

INNOVATION IN LOGISTICS: THE IMPACT ON TRANSPORT AND THE ENVIRONMENT

James Cooper

*Transport Studies Group, Polytechnic of Central London, London
NW1 5LS, United Kingdom*

1. INTRODUCTION

Freight transport activity, in common with all other forms of transport, creates an impact on the environment. Increasingly, solutions are being sought to reduce this impact, not least in road freight, where the lorry is frequently seen as an "environmental villain". Many studies have already catalogued the environmental complaints against lorries: pollution from exhausts, noise from engines and tyres, vibration and visual intrusion. There are also safety concerns, as lorries involved in accidents often cause fatalities, on account of their size and momentum. Taking a broader perspective, many environmental groups question the energy demands of road freight transport, which contribute to the depletion of world reserves of fossil fuels.

With increasing frequency, we now hear calls to restrict the use of lorries, supposedly to bring about environmental improvement. As a result, many cities now impose night and weekend restrictions on lorry operation. But some "solutions to the lorry problem" are unlikely to be successful until we understand why companies want to use lorries in the way that they do. In particular, we must recognise that lorry operation is a consequence of logistics planning and until we understand the objectives of logistics planning, attempts to control the growth of lorry traffic in the interests of the environment are unlikely to succeed.

Logistics is often known as "supply chain management" and this phrase is the key to understanding the role of lorries in the movement of goods. Increasingly, companies are concerned with looking at their flow of goods and materials in an integral way, rather than in separate stages. Logistics therefore represents a holistic approach, where component supply, production of finished products and the distribution of finished products to retail outlets must be considered as a continuous stream of activity. Crucially, this leads to the recognition that one element of the activity impacts on some or all of the others. Successful logistics planning means making sure that advantage is taken of exploiting trade-offs between these different elements; for example, storage and transport.

The evidence of successful logistics planning can be seen all around us. Two industries which have had an especially deep involvement with logistics are car manufacturing and consumer electronics. This has resulted in a number of important consequences for transport. Ford's engine plant in South Wales, for example, sends engines to car assembly locations all over Europe; engines are no longer made locally alongside each car production plant. Similarly, in electronics, many computers are now made to order, rather than being available off-the-shelf. Shortening product life-cycles, improved manufacturing techniques and innovations such as the just-in-time delivery of components, have all meant that electronics has become a demand-led rather than a supply-led industry.

It is beyond the scope of this paper to consider all possible logistics innovations - and their impact on transport and the environment. However, by examining just three of the more important ones, namely centralisation of inventory, 24-hour lorry operations, and just-in time delivery, we will be able to understand a little more about companies' motivations in relation to logistics and the consequences for transport. From this basis it is then possible to see what policy initiatives might succeed in reducing the environmental impact of road freight transport, in particular.

