Large or Small Terminals in Intermodal Transport: What Is the Optimum Size?

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Intermodal terminals are frequently large and serve wide catchment areas. Whereas many believe these terminals must be large in order to be cost effective, in this paper the advantages of small terminals and a denser network of terminals than most systems currently enjoy are discussed. In many countries the largest flows of traffic are over relatively short distances (400 miles and often less), where road collection and delivery account for between a third and a half of the overall costs of an intermodal movement. Research in Britain and West Germany suggests that a much denser network of container or trailer-on-flatcar terminals could substantially reduce these road costs without an equal increase in rail movement costs. Such a network would require small terminals with a suitable pattern of rail services, perhaps linked through one or more container or trailer sorting centers. Freightliner's experience during almost 20 years of service is that small and medium-sized terminals are less costly per unit to operate and provide the shipper with a higher quality of service than do large terminals. Also, they are unlikely to be more costly to build per unit of capacity provided. Intermodal operations, which now face growing competition from road carriers and the effects of world recession, require innovation in order to remain viable and to expand. Successful features of existing systems, such as Freightliners' high-speed fixed-formation trains, need to be welded together with new and radical ideas.

Intermodal terminals for container-on-flatcar (COFC) and trailer-on-flatcar (TOFC) are frequently large, and it appears that their average size is growing. Many people believe that, like breweries or supermarkets, they need to be big in order to be economical. However, the experience of Freightliners, the large British intermodal operator, is that the larger the terminal, the higher the unit costs and the lower the quality of service to the shipper.

Freightliner has been in operation for almost 18 years and now handles around 1 million containers [measured in twenty-foot equivalent units (TEUs)] annually at the 25 terminals it owns and an additional 10 that it serves (mostly container ports). The Freightliner company (Freightliners Limited) is a fully-owned subsidiary of the British Railways Board but enjoys much autonomy in management. Freightliner does not undertake the movement of trailers (TOFC) by rail, nor does any other operator in the United Kingdom, because of restricted clearances and the arched design of railway tunnels and bridges, which are mostly less than 12 ft above rail level as compared with mainland Europe.

The various attributes of intermodal terminals of various sizes are examined in this paper by drawing on Freightliner's experience. These include economies of scale in terminal operation and construction and service quality. Terminal coverage is also considered. This is the density of terminals in urban and rural situations in relation to market requirements, train size and rail operational strategies, the rail network, and land availability. In a transit of up to 500 miles in Europe, road-collection and delivery costs are frequently the major cost element in an intermodal movement and are greatly influenced by terminal coverage.

ORIGINS OF FREIGHTLINER

Rail terminals or freight stations developed in Europe in the 19th century at intervals of around 5 miles, which was considered a suitable distance for goods to be collected and delivered by horse and cart. Although some freight railheads in Britain closed in the 1930s as a direct result of the development of the motor lorry (truck), big changes in the pattern of rail terminals did not occur until the 1950s and 1960s. Initially at least, the lorry was seen as complimentary to rail as it was able to collect and deliver goods over longer distances than the horse and cart. The number of rail terminals contracted and some lines closed altogether in this later period as freight rationalization, as it was euphemistically called, was carried out.

Gradually, times changed and the truck became as much a competitor as a conveyor to and from rail terminals. When Freightliner emerged in the mid-1960s, it was designed to combat competition from the trucker for the throughput (origin-to-destination) movement of freight. British Rail planned a Freightliner grid that would saturate the country with container terminals--more than 100 in all--yet most of these terminals were never built.

There is no single answer to why Freightliner developed as it did and not as it was planned. First, the weight and size of lorries were increased dramatically, beyond what was anticipated at the time of planning; and second, the national motorway (expressway) network began to develop. Both of these developments increased road competition with rail, which was further intensified with the abolition of road carrier licensing and full deregulation in 1969. At the same time, motorways and larger lorries allowed collection and delivery of containers over greater distances.

Freightliner terminals exist in the main conurbations (metropolitan areas) and principal cities only, with many relatively large centers being served from terminals 20 or more miles distant. The network is shown in Figure 1. Examples of this are Stoke, which has a population of 257,000 and is 43 miles from Manchester, and Plymouth, which has a population of 256,000 and is 120 miles from Bristol. Certain less-heavily populated parts of the country, north Scotland, north and central Wales, and the Southwest do not have terminals at all. Yet, the original plans assumed terminals would be built in all of these areas.

The decision to use fixed-formation (unit) trains has been a major factor in determining the share of the market that Freightliner has obtained, and this in turn has influenced the shape of the terminal network. These high-quality trains have helped Freightliner carry the large, relatively long-distance flows efficiently. But they have prescribed the market to the extent that the network does not provide adequately for smaller or more fragmented flows. Thus, there is no requirement for a diffuse network of terminals. Modifications to the fixed-train concept have progressively developed, with trains usually comprising 20 wagons (cars), each 60 ft in length, that are now capable of being split into 5 wagon sections so as to serve a wider spread of terminals.

