A FREIGHT LOGISTICS MARKET SEGMENTATION METHODOLOGY FOR SOUTH AFRICA

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ABSTRACT

South Africa's annual State of Logistics survey indicates that the majority of dense long distance surface freight transport is on road, putting severe constraints on the freight logistics system and the growth aspirations of the country. This is a market segment that is very suitable for intermodal transportation where rail is utilised for the high-density long-distance component and road for the feeder and distribution services at the corridor end-points. In order to identify the freight flows that will exploit rail's economic fundamentals a market segmentation model was developed. A feasible target market is identified that enables key stakeholders (government, the national railroad and major road service providers) to engage in ensuring that the urgent planned billion-pound infrastructure spending by the public and private sectors is invested in suitable freight logistics infrastructure to support the country's growth ideals sustainably.

1 INTRODUCTION

The imperative for the revival of South Africa's freight rail system has been urged in key research projects [1, 2, 3] and propositioned in national policy frameworks [4, 5, 6] for almost two decades. During this time the railway has been underfunded continously and recent efforts for revival has been hampered by this backlog. Recent investments however looks promising for reival and the freight segments that could be targeted requires consideration.

The key indicators pointing to this revival imperative is that at 13.5% [7] South Africa's 2009 freight logistics costs as percentage of GDP is 35% higher than first world figures of around 10% [8, 9, 10] and at 48% freight transport's contribution to total freight logistics costs [7] is significantly higher than the world average of 39% [11]. One of the key driving forces of the status quo is the debilitating modal imbalance where the majority of dense long distance surface freight transport is on road [12].

The modal imbalance is a result of an historical rail investment backlog with related service challenges, and the rapid deregulation of the freight transport industry in the early 1990's which resulted in a proliferation of road transport service providers, further reducing rail density and its ability to invest [13]. 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 [14] as well as trade liberalisation which increased both imports and exports [15].

Worldwide, a similar decline in rail transport was experienced whilst highways were developed and markets were liberalised. The growth in transport demand and the drive for more environmentally friendly transport solutions, led to *inter alia* the implementation of intermodal freight transport solutions marking a clear trend for rail revival.

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 is transported in South Africa every year. This categorisation, in turn, informs the optimal modal split, facilitates policy development and enables appropriate investment.

Section 2 provides more detail on South Africa's national freight transport challenges. Section 3 describes the research methodology focusing on the market segmentation approach and key rail economic principles that support a modal shift. Section 4 shares the results of the market segmentation exercise and shows the application of the results to key rail economic principles and resulting cost saving opportunities. Section 5 concludes and provides recommendations for the way forward.

2 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 kilometers moving over an average transport distance (ATD) of 237 km and at a direct cost of R155 billion were delivered, with externality costs amounting to R23bn [7].

To put these figures into global perspective, South Africa produces less than half a percent of the world GDP, but requires 2% of the world's surface freight tonkilometres, 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 with inland mining deposits and consequent development around these deposits, as well as a relatively open mineral export and beneficiated product and energy import economy. This created long export and import corridor requirements [13].

As mentioned in the introduction, this is exacerbated by the fact that the majority of corridor freight transport is by road. In 2008 sixty six percent of surface freight transport cost (road and rail) was earned by road transport providers on corridors, and 95% of corridor transport cost was earned by road transporters. In addition, almost all growth over the already dense corridors also occurred in the road transport mode [12].

These dense corridors are ideal for rail or intermodal transport, as the density creates economies of scale due to the large volume of tonkilometres generated [16]. International research indicated that intermodal transport magnifies these scale effects and initiates cumulative economic growth [17]. In addition, the largest proportion of rail costs are fixed [18] 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 [19].

This is borne out by South Africa's data where externalities (such as emissions and congestion) are estimated to have added an additional R23bn or 15% to the freight transport costs of R155bn in 2009. Adding these costs to transport costs increases the cost percentage of freight transport from 6.5% to 7.4% of GDP in 2009. Ninety six percent of these externality costs were contributed by road transport [7].

