Innovation and globalization: Mainstreams and margins

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Summary: The present research questioned the sustainability of narrow gauge heavy haul railways under globalization, and contributed a unique strategic view thereon. Strategic adaptation of railways in Australia, Brazil, and South Africa was compared, particularly regarding their ability to source competitive cars and locomotives. Allowable axle load is a major challenge, followed by the size and rating of traction motors. The conclusions are somewhat teasing, in that they are best posed as questions for the reader to ponder.

Index Terms: Adaptation, locomotives, narrow gauge, networkability, strategy.

1 INTRODUCTION

1.1 Previous research

Previous research [1] found double stacking to offer heavy haul opportunities to railways that were able to network with others, to offer continental-scale hauls. Further corporate citizenship research [2] found Double Stacking, Distributed Power, Heavy Haul, Private Infrastructure Ownership, Axle Load, and Competing Parallel Infrastructure Operators, to underpin a factor named *Freight Rail Positioning*. It indicated that railways that exploit one or more of the variables mentioned were able to position themselves competitively and sustainably. However, narrow gauge railways cannot access double stack container traffic, because its centre of gravity is too high. In addition, they are excluded from rail's other strong market space, high speed intercity.

1.2 A narrow gauge strategic hurdle?

The abovementioned research also found narrow track gauge[1] to oppose a factor named *Exploring Horizons*. The latter factor indicated that standard gauge reinforced the ability to network, or *networkability*, mentioned in §1.1, whereas the presence of narrow gauge weakened networkability. Heavy haul is one of few railway applications where narrow gauge can make a pragmatic contribution to railway sustainability. However, widely dispersed mineral deposits mean heavy haul railways are unlikely to coalesce into continental networks that compete for non-heavy haul traffic. This situation confines narrow gauge railways to standalone heavy hauls: It challenges strategic positioning of such railways in Australia, Brazil, and South Africa that rely on bulk commodities to contribute substantial revenue. Even if they compare well with one another, they nevertheless need to export commodities against source competition from countries whose standard gauge railways go with the mainstream of standard locomotives and heavy axle load.

1.3 The research question

Sustainability is a system's ability to maintain itself with no loss of function for extended periods. The present research examined the competitiveness and sustainability of narrow-gauge heavy-haul railways in the globalized economy.

While classic wheel-rail interaction is gauge independent, some gauge dependent parameters do nevertheless influence railway competitiveness. Steel-wheel-on-steel-rail contact develops vertical- and lateral forces, which ensure precise application of vertical loads—the *Bearing* genetic technology, and secure application of lateral loads—the *Guiding* genetic technology. The *Coupling* genetic technology leverages both to create capacity. They support heavy axle load, high speed, and long trains respectively [1]. Speed is a non-issue, and narrow gauge railways are leaders in train length, so the remaining genetic technology challenge for narrow gauge heavy haul is to increase axle load.

[1] 914mm to 1067mm.

Insufficiently heavy axle load negatively influences rolling stock cost and performance. Indeed, the high cost of new locomotives is a critical problem for narrow gauge railways [3]. By comparison with diesel locomotives, electric locomotives exacerbate this problem.

2 KEY NARROW-GAUGE ISSUES

2.1 Constraining parameters

Several parameters constrain narrow gauge railways, in particular axle load and, axiomatically, distance between rails. First, standard gauge railways have attained 40 tonnes, while narrow gauge railways have not advanced beyond 30 tonnes: Competitiveness and sustainability are constrained pro rata. Second, the distance between rails influences vehicle stability vis-à-vis centre of gravity height and train speed. Third, back-to-back distance between locomotive wheels determines how large a traction motor will fit. This influences locomotives and cars as follows:

2.2 Gauge dependence—locomotives

The benchmark heavy haul locomotive is a standard-gauge, six-axle, 194 tonne diesel with AC traction motors, delivering 700kN tractive effort at 37% adhesion, for a purchase price of ≈USD2.3x10^6. All other things being equal, the torque of a traction motor is a function of the length of its armature conductors. Hence, narrow gauge traction motors cannot match the performance of standard gauge traction motors. To compare, USD2.0x10^6 buys a narrow gauge locomotive with DC traction motors that delivers around 300kN and 2300kW: Space between the wheels limits both these parameters.
In addition, low tractive effort locomotives do not cost materially less to maintain than high tractive effort locomotives. Since the narrow gauge locomotive fleet to perform a given transport task is larger than for standard gauge, the cost of locomotive maintenance is also higher.