Clearly, had road competition been less strong, Freightliner might have captured higher market shares and thus been able to operate more direct services than it does currently, including those over shorter distances. The reverse has been true, and as road competition has increased, the domestic container business has declined in 10 years from 406,000 to 315,000 containers/year. This decline,

Figure 1. Freightliner network.

though, has been more than matched by the most impressive growth in deep-sea maritime traffic, which has risen from 104,000 to 364,000 containers/year over the same period.

TERMINAL OPERATING COSTS

Freightliner has many types and sizes of terminals, all of which, except those at ports, are designed for the transfer of containers between road transport and rail wagon. Three particular types of inland container terminals, which are readily described as large, medium-sized, and small, have been selected for examination. All have rail-mounted, electrically driven portal cranes. Large terminals have wide-span cranes, with six lanes between the crane rails and two or three more lanes on either side served by cantilevers. These are described as having a 2.6.2 or 2.6.3 configuration (see Figure 2). The cranes at the medium-sized and small terminals that do not have cantilevers and serve only four lanes are described as 0.4.0. The 2.6.2, 2.6.3, and 0.4.0 cranes at medium-sized terminals are rated as class III, with a theoretical capacity of 3,000 operating hr/year. The small 0.4.0 cranes are rated class II and have a capacity of 2,000 operating hr/year. In practice, all types of cranes operate for longer periods, often up to 22 hr daily.

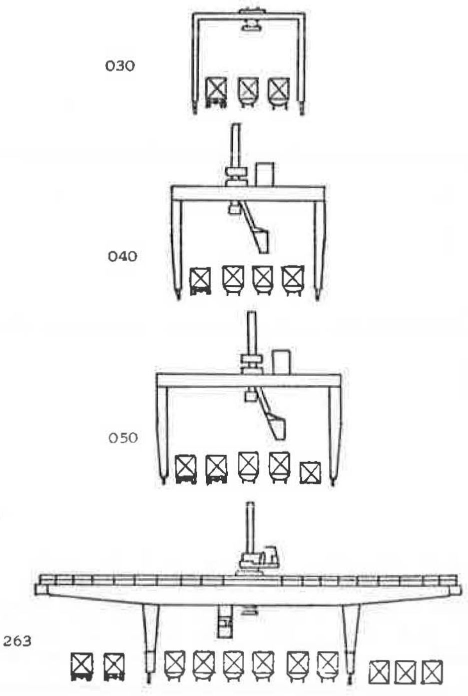
As far back as 1976, the Transport and Road Research Laboratory (TRRL) published a report (1) that concluded that unit costs were not lower at large terminals; indeed, they were higher. Comparison of unit costs between terminals operating at different levels of capacity is liable to create distortions, so the report also compared the three types of cranes already mentioned operating at maximum theoretical capacity. This gave the lowest unit cost for the class III 0.4.0 crane; followed by the class II 0.4.0 crane, which was 4 percent higher; and then the large 2.6.2 and 2.6.3 cranes, which were as much as 24 percent higher [see Table 1 (1)].

The earliest terminals on the Freightliner system, which were built almost 20 years ago, used Drott travelifts, which had rubber tires running on fixed heavy-duty concrete runways. As many as four were used in one terminal, although seldom did more than two operate at any one time. Throughputs in these terminals reached 250 containers/day, but the Drotts were fully stretched in meeting operational requirements, and it was decided to standardize on electric rail-mounted cranes. The basic design of the terminal has proved durable, with a crane transfer area (similar in length to the usual size of trains handled), one-way road circuit, and separate vehicle parking.

Apart from Kings Cross in London and Dundee where small class II portal cranes were used (so as to fit existing yard layouts), Freightliner's initial choice was class III 0.4.0 cranes, with 30 being supplied for use throughout the country from Edinburg in Scotland to Swansea in west Wales. For the conurbations, the much larger 2.6.2 or 2.6.3 cranes were used, with 13 going to inland terminals.

Freightliner was not alone in buying these very large portal cranes; a number of other European railways also ordered cranes of broadly similar configurations. These "goliaths," as they are called, are truly massive machines, weighing around 250 tons. On the face of it they have certain clear advantages over the 0.4.0 designs. Accommodation for trains can be increased with up to six being under the cranes at once, which is desirable given the train pattern in the United Kingdom of overnight movement between terminals, with trains standing in the daytime. Also, there is more container storage, and experience has showed that this had been greatly underestimated in the original planning. The cantilever provided the ideal means of servicing trucks without requiring them to cross one of the crane rails, as with 0.4.0 or similar cranes. These cranes also were designed with an ability to turn containers when lifted, not quite in a complete circle, but through 340°, which is a feature that the cantilever design made possible. Containers could thus be turned so as to ensure that end doors were positioned appropriately for both rail and road movement.

