ECONOMIES OF DENSITY IN RAIL FREIGHT TRANSPORT: POTENTIAL FOR UTILISATION IN SOUTHERN AFRICA

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Abstract

Road transport has replaced rail carriage as the dominant form of long-distance freight transport in Southern Africa. Road freight carriers can transport goods of various sizes and masses over long distances. This article highlights the significant cost-reduction opportunities possible through economies of density achievable in rail freight transport, especially over long distances, and the concomitant implications for increased profitability for railway organisations in Southern African countries. Traffic densification opportunities should focus on the development of transport corridors throughout the Southern African region.

Key Words: Economies of Density, Rail Freight Transport, Southern Africa, Transport Cost

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Introduction

During the 1970s road transport replaced rail carriage as the dominant form of long-distance freight transport in Southern Africa (Pienaar, 2007; Simuyemba, 2007). Today, almost forty years later, the long-distance modal share of rail freight transport in the region is still declining. The objective of this article is to illustrate how this trend can be reversed through creating conditions conducive to the achievement sufficient economies of density for the revival of long-distance rail freight transport in the Southern African Development Community (SADC) countries. This could form the backbone of more targeted rail investment planning in the region.

In the following section the concepts of economies of density and economies of distance are outlined. In the section thereafter the impact of these economies on rail freight transport cost is discussed. This is followed by an overview of the research methodology, a discussion of the research results and, finally, conclusions.

The Concepts of Economies of Density and Economies of Distance

Through economies of density and distance a rail transport operation may enjoy a natural monopoly on a particular route. On the condition that the utilisation of train carrying capacity is high the former economy stems from its cost structure, which is characterised by a high ratio of fixed cost to total cost -- the second-highest fixed-cost ratio of all modes of transport after pipeline transport (Pienaar, 2012).

Economies of density exist when the total cost to transport units of freight from their points of departure to their intended destinations decreases by increasing utilisation of existing vehicle fleet and infrastructure capacity within a market area of given size. Economies of density are enhanced by (1) using high-capacity technology to carry and handle large bulk loads; (2) minimising loading and unloading times; (3) utilising traffic consolidation (i.e. load, trip and route consolidation); and (4) maximising the immediate and continuous utilisation of vehicles. Immediate utilisation refers to the measure whereto the carrying capacity of vehicles is utilised, while continuous utilisation refers to the number of revenue-kilometres or revenue-trips covered per time period (Pienaar, 2012).

This type of economy stems from the fact that one can serve the largest possible portion of a market with the same technology. The same volume of throughput occurs, but the movement is concentrated (or consolidated) into one process, permitting more intensive use of the capital involved.

To achieve economies of density, one usually needs specialised technology to handle large volumes of a specific or homogeneous type of goods. The inherent danger of this is the empty return trip. To reap the optimum rewards of specialisation, handling equipment at terminals should allow for rapid loading and unloading of freight in order to maximise the number of full vehicle load-kilometres per unit of time. Economies of density necessitate the maximum utilisation of large, durable equipment over as long a period as possible.

Economies of distance (also known as long-haul economies) are attained when the total transport cost per ton-kilometre decreases as the trip distance increases. Economies of distance arise when there are trip-specific costs that are not affected by the distance of the journey. Examples of these cost items in rail freight transport are terminal costs, such as train marshalling costs; trip documentation; and loading, stowing and unloading costs. As these costs have to be paid regardless of the distance, doubling the length of a haul does not result in doubling the costs.

Rail Transport Efficiency

Overland pipeline transport is the cheapest mode for those types of commodities that can be transported by pipe. Wherever a competing pipeline does exist, either rail or road transport is the cheapest mode of transport for all those commodities that cannot be carried by pipeline. In view of the fact that rail transport achieves considerable economies of distance, it becomes cheaper than road transport for all classes of freight transport as trip distances increase above approximately 500 kilometres (Pienaar, 2012; World Bank, 2006). However, for trips shorter than roughly 150 kilometres, road transport is virtually always cheaper than rail transport. For all types of goods that can possibly be carried either by road or rail transport between the same trip origins and destinations, the equal cost distance lies between approximately 150 and 500 kilometres (Pienaar, 2012).

