FREIGHT RAILWAYS FOR THE NEW MILLENNIUM:

AFRICA AS GLOBAL PLAYER?

R.D. (DAVE) VAN DER MEULEN and G.J.C. (GEORGE) PARKER

Spoornet, Private Bag X637, Pretoria 0001, South Africa

Phone (012) 315 3182; Fax (012) 315 3089; E-mail davevdm@transnet.co.za

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SUMMARY

For several reasons, transcontinental railways did not materialise in Africa. However, indicators suggested that it was opportune to revisit the subject. The paper explores three sets of variables that are relevant to global railway renaissance. First, Axle Load and Speed, that ecologically define four railway eminent domains—city rail, heavy haul, intercity passenger, and intermodal freight. Second, Liberalisation and Networkability, that relate to the strategic development of railways. Last, Track Gauge and Wheelpair Gauge, that relate to wagon interchange. Thereafter, the authors examine African railway alignment with the relevant environment. First, Globalisation, that has become a significant driver of railways and their customers. Second, the Entrepreneurial Setting, that explores trends in sources of business. Third, Development Perspectives, that look at how business might develop in Africa. Last, the competitive arena, in which precise and secure transportation of value-added freight by railways seems to be displacing shipping lines. The authors conclude that the nexus between transcontinental railway links in Africa, and the economics to support them, is elusive and fragile. They explore outcomes that will shape infrastructure, rolling stock, and business models that will ultimately influence the format and competitiveness of African railways.

1. INTRODUCTION

During the 1870s, transcontinental railways were planned and built in many parts of the world. In America, they fostered the settlement of vast territories (Thomas, 1957: 189). In Europe and Asia, they formed the basis for widespread economic development. In Africa also, transcontinental railways stirred interest. A link from Algeria to the Niger basin seemed desirable. The Dakar-Niger railway, part of a scheme to connect the West African interior by rail to Algeria, was actually built (Jones, 1995: 2). However, a trans-Saharan railway, that would have stretched from Algeria to Sudan and contended with great physical difficulties, held little prospect of economic return. Its realisation became unlikely because of the great cost, the estimated light traffic, and disturbed political conditions (Schander, 1913: 553; Thomas, 1957: 248, 257). In the early years of the twentieth century, Cecil Rhodes envisaged a Cape-to-Cairo railway. Ultimately it did not materialise, for lack of commercial incentives and loss of visionary leadership upon his death (Weinthal, 1923: vol. 1., 1-15). In Africa, economic reality seems to have overtaken colonial aspirations. Nevertheless, given the simultaneous presence of world railway renaissance and African renaissance, it is apposite to explore the potential for convergence between them.

2. SOME AFRICAN ECONOMIC GEOGRAPHY

2.1. Background

Africa is the second-largest continent after Asia. It comprises a vast plateau rising steeply from narrow coastal strips. In a railway context, two geographic features — the Sahara desert, the largest in the world (Webster, 1999: 7), and the Rift Valley. The Sahara, roughly equal to the United States in area, is an inhospitable natural barrier that has compelled almost all surface transport to circumnavigate it. In many classifications, it divides the continent into North- and sub-Saharan Africa. The Rift Valley is at once barrier and opportunity. On the one hand, its rugged relief impedes terrestrial transport, but on the other hand, its non-contiguous but navigable water- bodies and courses offer several transport routes. Mineral wealth is widely distributed. During the spice trade era, parts of sub-Saharan Africa linked into international trading circuits through trading ports in Zanzibar and Mozambique, exporting ivory and gold. Camel caravans also moved across the Sahara into the Sahel and Savannah regions, but there was no maritime traffic between southern Morocco and the Limpopo. Africa’s geography made transport difficult and impeded trade links. The Western coast and the interior were almost completely isolated from outside contacts. Neither production nor trade grew in a sustained manner until the demand for Africa's industrial raw materials rose in the mid-19th century. Direct foreign investments in Africa are still likely to be in mining, petroleum, and other primary commodity extraction ventures (Bräutigam, 1999).