Figure 2. Examples of crane types and configuration used on Freightliner system.



The large cranes have generally proved more costly to operate and maintain and have proved less reliable, with overall maintenance costs being 20 to 100 percent higher than for the class III 0.4.0's. At many terminals the high dynamic loadings caused rail and beam failures and the costs of redesign and reconstruction have been high. Increased sophistication (partly untried) in electronic control equipment led to poor initial reliability, but advances in technology have allowed subsequent replacement of components at reasonable costs.

Throughputs and costs at selected Freightliner terminals are given in Table 2, together with a brief description of the transfer equipment used. To reduce the table to a manageable size, not all terminals have been included. The highest unit costs arise at the two largest terminals, although costs at Liverpool are appreciably lower than those at Manchester. Particularly interesting is the similarity in unit costs for medium-sized terminals, with throughputs ranging from 54,000 containers in 1981 at Leeds to as little as 23,500 at Nottingham. At Aberdeen, unit costs, which are well within the range of the other terminals, are achieved with a throughput as low as 9,800 containers/year. Kings Cross, surprisingly, achieved the lowest unit costs of all--10.2/container--and yet handled 31,100 boxes in 1981 with very basic equipment: class II 0.3.0 cranes. Freightliner unit costs are compiled on a comparable basis for all terminals. Comparison of costs with terminals in other countries is likely to be far less meaningful because different cost elements may have been included. There are two main elements in Freightliner terminal costs: basic handling costs and joint costs. These are as follows:

1. Handling costs--wages and other costs of handling staff, internal motor drivers, and maintenance staff associated with handling equipment; also included are repairs carried out by outside contractors, fuel and power, depreciation (of handling

Table 1. Freightliner portal cranes: theoretical costs per lift.

Equipment: Portal Cranes[a]	Capital Cost (£000s)		Life (years)	Annual Cost (£000s)		Working Hours per Year		Working Rates		Other Operating Cost[c] (£000s/yr)	Total Cost[d] (£/hr)	Cost per Lift[e] (£)
	Equipment	Installation[b]		Depreciation	Maintenance	Rated	Actual	Lifts per Hour	Maximum (lifts per day)			
Class III 0.4.0 30T rigid mast	140	112	15	17	4	3,000	5,000	20	380	94	25.7	1.35 = 100
Class III 2.6.3 30T rigid mast and turntable	350	280	15	42	10	3,000	5,000	25	475	115	40.1	1.68 = 124
Class II 0.4.0 30T rope hoist	70	56	8	16	2	2,000	5,000	15	285	74	19.8	1.39 = 103

Note: All costs are at October 1974 prices.

[a] For an explanation of configurations 0.4.0 and 2.6.3, see Figure 2.

[b] Installation costs for portal cranes are assumed to be 80 percent of capital costs of equipment.

[c] Other operating costs = (Freightliner terminal handling costs – depreciation and maintenance costs at throughputs equal to maximum working rate)/1.5 lifts per container.

[d] Total cost per hour = [total operating costs + interest at 10 percent (on average) annual investment]/number of hours working.

[e] Cost per lift = total cost per year/(maximum number of lifts per day x 250).

Table 2. Selected Freightliner terminals: traffic volumes and unit costs in 1981.

Terminal	Throughput (000s)	Unit Cost per Container (£)	Handling Staff Shifts (daily)		Main Transfer Equipment[a]	Ancillary Lifting Equipment[b]	Loading Area Serviced by Cranes[c]
			Main Cranes	Ancillary Equipment			
Large							
Liverpool	77.9	14.7	6	3	2 x class III 2.6.3; rail mounted, electrically driven	2 front-loaders (1L and 1E)	5400 (6x900)
Manchester (Trafford Park)	73.0	18.4	5	4	2 x class II 2.6.3; rail mounted, electrically driven	1 straddle carrier (L) and 1 front-loader (E)	5400 (6x900)
Medium-sized							
Leeds	54.4	10.9	6	1	2 x class III 0.4.0; rail mounted, electrically driven	1 front-loader (E)	2700 (3x900)
Nottingham	23.5	12.8	2	-	2 x class III 0.4.0; rail mounted, electrically driven	None	2700 (3x900)
Small							
London (Kings Cross)	31.1	10.2	4	-	2 x class II 0.3.0; rail mounted, electrically driven	None	1200 (2x600)
Aberdeen	9.8	12.1	1.5	-	2 x class II 0.4.0; rubber-tired, diesel powered	None	1200 (2x600)

[a] Crane configuration 2.6.3 and 0.4.0 are shown in Figure 2. The 0.3.0 crane spans 3 lanes as compared with the 0.4.0, which spans 4.
[b] Ancillary lifting equipment is provided for storing either loaded containers (L) or empty containers (E).
[c] Loading area is length of rail sidings (in feet).

equipment), and the hiring of any additional equipment; and

2. Terminal joint costs (of which only a proportion is attributable to terminal handling)--administration, management, and staff salaries; establishment costs (rents, rates, gas, water, and so on); maintenance of the terminal infrastructure; and terminal depreciation.

