FRAMEWORK FOR RAIL FREIGHT TRANSPORT REVIVAL IN SOUTH AFRICA

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Abstract

Most long-distance land freight in South Africa is transported by road, which (i) places harsh constraints on the country's transport infrastructure; and (ii) gives rise to excessive external costs. This is ascribable to the high demand for road freight transport, which is dependent on imported fuel at unstable prices and which is damaging to the environment. The critical requirement is to determine how much freight, and specifically which freight, can switch to rail transport. In order to identify the freight flows that can exploit the economic principles of rail transport, a market segmentation model was developed. A feasible target market was identified that enables key stakeholders (government, the national railway and major road transport service providers) to engage in ensuring that sufficient investment in suitable transport infrastructure takes place timeously to support the country's economic growth and development ideals in a sustainable fashion.

Keywords: Freight traffic, Market Segmentation, Modal Shift, Rail Freight Transport

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1 Introduction

South Africa produces less than half a per cent of the world product, but requires 2% of the world's land freight ton-kilometres to do so, resulting in a contribution of 1% to the world's carbon dioxide (CO_2) emissions. Approximately 1 530 million tons of freight were shipped in South Africa during 2009. A total of 360 billion ton-kilometres over an average transport distance (ATD) of 237 km at a cost of R155 billion were provided, with external costs amounting to R23 billion (CSIR et al., 2010). The key indicators pointing to the imperative for rail's revival is that at 13,5%, South Africa's 2009 freight logistics cost as a percentage of GDP is 35% higher than First-World countries' ratios of around 10%, and at 48%, freight transport's contribution to total freight logistics cost is significantly higher than the world average of 39%. One of the key driving forces of the status quo is the debilitating modal balance, whereby most dense long-distance land freight is transported by road (Havenga, 2010).

The disproportionate transport demand is, among other things, due to the country's economic development history of far inland mining and consequent development around these activities, as well as a relatively open mineral export and beneficiated product and energy import economy. These developments created long export and import corridor requirements. In addition, the majority of corridor freight is transported by road. In 2008 approximately two-thirds of the country's total land freight transport costs (road and rail) were spent on long-distance corridors, while 95% of the corridor transport costs were attributable to road transport. Almost all growth over the already dense corridors also occurred in the road transport mode (Havenga, 2010).

Dense corridors are ideal for rail or intermodal transport, as the density enhances 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 (Pienaar, 2009), whereas road transport costs are mostly variable and significantly exposed to volatile exogenous core cost drivers, for example the price of fuel. The external costs associated with road freight transport are also higher than those attributable to rail freight transport (Hesse & Rodrigue, 2004).

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 road network, irrespective of modal balance, and significant, feasible infrastructure investment decisions are, therefore, required. The research question addressed in this article is how to reform South Africa's freight transport industry to meet future demand sustainably,

while protecting the country against the cost impact of (negative) externalities.

Section 2 describes the research methodology, focusing on a market segmentation approach and key rail economic principles that support a modal shift. Section 3 shows the results of the market segmentation exercise as well as its application to key rail economic principles and resultant cost-saving opportunities. Section 4 concludes and provides recommendations for the future.

2 Research methodology

During the past two decades many railways experienced significant restructuring, including the Americas, Europe and Russia (Rennicke & Kaulbach, 1998; Sull et al., 2004; Pietrantonio & Pelkmans, 2004; Yvrande-Billon & Ménard, 2005; Bitzan, 2003; and Pittman et al., 2007). The case studies on this restructuring do not build a clear case for any specific model of rail reform. The literature study indicated that restructuring successes and failures could not be attributed to specific reforms, but to adherence to three basic principles, namely (i) sound economic principles to reduce logistics costs and improve the country's competitiveness; (ii) sound business principles for investment decisions; and (iii) sustainable development principles. The case studies presented in the literature provide a mixture of economic goals and investment drivers for rail reforms, but not a specific segmentation of the markets rail transport should serve, nor an explicit indication of where and to what extent the deemed benefits of rail transport could be pursued.

Bryan et al. (2007: 5) present 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 the first step in understanding demand or market opportunity, which should lead to the matching of an organisation'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 homogeneous needs, Harrison and Kjelberg (2010) and Quinn et al. (2007) maintain that the identification of homogeneous customer groups is a managerial assessment rather than a naturally occurring market phenomenon. Segmentation is, therefore, not a manifestation in it is own right, but rather a continuous matching of the organisation's capabilities with observed customer needs. In this continuum, capabilities can be upgraded, changed or streamlined given new lucrative observations, or customer groupings can be adjusted given entrenched capabilities. Consequently, freight flows can be segmented in detail to identify homogeneous groups according to utilisation of core competencies, in this case railroad core competencies. This was done by classifying all freight to enable strategic marketing segmentation of the land transport industry.