South Africa's freight transport requirements is also forecasted to grow by 108% in tonkilometre terms between 2009 and 2039, which cannot be moved on the current network irrespective of modal balance, therefore requiring sound investments decisions.

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.

3 RESEARCH APPROACH

In the latter part of the previous century, many railways experienced significant restructuring including those in the United Kingdom, Europe, the Americas, Russia and Eastern Europe [18, 20, 21, 22, 23 and 24]. The case studies do not build a clear case for any specific model of rail reform. Some models were necessary for extrinsic reasons (such as open access in the EU due to the political structure of the European Union; concessioning in Brazil due to the absence of funds for further investment; or interstate integration in Australia). The case study analysis indicated that there were successes and failures, not because of the specific form, but because of adherence to three basic principles namely (i) sound macro-economic principles to reduce logistics cost and improve the country's competitiveness, (ii) sound business principles for investment decisions and (ii) sustainable development principles.

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 there are several unique aspects to the country's economic and institutional context, 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.

The most appropriate approach is therefore to focus on the fundamentals. 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.

3.1 Freight flow segmentation

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

The research develops 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 it is moved (typologies) and what is moved (commodities). A 30- year forecast for low, medium and high scenarios is also developed. The output of the model contains flows for 62 commodities between 356 magisterial districts in South Africa and results in more than 1 million records of freight flow data between defined origin and destination pairs. (Refer to [13] for a detailed description of the model.)

The assimilation of freight flows are derived from the basic economic structure and its related logistics requirements, as illustrated in Figure 1.

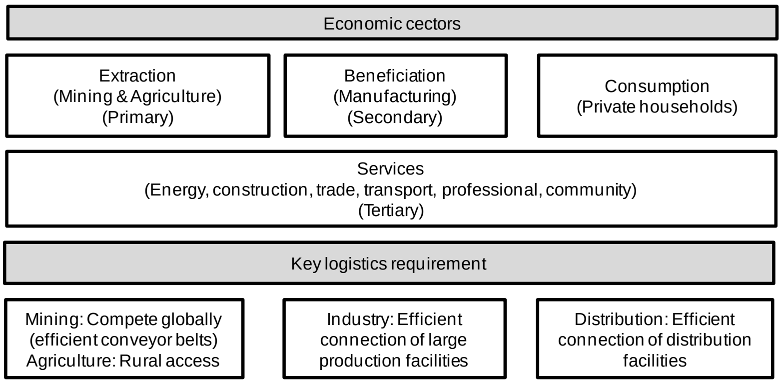

Figure 1: Basic economic structure and resulting logistics requirements

Freight flows take place from the place of extraction / manufacture to their place of utilisation or consumption, resulting in key flow patterns as indicated in Figure 2.

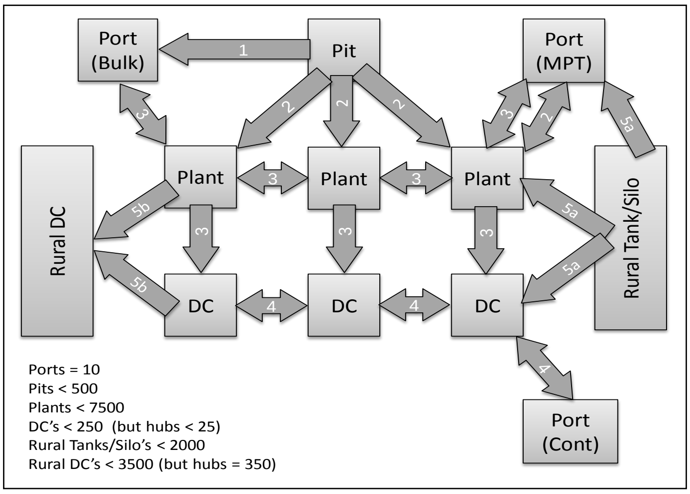

Figure 2: Freight flow patterns derived from the basic economic structure

These flow patterns result in the identification of 5 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[1]

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

[1] DC = distribution centre, SCM = supply chain management

Given the national freight transport challenges described previously, the next step is to match the freight flow segments with rail economic fundamentals.