A major reason why economies of scale do not arise in terminal operations is that large terminals with large wide-span cranes are much more expensive to construct and operate than smaller terminals but do not give an increase in throughput of the same magnitude. Wide-span portal cranes do not have double the working capacity of class III 0.4.0 cranes; indeed, cycle times may sometimes be longer with the greater multiplicity of tasks to perform and wider span. The effect of this is that, at large terminals, the cranes are frequently unable to meet all the various requirements for lifting at periods of peak demand. This problem is usually overcome either by accepting delays in servicing trains and turning around (loading and unloading) road vehicles or providing additional container storage with separate lifting equipment away from the main transfer area. In Freightliner, most container storage at large terminals is now carried out away from main transfer areas, despite the fact that spare space to stack containers under the main cranes is available. This is costly and is more responsible than anything else for pushing up costs at large terminals to much higher levels than were anticipated.

It is significant that TRRL calculations give theoretical costs per lift for the wide-span portal cranes that are 20 percent higher than those of smaller cranes, and that more recent Freightliner studies show that large terminals that use these cranes incur unit costs (per container handled) and storage that are some 17 percent above those at smaller terminals. This suggests that the large terminal with large cranes is inherently more costly per unit of output than the small terminal. It does not, of course, exclude the possibility that cost-effective large terminals exist or can be designed. At the same time, it is of some importance to have demonstrated that small terminals are likely to be more cost effective than many large terminals, rather than the reverse, which is commonly supposed.

The figures on Freightliner unit costs (Table 2) demonstrate a further important characteristic of small and medium-sized terminals: broadly similar unit costs at a wide range of throughputs (9,000 to 54,000 containers/year) in respect to the terminals in the table. This is achieved by closely matching labor costs, which account for between 50 and 75 percent of total costs, to work load. The progressive increases in shifts worked and time periods over which cranes are scheduled to operate are given in Table 2 for the various terminals. The slight step effect on costs of introducing or withdrawing handling-staff shifts is usually offset by variations that may occur at other levels of throughput, such as in the numbers of other staff, i.e., administrative, sales, maintenance, and supervisory.

TERMINAL CONSTRUCTION AND EQUIPMENT COSTS

Of the earliest Freightliner terminals, only Aberdeen remains virtually unchanged. At other terminals, Drott travelifts have been replaced by electric cranes, and large areas for containers and lorry parking have been added over the years. The majority of electric cranes were installed in the period between 1967 and 1971, when the major expansion of Freightliner took place, and are still in operation. During the past 10 years, inflation has greatly increased construction and labor costs, which are a large element in construction and have risen substantially in real terms. This and technology have changed relations between the different elements in construction costs as compared to when the terminals were built.

There are many reasons why exactly similar terminals would not be built today. Yet most of the research carried out in other container transfer systems has not produced any new method that is obviously more economical than overhead cranes. The Research and Development Division of British Rail, after examining most commercially built mobile handling equipment, along with various novel forms of horizontal and end transfer, concluded that only a rail-mounted transfer car (Linercrane) would produce significantly lower unit operating costs than overhead cranes. Advances in technology over the past 10 years have brought improvements in the cranes that would be applied in the construction of new terminals, particularly in the electronic field. Control gear would be less costly and more reliable, and the microchip makes automation readily attain-

Table 3. Hypothetical terminal construction and capacity costs.

Terminal	Container Capacity[a] (per year)	Construction Cost (£000 000s)			Lift Capacity per Year[c] (000s)	Unit Cost per 1 Container per Year Capacity (£)	Main Transfer Equipment
		Main Cranes	Other[b]	Total			
Large	90,000	1.9	2.28	4.18	247	46.4	2 x class IV 2.6.3
Medium-sized	60,000	1.1	1.32	2.42	168	40.3	2 x class III 0.5.0
Small	30,000	0.4	0.48	0.88	108	25.1	2 x class II 0.4.0

[a] Capacity assumed is based on experience and assumes some double lifting of containers by the main cranes, as well as unavoidable idle time.

[b] Other costs have been based on multiplying main crane costs by a factor of 1.2, but they are similar to notional costs, which are calculated to cover infrastructure (crane beams, roads, rail lines, and offices), power supply, and ancillary lifting equipment for the various sizes of terminals.