The first step was to develop a comprehensive freight-flow model. The model is data-intensive, translating the transportable gross domestic product of South Africa (the primary and secondary sectors of the economy) into detailed freight flows. The research developed a view of supply and 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.

The resulting flows can be illustrated according to the core constructs of the economic sectors of the economy and are summarised in Figure 1.

The role of rail declines downstream in the overarching value chain of the economy and clearly indicates an opportunity for revival.

These freight flows that take place from places of primary production and secondary manufacturing to places of intermediate use and final consumption, resulting in key flow patterns, can be illustrated in more detail such as in Figure 2.

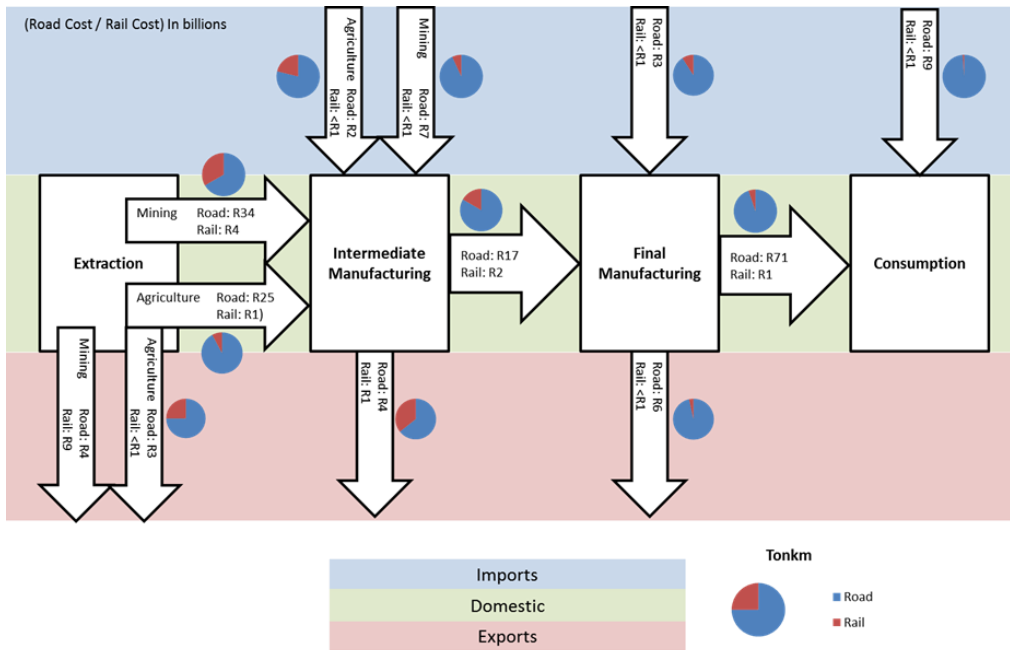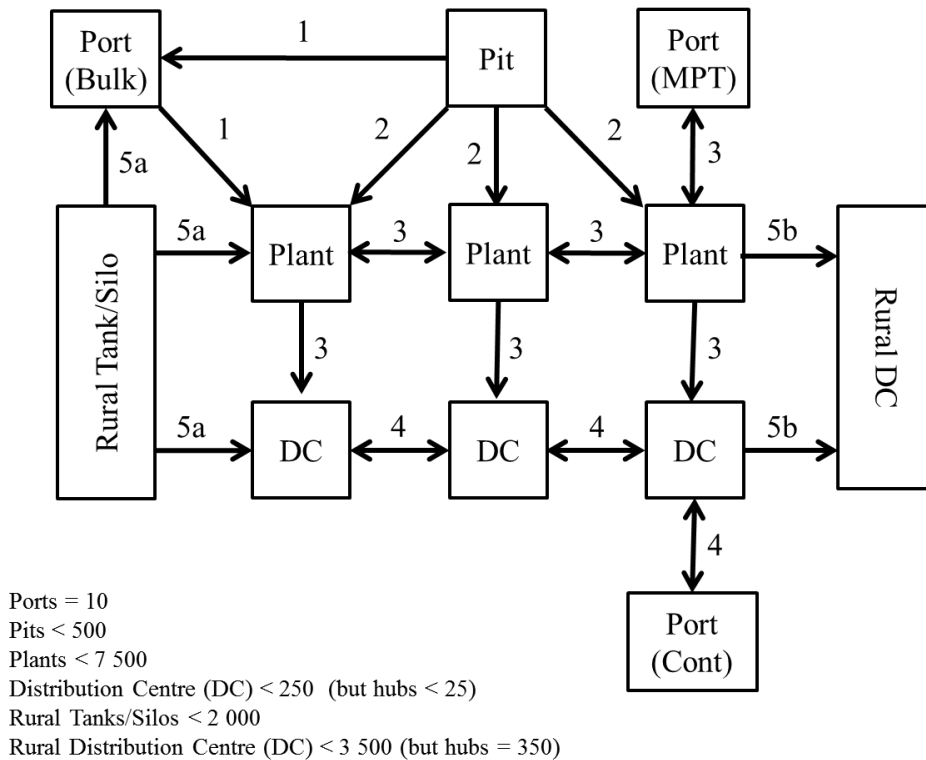**Figure 1.** Freight-flow summary based on economic sectors

