OPPORTUNITIES FOR THE ACHIEVEMENT OF ECONOMIES OF SCALE IN FREIGHT TRANSPORT

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Abstract

In the interest of both the national economy and the commercial freight industry, government freight transport policy formulators and freight transport industry decision makers should take cognisance of (a) the opportunities that exist for the achievement of economies in freight transport; (b) the subgroups of economies that can enhance efficiency attainment in the freight transport industry; (c) prevailing cost levels and structures within the five modes of freight transport; and (d) the salient economic features of the freight transport market. This paper presents an overview of these four aspects. The research approach and methodology combine (a) a literature survey; (b) an analysis of the cost structures of freight transport modes; and (c) interviews conducted with specialists in the freight transport industry.

Keywords: Economies of Density, Economies of Distance, Economies of Scale, Economies of Scope, Efficiency, Modes of Freight Transport, Transport Cost Structure

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1 INTRODUCTION

Defining the economic role of the various modes of freight transport should be one of the basic ingredients of both an economically rational government transport policy and the effective functioning of freight transport industries. The goal of the research was therefore to compile an overview of the most salient aspects of efficiency achievement that can give guidance in transport policy formulation and in corporate freight transport decision making. The research approach and methodology combine (a) a literature survey; (b) an analysis of the cost structures of freight transport modes; and (c) interviews conducted with specialists in the freight transport industry. In this paper, the results of the research are described qualitatively. Section 2 supplies a background and overview of opportunities for the achievement of economies in freight transport In Section 3, the subgroups of economies achievable in the freight transport industry are discussed. Section 4 deals with aspects of efficiency within the five modes of freight transport, and a concluding summary is contained in Section 5.

The intended meaning of certain terms used and conventions followed in this paper are as follows:

- *Cost structure* refers to the relationship between the fixed and variable components of total costs. Numerically, this is usually expressed as fixed cost or variable cost as a fraction of total costs. In this paper, preference is given to fixed cost as a proportion of total costs.
- *Cost*, *expenditure* and *price* are used synonymously.
- *Total costs* refer to the full transaction prices borne by an operator, including all indirect taxes, plus subsidies if any inputs are subsidised.
- *Fixed costs* refer to expenses that cannot be avoided if a trip does not take place.
- *Variable costs* refer to expenses that are avoided if a trip does not take place.
- *Direct costs* are specific to an individual product (or cost carrier), and are fully allocated to it.
- *Indirect costs* refer to costs that are incurred jointly or commonly on different products (or cost carriers) so that the deemed cost of each one can only be apportioned arbitrarily.
- *Cheaper* means at a lower total cost per output unit at similar load factors.
- *More expensive* means at a higher total cost per output unit at similar load factors.

2 BACKGROUND AND OVERVIEW

Economies of scale exist when an expansion of the output capacity of a firm, fleet or plant causes total production costs to increase less than proportionately to the increasing output capacity. However, economies of scale in transport often also refer to vehicle size rather than to that of a firm, fleet or plant, especially in the case of ships and pipelines. Ships –

notably bulk carriers – and pipelines often operate as separate business entities. In this sense, the prerequisite for economies of scale, and thus of falling average unit cost, is a cost structure that is characterised by a high ratio of fixed to total cost, so that with increasing output capacity, the fixed cost per unit of output declines faster than the variable cost increases per additional unit of production within the output capacity.

Contributing to scale economies is the spreading of a fixed cost over extended output capacity –for example fixed overhead costs spread over increased fleet output capacity. Fixed overhead costs, i.e. time-bound corporate management-related costs common to all the activities of a firm, remain constant within certain ranges of fleet size. The fact that dividing fixed overhead costs by an increasing number of output units, which are too small to necessitate larger overhead costs, results in smaller average overhead cost per unit is axiomatic. However, additional to overhead costs, the average cost of another (second) group of input units often becomes cheaper, while a further (third) group of inputs may enjoy increasing returns to scale as output rises. It is not always clear why an expansion of output capacity of a transport firm can cause average production costs per unit to decrease with the increasing output capacity up to a certain level of output. In freight transport, the answer lies in emerging efficiency gains (i.e. the second group) and productivity activators (the second group of inputs) that are specific to, firstly, vehicle fleets; secondly, individual vehicles; and, thirdly, transport facilities and infrastructure.[1] How the supply and utilisation of these three groups of assets can contribute to attaining economies of scale, and why these economies are eventually reversed, are discussed in the following three subsections.

2.1 Increasing fleet size and maximising use of its capacity

The following list contains five of the most pertinent factors that can contribute to economies of fleet size:

- *Specialisation and division of labour.* A growing fleet size, concomitant with more employees, can afford management greater opportunities for specialisation and labour division within its workforce. In a large fleet, skilled workers can be employed in specialised tasks and become more proficient at them. This should result in productivity gains. In small firms, individuals must perform a variety of tasks, in none of which they are probably afforded sufficient opportunity to excel, thus becoming the proverbial 'jack of all trades and master of none'. Owing to specialisation of labour, there is also division of labour, i.e. work is divided among several specialists. For example, transport activities will be conducted by drivers, packers, dispatchers, mechanics, schedulers, etc. Switching between tasks wastes time, which is avoided by division of labour.
- *Specialisation and scheduling of capital assets.* This is similar to specialisation and division of labour, but extends to the coordinated application of all inputs. An expanding fleet size generates opportunities for vehicles and handling equipment to be applied more productively: as fleet size increases, (a) diversity in customer needs may arise, creating opportunity for greater scope so that more suitable vehicles can be dedicated to more suitable tasks, which should enhance productivity; and (b) flexibilities may emerge by scheduling vehicles in such a way that the same ones are used productively during consecutive shifts by different crews. In so doing, the fleet is operated productively over the longest possible operating periods, thereby increasing the average productivity per vehicle.
- *Indivisibilities.* Large fleets can often afford to install special equipment and facilities that small operations would find too costly. These include vehicle workshops and terminal facilities, such as those for sorting and consolidation, whose aim is mainly to reduce average unit costs. Very large fleets can sometimes offer greater financial security to obtain the necessary loan funding to invest in extraordinary costly capital assets and infrastructure extensions with a view to improving efficiency (i.e. productivity) in the longer term. For example, in rail transport the conversion of a single- to a double-track system may quadruple the capacity of the line, given adequate future growth in demand, potentially geometrically increasing future productivity of the freight rail system.
- *Costly operational expenditure.* Large fleets may have enough financial strength to venture into costly operational actions that can potentially improve productivity. For example, promotional campaigns of similar scale in the national media cost the same regardless of the size of the advertising business. This is said to potentially benefit larger advertisers more than smaller ones because, firstly, the larger ones can perhaps better afford such campaigns and bear the risk of advertisement failure; and, secondly, in the case of success their sales volumes and concomitant revenue will increase, while smaller operators, for which the promotional expense and risk were too prohibitive in the first instance, will by default forfeit an opportunity to sell redundant transport capacity or to productively increase their scale of transport supply.
- *Reduced transaction costs.* Larger fleets can obtain bigger discounts or rebates with, for example, bulk purchasing of fuel, spare parts, group short-term insurance and finance costs (i.e. lower interest rates) with multiple-vehicle