[c] Lifting capacity per year is based on 225 working days/year and the following performance factors: class IV cranes = 25 lifts/hr x 22 hr/day; class III cranes = 20 lifts/hr x 18 hr/day; and class II cranes = 15 lifts/hr x 16 hr/day.

able. Computers can also be used to control operations hour by hour.

It is difficult to estimate accurately the cost of building an intermodal terminal today without designing it first and then pricing the materials and the work involved. That can be a long process and is itself costly. In using notional costs to compare the costs of building terminals, it is necessary to accept appreciable margins of error, but tentative conclusions can be valuable pointers for decision making and the need for further research.

It is commonly supposed that large terminals, although more expensive overall to construct, are significantly less costly in unit terms (cost per unit of capacity). This is not supported by the comparisons given in Table 3 between hypothetical terminals of various sizes, based on Freightliner practice. The levels of capacity that have been selected are in all cases less than 40 percent of the theoretical lift capacity available. Lift capacity has been calculated by multiplying the number of hours worked daily by the number of lifts possible per hour (assumed cycle times), both of which are also given in Table 3, and then multiplying this figure by 225, the likely number of days in a year that a terminal might operate. This margin of some 60 percent covers the double handling of containers--at most Freightliner terminals, containers are lifted between 1.5 and 2 times by the primary transfer equipment--and idle time, which is often unavoidable, particularly at night.

The prices shown for the various cranes are estimates of what they might cost if purchased today. Other costs include virtually everything else at a terminal apart from main cranes. The main items are rail lines, roadways, supporting crane beams, trailer parking, container storage (with ancillary equipment at the large terminal), power supply, lighting, offices, workshop, and so on. The figures used are somewhat arbitrary and are obtained by multiplying the costs of the main cranes by 1.2, but accord closely with estimates produced by Freightliner engineers of what existing Freightliner terminals might cost to build today at current prices.

Firm conclusions on economies of scale in terminal construction cannot be drawn without further and much more detailed research, but this preliminary work does suggest that small and medium-sized terminals can be built at no greater cost per unit of capacity provided than large terminals and most probably much more cheaply. A small terminal may also be able to make use of existing rail infrastructure, roadways, and rail sidings so as to reduce further expenditures. This had not been assumed in Table 3. At Kings Cross in London and Aberdeen, existing rail sidings, roadways, and offices were used, whereas at no large or medium-sized terminal has this been possible.

SERVICE QUALITY

Rail services that compete directly with road transport must match service quality as well as price to be competitive. The consequences of not doing so may be serious and result in a much lower rate (charge) level, up to 15 percent perhaps, than might otherwise have been obtained or a substantially reduced market share. Intermodal rail services operate in markets that are particularly vulnerable to road competition.

In recent years, as the road network in most countries has dramatically improved, so has vehicle technology. This, coupled with the simplicity of road haulage as compared with intermodal operations and the highly personalized service road operators are able to give, frequently gives road the competitive edge. Road businesses tend to be relatively small and sensitive to customer needs, whereas rail and intermodal operations are normally large and are all too often institutionalized and less responsive to the market.

An intermodal service is like a chain with many links: all must hold together for the service to perform efficiently. A recent study by the Research and Development Division of British Rail into service quality on Freightliner reached the following conclusions:

1. Road collection and delivery are the areas of activity where most failures occur,
2. Failures are most frequent where activities are operating close to capacity, and
3. Service failures are heavily concentrated in the largest terminals.

A road-collection and delivery service has many attributes, with some independent of terminal operations, but others--such as the ability to perform timed collections and deliveries efficiently--are closely linked to terminal performance. In Freightliner, as many as 50 percent of the shippers in the domestic business require timed (scheduled) collections and deliveries, which can only be achieved if vehicles are not unduly delayed at terminals.

Sixty percent of the complaints examined in the research study of service quality arose at only three terminals, all of which were large. As more traffic is handled (in aggregate) at large rather than small terminals, this is not surprising; but the position revealed was that complaints were between two and five times more likely at large than small terminals per unit of business actually handled.

An external consultant brought in to assist in establishing meaningful criteria for the assessment of system and terminal performance came to conclusions that were not too different from earlier work by the Research and Development Division. It was found that shipper appreciation of the service was influenced particularly by the following attributes: ease of booking, on-time collection of containers, on-time delivery of containers, container delivery in good condition, container contents complete and undamaged, quick turnaround of road vehicles at the terminal, trouble-free documentation, and prompt information in the event of problems.

The consultant then proposed various means of assessing performance in these critical areas of activity. Performance indicators were constructed that would measure the turnaround of private vehicles in the terminal, containers forwarded on the days scheduled, train punctuality, and security of the container and its contents. These were all considered important in relation to the service given shippers, because their perception of an intermodal service is influenced by performance in these areas.