Figure 2. Freight-flow patterns derived from the basic economic structure

Ports = 10
Pits < 500
Plants < 7 500
Distribution Centre (DC) < 250 (but hubs < 25)
Rural Tanks/Silos < 2 000
Rural Distribution Centre (DC) < 3 500 (but hubs = 350)

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

Table 1. Description of the 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 7 500 destinations; long distances from 400 - 900 km
Plant to plant/DC	Heavy break bulk requiring specialised wagons; plant to plant or plant to DC; high density; multiple origins (less than 7 500) with few destinations (250 DCs); transport distances nationally more than 500 km and within metros less than 100 km
Finished goods: DC-DC	Finished goods; palletised; complex supply chain 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
	Agricultural 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

The next step is to match freight-flow segments with rail economic fundamentals. The key rail economic fundamentals are **line and system density**, which enable the exploitation of rail's genetic technologies. Rail transport invests in assets with useful lives measured in decades. For this reason asset-driven fixed costs (a significant proportion of total costs) cannot be reduced rapidly in the event of traffic loss. Owing to this high level of fixed costs, the average cost per ton-kilometre and profitability are directly related to the degree of traffic density, i.e. the volume of traffic per kilometre of railway, expressed as ton-kilometres per route kilometre (ton-km/route-km). Harris (1977) stated: "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." This means that the cost per ton-kilometre of a railway will decrease with each additional ton-kilometre of activity over the same track length. This relationship is illustrated in Figure 3.

Figure 3. The relation between corridor traffic density and transport cost
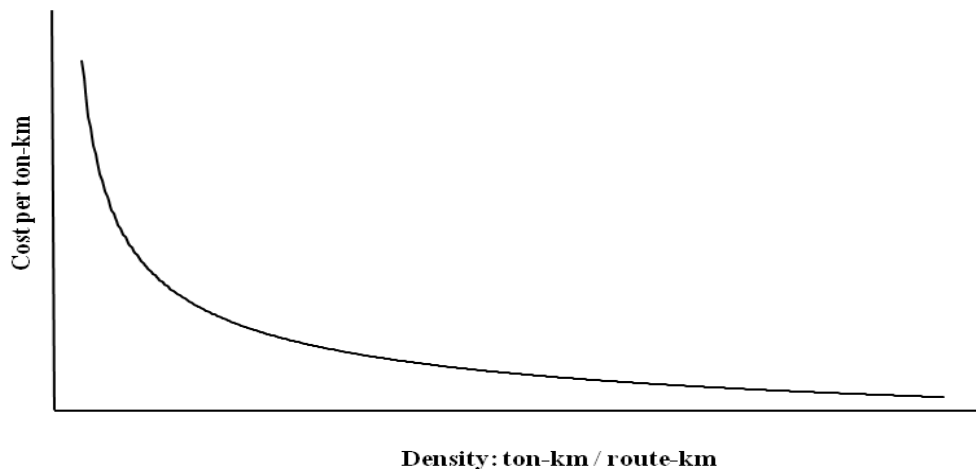
A study conducted by Mercer (2002) on Class I and regional railroads in the USA confirmed this curve. The study also emphasised that adequate traffic density is essential to meet the efficiency levels required to be competitive and to provide the economic returns necessary to justify investment. The

relevance of the Harris curve to sub-Saharan Africa has also been demonstrated (De Bod & Havenga, 2010). The effective repositioning of South Africa's national railway operator (Transnet Freight Rail) should thus strive for a core network with the greatest possible density based on a critical density threshold. (The threshold position is represented by the point on the curve where the gradient of its tangent is equal to –1, i.e. the point on the curve that separates the regions in which costs will decrease more slowly relative to improved density or decrease 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.