acquisition. Although opportunities for greater functional scope through vehicle specialisation may arise, the fleet may still have the opportunity to standardise on vehicle types and benefit from minimising spare-part inventories, hence directly reducing average costs.

Although the unit cost of production may fall as the firm or fleet size increases, there are several reasons why this process is eventually reversed:

- *Loss of management control.* As a fleet becomes bigger and more complex, a loss of management control over the entire organisation arises, problems of coordination increase, and the growth of bureaucracy distracts managers' focus from the production process. Communication lines become longer, with management finding it increasingly difficult to remain directly involved. This loss of management control decreases overall productivity.
- *Administrative creep.* As management grows, it generates administration: not only do more managers and the introduction of extra management tiers create more bureaucracy in the form of more non-core control processes, but the human-resource aspects of the greater number of managers also need to be administered, as well as the affairs of the new administrative staff themselves. Instead of managing transport production, it is the organisation itself which increasingly has to be managed, with additional costs associated with more office space, administrative computer and communication infrastructure, and stationery and stores, resulting in diseconomies of scale.
- *Geographical location.* When a fleet initially commences business, it will probably be at or close to the optimal location. As fleet activities increase in a growing market, (a) congestion at the plant will step in; and (b) transport costs to and from new distant customers will increase the fleet's average unit costs. Increasing fleet size in the longer term implies building additional fleet facilities, and these will not necessarily be at optimal locations. While this might relieve congestion at facilities, it may contribute to extra travel cost and unproductive driving time, and consequently productivity also decreases.

2.2 Increasing vehicle sizes and maximising use of their capacity

The spatial carrying capacity of a vehicle is the volume or cube of the payload space, the cost of which is proportional to the surface area of its outer dimensions. A vehicle's volumetric carrying capacity can thus increase at a greater rate than the costs of the increased capacity. This is known as the 'two-thirds rule' – the volumetric capacity of a vehicle or a freight container can be doubled at only a two-thirds increase in cost. Also, engine size and number of crew members required increase less than proportionally to an increase in vehicle size. These relationships account for the trend towards, firstly, wide-body aircraft, rail wagons and bulk-cargo vessels being built and operated as large as is technically feasible; secondly, long-haul road vehicles whose length, width and height are manufactured to the maximum that road-traffic legislation allows; and, thirdly, pipelines with a large diameter. Technological feasibility permitting, pipelines can be built to whatever size is required – the only effective limit on this comes from the demand side of the market. There is no sense in constructing pipelines of larger capacity than future demand will require.

2.3 Intensifying the use of facilities and infrastructure

When the capacity (i.e. maximum ability) of facilities and infrastructure is well utilised, the result is a lower average total unit cost for these facilities in relation to when they are underutilised. The unit cost decreases as long as there is no congestion. When increasing the utilisation of the links (i.e. the travelled ways) of a transport network, the unit cost decreases until the level of traffic starts to cause delays due to congestion. Whenever congestion endures and forecasting indicates that demand will grow even further, one should contemplate capacity expansion. Whenever demand growth can be sustained, incremental expansion of infrastructure may result in substantial economies of scale.

In the case of transport facilities, the reduced cost associated with size increase can be explained by simple arithmetic. A single-truck square-shaped garage with an area of 36 m^2 requires an enclosing wall of 24 linear metres. A square-shaped garage that is 100 times bigger, i.e. 3 600 m^2, requires an enclosing wall of only 10 times the length, i.e. 240 linear metres. In the case of infrastructure – for example with rail transport – converting a single- to a double-track line may quadruple the capacity of the line by eliminating directional conflict, and a quadruple track should more than double capacity as it permits segregation by speed.[2] However, there is no rationale for building infrastructure of larger capacity than will be required.

3 SUBGROUPS OF ECONOMIES IN FREIGHT TRANSPORT

From the above it is clear that while economies of scale in their strictest form are considerably important in the freight transport industry, there are circumstances under which it is not merely the pure size of the output capacity of a firm, fleet or plant that causes total production costs to increase less than proportionately to the increasing output capacity. but also a growth in output capacity, in which opportunities arise to obtain the benefits of increasing returns to scale. Returns to scale refer to the long-run relationship between inputs and output. The returns can be shown by their effect on long-run average costs – if output rises by a larger percentage than inputs, there are increasing returns to scale, and thus decreasing long-run average cost per unit of output, in this case contributing to economies of scale. Subsequently, economies of scale in freight transport are often enhanced by the attainment of one or more of three subgroups of economies: economies of density, economies of scope, and economies of distance. These are discussed in the following paragraphs.