2.2. Impact on Railway Development

The foregoing background shaped Africa’s railway legacy. North Africa is characterised by standard gauge (1435mm) railways. Contiguous networks representing some 7% of Africa’s railway route length stretch from Morocco to Tunisia, generally north of the Atlas Mountains. Egypt also has a standard gauge network that spans its width, with a southward line down the Nile to Aswan. Libya has no railways yet, although construction of a link between Egypt and

Tunisia seems imminent. East Africa is characterised by the narrow gauge (1000mm) network in Kenya, Tanzania and Uganda, representing some 5% of Africa's contiguous railway route length. Southern Africa, from the ports of Lobito in Angola to Dar es Salaam in Tanzania, operates a narrow gauge (1067mm) network that stretches to the Equator. It represents some 55% of Africa's contiguous railway route length (Railway Gazette, 1999). Africa is unfortunate that the remaining 33% of its railway route length comprises non-contiguous fragments. A miscellany of railways on a variety of gauges (1000mm, 1067mm and 1435mm) characterises West Africa, from Nouadhibou in Mauritania to Luanda in Angola. They link ports with their respective hinterlands. Located in Africa's most riverine region, including the strip separating the Sahara Desert from the Atlantic Ocean, it is not easy to imagine them being linked. The other fragments are the 1067mm Sudan and 1000mm Ethiopian railways, in the Red Sea vicinity (Railway Gazette, 1999).

2.3. Links and Routes

The foregoing legacy suggests missing links that one would expect to find on a globally relevant continent. The first expectation is intercontinental links from North Africa to Europe and Asia. One actually existed. Al Qantarah, south of Cairo, was the junction for the Palestine Railway. A removable bridge across the Suez Canal during World War I facilitated through transit between Cairo and Jerusalem, but the Suez Company objected to it after the war, and it was removed (Weinthal, 1923: vol. 2, 510). The link built during World War II between Jerusalem and Beirut, to access the standard-gauge Western European network in Turkey, is currently disused. A fixed link between Morocco and Spain via the Strait of Gibraltar has also received consideration, but remains missing. The second expectation is an intra-African transcontinental link. The Cape-to-Cairo, as an isolated system without feeders from the north, east and west, was an unthinkable proposition (Weinthal, 1923: vol. 2, 510). Its proponents had little doubt that it would be the main artery, being nearer completion than any other route. It would have been a main backbone connecting one end of Africa with the other, linking various mineral fields, connecting navigable river systems, as well as lateral railways to the coast (Williams, 1923: 120). A further consideration is whether such a link should pass west of the Rift Valley, where the missing links are shorter, or east of it, where business seems more likely.

3. RELEVANT RAILWAY VARIABLES

3.1. Axle Load and Speed

One may categorise transport modes by, among other, the number of degrees of freedom of translation. Aerial transport has three degrees of freedom of translation (longitudinal, lateral and vertical). Its vertical degree of freedom, that permits it to overfly natural obstacles in a direct path, comes at the cost of overcoming gravity. Surface transport (maritime or terrestrial) has two degrees of freedom of translation (longitudinal and lateral), because the surface supports it in the vertical direction. Surface modes offer versatility to link scattered origin-destination pairs, within the constraints of natural obstacles. Links such as canals (between water masses) and bridges (between land masses) extend versatility at the cost of overcoming such obstacles. Guided surface transport (i.e. linear movement permitted only in the direction of the guide) has only one degree of freedom of translation (longitudinal).

Clearly, the number of degrees of freedom implies a trade-off among desirable characteristics.

Single-degree-of-freedom guidance distinguishes railways from other terrestrial transport modes. It constrains origin-destination versatility, but does it not simultaneously confer compensatory advantages? What unassailable advantages inhere in single-degree-of-freedom guidance? First, precise application of forces to substructure supports a very high axle load (35 tonnes on rail versus 8 tonnes on road). Second, precise and unambiguous directional guidance supports very high speed (350km/h on rail versus 120km/h on road). Realistically, both attributes require relatively high traffic density to service the high costs associated with them. Axle Load is thus arguably a fundamental discriminant of railway competitiveness vis-à-vis competitive modes (Van der Meulen, 1997: 17). Road-vehicle populations comprising light- and heavy vehicles typically share roads, on multiple lanes on densely trafficked routes. It would be uneconomical to build suitably heavy infrastructure should heavy vehicles in such a distribution attempt to match railway axle loads. When incorporated into an appropriate product design, Speed enables a railway to compete for business in niches that other modes cannot match. Speed, or its alter ego, Time Value, is thus arguably another fundamental discriminant of railway competitiveness vis-à-vis competitive modes.