3.2 Rail economic fundamentals

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

Line and system density

In 1977, Robert G. Harris 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." [25]

Rail invests 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 cost per tonkilometre and profitability are directly related to the degree of traffic density, i.e. the volume of traffic per kilometre of railroad, expressed as tonkilometre per route kilometre (tonkm/routekm). This means that the cent per tonkilometre cost of a railroad will decrease with each additional tonkilometre activity over the same track length. This relationship is illustrated in Figure 3 below.

A study conducted by Mercer on Class I and regional railroads in the USA in 2002 confirmed this curve. The study also emphasized 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 [26]. The relevance of the Harris curve to Sub-Saharan Africa has also been demonstrated [27].

The effective repositioning of South Africa's railroad should thus strive for a core network with the greatest possible density based on the critical density threshold. Statistically the threshold is the inflection point of cost and density at the middle of the curve. 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.

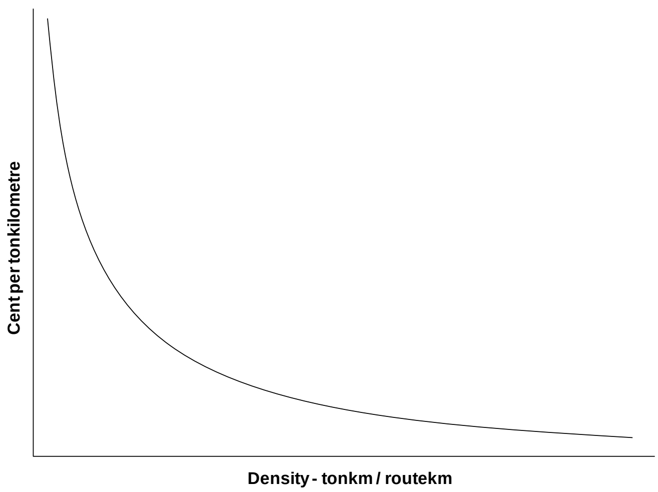

Figure 3: The economics of rail density (adapted from [24])

Pittman [28] argued 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 only 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 [26]. The "single-network characteristic" of South Africa's railroad based on density requirements has also been suggested [29].

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

Genetic technologies

The advantages of rail as a transport mode can be monetised by exploiting the intrinsic technologies of rail, i.e. bearing, guiding and coupling technologies. Bearing, which indicates the weight of axle load that can be maintained (and therefore volumes) 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 (therefore combining high volume time and long-distance solutions) [30]. These technologies naturally support four freight rail market spaces:

- General Freight: Bearing and guiding genetic technologies strengths 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 siding to siding break bulk general cargo;
- Heavy Haul: Requires easy gradients to limit coupler forces in heavy trains. Accepts tight curves due to low maximum speed. Bulk commodities with sufficient density to allow a heavy, competitive axle load (within a modest loading gauge. 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: Requires high throughput line haul transit and terminal transshipment characterised by bimodal road–rail technology solutions. Fast moving. light axle loads. Competes in the 300 – 1 000 km space – typically bimodal transport of high value palletised fast moving consumer goods; and
- Heavy Intermodal (double-stacked containers): Similar to heavy FMCG, but requires high vertical clearance. Fast moving, heavy axle loads. Competes in the 3 000 - 12 000 km space (continental or intercontinental) – typically long-distance (preferably) high volume container movements.

These market spaces are depicted in Figure 4. This grid provides a framework for strategic positioning of rail systems and is useful in assessing opportunities and selecting appropriate technologies for a railway in a chosen market space.

