Rail renaissance based on strategic market segmentation principles

J.H. Havenga

ABSTRACT

South Africa's annual State of Logistics survey indicates that the majority of dense, long-distance surface freight is transported by road, placing severe constraints on the country's freight logistics infrastructure and posing a significant exogenous risk to the growth aspirations of the country. This risk is attributable to the excessive demand for road freight transport, which is dependent on imported fuel at highly unstable prices and is more damaging to the environment – leading to uncertain future offset charges. A rail solution can utilise locally generated electricity (currently coal-based, but partially switchable to renewable energy in the future). The critical requirement, however, is to determine exactly how much freight, and specifically which freight, can switch to rail. In order to identify the freight flows that will exploit rail's economic fundamentals, a market segmentation model was developed. A feasible target market was identified that enables key stakeholders (government, the national railroad and major road service providers) to engage in ensuring that the urgent planned R300 billion infrastructure spending by the public and private sectors is invested in suitable freight logistics infrastructure to support the country's growth ideals sustainably.

Key words: rail renaissance, market segmentation, South Africa, state of logistics, modal shift, freight flows

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Introduction

The imperative for the revival of South Africa's freight rail system has been urged in key research projects (DoT 1998; CSIR, Imperial Logistics & University of Stellenbosch 2010; Barloworld Logistics 2011) and put forward in national policy frameworks (RSA Presidency 1994, 2007, 2010) for almost two decades.

The key indicators pointing to the imperative for rail's revival are that at 13.5% (Havenga et al. 2010), South Africa's 2009 freight logistics cost as a percentage of GDP is 35% higher than first-world figures of around 10% (Bowersox & Closs 1996; United Nations 2002; Wilson 2008), and at 48%, freight transport's contribution to total freight logistics costs (Havenga et al. 2010) is significantly higher than the world average of 39% (Rodrigue, Comtois & Slack 2009). One of the key driving forces of the status quo is the debilitating modal imbalance, in that the majority of dense, long-distance surface freight is transported by road (Havenga 2010).

The modal imbalance is the result of a historical rail investment backlog, with related service challenges, and the rapid deregulation of the freight transport industry in the early 1990s. This resulted in a proliferation of road transport service providers, further reducing rail density and rail's ability to invest (Havenga 2007). The challenges were exacerbated by an increased demand for freight logistics services, due to the country's democratisation in the early 1990s, which caused a step-change in local consumption (Hanival & Maia 2010), as well as trade liberalisation, which resulted in both increased imports and exports (Edwards & Lawrence 2006).

According to Pietrantonio & Pelkmans (2004), Europe experienced a similar decline in rail transport while highways were developed and markets were liberalised. The authors provide a detailed analysis of the underlying reasons for this decline. The key exogenous reasons proposed are a shift in demand patterns (for example, from high stock levels to just-in-time delivery, and from low-value/high-volume to high-value/low-volume freight), as well as policies and investments that favour road over rail. The endogenous reasons that they put forward relate to various aspects of rail service delivery. The OECD (2006: 70) also argued that the inefficiency and poor performance of the railways in "virtually all OECD countries" led to reform. Apart from institutional structure challenges (that can be correlated with governance at a country level), the OECD cites "under-pricing" of especially the road mode as a major driver of rail's demise.

The critical causality between these issues is often overlooked, however. On the one hand, rail's inability to provide services based on shifting demand patterns led to lower utilisation, in turn reducing investment, which led to even poorer service levels. On the other hand, regulated transport industries that favoured railroads (in order to protect public investments) were deregulated; yet the resulting market structure was not really free from institutional support, as modern road hauliers are institutionally supported through enforced cross-subsidisation from other road users. What has in fact happened is that the road mode is supported by regulation, because of its ability to serve the market better. The *a priori* reason for rail's decline is therefore poor understanding of shifting demand or an inability to adapt.

The decline in rail market share has, however, not been evidenced in the USA (Rennicke & Kaulbach 1998: 6). Hilmola (2006: 6) maintains that the reasons are simply the privatised nature of USA railroads (that is, the railroads are "not state monopolies and are not subsidised"). More detailed analysis cites, among others, consolidation and productivity improvements (especially for equipment requiring significant capital investment) (Rennicke & Kaulbach 1998: 6). The growth in transport demand and the drive for more environmentally friendly transport solutions (Hilmola 2006: 6) led, among others, to the implementation of intermodal freight transport solutions, marking a clear trend for the revival of rail transport. Case (2009) talks about the "second golden age of North American railroading" and highlights domestic intermodal transport as a growing industry.

The problem with these approaches is that, whereas the macroeconomic advantages around the management of fuel and environmental risk are often put forward and the levelling of the road and rail 'playing fields' (and the revival of rail) often supported, the exact positioning of a country's rail services is not clarified.

In order to inform the repositioning of South Africa's freight transport industry, a segmentation model for total freight was developed that enabled the categorisation of the billion tons of freight that are transported in South Africa every year. This categorisation, in turn, informs the optimal modal split, facilitates policy development and enables appropriate investment.

The next sections provide more detail on South Africa's national freight transport challenges; describe the research methodology, focusing on the market segmentation approach and key rail economic principles that support a modal shift; and show the results of the market segmentation exercise as well as their application to key rail economic principles and resultant cost-saving opportunities. In conclusion, recommendations for the way forward are provided.

South Africa's national freight transport challenges

In 2009, a total of 1530 million tons of freight required shipment in South Africa. A total of 360 billion ton-kilometres over an average transport distance (ATD) of 237 km at a direct cost of R155 billion were provided, with externality costs amounting to R23 billion (Havenga et al. 2010).