3.1 Economies of density

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, first, using high-capacity technology to carry and handle large bulk loads; second, minimising loading and unloading times; third, utilising traffic consolidation (i.e. load, trip, route and freight-handling terminal consolidation); and fourth, maximising the immediate and continuous utilisation of vehicles. (Immediate utilisation refers to the measure to which the carrying capacity of vehicles is utilised, while continuous utilisation refers to the number of revenue-kilometres or revenue-trips covered per time period.)

A quantity of goods can often be transported at a lower unit cost when moved together in one consignment or load, or in one uninterrupted flow, rather than in different consignments or loads. 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.

3.2 Economies of scope

Economies of scope are achieved when the cost of producing two or more products together, in either a joint or a common process, is less than the total cost of producing them separately.

Joint products (also called by-products) are the inevitable and inseparable consequence of a single production process. For example, an outbound journey automatically gives rise to an inbound one. This implies that if a full vehicle load has to be hauled from home depot A to point B, carriage of a back haul from point B to home depot A would reduce the average cost of the two hauls so that it would be lower than the cost of carriage from A to B only, as the vehicle inevitably has to return to its home depot. Failure to solicit available back-haul business is a lost revenue opportunity (i.e. a waste), and therefore implies failure to deal with joint costs profitably.

Common production (also called shared production) occurs when different products are deliberately produced together in a common process. In this case, the similarities of the production processes permit the use of the same technology. The cost that arises in this instance is common and therefore shared among the commonly produced products. For example, when the same vehicle can be used to transport passengers and freight, and when fleet capacity exceeds the demands set by seasonally fluctuating contractual agreements, the spare capacity can be filled with spot-market shipments solicited through reduced tariffs.

Achieving economies of scope requires compatible technology that can accommodate product diversification. This implies that one must be able to share the technology among two or more users, and capacity should be available to accommodate product diversification.

3.3 Economies of distance

Economies of distance (also known as long-haul economies) are attained when the total transport cost per ton-km decreases as the trip distance increases. Economies of distance arise when there are trip-specific fixed costs that are not affected by the distance of the journey, and also by cost items that increase less than proportionally to an increase of distance. Examples of the former are terminal costs, such as aircraft landing fees and seaport charges; train marshalling (shunting) costs; trip documentation; and loading, stowing and unloading costs. As one has to pay these costs regardless of the distance, doubling the length of a haul does not result in doubling them. An example of the latter is the declining aircraft fuel consumption rate on a flight after take-off when the cruising altitude has been reached.

Note that economies of distance are not synonymous with increasing the number of full vehicle-load kilometres – this is an economy of density. For example, making 10 trips of 12 km each is more costly than one trip of 120 km. The lower cost of the latter reflects an economy of distance. However, economies of density can be achieved in both cases if all the work is done with existing fleet capacity.

4 EFFICIENCY WITHIN MODES OF FREIGHT TRANSPORT

4.1 Air transport efficiency

4.1.1 Air transport cost level and structure

The cost to transport a unit of freight by air is the highest of all modes of transport. This results from the limited carrying capacity and high capital and other operating costs of aircraft. On a full-trip basis, the cost differential becomes bigger for door-to-door services when the origins and destinations of freight shipments are well separated from airports, necessitating the use of feeder and delivery services.

The cost structure of air transport is characterised by fairly balanced proportions of fixed and variable costs.[3] With freight-only services, the fixed costs normally exceed the variable costs somewhat, and vice versa for passenger-only services. With combined passenger–freight services, the fixed and variable cost components are approximately even. Because of the high start-up costs, the financial barriers to entry into the airfreight market are high, more so when commencing with freight-only services, and slightly less so with combined services where the common supply of passenger and freight service leaves room for less immediate investment in freight terminals.[4] The high cost of entry into the air transport market stems from the initial cost of acquiring aircraft, the immediate long-term commitment to essential overhead cost items (e.g. terminals) and the prior recruitment of highly skilled and specialised staff. The higher need for investment in freight terminals and related facilities when an airline's business orientation towards freight services increases suggests that significant economies of scale exist in air-freight operation.[5]

4.1.2 Economies achievable in air transport

4.1.2.1 Economies of fleet size

In air transport, there is a technical limit to the economies of scale that one can achieve by increasing the fleet size. Making use of a large fleet without increasing the number of airports visited requires frequent and large operations. This is feasible only if there is a continuously high demand for the large number of aircraft.[6] Although increasing fleet size does not necessarily result in significant economies of scale, a large fleet, but with mixed operations, may result in significant economies of scope. It may be more economical for one carrier to undertake both scheduled and charter flights than for separate carriers to specialise in one of the two types of service. Air and sea transport enjoy similar economies of fleet size – the second highest level after rail transport. However, air and rail transport do not generally compete with each other.

4.1.2.2 Economies of vehicle size

In seasonal or peak-oriented markets, operating large aircraft with flexible cargo–passenger combinations may result in increased loads and thus increased economies of scope.[7] In order not to prolong aircraft turnaround times at airports, large aircraft require effective procedures and equipment to load and unload them quickly. Air and sea transport enjoy similar economies of vehicle size – the second highest level after pipeline transport. However, air and pipeline transport are not in competition with each other.

4.1.2.3 Economies of infrastructure extension

An obstacle to effective logistics service delivery with air transport is its inability to provide door-to-door service. Airfreight operators are in direct competition with passenger airlines for airport access, as areas of high demand for passenger destinations are often also areas of high demand for freight. The prevalence of airport congestion (both in the air and on land) at major passenger hub airports contributes to the fact that freight-only operations tend to be at night and/or based around regional airports.[8] Adapting terminal facilities at regional and other subordinate airports that are close to concentrated areas of freight supply and demand to accommodate airfreight traffic effectively should enhance the accessibility and market coverage of this mode of transport. This could lead to total transit time savings, and reduce the cost of providing airfreight services. However, business logic requires that the value of improved airport accessibility, greater market coverage, transit time savings through less congestion and reduced cost of airport access and egress, and other benefits, must offset the cost of such airport infrastructure upgrades and extensions.