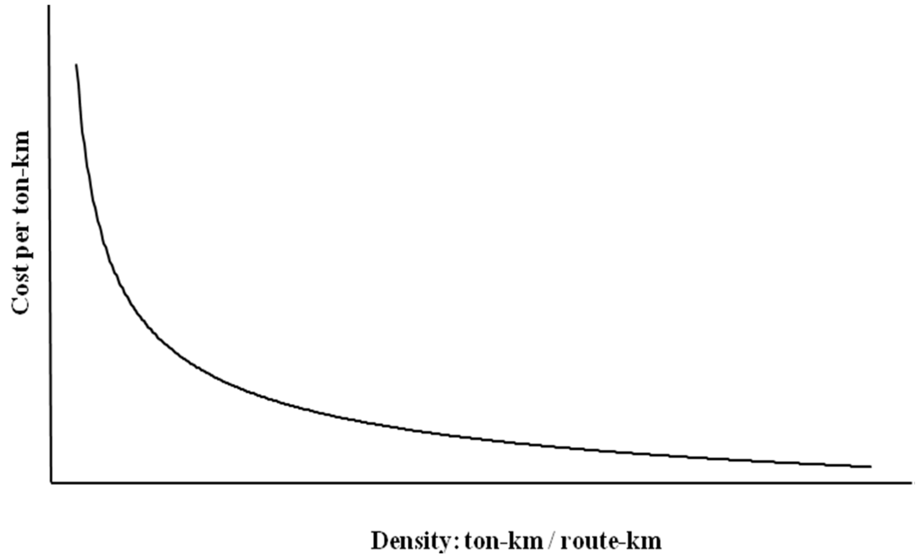
Owing to the high capital investment in rail infrastructure (railway lines and terminal facilities, such as large administrative buildings, stations, marshalling and classification yards, sheds, goods depots and workshops) and the longevity of rolling stock, such as locomotives and freight wagons, the ratio of fixed to total costs is relatively high – the second highest of all modes of transport (after pipeline transport). Approximately 75% of rail transport costs are fixed over the short term (Havenga & Pienaar, 2012).

In view of the fact that rail transport has relatively high terminal costs, it enjoys substantial economies of distance as trip length increases – the highest of all modes of transport (Pienaar, 2012).

Drew (2006), Havenga (2007) and Pittman (2007), among others, highlight the importance of traffic density in leveraging rail's cost-effectiveness over longer distances due to the mode's high fixed infrastructure component.

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 1.

Figure 1. 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 by De Bod (2008). 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 economies become increasingly difficult to achieve despite density improvements beyond the threshold point.

Research Methodology

A freight demand model for South Africa was developed in 2006 (and is updated annually) to establish a database for all South African freight flows as input for long-term infrastructure planning (Havenga & Pienaar, 2012). The modelling of total freight flows is based on gravity modelling of the supply and demand for 354 magisterial districts and 64 commodity groups.

For the research presented in this article, actual freight flows for Botswana and Zambia were recorded in the two countries, and gaps were modelled on similar principles as contained in the South African freight demand model (although at a more consolidated level due to the lack of detailed data). Owing to monetary constraints, this approach was not possible for all SADC countries. By using indicators such as population, GDP and trade, an estimate of freight flows in the various countries is possible. Network length is also available, which enables the estimation of potential rail freight traffic density.

Using the known freight flow volumes for South Africa, Botswana and Zambia the freight flows for the remaining SADC countries were modelled. The modelled results were then compared to established international research results (Harris, 1977; Ordover & Pittman, 1994; Mercer Management Consulting, 2002; Pietrantonio & Pelkmans, 2004). In these studies, figures for ton-km achieved were compared to available route-km in order to illustrate the impact of the potential density on rail costs in the various countries. The magnitude of this relation is deemed to be a reliable indicator of the profitability of both the railway organisations and the freight transported.

Discussion of Results

The road and rail ton-km estimate and the network length required to deliver this transport output are summarised in Table 1.

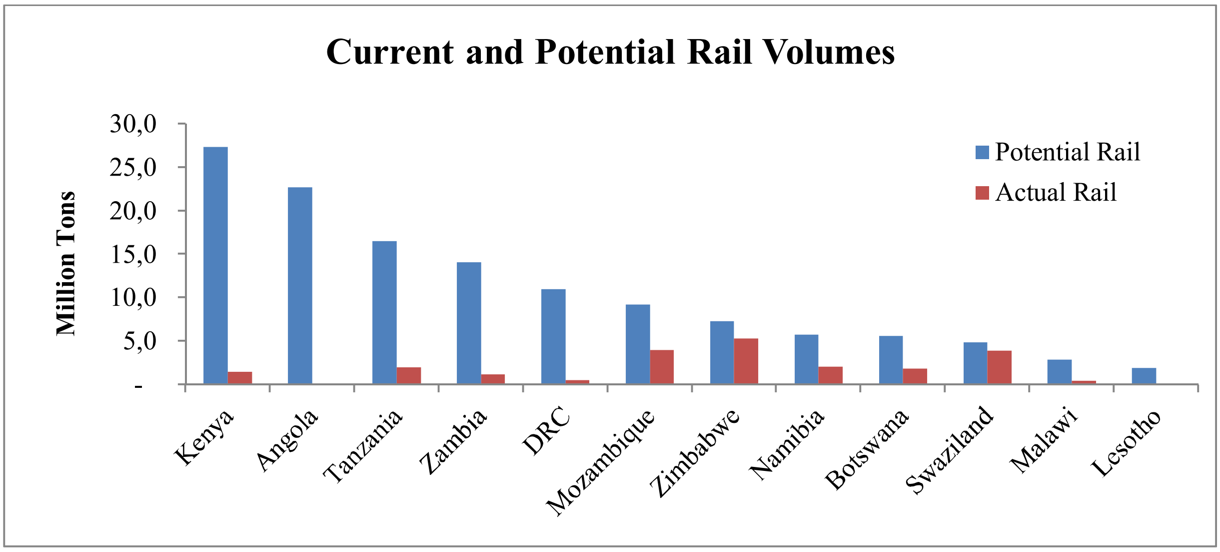
Table 1. SADC rail and road ton-km and network length in km (2006)