To put these figures into global perspective, South Africa produces less than 0.5% of the world's GDP, but requires 2% of the world's surface freight ton-kilometres to do so, resulting in a contribution of 1% to the world's CO^2 emissions. The disproportionate transport demand is *inter alia* due to the country's economic and political development history that resulted partly from development around the inland mining deposits, as well as a relatively open mineral export and beneficiated product and energy import economy. These developments created long export and import corridor requirements (Havenga 2007).

As mentioned in the introduction, this situation is exacerbated by the fact that the majority of corridor freight is transported by road. In 2008, 66% of the country's total surface freight transport costs (road and rail) were spent on corridors, while 95% of the corridor transport costs were attributable to road transport. In addition, almost all growth over the already dense corridors also occurred in the road transport mode (Havenga 2010). This compares extremely poorly with the USA's rail corridor market share trend, as illustrated in Figure 1, which is based on the Freight Demand Model for South Africa, as explained in Havenga (2007), and the Bureau of Transportation Statistics for the USA (n.d.).

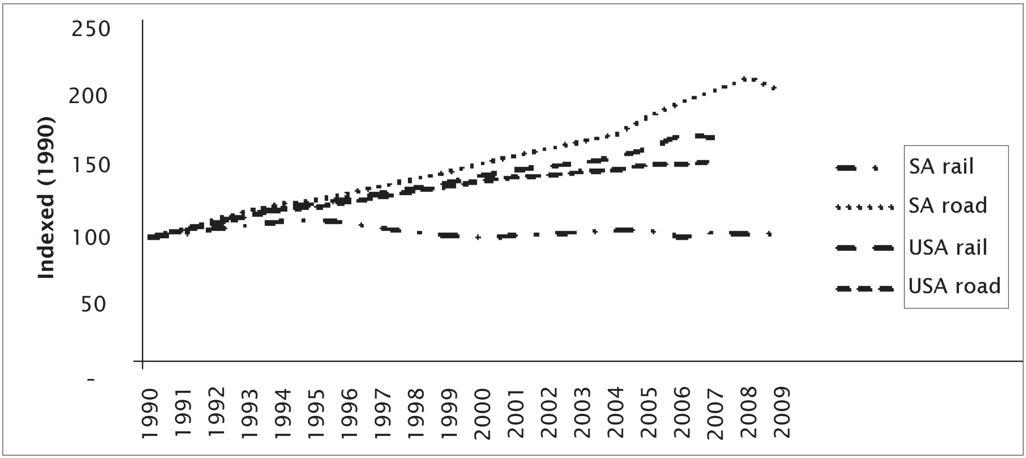


Figure 1: South Africa's road-rail corridor market share compared with the USA

These dense corridors are ideal for rail or intermodal transport, as the density creates economies of scale due to the large volume of ton-kilometres generated (Van Eeden & Havenga 2010). International research indicates that intermodal transport magnifies these scale effects and initiates cumulative economic growth (Yevdokimov 2000). In addition, the largest proportion of rail costs is fixed (Pietrantonio & Pelkmans 2004) due to long infrastructural life-spans, while road transport costs are mostly variable and significantly exposed to volatile exogenous core cost drivers, for example, the price of fuel. The externality costs associated with road freight transport are also higher than those attributable to rail freight transport (Hesse & Rodrigue 2004).

This is borne out by data from South Africa, where externalities (such as emissions and congestion) are estimated to have added an additional R23 billion or 15% to the freight transport costs of R155 billion in 2009. Adding these costs to transport costs increased the cost percentage of freight transport from 6.5% to 7.4% of GDP in 2009. Ninety-five per cent of these externality costs were contributed by road transport (Havenga et al. 2010).

South Africa's freight transport requirements are forecast to grow by 108% in ton-kilometre terms between 2009 and 2040. This additional freight will not be serviceable by the current network, irrespective of modal balance, and significant, sound infrastructure investment decisions are therefore required.

The question then is how to reform South Africa's freight transport industry to sustainably meet the demand for freight logistics services, while protecting the country against the risk of exogenous cost drivers and the cost impact of externalities.

Research methodology informed by existing literature

In the latter part of the previous century, many railways experienced significant restructuring, including those in Canada, elsewhere in the Americas, Europe, Britain and Russia (Rennicke & Kaulbach 1998; Sull, Martins & Silva 2004; Pietrantonio & Pelkmans 2004; Yvrande-Billon & Ménard 2005; Bitzan 2003; Pittman, Diaconu, Šip, Tomová & Wronka 2007). The case studies do not build a clear case for any specific model of rail reform. The literature analysis indicated that restructuring successes and failures could be attributed not to specific reforms, but to adherence to three basic principles, namely: (1) sound macro-economic principles to reduce logistics costs and improve the country's competitiveness, (2) sound business principles for investment decisions and (3) sustainable development principles. As such, the case studies provide a mixture of macro-economic goals and investment drivers for rail reforms, but not a specific categorisation of the markets that a railway should serve, nor an explicit indication of where and to what extent these so-called benefits of a railway could be exploited.

Therefore, in order to address the economic problems and choices around the optimal structuring and positioning of the freight transport and logistics industry, the industry must be considered within its economic context. This is especially relevant in the case of South Africa, because the country's economic and institutional context has several unique aspects, such as the institutional structure of the port, rail and pipeline network, the spatial location of economic activity and the modal balance of freight in the country.

Bryan, Weisbrod, Martland & Wilbur Smith Associates (2007: 5) distil five themes for consideration in rail's revival opportunities, one of which is segmentation. They state specifically that "public action needs to address specific segments due to their discrete behaviour".

Segmentation is a business fundamental. It is the first step in understanding demand or market opportunity, which should lead to the matching of a firm's capabilities with this demand and finally investment to create the mechanisms required to serve the opportunity. Whereas market segmentation can be defined as the search for customer groups with homogenous needs, Harrison and Kjelberg (2010: 784), like Quinn, Hines & Bennison (2007) before them, maintain that the identification of homogenous customer groups is a managerial assessment rather "than a naturally occurring market phenomenon". Segmentation is therefore not a gestalt in its own right, but rather a continuous matching of the firm's capabilities with observed customer needs. In this continuous dance, capabilities can be upgraded, changed or streamlined in response to new lucrative observations, or customer groupings can be adjusted according to entrenched capabilities.