The advantages of rail transport can be monetised by exploiting the intrinsic technologies of rail, i.e. bearing, guiding and coupling technologies. Bearing, which indicates the axle mass load (these masses are equivalent to associated 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 or voluminous payloads (thereby combining high-volume and long-distance solutions) (Van der Meulen, 2007). These technologies naturally support four freight-rail market segments:

- Bearing and guiding intrinsic technologies' strengths are elusive for general freight. Coupling enables the combination of vehicles into long trains, thereby attaining higher capacity, given a minimum headway that trains can safely maintain. But when bearing is light and guiding slow, only typically plant-to-plant break-bulk general cargo can be moved. For this specific cargo description, rail has been proven to be competitive over almost any distance, given enough volumes from dedicated siding to dedicated siding of commodities with the same cargo-handling requirements.

- Heavy Haul requires easy gradients to limit coupler forces in heavy trains. It can accept tight curves (i.e. constrained guiding) due to low maximum speed. It will need high bearing to move typically pit-to-plant/port bulk commodities with sufficient density to allow a heavy, competitive axle load (within a modest loading gauge). It normally competes over distances of less than 1 000 km against sources in other countries or other regions − typically minerals from mines to ports or plants, and mineral imports.

- Heavy FMCG freight requires high throughput line-haul transit and terminal transhipment characterised by bimodal road-rail technology solutions. This freight is typically DC-to-DC (short and medium distance); fast-moving traffic can be transported with light-axle loads (i.e. light bearing); and it can be competitive in the 200–500 km segment.

- Heavy intermodal (i.e. double-stacked containers), which 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 (i.e. high bearing). It will compete in the 300–2 000 km segment (continental or international) − typically long-distance (preferably) high-volume container movements.

These market segments are depicted in Figure 4. 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 segment.

Figure 4. Positioning framework for rail systems
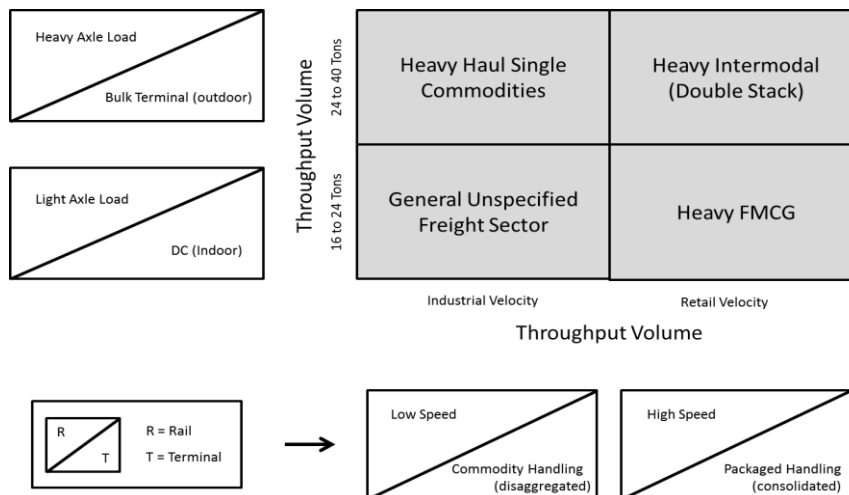
(Source: Adapted from Van der Meulen, 2007)