Cross-tabulating Axle Load and Speed (Figure 1) yields four quadrants in which the railway industry is rolling out new technologies and services — City Rail, Heavy Haul, Intercity Passenger, and Intermodal Freight. In quadrants that are *high* on at least one variable, railways appear to possess sufficient advantage to be ecologically sustainable in competition with other modes. Heavy Haul and Intercity Passenger have thus established eminent railway domains. The *low-low* quadrant fails to exploit the inherent strengths of railways, and is thus ecologically vulnerable and turbulent. In developed countries, City Rail is under attack from private cars, decentralisation, and telecommuting: In developing countries, buses and shared taxis are tough competitors. Technologically, light rail and hybrid systems are adulterating City Rail: Economically it seldom exists without subsidy. To pre-empt questions regarding the fate of railway general freight, it used to reside in the *low-low* quadrant, but road hauliers around the world have left it moribund. Railways have preferred to address Axle Load or Speed singly. Intermodal Freight is technologically demanding, because it addresses them simultaneously in the *high-high* quadrant. However, evidence is mounting that it is ecologically displacing shipping, in competition for long-distance high-value traffic. Intermodal Freight could be the killer app of the railway mode in the new millennium.

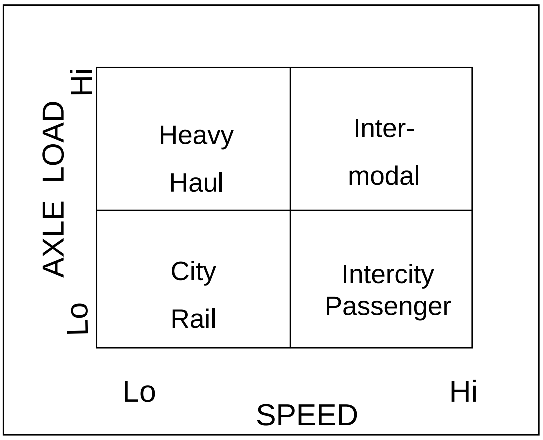

Figure 1 Axle Load / Speed Relations

3.2. Liberalisation and Networkability

The authors argue that the variables Liberalisation and Networkability predict the strategic development of railways. Lundgren (1998), in examining the potential for North American rail freight technology to cross the Atlantic, identified *nationalism*, *political patronage*, *bureaucratic policies*, *border and customs barriers*, *price excess*, *technical incompatibility*, and *indifference to customers*, as issues that allowed road hauliers to grab the prize. Liberalisation measures how freely railways make business decisions. It is *low* in the presence of state intervention, through ownership or regulation. It is *high* in liberal economies. Networkability measures how freely railways interchange consignments between an origin on one network and a destination on another. It is *low* in the presence of physical impediments (such as differences in track- and vehicle gauge, movement authority, and power supply) or administrative impediments (such as border formalities and crewing arrangements). It is *high* where operators have carefully refined interchange standards.

Cross-tabulating Liberalisation and Networkability (Figure 2) yields four quadrants in which various railway strategic development stages are evident. They are better described by example than generically. First, the United States (originally) and the rest of North America (more recently) typify the *high-high* quadrant. Their railways are privatised in a deregulated market, and their shares publicly traded along with those of many other businesses. From early in this century they have valued standard gauge and eschewed electrification, so that Networkability impediments are unknown. North America is regarded as both example and benchmark of how railways can survive and prosper in a competitive economy. Second, South America typifies the *high* Liberalisation, *low* Networkability quadrant. Its railways had suffered decades of unsustainable strategies, and many had become moribund, until privatisation turned their fortunes in recent years, and they again attract custom. Hence, Liberalisation is *high*. Unfortunately, their colonial legacy includes track gauges from 1000mm to 1676mm. Hence, Networkability is *low*. However, increasing revenue raises the prospect of one-day being able to forge a continental network. Third, Western Europe typifies the *low* Liberalisation, *high* Networkability quadrant. Networkability is relatively *high*, because track gauge is standardised, although power supply and signalling are imperfectly harmonised. However, public ownership still impedes structural adjustments required to compete effectively against other modes, hence liberalisation is *low*. Africa typifies the *low* Liberalisation, *low* Networkability quadrant. African railways are still generally publicly owned, hence Liberalisation is low. Furthermore, the colonial legacy includes track gauges from 1000mm to 1435mm. Hence, Networkability is *low*.

