this author will now further develop interpretation of that factor, which represents global freight railway industry drivers, with reference to that landscape. This is the present paper's unique contribution.

4.2 Territorial Orientation

The factor of primary interest to heavy haul, named Territorial Orientation by Van der Meulen & Möller [7], attracted the following variables (with their respective upper- and lower scale poles in italics):

Route Diversity	*parallel options–single only*
Heavy Intermodal	*present–absent*
Heavy Haul	*present–absent*
Distributed Power	*present–absent*
Relative Maximum Axle Load	*high–low*
Rolling Stock Ownership	*private–public*
Country Physical Size	*large–small*

The interpretation follows:

First, the factor suggested competition among railways themselves. Route Diversity, or parallel competition, indicated competition for the same traffic among railways. Rolling Stock Ownership indicated private rolling stock ownership and again the presence of competition. Such competition is found in the United States, where mergers between parallel railways are not sanctioned, the Quebec North Shore, and the Australian Pilbara: Together they represent the world's most intense railway competition. Second, and driven naturally by intense competition, the factor suggested freight railways that deployed advanced technology, signified by the presence of Heavy Intermodal and Heavy Haul, each exploiting and leveraging one or two of rail's genetic technologies Bearing and Guiding. Distributed Power, which leverages the Coupling genetic technology beyond basic coupler strength, also loaded onto this factor. Relative Maximum Axle Load measured the extent to which railways exploited state-of-the-art: The goalposts shifted over time as the leader increased axle load, hence this variable measured railways against best of breed. Together, the high loading of variables at the leading edge of freight railway technology, revealed a not unexpected relation between intense competition and high technology. Lastly, Country Physical Size loaded onto this factor—large countries have the geographic expanse to sustain high technology rail freight transportation. Long, heavy trains conveying bulk commodities and high-value manufactured goods thus suggested the name Territorial Orientation, in recognition of their contribution to exploitation of economic-, natural-, and spatial resources.

Variables that do not load onto factors are as significant as those that do. Readers who consult the source paper [7] (available at www.railcorpstrat.com), will note that electric traction loaded onto a comparable factor, Societal Orientation, that underlies the passenger aspect of railways. All railways use diesel traction, whereas only a subset uses electric traction: The presence of diesel traction is thus not variable, and cannot be statistically analyzed. Diesel traction nevertheless commonly associates with the train types that loaded onto Territorial Orientation. Furthermore, the fact that Freight Traffic Volume loaded onto Societal Orientation, and not onto Territorial Orientation, suggested that the latter factor relates to railways where traffic volume is a non-issue: Diesel traction and distributed power support train-size scalability that is absent in passenger-dominated railways, such as those in Europe.

4.3 Global Networkability and the Broad-gauge Conundrum

A subset of variables that loaded onto Territorial Orientation, namely Heavy Intermodal, Distributed Power, and Country Physical Size, suggested high-tech long-haul railway services. The magnitude of Heavy Intermodal haul lengths currently operated or contemplated, in the range 2000-12000km, requires consignments to traverse the networks of several independent railways. Networkability is thus an important adjunct of Heavy Intermodal. Two further factors were found to address this aspect [7].

First, Narrow Gauge Kilometers loaded negatively on the factor *Global Networkability*, which represents the same-gauge contiguous network surrounding each country. The intuitively obvious interpretation is that sub-standard-gauge track inhibits continental- and intercontinental network-ability that underpins Heavy Intermodal. Second, Broad Gauge Kilometers loaded negatively vis-a-vis Standard Gauge Kilometers on the factor *Broad-gauge Conundrum*. It suggested that, despite arguable technical superiority, Broad Gauge opposes the critical mass of Standard Gauge: Network economics predicts that market dominance will outweigh technological advantage, as in Betamax versus VHS [14]. African, South American, and Southeast Asian railways are thus at present excluded from freight rail's richest growth market space. Spain has recognized the conundrum, and has dealt with it. Broad-gauge Kazakhstan has exploited its strategic location between European, Middle Eastern, and Chinese standard gauge networks, by proposing a standard gauge landbridge to link them. Railways in Central Asia and the Indian Sub-continent will experience networking constraints as Heavy Intermodal becomes the mode of choice for moving containers.