Freight flows can therefore be segmented in detail to identify homogenous groups, but also, in light of the managerial assessment view of segmentation, segmented according to the utilisation of core competencies, in this case railroad core competencies. This was done by classifying all freight using basic economic principles and applying sound railway-economics principles to enable strategic marketing segmentation of the industry.

Freight-flow segmentation

The first step was to develop a comprehensive freight-flow model. The model is complex and data intensive, translating the transportable gross domestic product of South Africa (the primary and secondary sectors of the economy) into detailed freight flows. The modelling process was an extensive collective effort by experts from the fields of macroeconomics, econometrics, logistics and industry, and the results are regarded as the only authoritative source of comprehensive national freight-flow analysis in South Africa.

The research developed a view of supply (production and imports) and demand (exports, intermediate demand, stock and final demand) by weight, how it is moved (modal market share), where on the network it is moved (typologies), and what is moved (commodities). A 30-year forecast for low, medium and high scenarios was also developed. The output of the model contains flows for 62 commodities between 356 magisterial districts in South Africa and resulted in more than one million records of freight-flow data between defined origin and destination pairs. (Refer to Havenga [2007] for a detailed description of the model.)

The assimilation of freight flows is derived from the economy's basic structure and its related logistics requirements, as illustrated in Figure 2.

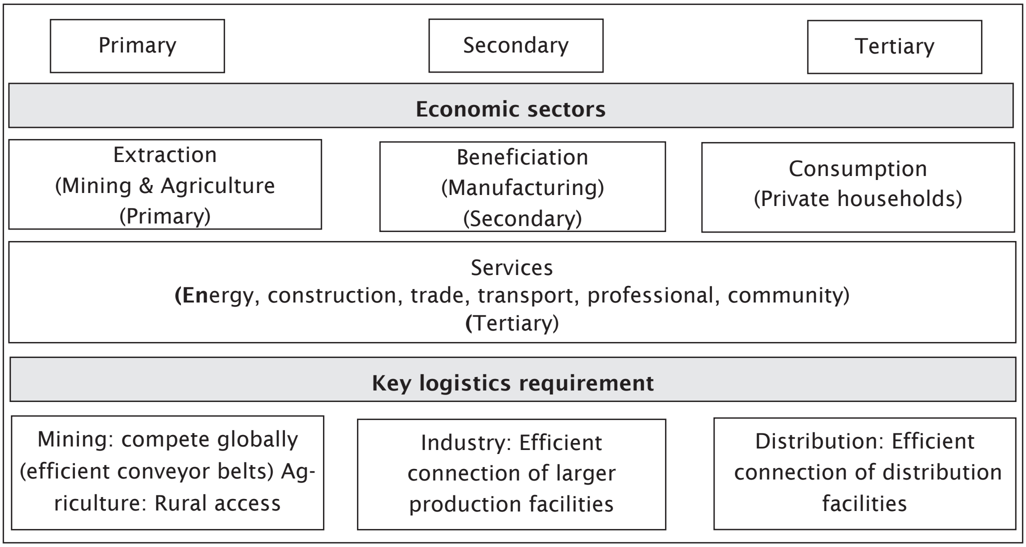


Figure 2: Basic economic structure and resultant logistics requirements

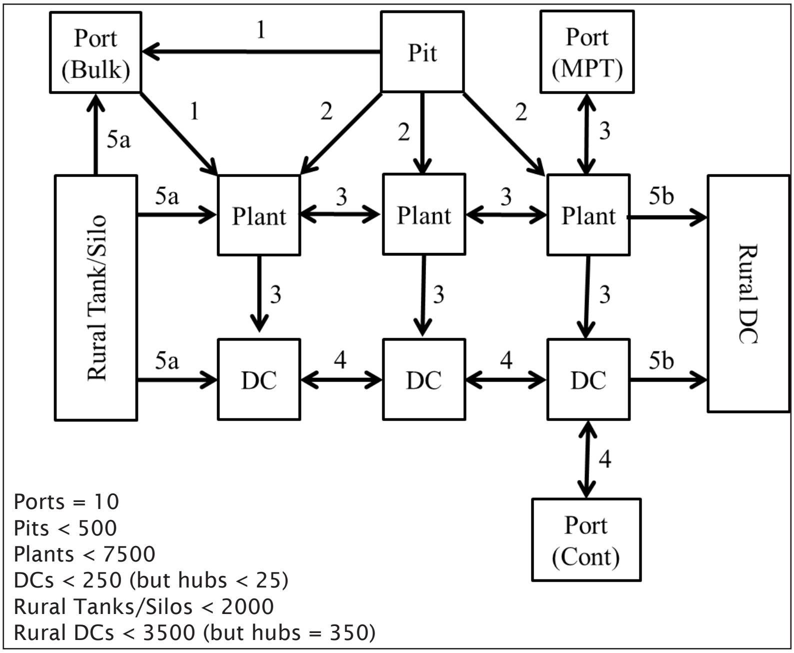
Freight flows take place from the place of extraction/manufacture to the place of utilisation or consumption, resulting in key flow patterns, as indicated in Figure 3.

These flow patterns resulted in the identification of five overarching freight-flow segments, described in Table 1 in terms of the nature of the commodity and service requirement.

Given the national freight transport challenges described previously, the next step – in line with the approach of Harrison and Kjelberg (2010) – is to match freight-flow segments with rail economic fundamentals.