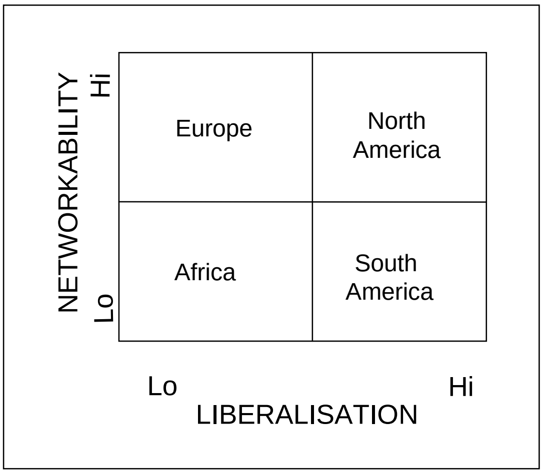

Figure 2 Liberalisation / Networkability Relations

3.3. Track Gauge and Wheelpair Gauge

Absent the ability to interwork between different track gauges, adjacent operators have long had two alternatives — transhipping loads and changing bogies or wheelsets. For unitised loads, such as containers or swap bodies, transhipment is feasible. As an example, transhipment takes place at Kidatu in Tanzania, between the Southern African 1067mm and East African 1000mm gauges. However, aside from interrupting what should be a seamless movement and introducing non value-adding activity, transhipment is tantamount to changing modes, and thus exposes such operators to the risk of disintermediation from the movement chain. Changing bogies or wheelsets accommodates non-unitised loads, like tank wagons. Clearly, the procedure also introduces non value-adding activity, but does not expose operators to the risk of disintermediation. As an example, bogie changing takes place between Spain's 1668mm broad gauge and Europe's 1435mm standard gauge at Hendaye in France. Both cases incur substantial capital investment in facilities, and operating cost for labour: Neither is attractive when traffic volume is high or transit time is important. The variables Track Gauge and Wheelpair Gauge relate to more attractive options for migrating from an incompatible-gauge impasse to the threshold of networkability, namely free wagon interchange.

Track Gauge is the nominal distance between running rails. North Africa uses predominantly 1435mm (standard gauge), and sub-Saharan Africa uses predominantly 1000- and 1067mm (narrow gauge). The authors find no evidence of relevant or competitive freight railways on gauges narrower than 1000mm: They thus ignore them in this paper. Track Gauge may be single or multiple, on the same sleepers. Multiple-gauge track is typically dual-gauge on three rails, for example 1067mm and 1435mm. Rail head width is of the order of 70mm, and flangeway is of the order of 50mm. Dual-gauge track on three rails should thus differ by at least 120mm (see Figure 3). A difference less than this would require four rails, in practice a prohibitively expensive solution. Dual-gauge track is thus unworkable between Africa's 1000mm and 1067mm tracks (67mm difference), and between Western Europe's 1435mm and Eastern Europe's 1520mm tracks (85mm difference) — in such cases adjustable-gauge wheelpairs may be the only viable solution. Because of high cost, dual-gauge track tends to be used over relatively short distances, typically to access joint facilities from several differently-gauged routes.

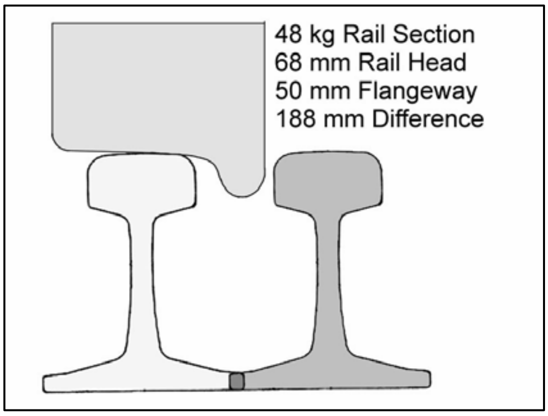

Figure 3 Minimum gauge difference

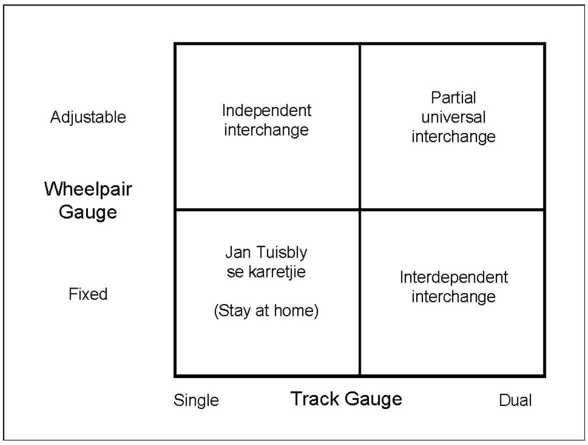

Figure 4 Wheelpair / Track Gauge Relations

Wheelpair Gauge is the distance between the flanges of a wheelpair. It is nominally equal to the track gauge on which the wheelpair runs. Wheelpair Gauge is usually fixed, although wheelpairs that adjust gauge at low speed are commercially available. Clearly, adjustable-gauge wheelpairs are more complex and hence more expensive than single-gauge wheelpairs. However, the cost is limited to the particular vehicles so equipped, hence the technology is suitable for long-distance operations. Adjustable-gauge wheelpairs first emerged on Spanish rolling stock working into France. They are now available for trailing stock; development of adjustable-gauge powered wheelpairs seems imminent. It is improbable that cost-effective design will permit an adjustable-gauge wheelpair to accommodate all track gauges.