5 HIGH TECH—A NEW RESEARCH AGENDA

5.1 Technology, competitiveness, and sustainability

To recognize the theme of the conference, what constitutes *High Tech in Heavy Haul*? This author argues that high tech is technology that supports leading edge development, in a strategic trajectory, which leads an industry to markedly superior competitiveness and sustainability. According to this definition, high tech is thus neither technology for the sake of technology, nor doing the present task better. The latter is of course always important, but it does not admit the possibility that an industry may be in need of strategic repositioning.

Heavy haulage of low-value bulk commodities is subject to *source competition*, among *different countries*. Double-stacking is subject to *modal competition*, among *different transport modes*. Source competition drives bulk commodity haul distance down, typically to less than 1000km. Double-stacking leverages the cost advantage of heavy haul vis-à-vis other transport modes, driving haul distance up, typically to several multiples of 1000km. In addition to heavy axle load, double-stacking also exploits the second strength of a single-degree-of-freedom transport mode, namely high speed: Stress state could thus be set to increase again. One would thus expect heavy haul railway researchers to seek out topics where their future efforts will produce the maximum impact on heavy intermodal.

5.2 Open systems

Within the Territorial Orientation that defines the gestalt of serious freight railways, what research themes will underpin future progress? One should expect systems to be open rather than closed, hence their complexity will increase. Consequently systemic issues, such as macro-interoperability, or the ability to support large scale continental- and intercontinental networking and business integration, rather than micro interoperability, or the present ability to support limited interoperability within geographic boundaries, will surface. They will subsume the classic heavy haul technologies, namely wheel-rail- and train-track interaction, but without the collegiality of closed systems, which will add a new set of challenges. To seed the agenda, the author proposes the following items:

What will future Heavy Intermodal axle load be? The more extensive a network, the more difficult is it to find a consistently high value.
The development of a slackfree connector for articulated railroad freight cars, that gained a Sperry Award for advancing the art of transportation in 1994, might be superseded: In a trend away from articulation, even in North America, separate bogies for each container well allow lower axle loads, but at higher capital cost of wagons. Steel bridges are remarkably tolerant of axle load increases, and there always seems to be a way to carry more: Concrete bridges seem less tolerant, so research will need to deliver requisite insight..

The high cost of aligning broad- or narrow track gauges with standard gauge opens opportunities to variable-gauge heavy-axle-load wheelsets. In some instances, such as under overhead electrification, it may be feasible to increase axle load without resorting to double stacking, by reducing the number of axles rather than increasing the payload. Revisiting Talgo's single wheelset roots may provide an elegant solution..

High-wire catenary will be essential for railways that prefer electric traction—pantograph sway could become a topical issue. Could third rail be made to work at 25kV? Selective electrification, to assist diesel locomotives by supplying direct current from an external source directly to the rectifier-inverter link may have merit [18].

Scalable, universal, braking- and traction control protocols will be needed. Irreconcilable differences exist between direct release and graduated release pneumatic braking, which could be unified by electronic control such as ECP braking. A researchable philosophic issue nevertheless remains regarding control network failure—whether degraded pneumatic emergency backup as per AAR 4200 is acceptable, or whether redundant electronic control per European thinking is essential [19]. The application of distributed power to heavy intermodal trains, which may not be uniformly loaded like unit trains, is another.

Interoperable train authorization, long topical in Europe, has provided railways with valuable experience in establishing Technical Standards for Interoperability. This will provide a sound foundation for future research on performance monitoring, and running maintenance over long hauls on multiple networks. Interoperable business systems could also prove novel for heavy freight railways.

Even the unthinkable might be thought. The maritime transportation industry strongly influenced ISO container dimensions. However, if container movements no longer need to use maritime transport, but move overland only, United States domestic containers, sized to equal road vehicles, could become an alternative global standard. While it can make sense to use the lowest common denominator (LCD) across the global logistics chain, raising the LCD could raise the game in favour of rail.