The system has only been operating a few months, so it is too early to draw firm conclusions. To ensure an acceptable overall performance, terminals will need the ability to handle current traffic, even in the busiest periods, with sufficient reserves of capacity to cushion shippers from all but major disruptions--and at a realistic cost.

The turnaround of private vehicles achieved at the various terminals in November 1982 is given in the table below:

Terminal	Trucks Detained More Than 45 Min (%)
Large	17
Medium-sized	13
Small	3
Network avg	16

That small terminals appear to produce the best results, with medium-sized terminals next and large terminals last, should come as no surprise, but it must be emphasized that these are from the early days in the performance measurement. Overall, there is an improvement as compared with a study undertaken in 1975 by TRRL, which concluded that the average dwell time for road vehicles (including Freightliner's own) was between 50 and 60 min. Figure 3 shows that now only 16 percent of the private vehicles entering terminals are detained more than 45 min. The figures are not, strictly speaking, comparable because the current results exclude Freightliner vehicles, but an improving trend is nevertheless apparent.

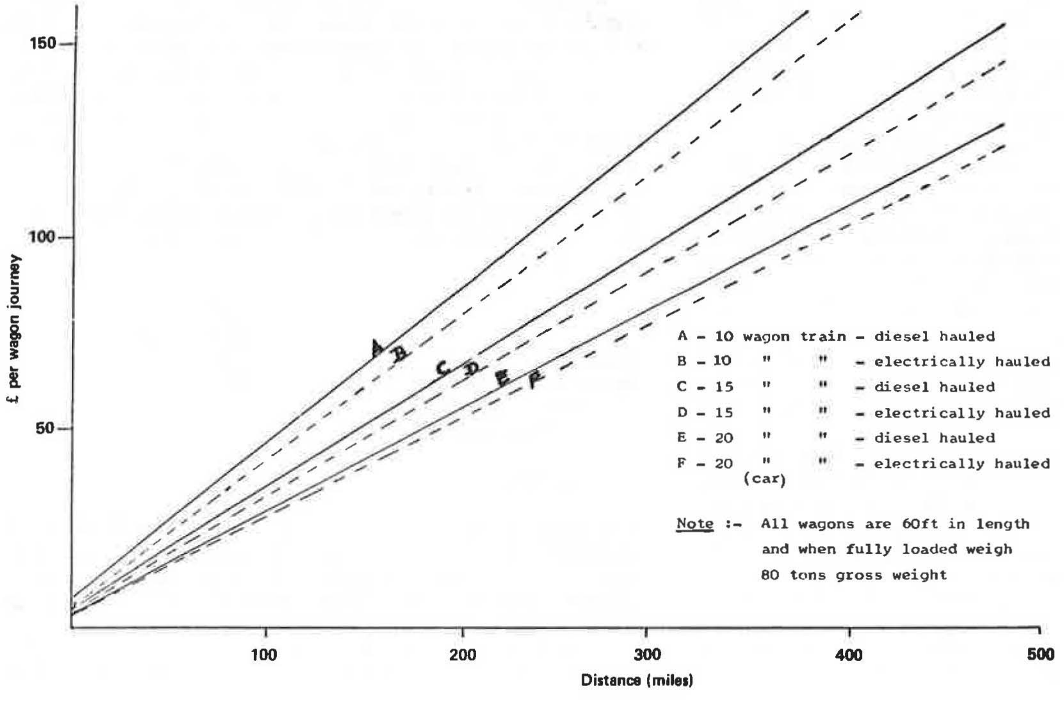
TERMINAL COVERAGE

The reasons why the Freightliner terminal network comprises large and widely spaced terminals, given the industrial nature of much of Britain, have already been discussed. The direct, permanently coupled trains have achieved a high quality of service and wagon use, but the large terminals have proved inherently expensive to operate in terms of unit cost. Widely spaced terminals also involve road collection and delivery of containers over long distances, which is more expensive (obviously) than delivering from closely spaced terminals.

The competitive situation in the United Kingdom has not favored rail in recent years. Whereas deep-sea (world-wide) and European (short-sea) container traffic have been reasonably buoyant, the effect of increased competition from road transport on inland traffic has been great. In short, carryings have fallen and margins have become depressed. This is not a recent phenomenon; the development of a national motorway network and increases in road vehicle efficiency and carrying capacity have been progressive over the past 10 years, but now these factors, which are exacerbated by recession, have depressed margins as never before. Road transport rates have not risen appreciably, and in some areas they have actually fallen over the past 12 months. In May of this year, the gross permitted weight for road vehicles was further increased from 32.5 to 38 tons.