The framework provides an interesting railway segmentation perspective. It was stated earlier that rail's market share declined at an accelerating pace because of the shift from low-value/high-volume to high-value/low-volume freight (Pietrantonio & Pelkmans, 2004), i.e. in terms of the model, from the top right to the bottom left. (This means that fewer heavy-haul single commodities that require high bearing and low guiding were transported.) This freight was replaced by more valuable assorted freight that requires lower bearing and high guiding. (This shift is typical during periods of national economic growth.) In this process many of rail's other intrinsic cost benefits were lost and it is maintained that 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 3). ("Gravimetric" means rail density capability fit, and "high-value" means the freight is less price sensitive or has 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.
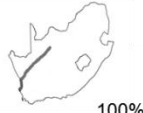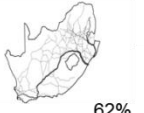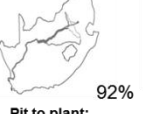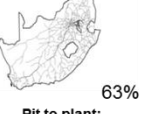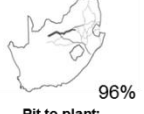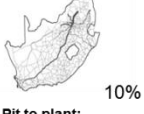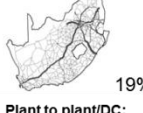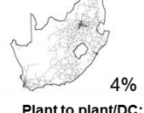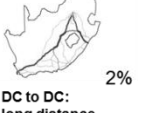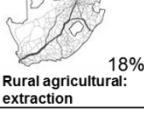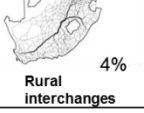
The output from the freight-flow model is segmented and summarised according to the national economy's basic structure, translated into flows for road and rail and then analysed on the basis of the intrinsic technologies of rail transport.

3 Results

3.1 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 5. Rail market share is also indicated, highlighting the dominant position (and core competence) of the national rail system in the transportation of mining commodities, as well as significant opportunities in other long-distance transport market segments.

Figure 5. Total freight flows per sub-segment in tonnage terms; rail share in 2009

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

4.2 Freight-flow market segment

When the freight-flow market segment 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 logistics, value relates to short and reliable transit times) when he analyses the technological advantages and disadvantages of rail, and relates it to bearing (weight) and guiding (speed). Harris considers density when he proves that higher throughput over the same network (or the same throughput over a reduced network) will lead to lower costs. A combination of these factors enables the description of freight-flow market

segments in terms of transport distance, cost and   density, as illustrated in Figure 6.

Figure 6. Freight-flow market segments based on distance, density and cost (2008)
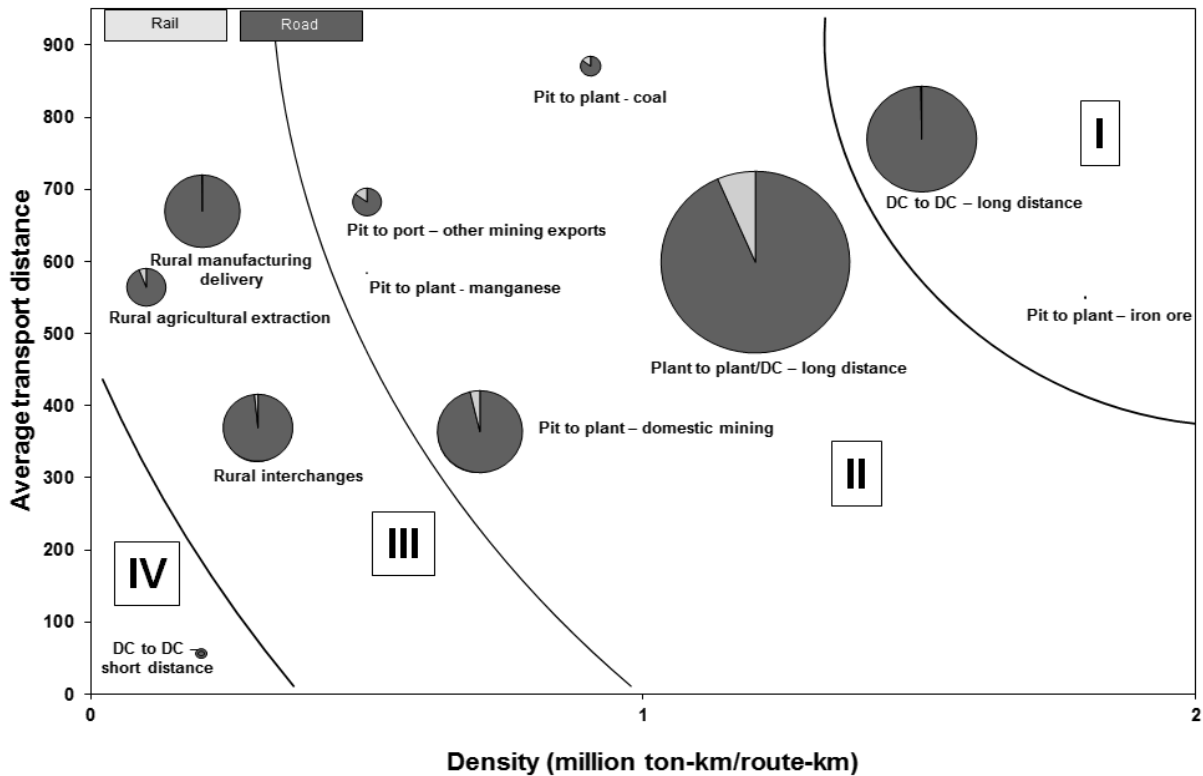
The low market share of rail transport is evident in all sub-segments, but is especially disconcerting in the traffic ideally suited for rail, i.e. with high-density traffic over long distances (long-distance transport from plants to distribution centres, and between distribution centres). The attributes of each of these sub-segments are summarised in Table 2, which also indicates the suitability of these sub-segments for carriage by rail.