Country	Length of (km)			Tons (million)			Ton-km (millions)	
	Rail	Road	Paved Roads	Rail	Road	Total	Rail	Road
RSA	20 070	358 596	59 753	178.00	553.0	731.0	108 000	170 000
Kenya	2 100	63 265	8 933	1.48	59.3	60.8	1 200	4 332
Angola	2 515	51 429	5 348	0.04	50.4	50.5	21	7 912
Tanzania	4 460	88 200	3 704	2.01	34.7	36.7	2 562	4 126
Zambia	916	91 440	6 779	1.15	30.1	31.2	625	2 851
DRC	3 256	17 250	2 250	0.5	14.1	24.4	465	2 084
Botswana	888	10 217	5 620	1.85	18.8	20.7	647	1 378
Mozambique	2 593	30 400	5 685	4.00	13.4	17.4	500	1 351
Zimbabwe	2 583	18 338	8 692	5.30	9.0	14.3	2 400	444
Namibia	2 382	64 808	5 378	2.07	10.8	12.8	1 262	1 119
Swaziland	301	14 597	1 064	3.90	3.6	7.5	710	8
Malawi	789	14 597	2 773	0.40	5.9	6.3	75	88
Lesotho	3	4 955	887	0.00	4.3	4.3	0	16

Source: De Bod, 2008

This result provides an estimate of rail market share in SADC countries other than South Africa. The major objective for developing this information was to guide further research. The research conducted on SADC countries indicates that there is significant potential available for rail systems in this region. Transposing actual and potential rail volumes to the density cost curve shows that significant potential for cost reduction exists. The results per country are summarised in Figure 2.

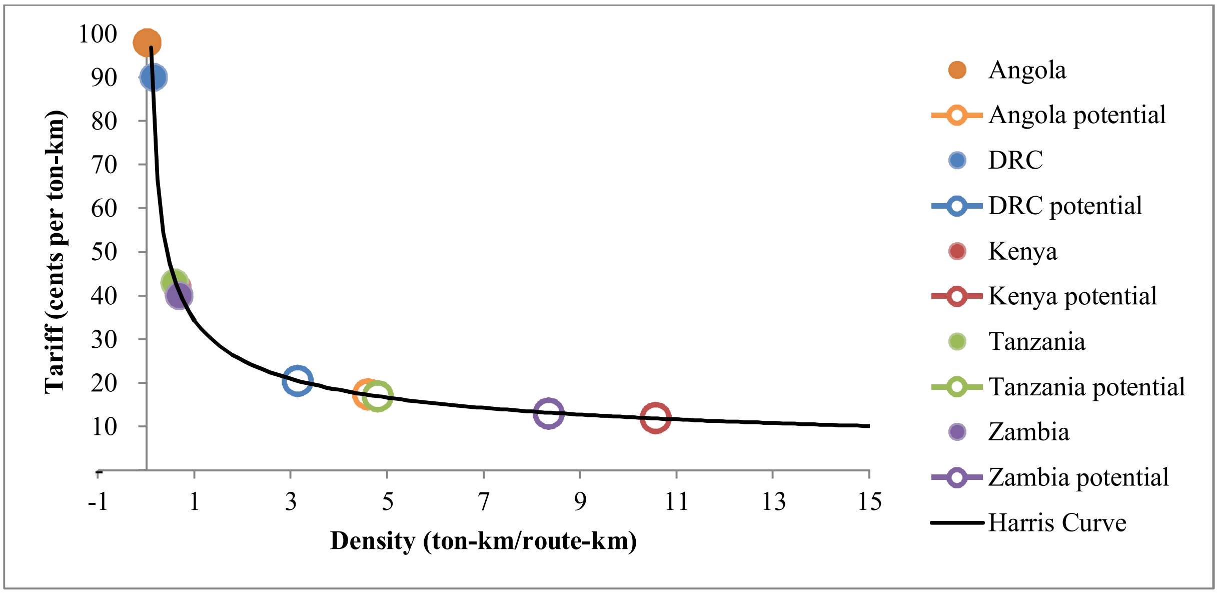
Figure 2. Actual and potential rail volumes



Source: De Bod, 2008

Tons carried were converted into ton-km given the network length required for each flow in order to apply the density principle, as estimated by De Bod (2008) and displayed in Figure 3.