Rail economic fundamentals

The key rail economic fundamentals are line and system density, which enable the exploitation of rail's 'genetic technologies'.[1]



Note: DC = Distribution centre; Cont = Container terminal; MPT = Multi-purpose terminal)

Figure 3: Freight-flow patterns derived from the basic economic structure

Table 1: Description of the country's overarching freight-flow segments

Pit to port	Bulk export mining; rail only transport with high density; long distances; less than 500 origins, and 10 destination ports
Pit to plant	Bulk mineral mining for domestic beneficiation; stockpile to manufacturing plant; more complex flows: less than 500 origins, less than 7500 destinations; long distances from 400–900 km
Plant to plant/ distribution centre (DC)	Heavy break bulk requiring specialised wagons; plant to plant or plant to DC; high density; multiple origins (less than 7500) with few destinations (250 DCs); transport distances nationally more than 500 km and within metros less than 100 km
Finished goods: DC to DC	Finished goods; palletised; complex supply chain management requirements but few origin-destination pairs (between DCs); high density; transport distances nationally more than 500 km and within metros less than 100 km
Rural	**Agricultural extraction** – to cities or production centres; low density; many origin-destination pairs; transport distances less than 500 km
	A**gricultural manufacturing delivery** – from cities/production centres to farms and rural areas; low density; many origin-destination pairs; transport distances less than 500 km
	Rural interchanges – between farming areas; low density; seasonal

Line and system density

In 1977, Robert G. Harris (1977) wrote a seminal paper stating:

> The extent of economies of traffic density in the rail freight industry is a matter of critical importance with respect to public investment in and the financial viability of the United States of America (USA) rail system. The evidence strongly supports the hypothesis that significant economies of density exist, and that many of the light-density lines, which comprise 40% of the rail system, should be eliminated.

Investment in rail results in assets with useful lives measured in decades; asset-driven fixed costs (a significant proportion of total costs) can therefore not be reduced rapidly in the event of traffic loss. Due to this high level of fixed costs, the average costs per ton-kilometre and profitability are directly related to the degree of traffic density (that is, the volume of traffic per kilometre of railroad, expressed as ton-kilometres per route-kilometre (ton-km/route-km). This means that the cent per ton-kilometre cost of a railroad will decrease with each additional ton-kilometre of activity over the same track length. This relationship is illustrated in Figure 4.

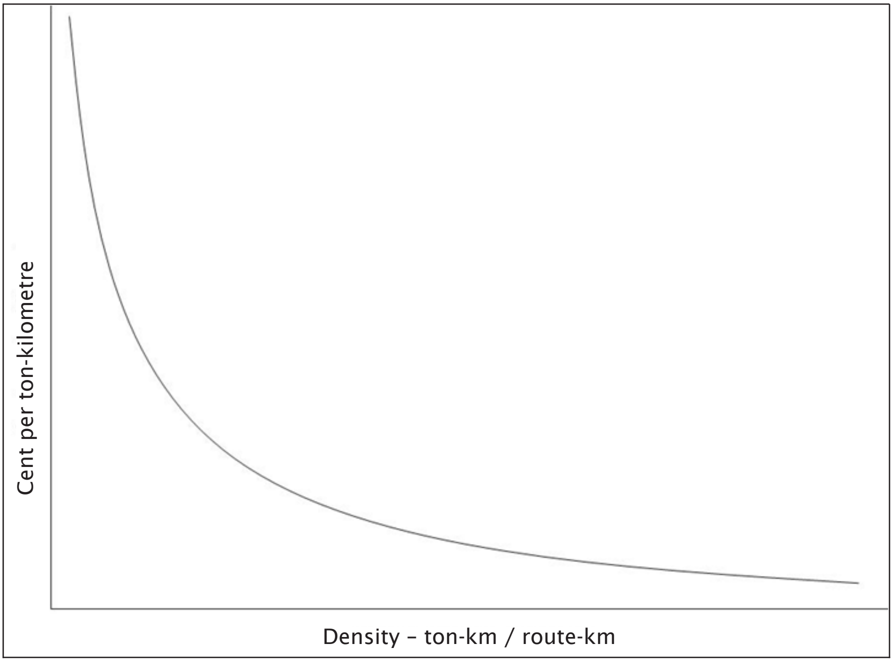


Figure 4: The economics of rail density (adapted from Harris 2007)

A study conducted by Mercer on Class I and regional railroads in the USA in 2002 confirmed this curve. The study also emphasised that adequate traffic density is essential to meet the efficiency levels required to be competitive and to provide the economic returns necessary to justify investment (Mercer 2002). The relevance of the Harris curve to sub-Saharan Africa has also been demonstrated (De Bod & Havenga 2010).

The effective repositioning of South Africa's railroad should thus strive for a core network with the greatest possible density based on a critical density threshold. Statistically, the threshold is the inception point of the curve (the point from which costs will either decrease more slowly relative to improved density or increase faster relative to deteriorating density). Initially, there are significant cost-reduction opportunities as density improves. These cost benefits become increasingly difficult to achieve despite density improvements beyond the threshold point.

Pittman (2007) argues that "the generally accepted result that most railways are operating in a region of continued economies of density suggests that neither open access nor vertical separation is likely to lead to a vibrantly competitive train operating sector in any but the most densely operated rail systems", which he identifies as existing only in Russia, China and India. Fragmentation of railways (the loss of system density) furthermore often results in penalties such as increased overheads, task duplication, loss of scale, higher industry coordination burden and increased regulation requirements (Mercer 2002). The "single-network characteristic" of South Africa's railroad, based on density requirements, has also been suggested (Simpson & Havenga 2010).

Railways will only be competitive if the dense flows exploit the genetic technologies that distinguish railways from other transport modes.