Most developed countries with medium- to high-density traffic in long-distance corridors have developed intermodal solutions. This intermodal potential, already successfully implemented in the Americas, Europe and Australasia, has not yet been realised in southern Africa.

Table 2. Description of market segments, sub-segment attributes and suitability for rail

Market segment	Sub-segment	Sub-segment attributes	Relationship to rail intrinsic 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	Plant to plant/DC – Long distance	▪ Core siding to siding business ideally suited to rail	▪ Low to medium speed ▪ Light axle load technology	▪ Outbound sidings – in serious decline
	Pit to port – Other mining exports	▪ Long distances, high density if shared network (core) is		▪ Heavy haul shuttles – established

Market segment	Sub-segment	Sub-segment attributes	Relationship to rail intrinsic technologies	Key requirement from rail and current status
distance	Pit to plant – Coal, manganese and domestic mining	monetised as an integrated network ▪ Low terminal density challenges remain ▪ Non-uniform/standardised product		▪ Inbound sidings – reasonable
III Low density	Rural manufacturing delivery Rural agricultural extraction Rural interchanges	▪ 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 ▪ genetic technologies, this segment requires
IV Short distances	Plant to plant/DC – Short distance DC to DC – Short distance	▪ Distances too short ▪ Density too low ▪ Not viable for rail	▪ Not viable for rail	

The sub-segment attributes can also be presented through the relationship between ton-kilometre and cost (Figure 7). In such sub-segments as DC-to-DC long distance, costs (for the country) are arguably higher than they ought to be, and they could be reduced if additional volumes of such freight were to move by rail. Consequently, there are opportunities for efficiency improvements in the country through modal shifts to rail and intermodal transport in certain sub-segments.

Figure 7. Relationship between ton-km and cost per sub-segment (2009)
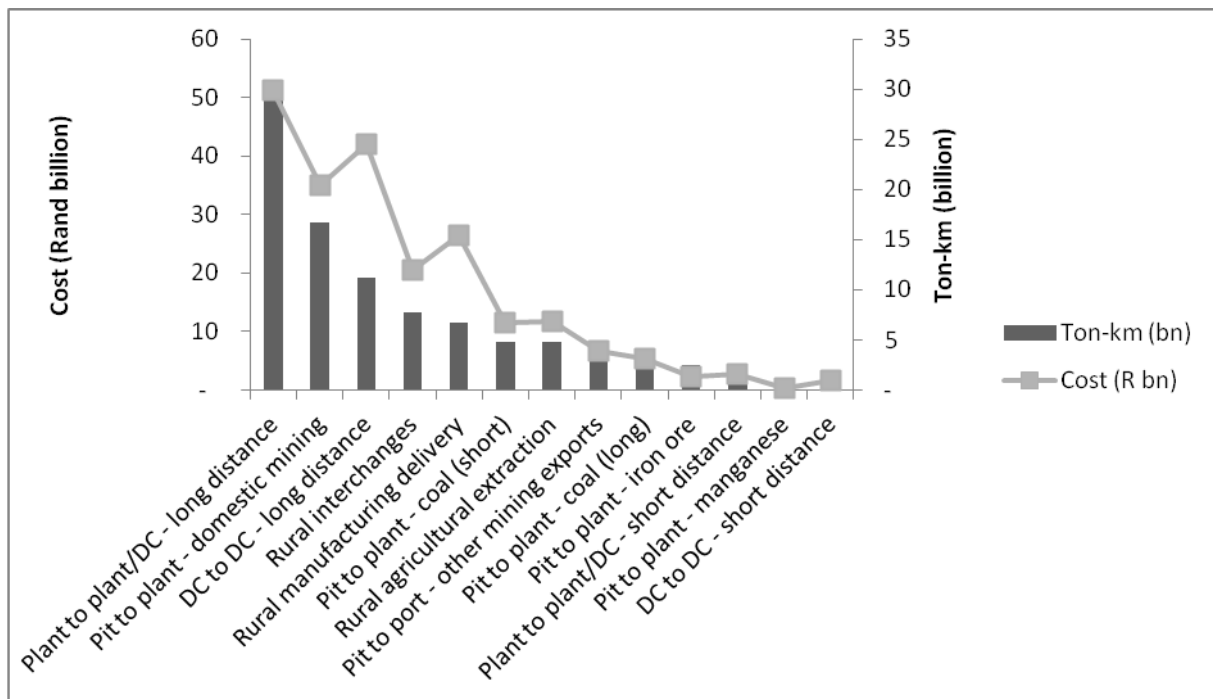
Analysis (utilising the Harris curve) indicates that if 50% of long-distance heavy intermodal and siding-to-siding break-bulk road traffic could be shifted to a core rail network, significant cost savings can be achieved. In this model, average rail costs could be reduced from 30 cents/ton-km to less than 15 cents/ton-km for general freight, as depicted in Figure 8. Such savings point to the potential feasibility of intermodal solutions for South Africa's long-distance land freight transport market.