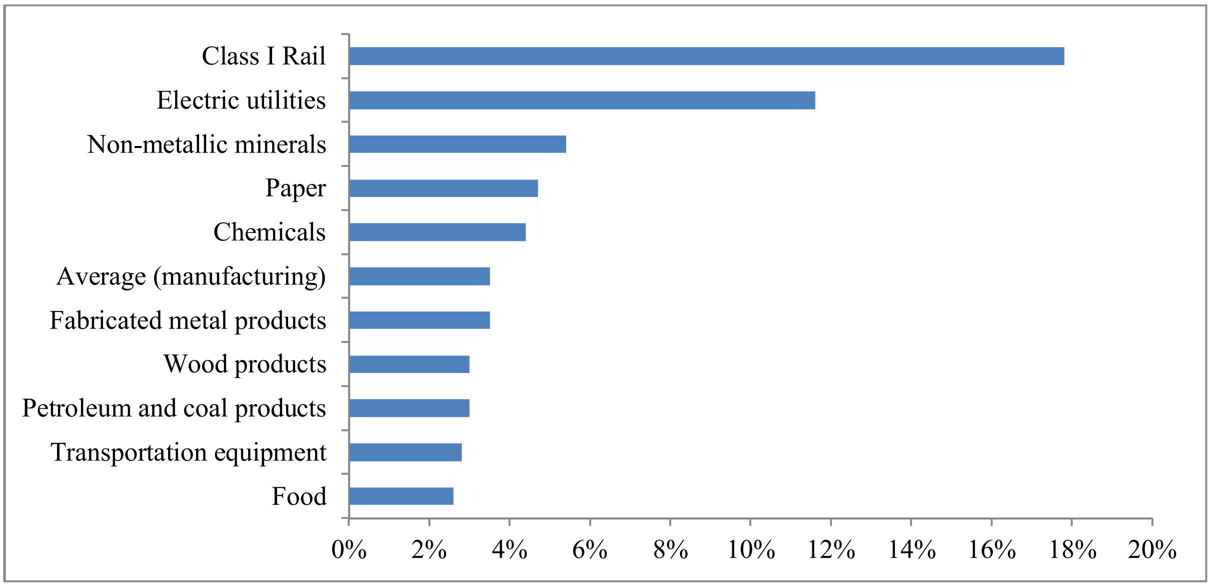
Figure 3. Potential density cost curve for SADC countries



Source: De Bod, 2008

Increases in density go hand-in-hand with upgrading rail infrastructure, and the potential for density should improve the business case for private investment in rail infrastructure. This is achievable because a reduction in the cost of transport (as indicated by the downward slope of the density cost curve) serves three major SADC economic growth objectives: Firstly, businesses should become more competitive and increase the scale of their business. Secondly, railway organisations should be able, through the resulting density gains, to negotiate more profitable rates. For example, if transport costs can be reduced by 30%, railway organisations could charge, say, 15% less and business shippers would save 15% on their transport bill, while the railway organisations would also be 15% better off. Thirdly, the investment in infrastructure could, by itself, induce economic growth. Density cost savings are possible by decreasing fixed infrastructure cost per ton-km. As indicated in Figure 4, the fixed cost component tied in rail transport is high; hence, cost savings gained from density advantages are high too.

Figure 4. Capital expenditure as a percentage of revenue



Source: Rodrigue, 2009

The corridor concept, already the focus of regional development initiatives (SADC, 2006), is ideally suited to taking advantage of this potential density. Initially based on making existing transport routes more efficient, corridors are critical to achieving the region's economic and political objectives. Several Southern African coutries are landlocked and require efficient regional transport links for access to ports. Furthermore, the transport distances for all these countries are long, over routes that can be densified, and, therefore, provide ideal opportunities for rail transport organisations to improve their efficiency.

Conclusion

Regional specialisation, surplus production, and regional and international trade is central to economic growth, and efficient transport is at the heart of competitive trade. Most countries in Southern Africa are too small individually to generate the economies of scale required for international competitiveness. The international trade routes for these countries, especially the landlocked ones, are long. Over longer distances and with adequate density, rail transport is considerably more efficient than road transport. The potential for economies of density in rail transport in Southern Africa is available for rail transport organisations to improve their efficiency. The corridor concept, already the focus of regional development initiatives, is ideally suited to taking advantage of this potential density. Exploiting this potential requires effective cooperation among the countries in the Southern African Development Community.

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