Genetic technologies

The advantages of rail as a mode of transport can be monetised by exploiting the intrinsic technologies of rail (namely, bearing, guiding and coupling technologies). Bearing, which indicates the axle-load (and therefore volumes) that can be maintained, and guiding, which indicates the wheel-on-track differentials (and therefore speed of movement), are added to coupling, which means long trains with massive volumes (thus combining high-volume time and long-distance solutions) (Van der Meulen 2007). These technologies naturally support four freight-rail market spaces:

- General Freight: The strengths of bearing and guiding genetic technologies are elusive. However, coupling combines vehicles into trains, thereby attaining higher capacity within given headways than autonomous vehicles can. Slow-moving, light-axle loads – typically plant-to-plant – break bulk general cargo. This market space has been proven to be competitive for rail over almost any distance given enough volumes from dedicated siding to dedicated siding of commodities with the same cargo-handling requirements.

- Heavy Haul: This requires easy gradients to limit coupler forces in heavy trains and accepts tight curves due to low maximum speed. This freight is typically pit-to-plant/port bulk commodities with sufficient density to allow a heavy, competitive axle load (within a modest loading gauge). Heavy haul competes over distances of less than 1000 km against sources in other countries or other regions – typically minerals from mines to ports or plants and mineral imports.
- Heavy Fast-Moving Consumer Goods (FMCG): This requires high throughput line-haul transit and terminal trans-shipment characterised by bimodal road-rail technology solutions. This freight is typically DC-to-DC (short and medium distance), fast-moving, light-axle loads of high-value finished products, often palletised, and competes in the 200–500 km space.
- Heavy Intermodal (double-stacked containers): This is similar to heavy FMCG, but requires high vertical clearance. This freight is typically fast-moving, DC-to-DC and long-distance with heavy-axle loads, and competes in the 300–2000 km space (continental or intercontinental) – typically long-distance and preferably high-volume container movements.

These market spaces are depicted in Figure 5. This grid provides a framework for the strategic positioning of rail systems and is useful in assessing opportunities and selecting appropriate technologies for a railway in a chosen market space.

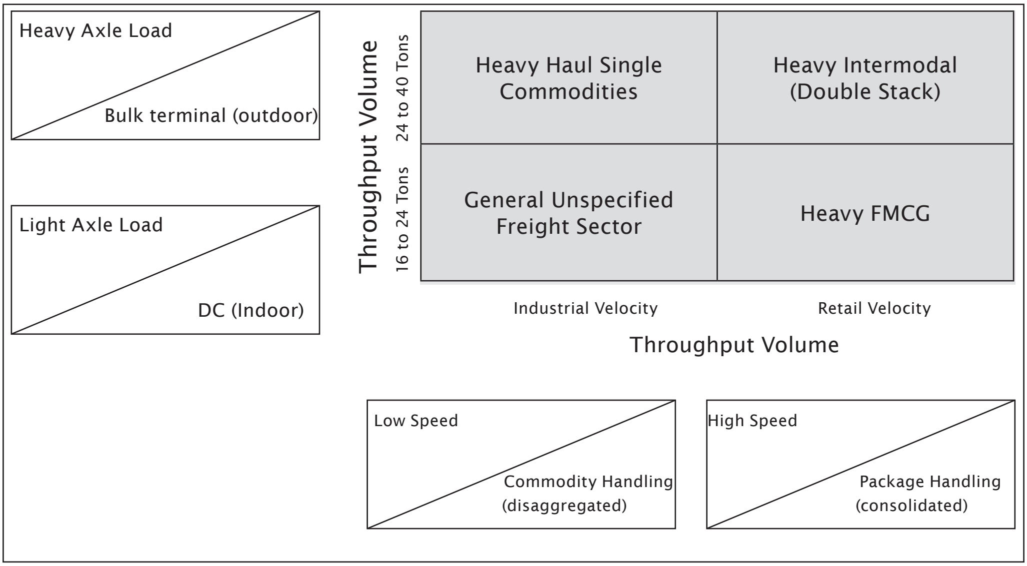


Figure 5: Positioning framework for rail systems (adapted from Van der Meulen 2007)

Van der Meulen's (2007) adapted model provides an interesting railway segmentation perspective. It was stated earlier that rail's market share decline accelerated because of the shift from low-value/high-volume to high-value/low-volume freight (Pietrantonio & Pelkmans 2004: 1) (in other words, in terms of the model, from the top right to the bottom left). At the same time, high gravimetric freight of high value should ultimately be beneficial to rail and also to freight owners if it can be transported efficiently (the top right area in Figure 5; gravimetric means rail density capability fit, and high-value means the freight is less price sensitive or has a low price elasticity). As such, a hypothesis for a potentially lucrative rail-freight segment was created that can be tested by the segmentation regime in terms of size, cost and density.

The output from the freight-flow model is segmented and summarised according to the economy's basic structure, translated into flows for road and rail, and then analysed based on rail's genetic technologies.

Results

Total freight flows resulting from the freight-flow model are depicted in Figure 6, as well as rail's share of these flows. This highlights the importance – and opportunities – of flows not being served by rail. (South Africa's world-class rail-only coal and iron ore export flows are included in this picture for completeness – the dense rail volume lines flowing south west and south east to the ports).

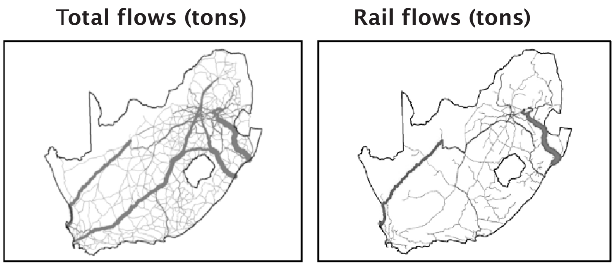


Figure 6: Total surface freight transport flows compared to rail flows for 2009

Freight segments

Analysis of the total freight flows in the country within the five overarching segments described previously led to the identification of 15 sub-segments, as illustrated in Figure 7. Rail market share is also indicated,[2] highlighting the dominant position (and core competence) of the national railroad in the transportation of mining commodities, as well as significant opportunities in other long-distance transportation market spaces.