5.3 Contention and direction

The early stages of large scale systemic change are naturally turbulent. Multi-final outcomes are possible, and the end-state is far from clear: What it might not be is frequently clearer, at least to stakeholders who are aware of the underlying global drivers. The challenges are real, particularly in developing countries where limited resources highlight contention between railways' Territorial Orientation and their Societal Orientation. An example is the unavoidable mixing of freight and passenger traffic on networks that are too large to duplicate [20]. Railways that do not have standard gauge are also inclined to contend or deny the issue [21]. There is thus value in identifying opposing and ambiguous forces through engaging stakeholders in dialectic inquiry to achieve consensus on a robust outcome. Positioning that is contrary to the mainstream can simply delay the inevitable outcome.

5.4 Resistance to change

The railway industry is reputedly asset heavy, which has led to claims that it is a special case subject to special rules, and is notoriously resistant to change. In considering where heavy haul might be headed, it is useful to examine barriers to adaptation. The author therefore examined the asset base of railways versus that of other industries, using the aggregate per industry for companies listed in the *Fortune* Global 500 [22], as presented in Table 1.

Table 1

Industries ranked by assets in US$ billions

Rank	**Industry**	**Assets**
1	Banks: Commercial and Savings	678344
2	Securities	598659
3	Diversified Financials	442152
4	Insurance: Life, Health (Stock)	308713
5	Insurance: P&C (Stock)	245482
6	Insurance: Life, Health (Mutual)	239097
7	Insurance: P&C (Mutual)	127187
8	Oil and Gas Equipment, Services	97893
Average	Telecommunications	81266
10	Energy	74950
11	Motor Vehicles and Parts	69486
12	Petroleum	62570
13	Entertainment	60081
14	Utilities	58073
15	Mail, Package, Freight Delivery	54395
16	Pharmaceuticals	52188
17	**Railroads**	**51766**
18	Tobacco	44972
19	Electronics, Electrical Equipment	42595
20	Health Care: Insurance, Managed Care	37775
21	Aerospace and Defence	37660
22	Computers, Office Equipment	36804
23	Food Consumer Products	34155
24	Trading	34007
25	Mining, Crude-oil Production	33531
26	General Merchandisers	33497
Median	Chemicals	31313
28	Industrial and Farm Equipment	31036
29	Household, Personal Products	30613
30	Shipping	30479
31	Network, Other Communication Equipment	29396
32	Building Materials, Glass	28873
33	Metals	27641
34	Computer Services and Software	27451
35	Forest and Paper Products	26115
36	Beverages	24783
37	Semiconductors, Electrical Components	23988

38	Miscellaneous	23774
39	Airlines	23298
40	Apparel	23246
41	Food and Drug Stores	21886
42	Scientific, Photo, Control Equipment	20290
43	Food Services	18180
44	Engineering, Construction	16658
45	Homebuilders	14867
46	Specialty Retailers	14771
47	Wholesalers: Health Care	14340
48	Health Care: Other	13568
49	Food Production	13516
50	Wholesalers: Other	8484
51	Temporary Help	6818
52	Hotels, Casinos, Resorts	5925
53	Wholesalers: Electronics, Office Equipment	5720

Railways ranked 17th in terms of assets, below the US$79 billion average (between 10th and 11th), but, in a setting skewed by big financial institutions, above the US$31 billion median. For comparison, railways ranked behind *Telecommunications*, considered to be an agile industry, and behind *Mail, Package & Freight Delivery*, a member of the asset-light logistics industry. Railways did however rank higher than *Shipping* and *Airlines*, two potential competitors. One must therefore conclude that railways are less asset heavy than they are reputed to be, and that they therefore ought not to be less agile than their competitors in physical distribution. Resistance to change seems to reside in their venerability rather than in their tangible assets.

Uncontrolled variances could be present, and the following qualifications are therefore noted. First, the *Fortune* 500 by no means represents all railways. However, it does include Deutsche Bahn, on the brink of transition from state- to listed ownership, state-owned SNCF, and listed East Japan Railway. It therefore arguably represents all major railway ownership models. Second, a significant competitor, the trucking industry, is absent, possibly because its structure is so fragmented that even major players do not make the *Fortune 500* league. Third, financing may be off balance sheet, so assets deployed by individual railways may show up as assets owned by other entities. It is noted that the most asset heavy industries are indeed in the financial sector. Fourth, ranking by assets is not the only possible criterion. Nevertheless, with due respect to *Fortune*, its profitability and return-on-assets numbers varied so widely that this author did not attempt to draw inferences from them. The present examination of assets is therefore offered as a dipstick measure only, subject to the stated qualifications. The asset heaviness of railways is evidently a field that could justify further research.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 The third mainline