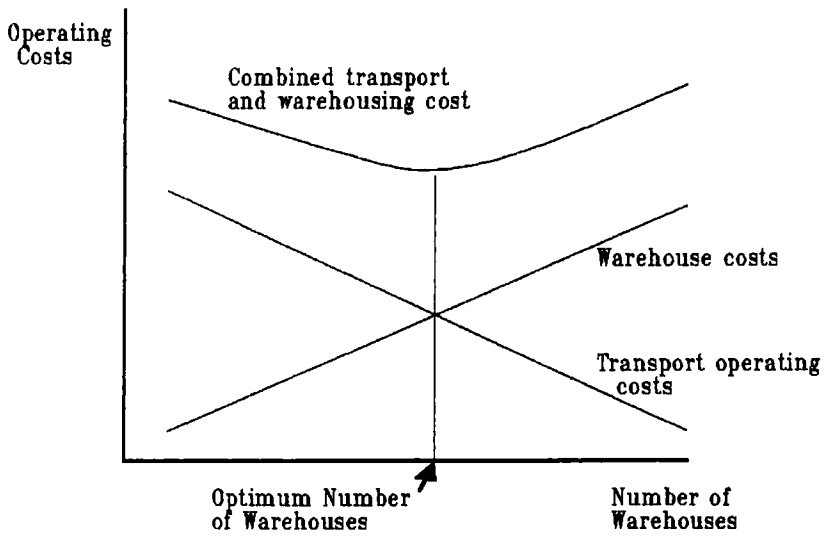
2. CENTRALISATION OF INVENTORY

One of the classic relationships in logistics is the trade-off between warehousing and transport: as the number of warehouses is increased, the cost of operating them also increases, but transport operating cost falls, for a constant throughput of goods through the warehouse. This rule is usually presented as a diagram, to illustrate the implications for combined warehouse and transport operating costs and the choice of an optimum number of warehouses in a distribution system (See Figure 1)

Over the years, there has been a modification of the rule, which now takes into account the cost of holding inventory in warehouses. Variations in this cost have been formulated into the "square root law" (1), which states that safety and cycle inventory requirements are related to the square root of the number of warehouses in a distribution system. Thus moving from a system of ten depots to a completely centralised system using one depot would, in theory, reduce the inventory requirement by 68% (2).

FIGURE 1.

Trade-off in Transport and Warehouse Operating Costs



Although there are some important objections to an unbounded application of the square root rule (see, for example, Das (3)), practice has shown that the square root law performs reasonably well (4). For this reason many companies, and especially those carrying high-value inventory, have been keen to convert to a system of distribution based on a central warehouse, rather than maintain a network of, say, 10 regional warehouses.

The powerful attraction of inventory cost reduction resulting from warehouse centralisation can be seen using an example from the UK. The model used also indicates the consequences for transport operating costs.

Figure 2 shows an existing system of decentralised warehousing which can be described as Scenario 1. Production within Scenario 1 is based upon two production plants, one at Telford and the other at Cambridge. In total, there are 161 customer locations throughout the UK which are served by seven warehouses. The combined throughput for the warehouses is 50,000 tonnes annually.

Figure 3 illustrates the spatial details of Scenario 2, with the same two production centres, but now with all inventory held at one warehouse located at Atherstone, which is very close to the geographical centre of the UK. Under Scenario 2, all the main features of the distribution requirement are held constant (ie, customer locations, total warehouse throughput). For both Scenarios it is also assumed that the inventory value is £2,000 per tonne and that there are 10 inventory turns each year.

The consequences for transport of centralising inventory have been calculated using P-E International's TRANSPLAN distribution software package. These are summarised in Table 1, which also includes a calculation of inventory reduction based on the square root law, but with the theoretical savings being reduced by about a third to take into account the application of the law in practice.

FIGURE 2.