Freightliner has pruned its costs with vigor, but unfortunately this has not improved margins by the

Figure 3. Comparative line-haul costs by size of block train for diesel and electric traction.



required amounts. Road collection and delivery costs that absorb around half the revenue--and this may be true of other intermodal networks--are a prime target for reduction. Road vehicles are now more expensive (in real terms) to purchase, operate, and maintain than 5 years ago; and whereas the motorways have increased the productivity of vehicles operating over long distances, urban traffic congestion has worsened the productivity of vehicles operating from Freightliner terminals.

Road-collection and delivery costs have to be reduced if intermodal operators are to remain in business on the short-haul routes of up to 400 miles. In Freightliner, great efforts are being made to improve the efficiency of the vehicle fleets based at the various terminals. This is important, but by itself it is unlikely to transform the economics of the inland services. An expansion of terminal coverage through a denser network of smaller terminals could reduce road-collection and delivery costs by as much as 30 percent, according to the Research and Development Division. A national study showed that the current 25 inland terminals would be replaced by around 100. In greater London--one of the largest urban areas in the world--the current 3 terminals would be replaced by 12. The small terminals, as we have seen, need be no more costly to build or operate than large terminals.

Rail movement costs in the United Kingdom are around one-sixth of the road movement costs, so if rail movement is increased and road costs reduced, overall costs of intermodal transit should be reduced. In theory, increasing terminal density or coverage should have that effect, but in practice it is not quite so simple. There are implications for rail line-haul costs of fragmenting traffic between a greater number of terminals. Line-haul costs for different sizes of trains that use electric and diesel haulage over various distances are shown in Figure 3. The aim must be to provide wider terminal coverage with reduced costs of road collection and delivery, without appreciably increasing line-haul costs, through using less-economic sizes of trains or increased shunting (sorting) of wagons.

On the European continent, there generally exists a denser network of container terminals than in the United Kingdom, although there has been a trend in recent years toward closing smaller terminals and concentrating traffic in the larger terminals. The European railways achieve this denser terminal network by continuing to send individual container wagons by conventional freight services and sorting them at intermediate marshaling yards.

Research in the United Kingdom and in West Germany has supported this wider terminal coverage but has rejected the individual movement of wagons and the use of marshaling yards for sorting. Schwanhäuser (2) of Aachen Technical University argued that container transfer stations were necessary in West Germany because the movement of wagons through marshaling yards was slow and expensive and uncompetitive with road transport. He went on to describe a container transfer station where a mobile transfer machine mounted on rail tracks (containerumschaggerat) would exchange containers between trains.

In the United Kingdom, research has been undertaken in container network design, with the principal aims being to reduce the break-even distances at which Freightliner is competitive with road, to increase the density of terminal coverage, and to permit the movement of containers between any pair of terminals. The most obvious way of achieving this denser terminal coverage and wider choice of destination is through sorting containers, preferably at terminals built especially for that purpose.

There are a number of forms that these terminals or sorting centers might take, where Schwanhäuser's ideas differ in detail, if not entirely in concept, from those researched in the United Kingdom. The basic ingredients in a sorting center are low cost and rapid transfer of containers between trains. Trains would remain coupled during the sorting or exchange of containers and no wagons would be shunted. In a small country there might be one central sorting center, whereas in a large country there might be a number that cover defined regions. All terminals would forward all containers, except those in sufficient quantities to justify direct rail services, to a sorting center. In the United Kingdom it is unlikely that containers would need to pass through more than one sorting center; in a large country, though, it is possible that they might need to be sorted more than once.

A sorting center might have one or more (probably two) container transfer areas where wide-span portal cranes would serve six trains standing alongside each other, among which containers would be exchanged. No containers would be transferred from rail wagon to road or vice versa. In the United Kingdom, research has shown that a typical sorting center might need to be capable of handling 820 container wagons and 1,500 containers in 24 hr. The table below compares the cost and efficiency of a container sorting center with modern marshaling (classification) yards in Switzerland (note that marshaling yard figures are based on Muttenz II, Basle, and Limmental in Switzerland):

Item	Container Sorting Center	Marshaling Yard
Capital cost (£000,000s)	6.5	25
Unit cost (£)	5.8	16.4
Area (acres)	20	300

A sorting center requires only 10 percent of the land of a marshaling yard, and construction and operating costs are calculated to be 25 and 33 percent, respectively, of marshaling yard costs. Also, there would not be the damage to wagons and merchandise that frequently arises from the impact of wagons striking each other during shunting.