Following emergence of high-speed intercity passenger trains in the 1960s, and heavy haul in the 1970s, sustainable freight railways have successfully leveraged their genetic technologies, Bearing, Guiding, and Coupling, to

dominate the Heavy Haul and Heavy Intermodal market spaces. In contrast to their common carrier forebears, today's top freight railways are high volume, extraordinary carriers. Convergence of high growth, high-volume global trade [23], and the inherently competitive positioning of heavy haul, has nurtured the third mainline of the railway renaissance, namely Heavy Intermodal. Identification of the Territorial Orientation factor has demarcated a solution space in which high tech freight railways can cognitively and confidently position themselves for vigorous growth.

Heavy Intermodal is closely related to Heavy Haul, yet the market space in which it exploits rail's genetic technologies makes it almost a distinct transport

mode. It is therefore recommended that the heavy haul community recognizes it for what it is, and also that countries whose railways are not yet in heavy haul and/or heavy intermodal reassess their ability to embrace the new business models of rail's third century. By cross-breaking the Bearing and Guiding genetic technologies, one can predict that there will be no fourth mainline of the railway renaissance. Noting that the drivers of heavy haul's success also contain the seeds of stagnation—the Law of Diminishing Returns—it is also recommended to extend heavy haul's application domain.

6.2 Extending the application domain

Informed by the foregoing interpretations of the factors Territorial Orientation, Global Networkability, and Broad-gauge Conundrum, conclusions regarding several settings around the world come to mind. As bounded technologies inescapably yield to unbounded technologies, new freight railway developments are more likely to extend heavy haul domain boundaries than to increase axle load, as follows.

First, on some European motorways, trucks and trailers follow one another so closely that they appear as trains. The aspirations of the Strategic Rail Research Agenda could even be jeopardized. Europe has to separate freight from passenger trains. Second, narrow- and diverse track gauges do not support the high centre of gravity that associates with double stacking, and the networking that is required to provide its long hauls. Furthermore, narrow gauge heavy haul railways are unlikely to become parts of an extensive continental network. This will challenge major freight railways in Australia, Brazil, and South Africa, and Southeast Asian aspirations regarding the Trans Asia railway network. The Community of Independent States and the Indian Sub-continent, both major railway regions, are liberalizing and growing their economies. Networking economics theory predicts that they will ultimately need to conform to global railway standards, although the modalities are without doubt complex and expensive. In a conservative industry, holding out against the inevitable might be an initial reaction,. Fortunately, where standard gauge already exists, there is ready acceptance of the value of global networking.

It is therefore recommended that railways open a front to examine and to promote a transition from bounded technologies to unbounded opportunities in information-bonded open global logistics systems. This might unnerve

some present incumbents: The industry will certainly need to acquire new skills to participate in open systems, and may even need different types of people, as it advances to the next higher level of work in stratified systems theory. Leading railways have advanced to the threshold of global industry standards, like other transport modes. It is recommended that they do not baulk at the price, but forge global industry standards that will allow them to enter into a domain where flow of investment is not impeded by deficient physical- and business interoperability.

6.3 The best is yet to come

This paper has developed scientifically grounded insight into the global drivers of heavy haul and heavy intermodal. It examined the underlying economic and technological issues, and related them to the growing application domain of heavy intermodal. It also compared railway assets with those of other industries, and found railways to be less asset heavy than commonly thought. The competitive nature of Heavy Haul works assets aggressively; therefore the industry should have faster obsolescence and hence faster renewal. Rapid adaptation to the challenges and opportunities of new business models should therefore be an attainable objective rather than an insurmountable obstacle.

Railways can and should enter their third century boldly, an unprecedented long-lived industry that can still participate meaningfully and proudly in leading edge 21st Century global logistics. The Territorial Orientation factor has prospected system boundaries where rich rewards await exploitation. Roll out the offensive—the challenge has been issued! In respect of freight railways, heavy haul has established one railway renaissance mainline (the other being high speed). Recognizing the potential synergy between physical- and networking technologies, corporate strategy research has found insights that conclude that the competitive strengths of heavy haul railways could be extended to an enlarged set of infrastructure- and train operators in a globalized freight railway setting—the third railway renaissance mainline. The best is yet to come!