Scenario 1: Decentralised Warehousing

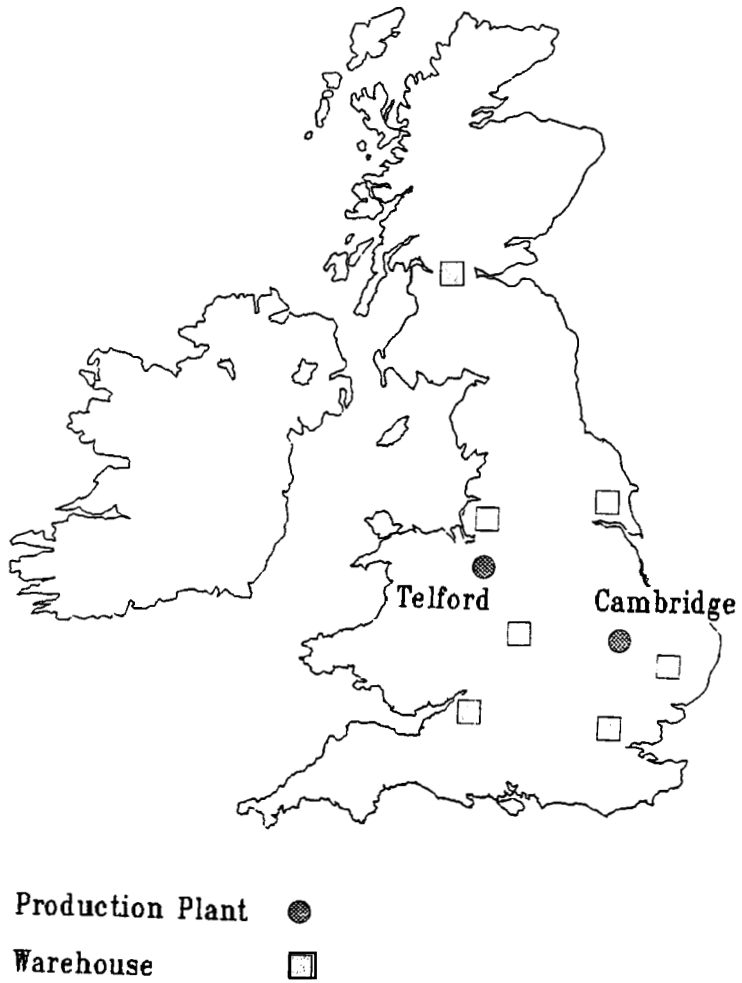


FIGURE 3.

Scenario 2: Centralised Warehousing

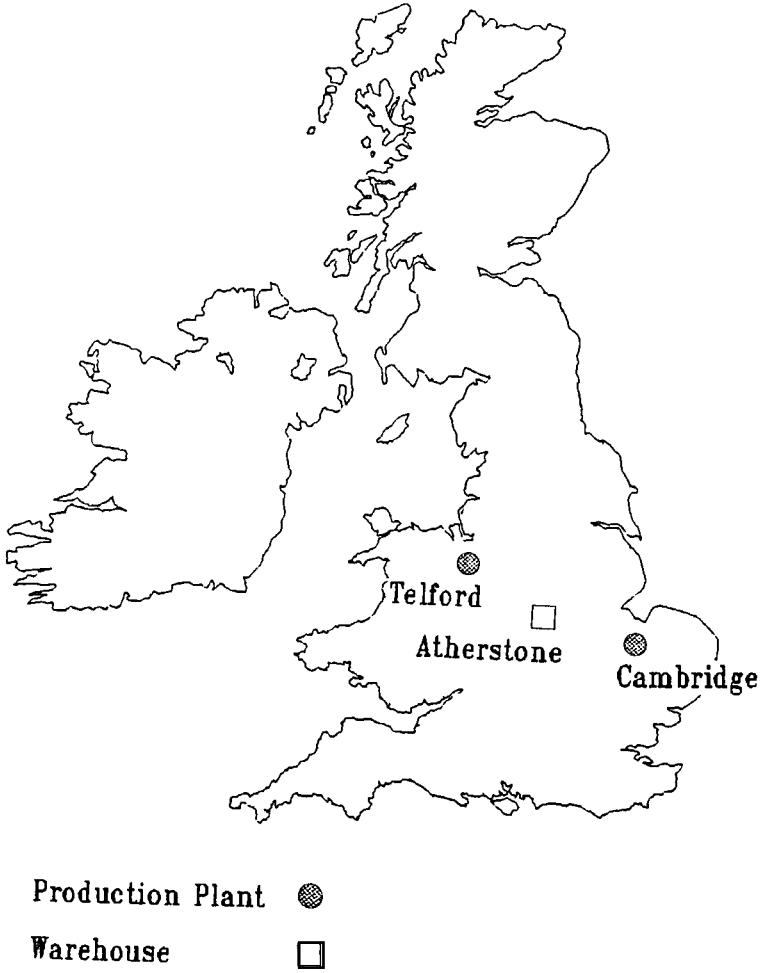


TABLE 1

Comparison of Selected Distribution Costs Under Scenario 1
(Decentralised Warehousing) and Scenario 2 (Centralised
Warehousing)

	Annual Cost (£000)	
<u>Scenario 1 (Seven Regional Warehouses)</u>		
Inventory holding costs	1,000	
Primary transport operating costs (ie factory to warehouses)	185	
Secondary transport operating costs (ie warehouses to customer locations)	453	
	<hr/>	
TOTAL	1,638	
<u>Scenario 2 (One Central Warehouse)</u>		
		% Change From Scenario 1
Inventory holding costs	600	- 40%
Primary transport operating costs (ie factory to warehouse)	173	- 6%
Secondary transport operating costs (ie warehouse to customer locations)	570	+ 26%
	<hr/>	<hr/>
TOTAL	1,343	- 18%