The global narrow gauge locomotive market is at best 1% of the standard gauge market: Despite sharing equipment with standard gauge designs, non-recurring engineering, low production volume, and low axle load in particular, substantially increase the price per kN and per kW for narrow gauge locomotives.

2.3 Gauge dependence—cars

Car attributes, such as corrosion-, penetration-, and wear resistance, as well as high-value-added components and subsystems, such as bearings, brake cylinders, control valves, couplers, drawgear, side frames, slack adjusters, springs, and wheels, are gauge independent: Standard gauge cars thus support higher load/tare ratios, which decrease capital- and operating expenditure for given system capacity. Figure 1 shows how narrow gauge impairs coal and ore cars: Naturally, their carrying capacity is less, but their load-to-tare ratios are also lower. This means that a narrow gauge railway could need up to 30% more cars than a standard gauge railway for the same throughput.

Fortunately, the number of cars per locomotive is in the range 40-100. This means that narrow gauge cars can leverage whatever economies of scale they can attract, better than can narrow gauge locomotives. Railways can pursue the most advantageous source for high-value-added components and subsystems (which

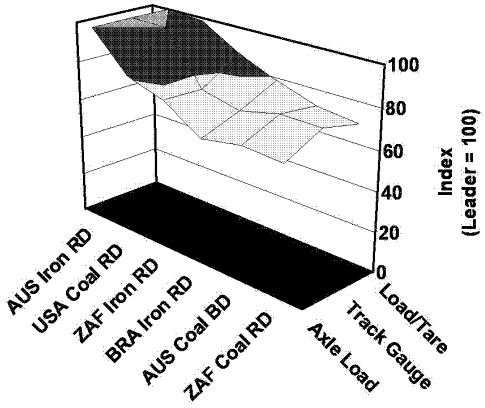

Figure 1: Comparison of Axle Load, Track Gauge, and Load/Tare Ratio for countries and commodities (BD = bottom dump, RD = rotary dump)

come from global centres of excellence), for bodies (where local manufacture competes against global sourcing), or for complete vehicles.

3 STRATEGIC ADAPTATION

3.1 A reference framework

The present research methodology used content analysis of trade periodicals, complemented by liberal use of the Internet, to examine high-level strategic adaptation as narrow gauge railways sought to offset their impairment. Operational efficiency was excluded, because it should not affect strategic positioning.

Previous research [2] found an array of variables, in the groups *Business*, *Competitiveness*, *Contribution*, *Networkability*, *Ownership*, *Society*, *Sustainability*, and *Time*, to be relevant to railway positioning. They guided the selection of narrow-gauge heavy-haul railway attributes, in Australia, Brazil, and South Africa, to address the research question through the following brief reviews.

3.2 Australia

In Australia, only Queensland operates coal heavy haul on narrow gauge. Since 2006, its railways have operated under an open access undertaking overseen by the Queensland Competition Authority. QR Network Coal Systems now manages the narrow gauge heavy haul network, formerly the vertically integrated domain of Queensland Rail. Operators Pacific National (PN) [5] and QR National (QRN) compete on-rail for export- and domestic coal traffic. They currently transport 160Mtpa to six ports [4].

Queensland's coal hauls are around 400km from mine to port. Trains are comparatively short, 40-120 cars, thus locomotive consists are not large. Radio distributed power is used on longer trains [6].

The operators use mainly electric locomotives. New electric locomotives tend to be expensive, so QRN has upgraded some of its older locomotives. QRN and PN are acquiring respectively 45 and 23 new electric locomotives from Germany, at ≈USD5.6x10^6 each [7]. The six-axle locomotives are relatively light, at 132 tonnes [8]. Their bottom-dump cars cost ≈USD105 000 [6].

QR Network currently has a five-year

investment plan that exceeds USD2 billion, with more expansion projected later [9].