Figure 8. Potential cost savings resulting from a road to rail modal shift
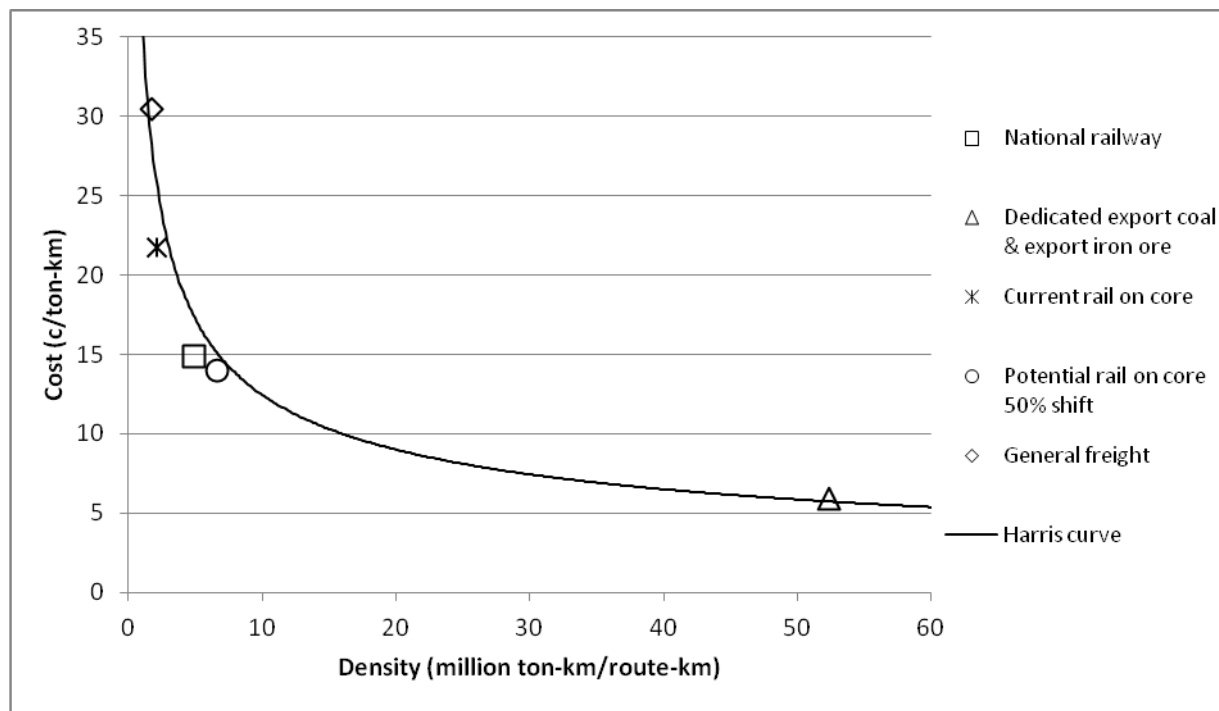
4 Conclusion

Given South Africa's high logistics costs, dense long-distance road corridors and significant growth forecast in freight flows, a restructuring of the freight transport system and related investment is critical. The research outlines potential opportunities for intermodal solutions where both road and rail transport can benefit, allowing South Africa to move closer to its economic growth and development ideals. Solutions need to be found that optimise South Africa's origin-to-destination product supply chains, considering the manner that the country's rail, road, inland terminals and ports could complement one another. This may enable the country to better compete with offshore product supply chains. As a next and important research step, a more detailed analysis of the long-distance domestic intermodal freight transport segment is required, followed by feasibility studies and implementation if a financially viable and economically justified investment case can be proven.