Cross-tabulating Track Gauge and Wheelpair Gauge (see Figure 4) yields four quadrants that describe migration options out of a gauge-difference impasse. First, fixed-gauge wheelpairs on single-gauge track define a quadrant that the authors name, in the apt Afrikaans idiom, *Jan Tuisbly se karretjie*. Freely translated into English it means *stay at home*, home being within the limits of the particular network. Second, fixed-gauge wheelpairs on dual-gauge track define a quadrant named *interdependent interchange*, in which two differently-gauged rolling stock fleets share a segment of joint infrastructure. Such an arrangement is limited in scope, it being questionable to dual-gauge a route over a long distance. It is also impossible to convey consignments between non-intersecting origin-destination pairs without transhipment. Third, adjustable-gauge wheelpairs on single-gauge tracks define a quadrant named *independent interchange*. In a competitive- or open-access environment, an operator using adjustable-gauge wheelpair technology could service the union of different-gauged networks that otherwise offer only transhipment facilities, but without the necessity for transhipment. Fourth, the intersection of multiple-gauge track and adjustable-gauge wheelpairs might appear to be redundant and hence an empty set. However, designs for both multiple-gauge track and adjustable-gauge wheelpairs accommodate discrete and restricted numbers of gauge. The fourth quadrant thus accommodates partially intersecting wheelpair- and track gauges. If one of the adjustable wheelpair gauges is always standard gauge, and the other wheelpair gauge(s) is (are) either narrower or broader than standard, a core standard-gauge network could serve both broader- or narrower-gauged adjacent networks. For example, a unified Western European and North African 1435mm gauge network could offer extensive intersection, for interworking or for single-point transhipment, to adjustable-gauge vehicles from both the 1520mm gauge of Eastern Europe, as well as the 1000mm and 1067mm gauges of sub-Saharan Africa. The authors named this quadrant *partial universal interchange*. Clearly, full universal interchange requires all wagons and all tracks to have the same gauge.

4. ENVIRONMENTAL ALIGNMENT

4.1. Globalisation

Customers, competitors and suppliers that play globally, draw railways to a similar worldview. Globalisation is also a significant driver of the railway industry in its own right, particularly regarding continental-scale infrastructure networks and globalised rolling stock designs. In this context, networks tend to acquire at least a continental orientation, with intercontinental interests starting to emerge. At the very least, globalisation encompasses physical interfaces such as track gauge and vehicle profile. It logically also includes systems relating to interchange (such as coupling and braking), to interworking (such as communications and energy supply), and to business (such as organisation form and information flow). Regarding the latter, development of manufacturing in sub-Saharan Africa lagged Southeast Asia by thirty to forty years, and no region of the continent is well integrated. By the end of the twentieth century, structural transformation and industrial advance in Southeast Asia was still better than most of Africa. Manufacturing output first exceeded agricultural output in Thailand in 1981, whereas in 1995, only Lesotho, South Africa, Zambia, and Zimbabwe had reached that level of structural transformation.

Government policies were critical in creating, or not creating, an enabling environment for entrepreneurs in both regions, but history also presented different paths to different groups of entrepreneurs in each region. Some have been more able than others to tap networks for support, accumulate capital, and expose themselves to capitalist rationality and external catalysts that can provide the acumen for an initial industrial investment. While Africa remained largely untouched by the "Asian flu", the continent has missed the benefits of engagement with the global market (Bräutigam, 1999). It thus seems that Africa needs further development before it can rate as global player.

4.2. Entrepreneurial Setting

To benchmark Africa's development against prior comparable development, the case of Southeast Asia is useful. The latter was well integrated into Asian and European maritime trading networks several centuries before maritime trade reached most of sub-Saharan Africa. Significant industrialisation began there in the late 19th century, three or more decades before any significant modern industrial development occurred in Africa, giving Asian entrepreneurs and workers a longer experience with industrialisation. Proximity to Japan stimulated entrepreneurial development, as Japanese firms appeared to be more likely to enter joint ventures in manufacturing with domestic firms, and at a lower level of technology than western firms are. African entrepreneurs had no similar catalyst (Bräutigam, 1999).