Sorting centers should reduce overall transit costs, thus reducing break-even distances for container services by shortening the distances over which containers are collected and delivered by road and by improved use of rolling stock. It is calculated that overall costs would fall by 12 percent on a movement of 250 miles, and collection and delivery costs, which are currently 50 percent of overall Freightliner costs, would fall by 40 to 34 percent of the total, as given in the table below (note that operating costs are for a typical transit of 250 miles):

Item	Operating Costs (%)
Rail haulage	20
Wagon and container provision	16
Terminal handling	14
Road collection and delivery	50

CONCLUSIONS

The fear of reproducing the complex network of rail terminals that existed before intermodal transport and the perceived economies of large and small terminals have led to a wide spacing of terminals in some countries. This simplifies the rail operation and increases road-collection and delivery distances, which is perhaps what some operators had intended to achieve. Yet rail movement costs are substantially lower than road movement costs, and road collection and delivery of containers or trailers are particularly expensive because of the low level of use of the motor units usually obtained. On the other hand, a denser terminal network could substantially reduce that cost without necessarily increasing rail costs by an equal amount.

After describing why the development of Freightliner took the form that it has today, the extent to which economies of scale have been achieved in terminal operation (by contrasting costs and performance at terminals of various sizes) was examined. The results of work undertaken by TRRL in 1976 and by the Research and Development Division of British Rail and Freightliner more recently show that unit costs for small or medium-sized terminals that are between 15 and 25 percent lower than those at large terminals. Interestingly, both theoretical studies, which cover per-lift costs for different sizes of cranes and average costs per container of throughput for various sizes of terminals, show broadly the same magnitude of difference between the large terminal, which uses the large crane, and small or medium-sized terminals. Average costs per container are a relevant measure of cost-effectiveness, provided that terminals are not operating well below rated capacity. Such costs reflect field conditions, where the pattern of terminal activity is influenced by the characteristics of rail and road traffic movement.

Small terminals with small cranes appear to be inherently less costly, the equipment and infrastructure required being much less elaborate and less expensive both to provide and maintain. At small terminals, labor costs are a higher proportion of total costs, but providing these can be varied to match throughputs; relatively uniform levels of unit costs can be achieved at almost any level of throughput. Initial performance measurements carried out at Freightliner terminals also appear to point to higher-quality service to the shipper at small rather than large terminals.

It needs to be said that perhaps these conclusions apply only to large terminals as Freightliner has designed them. It is likely that there are parallels elsewhere, but this has to be demonstrated. It is also likely that large terminals could be designed so as to avoid many of the defects discussed. However, that is a subject in itself. Freightliner experience does suggest that large terminals, if they are to be built at all, should not have just a few sophisticated and expensive cranes, but a greater number of smaller transfer devices.

The significant point about the comparisons is that it is the small terminal that both exhibits the lowest unit costs and offers the best opportunity for reducing road-collection and delivery costs through increased terminal coverage or density.

Increased terminal coverage need not result in dramatically increased rail haulage costs or in sacrificed service quality. The central sorting of containers or trailers at specially designed interchange centers facilitates a network of small terminals and private sidings that are served by intensively used low-cost block trains that operate to and from the centers.

As the recession continues and competition grows, intermodal operators must pursue not only technical innovation, but must also thoroughly explore new concepts and ideas in terminal and system design.

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Intermodal Freight Terminal—An Open System: The Infrastructural Perspective

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Attention is focused on those people who are involved with the planning, design, and operation of intermodal freight terminals and their essential support systems, i.e., their infrastructures. The interface role of intermodal terminals is significantly constrained by the quality of the related infrastructure, how it is operated, how access to it is controlled or regulated, and what pricing practices are applied. The intermodal freight terminal is a characteristically complex system operating, as it does, between two dissimilar modes of transportation. This means that terminal performance is affected by at least two separate operating policies. The terminal's administration must accommodate to the scheduling and performance standards of the management of the two modes and at the same time achieve acceptable levels of throughput—at a profit. Confounding these and other related matters is the infrastructure issue. Where two modes are involved, there are, necessarily, two dissimilar rights-of-way. Each may have different capacities and restrictions, neither of which is under the control of the intermodal terminal operator. For example, an ocean container terminal may be faced with uncertain channel depths, custom delays, tugboat and pilot shortages, and limited crane capacities on the waterside and, on the landside, traffic congestion, length and weight limits, clearance restrictions, and oppressive traffic regulations. Other infrastructural elements of concern include communications; labor quality and availability; services such as refrigeration, chandlery, fire, and police; medical services; and line-haul and distribution networks for the modes in question. The infrastructure concept is presented descriptively along with systems planning and analysis. Examples of intermodal freight terminals in the context of their infrastructure are offered to illustrate the need to take infrastructure into account in planning, designing, and operating intermodal freight terminals.

Intermodalism is the fusion of the services of distinct carrier types designed to improve the physical distribution performance of freight movements, thereby achieving less costly and wider access to product markets and supply sources. Intermodal applications apply to freight movements that may require or benefit from transfers of freight between