4.1.2.4 Economies of distance

On condition that intermediate landing is not necessary and that the crew does not need to change, longer route lengths give rise to significant economies of distance. With no intermediate landings, large time savings are achieved, as well as savings with those variable cost items that do not vary according to the length of flights. These are:

- aircraft maintenance necessitated by the number of landings (e.g. wheel fittings, tyres);
- charges for traffic control and navigation close to airports;
- landing charges;

- terminal services (such as cleaning; power connection; and charges for cargo handling, loading and unloading, and parking); and
- additional fuel consumption immediately after take-off.

These five points become less significant as flight lengths increase. For example, the fuel consumption rate of a Boeing 737-200(F) between Johannesburg and Cape Town (in South Africa) carrying a payload of 20 tons over the route length of 1 271 km is 330 litres per ton payload. The comparative fuel consumption with the same aircraft and payload for the 502 km route between Johannesburg and Durban is 170 litres per ton payload carried. The fuel consumption rate per ton of freight on the latter route is 52 per cent of the former, while the route length of the latter is only 40 per cent of the former. This is because the aircraft consumes between 1 200 and 1 300 litres of extra fuel to reach its cruising altitude, after which it cruises at 4,24 ℓ/km, hence an economy of distance.[9]

Air and sea transport enjoy similar economies of distance – after rail transport, the second highest level.

4.2 Road transport efficiency

4.2.1 Road transport cost level and structure

The cost to transport a unit of freight by road is (after air transport) the second highest, and the third highest of all modes of transport on short trips, where road is cheaper than rail transport.[10] In view of the fact that rail transport achieves considerably more economies of distance than road transport, road transport becomes progressively more expensive than rail transport for all classes of freight as trip distances increase above approximately 500 km. For trips shorter than roughly 150 km, 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 of the two modes lies between approximately 150 and 500 km. (For example, the equal-cost distance for the shipment of standard intermodal containers and units of palletised freight by road and rail is approximately 500 km.) Comparing road freight costs with other modes over all route distances, pipeline is cheaper than road transport. Over equal distances, the unit cost in ton-km to carry freight by sea is substantially lower than road transport. However, road transport is cheaper than inter-port sea carriage when, firstly, the sailing distance between the ports is too short for vessels to gain sufficient economies of distance; and/or, secondly, the trip origins and destinations of freight shipments are significantly remote from the ports, and vice versa when the inter-port distance is substantially long and/or the origins and destinations are close to the ports.

The fixed costs of operators with non-specialised fleets who carry truck loads and do not own any terminal facilities are very low. The financial barriers to market entry for these operators, especially in cases where their vehicles are hired or leased, even more so for single-vehicle operations, are very low, and this market segment is highly competitive.[11] Of all freight transport industry segments, the aforementioned non-specialised truck-load (TL) road haulage is the closest to perfect competition. Against this, specialised carriers and carriers of part-loads, also called less-than-truck-load (LTL), and parcels generally require terminals. This increases their fixed costs, and they face some financial barriers to entry. Their unit costs decrease with increased traffic volume (economies of density) and distance of haulage (long-haul economies). Although specialised and LTL carriers operate in an oligopolistic market, it is one in which competition is reasonably intensive and mostly based on the price charged. Fleet sizes in the road freight market vary between one vehicle (often owner-driver operators) and more than a thousand.

Larger road transport carriers who own suitable terminals can achieve considerable economies of scope by sorting and then consolidating heterogeneous part loads effectively into homogeneous containerised shipments, thereby creating an economy of density, which in turn enhances economies of scale. However, none of these potential advantages preclude competition from smaller operators, which indicates that the achievement economies of scale in road transport is not strong.[12]

Of all forms of transport, road transport has the smallest proportion of fixed costs to total costs, making this market sector highly competitive, and thus less prone to monopolistic or oligopolistic behaviour. Among the factors leading to the high proportion of variable costs are the following:

- The fuel consumption of road transport vehicles is relatively high, making fuel cost a proportionally large variable cost component.
- Road infrastructure is publicly owned. Governments to a great extent recover road-user cost responsibility through levies included in the price of fuel (of which the consumption is already high) and toll tariffs, thereby converting a fixed cost responsibility into a variable transport expenditure.
- Freight terminal facilities (whenever a road haulier actually owns such facilities) are less capital intensive than the terminal facilities of other forms of transport.

As can be deduced from Table 1, combination vehicles that are permanently engaged in long-distance carriage, fixed costs vary between approximately 35 and 40 per cent of total costs, and for rigid goods vehicles permanently employed in local delivery and collection work the fixed and variable costs are fairly evenly balanced. Whenever long-distance operations involve frequent travelling on tolled roads and high payments of overtime remuneration and overnight allowances, variable costs may rise to 70 per cent of total costs.[13]

Table 1. Typical cost structures of different sizes of road freight vehicles based in the Western Cape and used in professional haulage (May 2012 values)