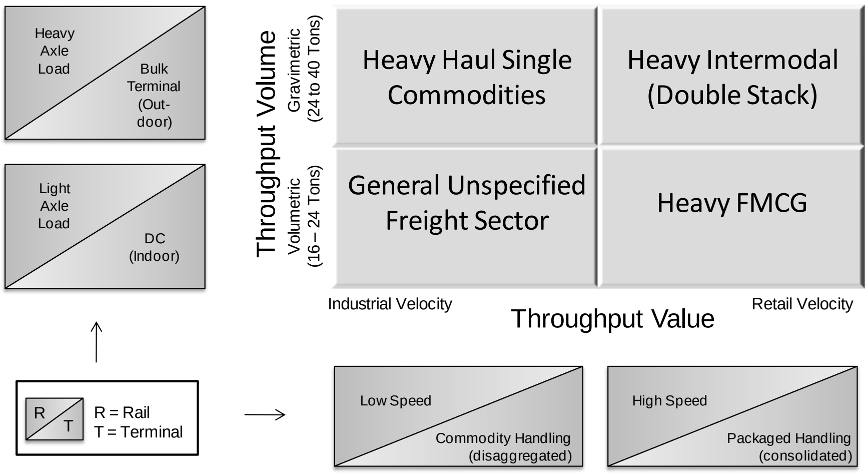

Figure 4: Positioning framework for rail systems (adapted from [27])

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

4 RESULTS

Total freight flows resulting from the freight flow model are depicted in Figure 5, as well as rail's share of these flows. This highlights the importance – and opportunities – of flows not being served by rail.

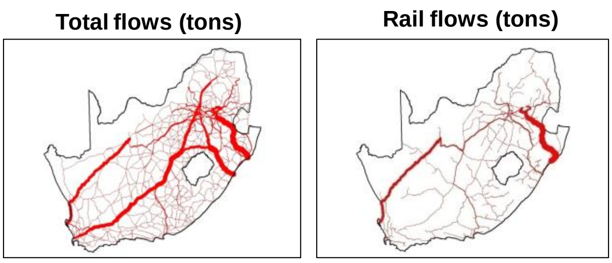

Figure 5: Total surface freight transport flows compared to rail flows for 2009[2]

4.1 Freight segments

Analysis of the total freight flows in the country within the 5 overarching segments described previously, led to the identification of 15-sub segments as illustrated in Figure 6. Rail market share is also indicated[3]**,** 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.

[2] 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)