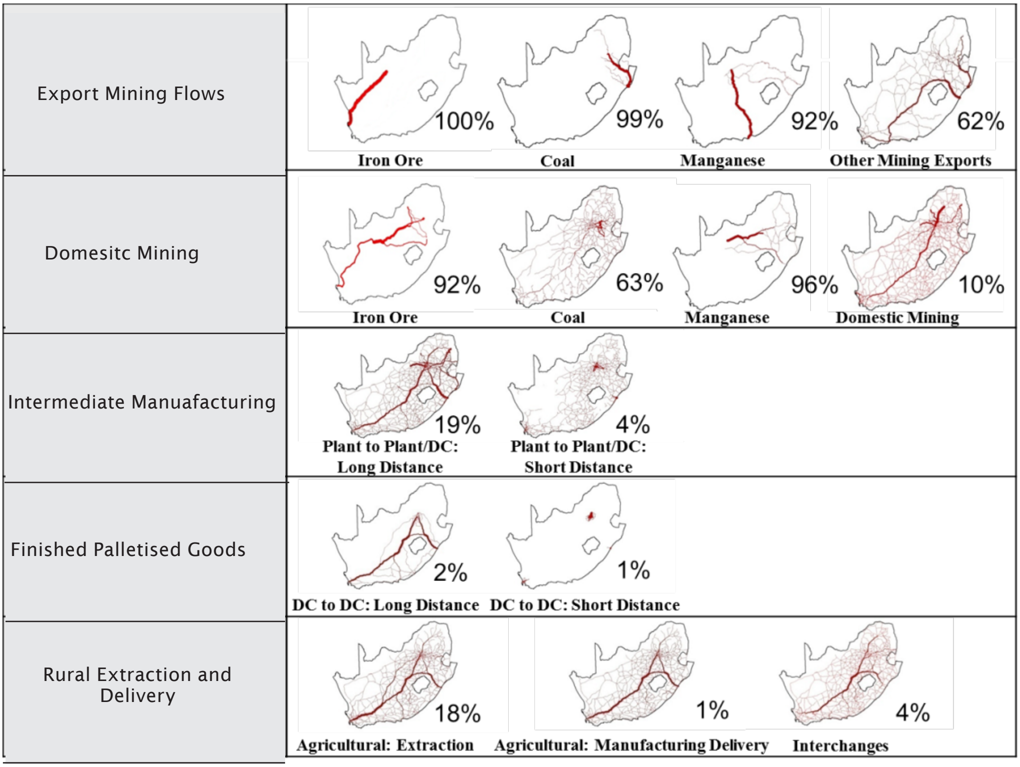


Figure 7: Total freight flows per sub-segment in tonnage terms; rail share in percentage (2009)

The rail-economics principles discussed previously indicate that freight flows with high density over longer distances are well suited to transportation by rail. The next section therefore focuses on a density analysis of these segments.

Freight-flow market space

When the freight-flow market space is further analysed, the combination of Van der Meulen's grid (2007) and Harris's curve (1977) come into play. Van der Meulen considers volume and value (in logistic terms, value relates to velocity; in other words, higher value locks capital in inventory if it turns more slowly), and Harris considers density.

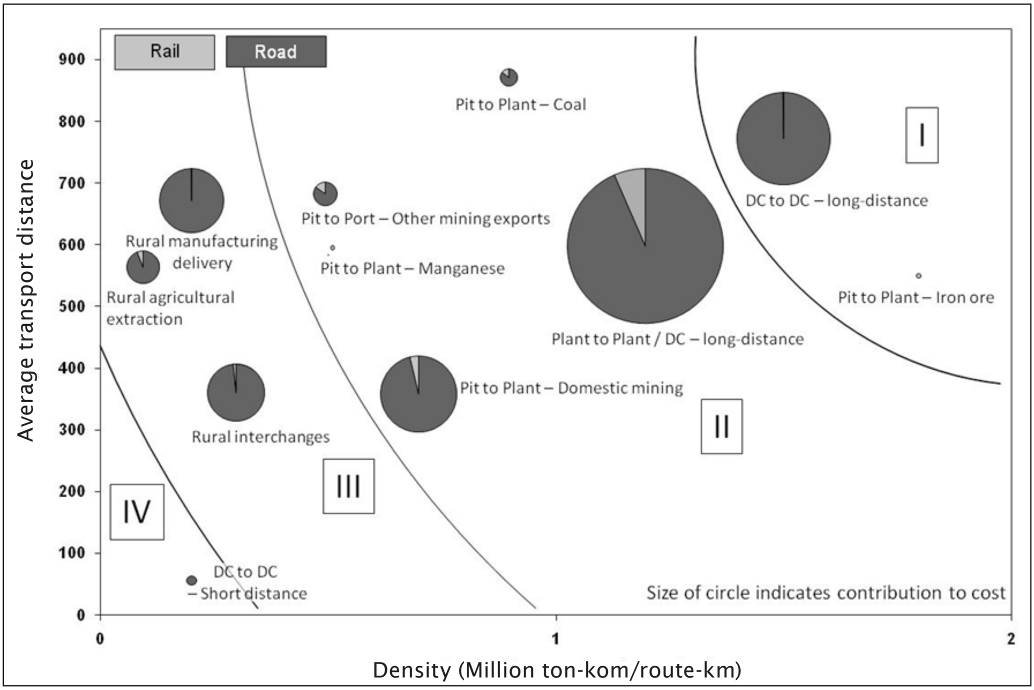


Figure 8: Freight-flow market spaces based on distance, density and cost (2008) (excluding export iron ore, coal and manganese)

A combination of these factors enables the description of freight-flow market spaces in terms of transport distance, cost and density, as illustrated in Figure 8.[3]

Rail's low market share is evident in all sub-segments, but is especially disconcerting in the traffic ideally suited for rail – namely, with high density over long distances (long-distance transport from plants to distribution centres, and long-distance transport between distribution centres). The attributes of each of these sub-segments are summarised in Table 2, which also indicates the suitability of these sub-segments for transportation by rail.