By contrast, business development in Africa is still at a relatively low level. A recent Turmoil Rating ranked only four countries, Democratic Republic of Congo and Sudan, together with Colombia and Haiti, in the category *Very High*. African countries that ranked *High*, namely Algeria, Angola, Cameroon, Congo, Guinea, Kenya, Nigeria, South Africa, and Zimbabwe, found themselves in the company of Costa Rica, Indonesia, Iraq, Iran, Nicaragua, Pakistan, Peru, Papua New Guinea, Suriname, and Venezuela (Doyle, 1999). In an industry that is unfortunately characterised by high asset specificity, particularly regarding infrastructure, but in Africa even regarding rolling stock (because of the small proportion of standard gauge), such ratings could dampen investment initiatives. Hopefully the positive spirit of African renaissance can offset such issues in the overall force field.

The development of entrepreneurs relates to the development of societies that allow and encourage private accumulation of capital for investment. Although traders are the foundation of a market economy, it is primarily the rise in manufacturing investment and social division into owners and workers that distinguishes a pre-capitalist from a capitalist system. It is necessary to appreciate relations between entrepreneurs and the state by which societies move from state-business relations characterised by patronage, cronyism, and corruption, to those characterised by productivity, dynamism, and synergy. Regarding the networks, clusters, and association among entrepreneurs and the ways in which they become globalized, one can

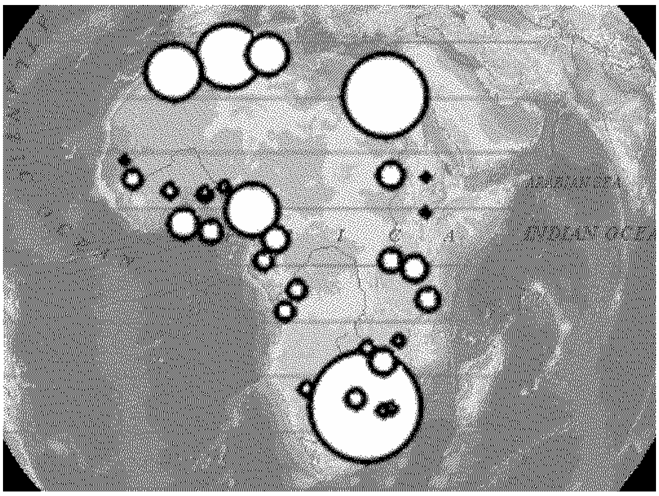

Figure 5 Gross National Product

categorise them into *local* and *globalizing*. While local networks reduce uncertainty for entrepreneurs in marginal and traditional industries, globalizing networks provide larger, more modern enterprises with the information they require about technologies, markets, and the external world (Bräutigam, 1999). Africa is starting off a low base in this regard.

4.3. Developmental Perspectives

The accompanying spatially depicted Gross National Product (see Figure 5) illustrates the challenge faced by railways in Africa. In North Africa, three relatively large economies (Morocco, Algeria and Tunisia) cluster together. Upon completion of a railway link through Libya, the Egyptian and Libyan economies will join this cluster. It will be Africa’s largest economic cluster, favourably located relative to Europe and Asia. The Southern African economic cluster already contains Africa’s largest contiguous railway network, but does not link other than by transhipment to the railway network of any other cluster. The East African cluster comprises small economies, linked by a small, regional railway network. The West African cluster, the most dispersed grouping, has no intra-regional railway links. It is sobering to reflect that most African railways are struggling against road hauliers even within the larger clusters — what opportunities exist for railways in the sparsely-developed spaces between major clusters? If one subtracts the heavy-haul mineral export lines, what remains for railways in Africa? In many developing countries, isolation has lead to self-sufficiency and subsistence economy. Without efficient transport, this outcome is inevitable for two reasons. One, there is a limit on goods that can be imported. Two, if goods can not move to markets, whether local or international, a market economy will not evolve (Cole, 1995: 305). However, the construction of a new transport link does not mean that development will automatically or necessarily follow. Post-modern and other critiques have challenged the modernist rationale, political economy and other theories in seeking to universalise their applicability to developmental issues (Simon, 1996: 58). In an issue as important as continental-scale development, one hopes for an early meeting of minds of politicians, investors and theorists.