COST ITEM	TYPE OF VEHICLE AND CARRYING CAPACITY					
	Light delivery vehicle: 1 ton	**Rigid truck: 4 tons**	**Rigid truck: 8 tons**	**Rigid truck: 15 tons**	**Combination vehicle: 20 tons**	**Combination vehicle: 32 tons**
Overhead cost per year	**R25 090 (10,1%)**	**R48 150 (10,0%)**	**R60 640 (9,1%)**	**R81 150 (9,0%)**	**R104 700 (6,9%)**	**R119 780 (6,6%)**
Standing costs per year	**R125 452 (50,8%)**	**R240 742 (49,8%)**	**R303 207 (45,6%)**	**R405 772 (44,7%)**	**R523 509 (34,7%)**	**R598 904 (33,2%)**
Depreciation						
Interest	R28 640	R46 430	R65 980	R102 060	R122 570	R134 900
Insurance	R9 110	R15 260	R23 480	R39 120	R39 000	R59 040
Licence	R15 180	R25 430	R39 130	R65 200	R75 450	R90 110
Crew	R492	R1 302	R4 467	R9 732	R14 439	R19 524
	R72 030	R152 320	R170 150	R189 660	R272 050	R295 330
Annual running costs	**R96 540 (39,1%)**	**R194 450 (40,2%)**	**R300 500 (45,3%)**	**R419 650 (46,3%)**	**R881 690 (58,4%)**	**R1 085 360 (60,2%)**
Fuel						
Lubricants	R57 180	R114 370	R166 350	R213 130	R559 910	R655 220
Maintenance	R1 430	R2 860	R4 160	R5 330	R14 000	R16 380
Tyres	R31 130	R63 640	R98 070	R148 060	R183 700	R233 550
	R6 800	R13 580	R31 920	R53 130	R124 080	R180 210
Total annual haulage cost	**R247 082 (100%)**	**R483 342 (100%)**	**R664 347 (100%)**	**R906 572 (100%)**	**R1 509 899 (100%)**	**R1 804 044 (100%)**
Annual kilometres	48 000	48 000	48 000	48 000	110 000	110 000
Operating days per year	225	225	225	225	245	245
Fuel cost (diesel)	11,0ℓ/100km @1 083,0c/ℓ	22,0ℓ/100km @1 083,0c/ℓ	32,0ℓ/100km @1 083,0c/ℓ	41,0ℓ/100km @1 083,0c/ℓ	47,0ℓ/100km @1 083,0c/ℓ	55,0ℓ/100km @1 083,0c/ℓ
Lubricants	2,5% of fuel	2,5% of fuel	2,5% of fuel	2,5% of fuel	2,5% of fuel	2,5% of fuel
Maintenance	64,85c/km	132,58c/km	204,31c/km	308,46c/km	167,0c/km	212,32c/km
Tyres	14,17c/km	28,29c/km	66,50c/km	110,69c/km	112,80c/km	163,83c/km

Source: Compiled by the author from various sources
Notes: Diesel price: coastal wholesale price for the period 2 May to 5 June 2012 of low-sulphur diesel plus 5c/ℓ; licence fees for the Western Cape applicable throughout 2012.

4.2.2 Economies achievable in road transport

4.2.2.1 Economies of fleet size

Increased road vehicle fleet sizes, coupled with productive utilisation of this greater capacity, can result in some economies of scale. Although the achievement of economies of scale emanating from fleet size is moderate, it is, in relative terms, the second highest of the various modes after rail transport. Own facilities, such as terminals – particularly for specialised carriers – provide opportunities for economies of scale.[14] Potential sources of economies of scale are a workshop owned by the business for vehicle maintenance and repairs; standardisation of vehicles, which reduces the quantity of spare-part inventories; discount on bulk purchases; and so on.

4.2.2.2 Economies of vehicle size

As the carrying capacity of road vehicles increases, vehicle-specific costs increase less than proportionally. Vehicle-specific costs are running costs, such as fuel and oil consumption, maintenance and tyre wear. Also, engine size and the number of crew members required increase less than proportionally to an increase in vehicle size.[15] The costs of dispatching and load documentation tend to remain the same regardless of the size of the load or shipment that various vehicles can carry. These relationships account for the trend towards long-haul road vehicles whose length, width, height and gross mass are often the maximum that road-traffic legislation allows. Although the achievement of economies of vehicle size in road transport is significant, it is, in relative terms along with rail transport, the lowest, resulting mainly from the limits of vehicle dimensions prescribed through legislation.

4.2.2.3 Economies of infrastructure extension

In view of the fact that governments typically recover road-user cost responsibility, except licence fees, through levies included in the price of fuel and through toll tariffs, thereby converting a fixed-cost responsibility into variable transport expenditure, road transport businesses do not gain significantly from enlarged road capacity. However, with standing costs being fixed, at least on a monthly basis, extensive travelling (many kilometres per month) and the avoidance of travelling during periods of traffic congestion so as to increase trip speeds, some economies of density, albeit small, in terms of infrastructure use can be attained.

4.2.2.4 Economies of distance

Generally, owing to the high ratio of vehicle running costs (which accumulate as distances increase) to total costs of individual vehicles, and the relatively small terminal facilities or absence of own facilities, road transport does not enjoy significant economies of distance – in fact it is the second lowest of all modes of transport, with pipeline transport having the least.

A few trip-specific operating cost items are incurred on certain journeys. These are:

- toll fees payable where applicable;
- permit fees, in the case of trips into neighbouring countries;
- escort fees, when certain abnormal loads are carried;
- overtime remuneration and accommodation allowances for vehicle crews; and
- documentation and handling costs at trip ends when consignors and consignees are unable to provide handling equipment.

The first four of the five points above are, whenever they occur, usually less than proportionally related to distance, therefore they can contribute somewhat to economies of distance. It is only the fifth item that is not affected by trip distance at all. Being a relatively small cost item, it is too small to contribute significantly towards economies of distance. All five of these cost items are avoided if a trip is not undertaken, and therefore they are variable costs. Their occurrence will increase the variable cost as a proportion of total cost.

4.3 Rail transport efficiency

4.3.1 Rail transport cost level and structure

Overland pipeline transport is the cheapest mode for those types of commodities that can be transported by pipeline. 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 km. However, for trips shorter than roughly 150 km, 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 km.[16]

Owing to the large initial cost as an absolute quantum and the high ratio of fixed costs in freight rail transport, the breakeven point between revenue and total cost occurs at a very high level of production. This means that a large volume of freight services must be sold before a profit can be realised. This may imply that a profit can only be realised if there is one incumbent rail operator in the market, i.e. a natural monopoly.[17]

Economic features such as high barriers to entry, economies of scale and high breakeven points have historically meant that rail freight transport has been a highly concentrated intramodal market. In terms of the number of market participants, the supply of rail freight transport is (after pipeline transport) the second most highly concentrated of all transport modes. Since the 1990s in Europe and Australia, ownership of rail infrastructure and of train operations have been organisationally divorced. With this arrangement, any prospective rail transport operator may gain open access to existing rail infrastructure and tracks under certain prescribed conditions. The advocates of this new rail transport agreement argue that this reduces the barriers to entry and limits monopolies, making the rail transport market more competitive. The potential (or possible threat) of easy market entry is said to incite the incumbent operator to function more efficiently and effectively. Despite these reforms, few new operators have entered the rail freight market.[18] In countries where the infrastructure ownership and train operations have been divorced, operators have mainly entered the market to satisfy a very specific shipper need or small niche market. Experience has thus far shown that intra-rail competition under the new dispensation gives room for the formation of duopolies, and not larger oligopolies with three or more incumbent competitors.[19]