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

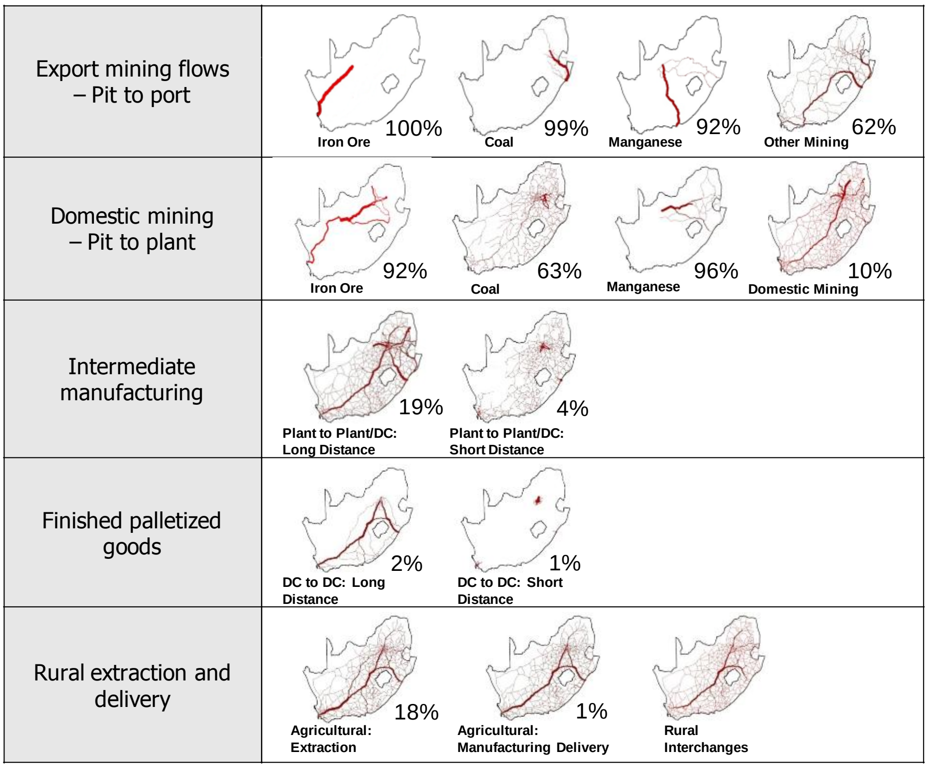

Figure 6: Total volumetric freight flows per sub-segment, rail share in percentage (2009)

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.

4.2 Freight flow market space

Transport distance, density and cost are considered to describe the freight flow market space, as illustrated in Figure 7[4].

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

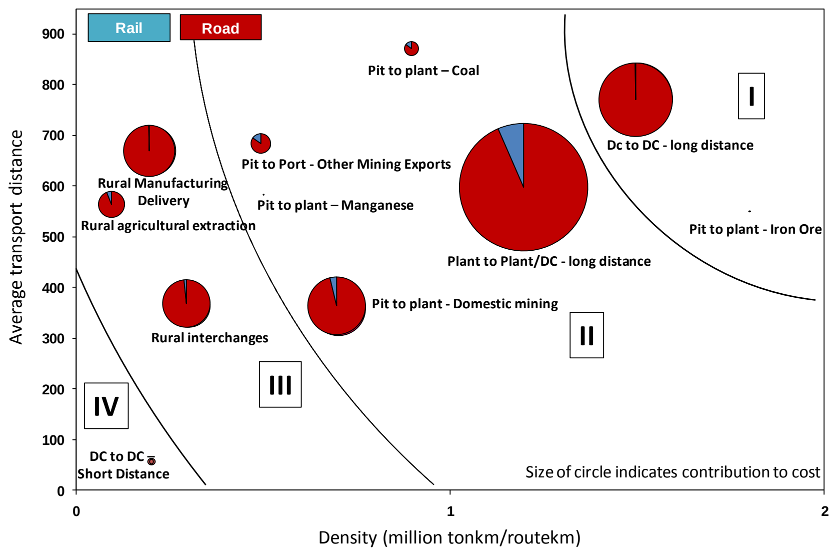

Figure 7: Freight flow market space based on distance, density and cost (2009) (excluding export iron ore, coal and manganese)

Rail’s low market share is evident in all segments, but especially disconcerting in the traffic ideally suited for rail, i.e. 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 segments is summarized in Table 2 which also indicates the suitability of these segments for transportation by rail.

Most developed countries with medium to highly densified transport distances have developed intermodal (or multimodal) solutions. South Africa has not exploited this market.

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

	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	▪ Low to medium speed ▪ Light axle load	▪ Less than train loads – in serious decline ▪ genetic

	Sub-segment	Sub-segment attributes	Relationship to rail genetic technologies	Key requirement from rail and current status
	Rural Agricultural Extraction	operating model where capacity is already installed	technology	technologies, this segment requires
	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			

These sub-segment attributes can also be presented reflecting the relationship between tonkilometre and cost (Figure 8). 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 volume of such freight was to move by rail. There are thus opportunities, to the country, of modal shift in certain sub-segment.

High-level analysis indicates that if 50% of long distance road traffic can be shifted to a core rail network cost savings from 30 cents/tonkilometre to less than 15 cents/tonkm for general freight can be achieved, as depicted in Figure 9. This points to the high-level feasibility of intermodal solutions for South Africa's long distance freight.