4.4. Competitive Arena

Railways are predominantly freight operations in Africa. Except in southern Africa, road transport has eclipsed their importance. Developing countries in general appear to concentrate on road building programs, because their construction and maintenance costs are less than for railways, and because they give a flexibility of origin-destination pairs without the need for

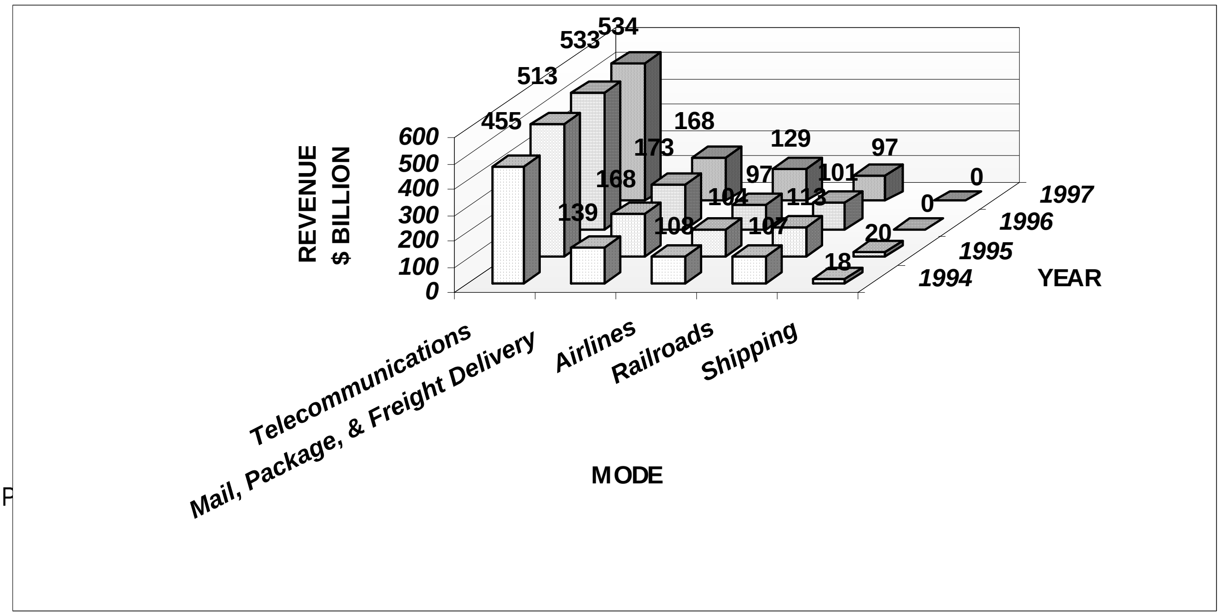

Figure 6 Modal Performance Trend

transhipment. They can also serve a wider range of purposes, including tourism (Cole, 1995: 299). What opportunities does this leave for railways? The accompanying chart (see Figure 6), using Fortune Global 500 statistics (Fortune Global, 1995-1998), shows that, among top companies, shipping has fallen by the wayside. The accompanying chart (see Figure 7), using MaritimeData statistics (MaritimeData, 1999), appears to confirm that inference, for other than bulk carriers. In the case of dry-bulk carriers, there is frequently a railway involvement, so that trend augurs well for railways. There is mounting evidence, in line with the high axle-load, high speed strengths mentioned in Paragraph 3.1, that railways seem to be displacing shipping for transporting time-sensitive freight in containers, over transcontinental distances where contiguous land mass allows suitable links. If this proves to be the killer app for railways in the new millennium, African railways need to align themselves therewith.

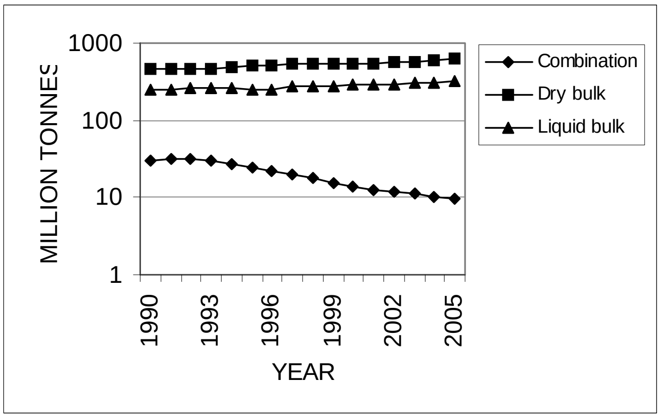

Figure 7 Shipping Capacity Trends

5. RESEARCH QUESTIONS

Paragraph 3.1 identified four active railway quadrants, whereas the paper addresses only freight railways. Africa seems unready for high-volume time-sensitive passenger traffic, and shared taxis or buses dominate local passenger transport. Hence the emphasis on freight railways. Heavy-haul railways prosper in some of the remotest sites on earth. The authors therefore seek to stimulate interest in the remaining railway industry quadrant. Will intermodal reasonably be ecologically sustainable in Africa, under what conditions that might that occur, and what appropriate technology-business mixes can one identify? Will Africa acquire global relevance as an inevitable consequence of globalization elsewhere? Will the popular mood support globalization? What impact will such issues have on terrestrial transportation, but particularly railways? Given the renaissance of railways worldwide, is there opportunity in Africa to replicate such renaissance? The next section attempts, at high level, to draw some inferences.