7 REFERENCES

[1] Colvin, G, **Managing in Chaos**, *Fortune*, Vol. 154*(6)*, 2006, pp. 26-28, 30-32.

[2] Loomis, C.J., **The Tragedy of General Motors**, *Fortune*, Vol. 153*(3)*, 2006, pp. 30-34, 36, 38-40, 42, 44-45.

[3] Kirkpatrick, D., **Microsoft's New Brain**. *Fortune*, Vol. 153*(8)*, 2006, pp. 52-55, 58, 60, 62-63.

[4] Levinson, M., **The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger**, Princeton University, Princeton, NJ, 2006.

[5] Orenstein, J., **US Railroad Policy: Uncle Sam at the Throttle**, Nelson-Hall, Chicago, 1990.

[6] Meng, Y. & Niemeier, D.A., **US Double-stack Rail Technology and Infrastructure: Corollaries for China**, *Int. Jnl. Services Technology and Management*, Vol. 1*(2/3)*, 2000, pp. 224-235.

[7] Van der Meulen, R.D. & Möller, L.C., **Railway Globalization: Leveraging Insight from Developed- into Developing Regions**, *Proc. 7th World Congress Railway Research, Montréal*, 2006.

[8] Dorfman, R., **Prices and Markets**, Prentice-Hall, Englewood Cliffs, NJ, 1967, pp. 90-91.

[9] Curtis, R.D., **Evolution in Rail Car Design for Double Stack Service**, *Proc. 4th International Heavy Haul Railway Conference*. Brisbane, 1989.

[10] Khan, A.M., **Intermodal Service Requirements in Canada: Role of Heavy Haul Technologies**. *Proc. 5th International Heavy Haul Railway Conference*. Beijing, 1993.

[11] Lai, Y-C. et al., **Machine Vision Analysis of the Energy Efficiency of Intermodal Trains**, *Proc. 8th International Heavy Haul Railway Conference*, Rio de Janeiro, 2005.

[12] International Heavy Haul Association, **Guidelines to Best Practices for Heavy Haul Railway Operations: Wheel and Rail Interface Issues,** Virginia Beach, VA, Author, 2001.

[13] Kelly, M., **The Dynamics of Smithsonian Growth**, *Quarterly Journal of Economics*, 112(3), 1997, p. 939-964.

[14] Mankiw, G.N., **Why we don't speak Esperanto**, *Fortune*, Vol. 138*(7)*, 1998, p. 30.

[15] Donlan, T.G., **Editorial Commentary: Network Power**, *Barron's*, 78*(5)*, 1998, p. 62.

[16] Kirkpatrick, D., **Life in a Connected World**, *Fortune*, Vol. 154(1), 2006, pp. 58-60.

[17] Oliver, J.A. 2006. **The Bering Strait Crossing: A 21st Century Frontier between East and West**, Information Architects, United Kingdom.

[18] Van der Meulen, R.D., **A Challenge to Traditional Perspectives on Freight Railway Energy Provisioning**, *Proc. Alternate Traction Technologies*, Spoornet & International Union of Railways, Johannesburg.

[19] Bergstedt, R. **Private Communication**, circa 2003.

[20] Besedin, I.S. & Muginshtein, L.A., **Technical and Economic Challenges and Decisions for Heavy Haul Operations in Russia under Conditions of Combined Traffic of Freight and Passenger Trains**, *Proc. 8th International Heavy Haul Railway Conference*, Rio de Janeiro, 2005.

[21] Editorial, **Putin Rules Out Gauge Change**, *Int. Railway Jnl.*, Vol. 46*(10)*, 2006, p. 16.

[22] Editorial, **Global 500 Ranked within Industries,** *Fortune*, Vol. 154*(2)*, 2006, pp. F–16-F–23.

[23] Fadeyev, G., **Container Landbridge will Assure RZD's Future Prosperity**, *Railway Gazette International*, Vol. 160*(3)*, 2004, pp. 148-149.