References

1. Barloworld Logistics. 2011. *Supply chain foresight – Evolving strategies: Competitive supply chains in emerging economies*. [Online] Available at <http://www.barloworld-logistics.com/bwlogistics/action/media/downloadFile?media_fileid=3143> (Accessed 15 May 2011).
2. Bitzan, J.D. 2003. Railroad costs and competition – The implications of introducing competition to railroad networks, *Journal of Transport Economics and Policy*, 37(2): 201–225.
3. Bryan, J., Weisbrod, G., Martland, C.D. & Wilbur Smith Associates Inc. 2007. *Rail freight solutions to roadway congestion – Final report and guidebook*. National Cooperative Highway Research Program: Report 586. Transportation Research Board of the National Academies, Washington DC.
4. CSIR, Imperial Logistics & University of Stellenbosch. 2010. *Seventh Annual State of Logistics Survey – Value creation towards global competitiveness and sustainability*. [Online] Available at <http://www.csir.co.za/sol/> (Accessed 16 May 2011).
5. Harris, R.G. 1977. Economies of traffic density in the rail freight industry. *The Bell Journal of Economics*, 8(2): 556–564.
6. Harrison, D. & Kjelberg, H. 2010. Segmenting a market in the making: Industrial market segmentation as construction. *Industrial Marketing Management* 39 (2010): 784–792.
7. Havenga, J.H. 2010. Logistics costs in South Africa – The case for macroeconomic measurement, *South African Journal of Economics,* 78(4): 460–478.
8. Hesse, M. & Rodrigue, J.P. 2004. The transport geography of logistics and freight distribution. *Journal of Transport Geography,* 12(3): 171–184.
9. Mercer Management Consulting Incorporated. 2002. *Infrastructure separation and open access: Lessons from experience*. Unpublished confidential report.
10. Pienaar, W.J. 2009. Transport cost structures and pricing principles. In: Pienaar, W.J. & Vogt, J.J. (Eds.), *Business logistics management: A supply chain perspective,* Third edition. Cape Town: Oxford University Press.
11. Pietrantonio, L.D. & Pelkmans, J. 2004. *The Economics of EU Railway Reform*. Bruges European Economic Policy Briefings, College of Europe, Brugge.

12. Pittman, R., Diaconu, O., Šip, E., Tomová, A. & Wronka, J. 2007. *Will the train ever leave the station? The private provision of freight railway service in Russia and Central and Eastern Europe.* U.S. Department of Justice, report EAG 07-5, January.

13. Quinn, L., Hines, T. & Bennison, D. 2007. Making sense of market segmentation: A fashion retailing case, *European Journal of Marketing*, 41(5/6): 439–465.

14. Rennicke, W.J. & Kaulbach, A.E. 1998. *Myths and realities of rail access and competition issues – An overview of rail access and competition issues related to Canada railways and the North American railway industry.* The Railway Association of Canada, October.

15. Sull, D.N., Martins, F. & Silva, A.D. 2004. *America Latina Logistica.* Harvard Business School. Case study number 9-804-139.

16. Van der Meulen, D. 2007. *Leveraging the competitive strengths of railways in South Africa*, Proceedings of Transport Infrastructure and Development Conference, Sandton, 30–31 May 2007.

17. Van Eeden, J. & Havenga, J.H. 2010. Identification of key target markets for intermodal freight transport solutions in South Africa. *Journal of Transport and Supply Chain Management*, November: 255–267.

18. Yevdokimov, Y.V. 2000. Measuring economic benefits of intermodal transportation, *Transportation Law Journal*, 27(3): 439–452.

19. Yvrande-Billon, A. & Ménard, C. 2005. Institutional constraints and organizational changes: The case of the British rail reform. *Journal of Economic Behavior & Organization*, 56: 675–699.