Most developed countries with medium to highly densified transport distances have developed intermodal (or multimodal) solutions. Case (2009: 4) describes this for both maritime and domestic intermodal for the USA, and the International Union of Railway's (UIC's) analysis of the intermodal market points out that in spite of the recession, this specific market is seen as "attractive and stable", with a "potential for development" (UIC 2010: 11). This is also confirmed for Central and Eastern European countries where "significant" future levels of intermodal are expected (UIC 2011: 1). South Africa has not exploited this market, and as Jorgensen (1999: 1)

Table 2: Description of market spaces, sub-segment attributes and suitability for rail

Market space	Sub-segment	Sub-segment attributes	Relationship to rail genetic technologies	Key requirement from rail and current status
I Low-hanging fruit	DC to DC – Long-distance	• Long distances, high line density, bi-directional • High terminal density • High value, uniform/ standardised product • Between logistics hubs – ideal for intermodal (road/ rail)	• High speed • Light axle load technology (double stacking of containers could require higher axle loads)	• Heavy intermodal shuttles – non-existent
	Pit to plant – Iron ore	• Long distances, high line density	• Low to medium speed • Light axle load technology	• Inbound sidings – reasonable
II Higher density, long-distance	Plant to plant/DC – Long-distance	• Core siding to siding business ideally suited to rail • Long distances, high density if shared network (core) is monetised as an integrated network • Low terminal density challenges remain • Non-uniform/ standardised product	• Low to medium speed • Light axle load technology	• Outbound sidings – in serious decline
	Pit to port – Other mining exports			• Heavy haul shuttles – established
	Pit to plant – Coal, manganese and domestic mining			• Inbound sidings – reasonable
III Low density	Rural manufacturing delivery	• Long distances, but low density • Viable with different operating model where capacity is already installed	• Low to medium speed • Light axle load technology	• Less than train loads – in serious decline
	Rural agricultural extraction			
	Rural interchanges			
IV Short distances	Plant to plant/DC – Short-distance	• Distances too short • Density too low • Not viable for rail	• Not viable for rail	
	DC to DC – Short-distance			

states, “this (domestic intermodal) potential, already successfully implemented in the Americas, Europe and Australasia, has unfortunately not been realised in Southern Africa”.

These sub-segment attributes can also be presented through the relationship between ton-kilometre and cost (Figure 9). In such sub-segments as DC to DC long distance, costs (for the country) are arguably higher than they ought to be and could be reduced if additional volumes of such freight were to move by rail. There are thus opportunities for the country of a modal shift in certain sub-segments.

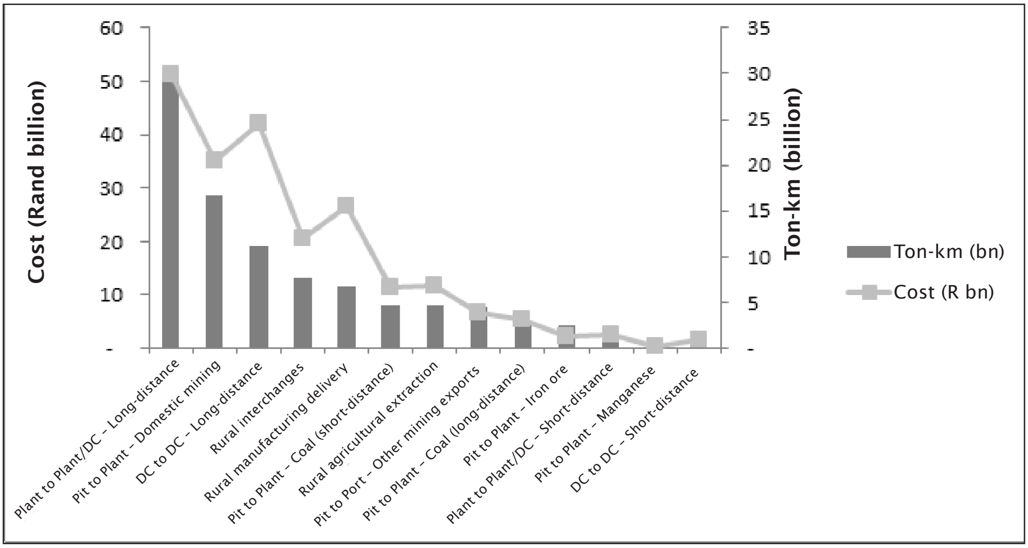


Figure 9: Relationship between ton-kilometre and cost per sub-segment (2009)

A high-level analysis indicates that if 50% of long-distance heavy intermodal and siding-to-siding break-bulk road traffic could be shifted to a core rail network,[4] cost savings ranging from 30 cents/ton kilometre to less than 15 cents/tank for general freight could be achieved, as depicted in Figure 10. These potential savings point to the high-level feasibility of intermodal solutions for South Africa's long-distance surface-freight transport market. As a next and important research step, a more detailed analysis of the long-distance domestic intermodal segment is required, followed by feasibility studies and installation if a sound investment case can be proved.