6. THE WAY FORWARD

6.1. Liberalisation

In practice, movement in Figure 2 occurs first from left to right, thereafter from bottom to top. That is, liberalisation seems to be a prerequisite for networkability. In a world that is reluctant to invest in state-owned enterprises, the warchest required to enhance networkability must be internally generated. In order to survive, railways need to change fundamentally, so that they can respond quickly to a dynamic market and user needs in the changing business and competitive environment. In Africa, there exists appreciation that it is necessary to eliminate political interference, provide access to capital and technology, and introduce a competitive management culture. Delay in restructuring is not attractive, because any deterioration in the financial performance of marginally viable railways will make them less attractive for investors. The time for action is now (Southern Africa Transport and Communications Commission Technical Unit, 1997: 40).

6.2. Missing links

As discussed in Paragraphs 2.2 and 2.3, Africa's railway network is fragmented. It is arguably a major impediment to railway progress. On three rails, dual-gauge 1000mm or 1067mm and 1435mm track is workable (Western Australia is an example), but dual-gauge 1000mm and 1067mm track is physically not possible. Thus, links between East Africa's 1000mm gauge and the 1067mm gauge of Sudan and Southern Africa will require either bogie changing or adjustable-gauge wheelpairs. The missing links to complete a Cape-to-Cairo network are modest. The shortest option is west of the Rift Valley. It requires new links, ±360km from Egypt's 1435mm gauge at El Sadd el Aali to Sudan's 1067 mm gauge at Wadi Halfa, as well as ±1280km from Waw in Sudan to the Southern African 1067mm gauge at Kindu in Democratic Republic of Congo. Both network-completion and gauge-interchange issues suggest that adjustable-gauge wheelpair technology is worthy of serious consideration to advance Africa's railways to global relevance.

6.3. Technology

With relatively few exceptions, Africa's railways are diesel-hauled. This reduces incompatibility essentially to track gauge. It is therefore necessary to appreciate the implications. First, can one establish a permissible maximum axle load for Africa? If it is too low, it may preclude railways from playing a significant role on the continent, through not being competitive with road (low railway axle load is only competitive with poor roads). If it is too high, it may be too expensive for the traffic volume available. Second, there exists a trade-off between the cost of dual-gauging or re-gauging track, and deploying variable-gauge wheelpairs over relatively long distances. Third, interworking vehicles with multiple track- and wheelpair gauge capabilities requires that, ideally, the common vehicle profile should be the union of the vehicle profiles of the participating railways. In practice, many narrow-gauge vehicle profiles are limited below platform width, which constrains both running gear and load size, and may force the common vehicle profile to the intersection of the vehicle profiles of the participating railways. Fourth, partial universal interchange (Paragraph 3.3) has vehicle-profile implications beyond African interchange — it elevates the level of discourse to full universal interchange. Fifth, can variable-gauge wheelpairs work on the three-piece bogies that cope well with the relatively lower track standards associated with the narrow track gauge so prevalent in Africa?

6.4. Strategic

The precision and security required for acceptable transportation of value-added freight has driven containers to dominance. Such non-bulk international trade as there is, tends also to be in containers. Railways can competently handle such traffic over intra- and intercontinental distances. Land-based trade routes could significantly shift global trading and manufacturing patterns. South Africa, the largest though most remote African economy, has recently concluded a free-trade agreement with the European Union. Such drivers represent a wake-up call to new opportunities and prospects. Against this, the turmoil in Central African politics is probably too intense to attract long term investment in railway infrastructure.

7. CONCLUSION

The authors conclude that the nexus between transcontinental railway links in Africa, and the economics to support them, is elusive and fragile. It is elusive, because existing spatially dispersed development in Africa incurs the risk that trade routes will evolve externally to the continent rather than internally, which may render railways irrelevant. It is fragile, because if a sufficient African railway network does not develop timeously, when economic development eventually does take off, railways other than heavy haul may no longer exist. If such a nexus emerges, investors will need to address at least the following three issues. First, *Routes* northwards from the relatively developed south, that could pass the Rift Valley to east or west. Second, *Links* to the Asia/Europe landmass, that could pass through Gibraltar or the Middle East, or both. Last, *Technology*, that requires balancing the cost of changing track gauge against deploying adjustable-gauge wheelpairs, to link presently non-linked networks. The answers will shape the infrastructure, rolling stock, and business models that will ultimately influence the format and competitiveness of African railways.

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