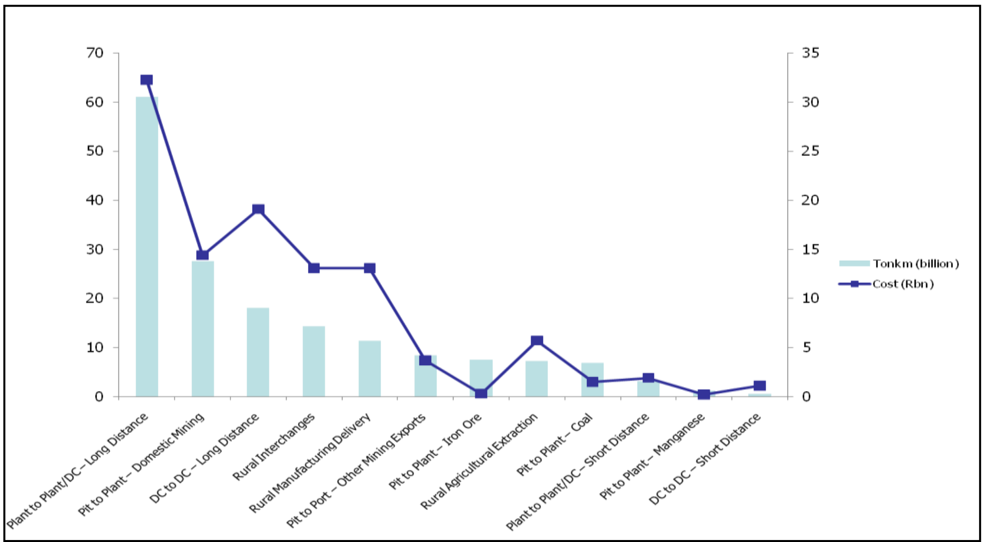

Figure 8: Relationship between tonkilometre and cost per sub-segment (2009)

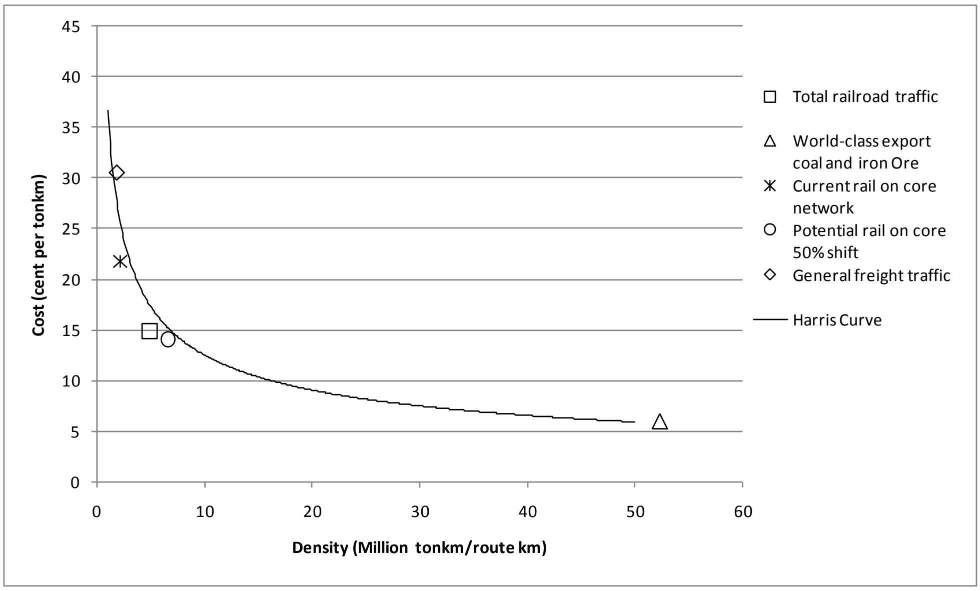

Figure 9: Potential cost savings resulting from a modal shift

5 CONCLUSION

South Africa's freight flow challenges amidst 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, and South Africa can 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 each other to compete as a whole against other global supply chains.

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.

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