Rail transport competes with road transport for break-bulk and containerised freight. Because the unit cost decreases when output capacity increases, rail transport gains substantial economies of scale (mainly through advantages of density and of distance) with high utilisation – and even more so in the case of a double-track operation with long trains.[20]

Although rail transport is more expensive than pipeline transport, it can effectively compete with a parallel pipeline service when it has adequate available capacity, and the pipeline operates at levels close to capacity.[21]

Rail transport competes with inter-port sea transport for all types 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 very high – the second highest of all modes of transport (after pipeline transport). Approximately 75 per cent of rail transport costs are fixed over the short term.[22]

4.3.2 Economies achievable in rail transport

4.3.2.1 Economies of fleet size

Economies of fleet size in rail transport are attained through operating long trains, the carrying capacity of which is well utilised, and not simply by operating a large vehicle fleet of wagons and locomotives. In this context, rail transport enjoys the highest level of economies of fleet size of all modes of transport.

There are considerable economies in hauling more wagons per train and employing a stronger locomotive whenever train lengthening requires this. However, there comes a point where an additional locomotive will be needed with further train lengthening. Demand permitting, logic dictates that several wagons should be added when an extra locomotive is employed to keep the required train and locomotive traction power efficiently in balance. The economies stemming from operating the longest trains technically possible and employing multiply-linked locomotives are that, firstly, only one locomotive crew remains necessary for multiply-linked locomotives; secondly, traffic scheduling and control of a few long trains are simpler and potentially safer than operating several short trains, which in total carry the same payload volume or mass as a single long train; and, thirdly, the utilisation of railway lines increases because the required minimum-time headways and following distances between short and long trains differ proportionally less than the difference in train length.

4.3.2.2 Economies of vehicle size

As efficiency requires that the same gauge be used throughout the system, the width of rail wagons is limited by the gauge of the railway line, and the height by overhead clearances along the way. The length of wagons is limited by their structural robustness to withstand the pressure exerted by payload mass on wagon sections not directly supported by sets of axles and wheels, and by the maximum axle mass loads that railway infrastructure can accommodate. Although the achievement of economies of vehicle size in rail transport is significant, it is in relative terms along with road transport the lowest, resulting mainly from the limits of vehicle dimensions dictated by technical considerations described above.[23]

4.3.2.3 Economies of infrastructure extension

With rail transport, the move from a single- to a double-track system may quadruple the capacity of the line by eliminating directional conflict, and a quadruple track should more than double the capacity as it additionally also permits segregation by speed. However, there is no sense in building railway lines of larger capacity than will be required.[24] As is indicated in the next subsection, extension of rail route lengths to link distant origins and destinations has the potential to encapsulate long-haul advantages, therefore, under the banner of infrastructure extension, both economies of density and of distance may accrue. However, such beneficial interaction between increasing returns to scale due to greater traffic density and a gain in efficiency through long-haul advantage is dependent on (a) sufficient demand; and (b) firm size. In rail transport, 'size of the firm' conventionally incorporates 'fleet size' and 'network size'.

4.3.2.4 Economies of distance

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.

As is indicated in subsection 4.3.2.3, when analysing rail transport, one should distinguish between unit costs (for example the cost per ton-km) decreasing due to economies of density and of distance. Through economies of density and distance, a rail transport operation may enjoy a natural monopoly on a particular route. On condition that the utilisation of train-carrying capacity is high, the former economy stems from its cost structure, which is characterised by a relatively high ratio of fixed to total cost so that with increasing the annual distances of all trains collectively, the fixed cost per unit of performance (train-kilometres and eventually ton-km) declines faster than the variable cost increases per additional unit of performance within the output capacity, and the latter economy from the high amount of terminal operating costs (at trip ends) that do not change as trip distances increase.

4.4 Pipeline transport efficiency

4.4.1 Pipeline transport cost level and structure

Overland pipeline transport is the cheapest mode of transport, and is substantially cheaper than road and rail transport.[25] For example, between Durban and Gauteng in South Africa, pipeline tariffs per litre of fuel over a route of 704 km are approximately half those of rail and one-fifth of those of road transport.[26] It is therefore clear that a Durban-based petroleum wholesaler that does not have access to pipeline or rail transport between Durban and Gauteng is subject to the likelihood of competitive foreclosure of marketing its product(s) in Gauteng.[27]

In terms of the number of market participants, the supply of pipeline transport is the most highly concentrated of all transport modes. The absolute number of firms is low, but the significant measure of concentration is the number of participants in a specific transport market segment or corridor. With a few exceptions, there is but one crude oil, one products and one natural gas pipeline connecting producing areas or refineries and areas of consumption. This high degree of monopoly power results from declining unit costs with increases in capacity, so that the lowest costs are achieved by a concentration of output in a single pipeline. A high degree of concentration is efficient, and changes towards a more competitive market structure through economic regulation would entail high losses in efficiency, therefore pipeline operations that can fulfil entire market demand are natural monopolies.[28]

In view of the abovementioned considerations, financial stakeholders in pipeline operations tend to consolidate and start with a large initial investment, which tends to yield higher returns, partly because of economies of scale and partly because of inherent performance characteristics (for example, a 30 cm pipe operating at capacity transports three times the quantity carried by a 20 cm pipe).[29] The gains from scale are substantial. For example, the lowest cost for a throughput of 100 000 barrels of crude oil per day in a 45 cm pipeline would be approximately double the cost per barrel when compared to carrying 400 000 barrels per day in an 80 cm pipeline over the same distance.