Interestingly, though expectedly in an open access setting, QRN has repositioned itself as an Australian national operator with substantial standard gauge interests. In so doing, it has strategically hedged itself against narrow gauge unsustainability.

3.3 Brazil

In Brazil, the Estrada de Ferro Vitória a Minas (EFVM) heavy hauls iron ore on narrow gauge from Minas Gerais mines to Tubarão port. In 1997, Companhia Vale do Rio Doce, now Vale, won a thirty-year concession on the route, with a possible thirty-year extension. The vertically integrated operation conveys some 120Mtpa [3], 80% of which is iron ore [10], over 550-650km hauls. It has a record of long trains, 150 cars in 1970, and up to 320 cars with distributed power in 2002 [11].

A diesel railway, EFVM has cleverly modified North American locomotives to meter gauge. It substitutes eight smaller narrow-gauge traction motors for six original standard gauge traction motors, which simultaneously keeps axle load within acceptable limits. For rebuilds, it yields practically new locomotives for around USD1.0x10^6 each [3]: For new locomotives, it attracts a price premium of some 6% [Private communication, 2007]. Vale has also acquired some new iron ore cars from China [12]. Global sourcing can secure highly competitive pricing—around USD50 000 per rotary dump car [Private communication, 2008].

EFVM's short-term expansion seems focused on rolling stock. Longer term, Vale has engaged contractors to provide specialist services to increase the average current axle load of 25 tonnes to 35 tonnes, with steps at 27.5, 30 and 32.5 tonnes [13].

3.4 South Africa

South Africa's Transnet Freight Rail (TFR, formerly Spoornet) operates two narrow-gauge heavy-haul lines, Ermelo-Richards Bay for coal export, and Sishen-Saldanha for iron-ore export. The Department of Public Enterprises is national government's shareholder representative with oversight responsibility for state-owned enterprises, among other Transnet [14].

The Sishen-Saldanha line features rare 50kV AC traction. TFR currently uses 80 diesel locomotives to augment its 31 six-axle 168-tonne electric locomotives. It recently installed a new computer control and diagnostic system. The inefficiency of mixing locomotives with different kW/kN ratios, on the same train, highlights the challenge of expanding a 50kV narrow-gauge locomotive fleet in small increments. Thirty-two new six-axle, 180-tonne, locomotives are on order, priced at USD 4.8 million each [15].

Maximum axle load is 30 tonnes, so TFR leads narrow-gauge railways in respect of this parameter at this time. Radio distributed power controls 342-car trains, hauled by locomotives in four consists.

Expansion of the 861km single line from 47Mtpa to 60Mtpa was announced in 2008, to attain full capacity in 2013. Additional locomotives, cars, crossing loops, and upgraded electrification infrastructure, are required [16].

The Ermelo-Richards Bay line currently serves mines located 400-600km from the port. Its double track allows 26-tonne car axle load. The forty-five 25kV AC, six-axle, 168-tonne, locomotives were recently upgraded by installation of a new computer control and diagnostic system [17]. One hundred and ten four-axle, 104-tonne, locomotives are on order, priced at USD5.2x10^6 each [15]. Rotary-dump cars are sourced from sister division Transnet Rail Engineering. The consulting profession has priced the cars at USD75 000.

Trains convey 200 cars. A positive business case for integrated ECP braking and wire distributed power projected a safer, faster railway [18]. Although TFR initiated fleet conversion in 2002, the project is still incomplete. Throughput has declined in recent years, to around 60Mtpa [19]. Meanwhile, Richards Bay Coal Terminal is ready to raise exports to 91Mtpa [20]. The discrepancy has attracted contention.

4 FINDINGS AND COMMENTS

4.1 Survival of the fittest

The three countries reviewed developed very different responses to the challenge of narrow-gauge heavy-haul sustainability. The following sketches extract and discuss key differences. Note that exchange rate comparisons over time can be fuzzy: Therefore, prices mentioned in this paper indicate order of magnitude only.

4.2 Queensland

Queensland enjoys on-rail competition. PN and QRN are competitors, but they share a destiny in source competition with other countries. Multiple ports facilitate short hauls: With bottom dump cars turn-around time should be short. Cost of transport is arguably as low as it could be.