Conclusion

South Africa's freight-flow challenges, amid the imperative for urgent large-scale infrastructure investments, require innovative, mature approaches. Given the country's high logistics costs, dense long-distance road corridors and significant growth forecasted in freight flows, a restructuring of the freight transport system and related investment is critical. The research illustrates clear opportunities for intermodal solutions where both road and rail can benefit, allowing South Africa to move closer to its growth ideals. Furthermore, solutions need to be found that optimise South Africa's end-to-end supply chain, including the way that South Africa's rail, road, inland terminals and ports complement one another to compete as a whole against other global supply chains.

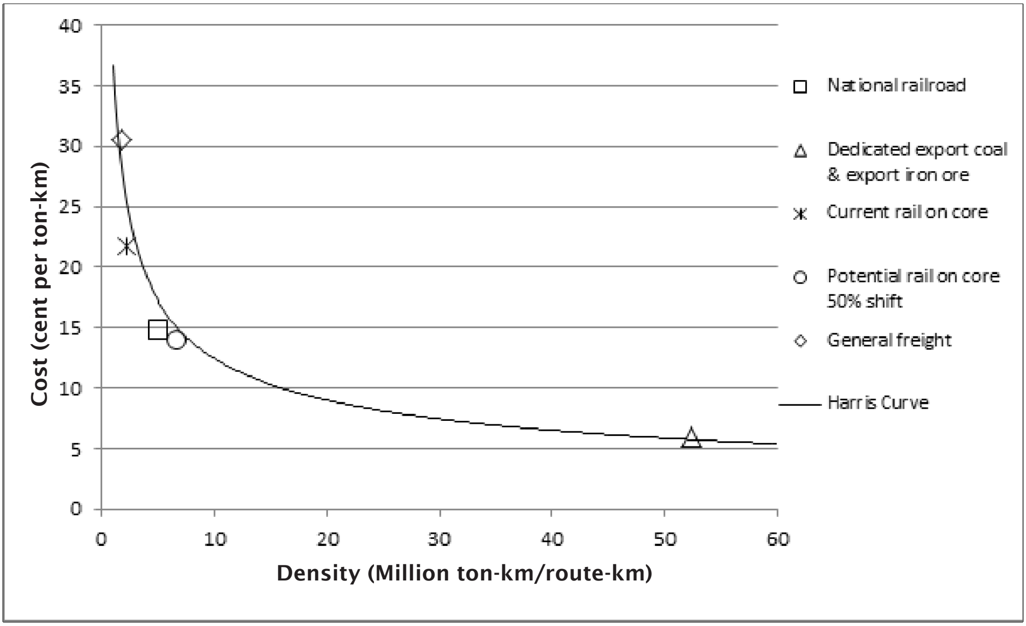


Figure 10: Potential cost savings resulting from a modal shift

While acknowledging the importance of private-sector investment, given the density imperatives, the size and scale of South Africa's rail system is probably not large enough to support a number of smaller stand-alone railways. Government policy initiatives currently underway must take cognisance of this fact, and reform decisions should be based on sound economic and environmental research. This should be fast-tracked, as action is long overdue.

Endnotes

1 The term 'genetic technologies' is first used in a rail engineering context by Van der Meulen (2003: 1) when he examines railroad architecture to answer the question, in his own words, "what makes a transport mode a railway, and not some other mode?" (Van der Meulen 2003: 3). The term 'genetic algorithms', which is more commonly known, "refers to a family of computational models inspired by evolution" (Whitley 1994: 1). Whitley argues that although these algorithms are used as function optimisers, the range of problems to which these algorithms could be applied is quite broad.

Genetic algorithms are also used in financial markets to describe problem-solving methods (or heuristics) that mimic the process of natural evolution. These algorithms are created mathematically using vectors, which are quantities that have direction and magnitude. Parameters for each trading rule are represented with a one-dimensional vector that can be thought of as a chromosome in genetic terms, while the values used in each parameter can be thought of as genes, which are then modified using natural selection. (Investopedia 2012). Lin, Cao, Wang & Zhang (2000: 3) developed genetic algorithms for stock market data-mining optimisation and stated that "this type of heuristic has been applied in many different fields, including construction of neural networks and finance".

According to Forrest (1993: 872), "many systems evolved over time that can be modelled with a genetic algorithm including biological systems and social systems". Van der Meulen is the first to apply the term in a rail-engineering context in order to identify unique technical fundamentals of a railroad and with intentional reference to the 'genes' origins of the genetic algorithm construct.

Van der Meulen's construct of 'genetic technologies' carefully considers the juxtapositioning of 'genetics' and 'technology' to assess how a railway with only one degree of freedom in propagation can compete with more sophisticated modes such as road transport (two degrees of freedom in propagation) and air transport (three degrees of freedom in propagation). According to Webster's dictionary, 'technology' is "a capability given by the practical application of knowledge". Similarly, Websters defines 'genetic' as "relating to or determined by the origin, development, or causal antecedents of something".

In Van der Meulen's definition, the juxtapositioning of these two terms can therefore be construed to mean "the capabilities given by the practical application of the knowledge of the origin and development of railways". The three 'genes' that railways have to build their DNA are bearing, guiding and coupling.

Unfortunately the Guiding 'gene' condemns railways to but one degree of freedom in propagation. Unless these three 'genetic technologies' are exploited to the full, railways will be obsolete as a mode in any economic sense. Therefore to survive in a Darwinian sense, railways have to remain fit for purpose given the advantages of freedom of propagation in the road and air transport modes.

2 Unique ring-fenced flows that are not suitable for road or rail (that is, commodities in pipelines, quarries and on conveyer belts) were identified and have been excluded from further analysis.

3 This analysis excludes the world-class iron ore and coal exports, as well as manganese exports, which are rail-only flows and are potentially viable stand-alone businesses with unique operating models.

4 A core network was defined based on certain fundamental principles (namely, high-density over more than 500 km with contributions by four or more segments). Density was required to satisfy the Harris curve requirement; distance for transport economics and multiple contributions were required in order to distil a 'network' rather than a 'pipeline'.

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