The implications for the industry are important. It would be extremely wasteful, for example, for four competing refineries in a consuming area in which each used crude oil from the same area of origin to build four pipelines. If, for example, each required 100 000 barrels per day, then building four parallel 45 cm pipelines instead of a single 80 cm pipeline would double the cost per barrel for transport. Efficiency dictates a common system for use of the same pipeline in such circumstances. It also follows that costs for carrying petroleum on a route that has a large pipeline will be much lower than on other routes not thus provided. There will be external economies in locating large refining capacity in the same area.

Although pipeline transport is the least expensive mode of transport overland, rail transport can effectively compete with a parallel pipeline service when it has adequate spare capacity and the pipeline operates at levels close to capacity.

Despite the fact that tank ships run empty during return trips, pipeline transport can only compete cost-wise with sea transport between the same origin and destination if the pipeline route is considerably shorter than the sea route, or where sea transport is subject to exceptional charges, such as heavy canal dues.[30] An example is the 254-km long trans-Israel crude oil pipeline route between Eilat on the Red Sea and Ashkelon on the Mediterranean coast. This route is substantially shorter than the one around Africa, and cheaper than using the Suez Canal.[31]

As with rail transport, pipelines provide their own right of way. Since the pipe component, the pumps and the tank and plant facilities are highly specialised and durable, fixed cost constitutes a high portion of the total cost – the highest of all modes. Pipeline transport is highly efficient when the utilisation of capacity remains consistently high. Transport cost per unit carried rises rapidly if actual usage falls below capacity because of the high ratio of fixed to total operating cost. Because the fixed costs of pipeline transport are proportionately much higher than variable costs, and continuous pumping may take place with no need for any return flow and there is no materials handling, economies of scale prevail in pipeline transport. Because of the high capital costs of a pipeline, the financial barrier to entering the market is high. Approximately 85 to 90 per cent of pipeline transport costs are fixed over the short term.[32]

4.4.2 Economies achievable in pipeline transport

4.4.2.1 Economies of vehicle size and infrastructure extension

Pipeline transport has unique characteristics: the carrying unit (i.e. the 'vehicle') is also the infrastructure. On the principle of economies of density, an increase in pipe diameter can result in a lower unit cost. The fundamental relationships involved depend upon the principles of geometry concerning the relation between the surface area of a pipe's wall and its volume. Consider a circular cross-section of a pipe. Because the area of a circle is πr^2, its area increases with the square of the radius. The circumference increases only in proportion to the radius, since the circumference is $2\pi r$. The friction that must be overcome to move a liquid commodity through a pipeline is the friction between the liquid and the wall of the pipe, therefore increasing the diameter of a pipe will increase the quantity of liquid in the pipe faster than it will increase the area of the wall of the pipe in contact with the liquid. Consequently, there are gains in economies in the propulsion power required to pump the same quantity of commodity by increasing the diameter of the pipe. There are also economies in the cost of the pipe itself. For larger pipes, the quantity of body steel per unit of pipe-carrying capacity is less than for smaller pipes.

Pipeline transport does not necessarily require a return journey or return pumping process. This eliminates joint costs. Because cost is incurred without adding value each time goods are handled at a terminal or storage facility, a primary logistics objective is to eliminate handling wherever possible. With the carriage of crude oil and petroleum products by pipeline, this objective is fully met. Commodity intake, haulage and discharge are combined in one process, usually a remote-controlled one.

An uninterrupted and prolonged throughput of a large volume of homogeneous product increases economies of density. Should such continuous pumping with a specific product not be sustainable, common production can make petroleum pipelines more cost effective, since a variety of petroleum products can be pumped consecutively, thereby enhancing the achievement of economies of scale through economies of scope.

4.4.2.2 Economies of distance

Longer pipelines do not give rise to significant economies of distance; in fact this is almost non-existent – the lowest of all modes of transport. The reason for this is that additional pump stations and more pipes in direct proportion are required for longer distances.[33]

4.5 Sea transport efficiency

4.5.1 Sea transport cost level and structure

The total unit cost to carry freight by sea is the lowest of all modes of transport. Over equal distances the unit cost in ton-km to carry freight by sea is substantially lower than any of the three modes of land transport. However, these three modes can be cheaper than inter-port sea carriage when, firstly, the sailing distance between the ports is too short for vessels to gain sufficient economies of distance; secondly, the trip origins and destinations of freight shipments are accessible by road, rail or pipeline, but are significantly remote from the ports, and vice versa, when the inter-port distance is substantially long and/or the origins and destinations are close to the ports; and thirdly, where sea transport is subject to exceptional charges, such as heavy canal dues.

The cost structure of sea transport is similar to that of air transport. It is characterised by balanced proportions of fixed and variable costs. Sea transport does not need a supplied right of way. The travel 'way' involved, namely the sea, does not require investment, and seaports are not owned or supplied by shipping firms. Expenses in ports can be as high as a third of direct voyage costs;[34] however, these obligations only arise when a port is visited.

4.5.2 Economies achievable in sea transport

4.5.2.1 Economies of fleet size

As is the case with air transport, economies of scale are possible with large individual vessels and not necessarily with large fleet operations. Single-ship operators or those operating a few ships – for example charter ships – are often able to compete with larger scheduled conference liners, which indicates that sea transport enjoys little in terms of economies of fleet size.

4.5.2.2 Economies of vehicle size

Like most forms of transport, shipping benefits through economies of scale are associated with operating larger ships.[35] Larger ships result in lower costs per ton (in the case of bulk shipping) and lower costs per standard container (in the case of container shipping);[36] however, larger ships may cause problems for other areas of the maritime industry, mostly at the ports. Bigger ships require wider entrance channels, deeper draughts, larger cranes and other loading and unloading equipment, as well as sufficient storage space to hold the volumes of freight before or after loading and unloading them. Air and sea transport enjoy similar economies of vehicle size –, the second highest after pipeline transport.