However, 26-tonne axle load just beats the heavy haul threshold. Locomotives are relatively light and expensive, coming in at USD42 000/tonne. Cars are the most expensive of the three, but bottom-dump cars are naturally more expensive than rotary dump cars. The short haul distance reduces turnaround time to offset a possibly higher cost structure due to higher rolling stock prices. Low axle load arguably reflects QR’s former state ownership.

4.3 Brazil—EFVM

Vale’s long-term vertically-integrated concession on EFVM should support effective strategic development. It has sourced benchmark locomotives and modified them at fair cost—even new diesel locomotives should cost USD15 000/tonne. Haul distances are moderate. Cars are least expensive of the three. It is positioned as an aggressive global competitor.

Its 25-tonne axle load is on the heavy haul threshold, but it has recognized the challenge of increasing it, and looks set to lead this parameter in due course.

4.4 South Africa—TFR

State-owned TFR's throughput appears to have lagged, although mineral reserves are available and miners have declared their willingness to extract. While EFVM and Queensland each export far in excess of 100Mtpa, TFR's combined coal- and iron ore exports barely make 100Mtpa.

While iron ore throughput is ramping up slowly, locomotive shortages have curtailed capacity. Mixing diesel- and electric consists to minimize the opportunity cost of insufficient 50kV locomotives is a desperate measure. Its new electric locomotives, at USD27 000/tonne, place it between EFVM and Queensland. Car price is mid-range. Noting its long haul distance, TFR will need to work on overall competitiveness in iron ore haulage.

Coal export has encountered a rough patch. Unique locomotives have taken long to commission, and come in as most expensive, at USD50 000/tonne. ECP braking and DP have been slow in rolling out. Car axle load has not followed the Sishen-Saldanha example. Its haul distance exceeds that of Queensland. TFR needs to work hard to find competitive advantage.

4.5 What future for narrow gauge?

Narrow gauge heavy haul railways have lagged the crucial axle load parameter: IHHA conference proceedings suggest they have not yet tried to catch up. They appear to pay a premium for rolling stock. Inability to network widely excludes them from modal- or parallel competition, confining them to source competition. Therefore, even exposing them to open access competition, as in Queensland, cannot directly respond to the challenge.

Even if narrow-gauge axle load were to increase, would space between the wheels accommodate traction motors that could develop sufficient torque to utilize a materially higher axle load? Who would do the development? What would be the cost premium? Whatever the outcome, narrow gauge cannot match standard gauge in this respect.

No meaningful secondary market exists for narrow gauge locomotives. Electric railways thus buy new locomotives and do a mid-life upgrade. However, an active secondary market in standard gauge heavy haul diesel locomotives does exist: They can be re-gauged if the vehicle profile allows. Few railways have standard gauge heavy haul electric locomotives, although Sweden's IORE locomotive has migrated to China. Even if they did, common narrow gauge traction motors do not exist, so re-gauging electric locomotives would be prohibitively expensive.

Despite their many distributed power applications, standard gauge railways appear to prefer heavier axle load and shorter trains: Narrow gauge railways work exceptionally long trains at a higher stress state than standard gauge, seemingly to bolster competitiveness and sustainability.

5 CONCLUSIONS AND FURTHER QUESTIONS

Narrow gauge heavy haul railways have lagged in the axle load contest. To compensate, they have maximized train length. However, as long as locomotive traction motors must fit between the wheels they drive, must they always trail standard gauge ratings?

It is imperative to find a way of raising axle load. While that could align cars with standard gauge, locomotives pose a higher challenge. For diesels, one might move traction motors off the axles by using hydraulic transmission. Vale's predecessors and Southern Pacific went there in 1961, when they bought respectively narrow- and standard gauge versions of the most powerful diesel locomotive of the time. What about electric locomotives—does a mainstream solution exist?

In conclusion, unless they innovate, globalization could move narrow-gauge heavy-haul railways from mainstream to margin, as has already happened in the double stack and high-speed intercity market spaces. PN, QRN, and Vale already participate in other standard- or broad gauge operations. Quo Vadis TFR?

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