4.5.2.3 Economies of infrastructure extension

Evidence exists that in port operations a fourfold increase in container port size can reduce the cost of handling container traffic by approximately one-quarter.[37] However, seaports are not owned or supplied by shipping firms, so ship owners may not automatically reap the benefits of improved port efficiencies. Port charges are levied by the owning port authority. Whether or not a portion of the value of efficiency improvements and other cost advantages are passed on to visiting ships will depend on the policy of the governing port authority. Often, the various commercial ports in a country reside under the control of a single port authority, which may set uniform port charges for similar port services throughout, regardless of the different cost structures and changing degrees of competitiveness among ports.

4.5.2.4 Economies of distance

Generally, for container vessels and the various types of bulk carriers, expenses in ports are in the order of a third of direct voyage costs (this can constitute up to roughly 40 per cent if the ship itself or its cargo requires prolonged and/or special berthing and handling arrangements).[38] In view of the high terminal expenditure and the fact that the 'way' of travel involved – the sea – does not require investment or any significant expenses apart from navigational support that may sometimes be necessary, ships enjoy substantial economies of distance as voyage lengths increase. Air and sea transport enjoy similar economies of distance – the second highest after rail transport.

5 SUMMARY

The cost to transport a unit of freight by air is the highest of all modes of transport, and by road the second highest on long trips and third highest on short trips, where road is cheaper than rail transport. In view of the fact that rail transport achieves considerably more economies of distance than road transport, the latter becomes progressively more expensive than the former for all classes of freight as trip distances increase above approximately 500 km. For trips shorter than roughly 150 km, road transport is almost 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 of the two modes lies between approximately 150 and 500 km. Overland pipeline transport is the cheapest mode for those types of commodities that can be transported this way. Either rail or road transport is the cheapest mode of transport for all those commodities that cannot be carried by pipeline. The total unit cost to carry freight by sea is the lowest of all modes of transport. Over equal distances, the unit cost in ton-km to carry freight by sea is substantially lower than any of the three modes of land transport. However, these three modes can be cheaper than inter-port sea carriage when, firstly, the sailing distance between the ports is too short for vessels to gain sufficient economies of distance; secondly, the trip origins and destinations of freight shipments are accessible by road, rail or pipeline, but are significantly remote from the ports, and vice versa when the inter-port distance is substantially long and/or the origins and destinations are close to the ports; and thirdly, where sea transport is subject to exceptional charges, such as heavy canal dues.

The factors contributing to scale economies in freight transport are, firstly, the spreading of fixed cost commitments over extended output capacity; secondly, certain inputs that can be obtained more cheaply as output rises; and thirdly, the employment of new indivisible inputs that enjoy increasing returns to scale. In freight transport, the latter two factors are achieved through emerging efficiency gains and productivity activators that are specific to, firstly, increasing fleet size and maximising use of its capacity; secondly, increasing vehicle sizes and maximising use of their capacity; and thirdly, extending the capacity of transport facilities and infrastructure, and intensifying the use thereof. Subsequently, economies of scale in freight transport are often enhanced by the attainment of one or more of three subgroups of economies: economies of density, economies of scope, and economies of distance.

Economies of scale in transport often refer to vehicle rather than firm, fleet or plant size, especially in the case of ships and pipelines. Ships, notably bulk carriers, and pipelines often operate as separate business entities. **Pipeline transport** has unique characteristics: the carrying unit (i.e. the 'vehicle') is also the infrastructure. On the principle of economies of density, an increase in pipe diameter can result in a lower unit cost. An uninterrupted and prolonged throughput of a large volume of homogeneous product increases economies of density. Should such continuous pumping with a specific product not be sustainable, common production can make petroleum pipelines more cost effective, since a variety of petroleum products can be pumped consecutively, thereby enhancing the achievement of economies of scale through economies of scope.

In **rail transport**, under the banner of infrastructure extension, economies of both density and distance may accrue. However, such beneficial interaction between increasing returns to scale due to greater traffic density and a gain in efficiency through long-haul advantage is dependent on (a) sufficient demand; and (b) firm size. In rail transport, 'size of the firm' conventionally incorporates both 'fleet size' (where this refers to train length) and 'network size' (where this refers to route kilometres).

Although increasing fleet size in **air transport** does not necessarily result in significant economies of scale, a large fleet, but with mixed operations, may result in significant economies of scope. It may be more economical for one carrier to undertake both scheduled and charter flights than for separate carriers to specialise in one of the two types of service. Similarly, it may be more economical for one airline operator to offer both passenger and freight services than for separate carriers to specialise in one of the two types of service.

Large **road transport** carriers who own suitable terminals can achieve considerable economies of scope by sorting and then consolidating heterogeneous part loads effectively into homogeneous containerised shipments, thereby creating an economy of density, which in turn enhances economies of scale. It is therefore clear that while in freight transport, economies of scale in its strictest form – that of being dependent on the size of the firm (i.e. the number of vehicles in its fleet) -- are considerably important, it cannot be divorced from the attainment of one or more of three subgroups of economies: economies of density, economies of scope, and economies of distance.

Table 2 provides a comparative summary of the most salient economic features of the five modes of freight transport.

Table 2. Comparison of salient economic features of transport modes

Economic charateristics	**Air**	**Road**	**Rail**	**Pipeline**	**Sea**
Cost level	Highest	Second highest	Moderate	Second lowest	Lowest
Cost structure (fixed-to total-cost ratio)	Balanced (second lowest, similar to sea)	Lowest	Second highest	Highest	Balanced (second lowest, similar to air)
Economies of fleet size	Second lowest (similar to sea)	Second highest	Highest (achievable through long trains)	Lowest, non-existent (referring to number of pipes)	Second lowest (similar to air)
Economies of vehicle size	Second highest (similar to sea)	Lowest, although achievement is still significant (similar to rail)	Lowest, although achievement is still significant (similar to road)	Highest (referring to pipe diameter)	Second highest (similar to air)
Economies of distance	Second highest (similar to sea)	Second lowest	Highest	Lowest (almost non-existent)	Second highest (similar to air)

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