From Table 1 it is clear why achieving savings in inventory cost has been an important focus of logistics policy for many companies. An inventory saving of 40% from centralisation is evident, even using a more conservative estimate than that suggested by the square root law. Overall, for inventory and transport costs combined, Scenario 2 achieves an 18% cost reduction over Scenario 1, a level of saving which would easily merit implementation of a centralised warehouse system for the company concerned.

Yet within this overall reduction in costs, it is evident that there is a substantial rise in secondary transport costs as a result of opting for Scenario 2. This is what causes concern for environmentalists since a 26% increase in the costs of operating secondary transport means a similar increase in lorry activity. Amongst other things, there will be about 26% more visual intrusion, pollution and fuel consumption, together with increased demand for roadspace. Yet on the "environmental balance sheet", the reduction of inventory offers no compensating environmental gain. This is the crux of the problem; a commercial decision, sensibly taken, results in significant social costs. The need is for policy initiatives which can allow companies to continue to enjoy benefits of logistics initiatives while, at the same time, ensuring little or no environmental deterioration. Two possibilities are:

- i) Improving lorry design: This approach offers some marginal improvement to the environment. For example, improvements in engine design can reduce fuel requirements, noise and pollution. Better suspension design can lead to less vibration. But there will be no discernable difference in visual intrusion or demand for roadspace. Scenario 2 in the above illustration will therefore still mean a net environmental loss compared with Scenario 1 if improving lorry design is the only policy initiative chosen by government.
- ii) Combined Transport: Centralisation of inventory leads to a concentration of flows along primary transport routes: lorries from production centres will only be going to one warehouse destination rather than several. This can prove favourable to rail transport, rather than road, so some switching of primary transport mode in the move from Scenario 1 to Scenario 2 may be a possibility. In turn this can bring a beneficial change to the environmental balance sheet. Environmental deterioration caused by more secondary transport can be counterbalanced by primary transport being undertaken by a more "environmentally friendly" mode. However, companies which are alert to the benefits of logistics planning may find some difficulty in making this transfer of

primary transport from road to rail. They will, amongst other things, need to be reassured about the capabilities of rail as an alternative to road. Moreover, rail capacity needs to be available to absorb new freight traffic, a condition which is increasingly difficult to meet in some countries.

If there appears to be no immediate way of making the centralisation of inventory more acceptable in terms of transport and the environment, then one other policy approach must be to consider the scope for encouraging the decentralisation of inventory. In effect, the process of centralisation may have come about simply because companies regard transport as too cheap; they are happy to spend more upon it because the extra cost is so readily recouped in savings on inventory. But if transport is suddenly made more expensive, then the trend towards centralisation could be reversed.

Yet the scope for making road freight transport more expensive may not be great, given the wider political implications for governments. Table 1 shows that combined primary and secondary transport costs under Scenario 2 would have to be raised by £400,000 to balance the savings in inventory cost. This means raising transport operating costs by over 50%.

Government could seek to achieve this increase by raising taxation on fuel. But since fuel costs are often only about 20% of total operating costs in transport, this would mean the introduction of a swingeing fuel tax. In the example used, a rise in fuel duty of about 250% would be needed to raise transport operating costs to a level that would cancel out savings in inventory cost resulting from warehouse centralisation. There must be serious doubts about the preparedness of governments to introduce policies aimed at raising fuel duty by so much. Hostile reaction could be expected, not just from the business community, but from others such as private motorists, whose fuel costs may also need to rise as part of a general policy of making transport more expensive.

3. 24-HOUR LORRY OPERATION

The decision to operate lorries round the clock is often linked to warehouse centralisation. As supply lines between customer locations and centralised depots become longer there is the danger that levels of customer service will deteriorate. The multiple-shifting of vehicles is one way of ensuring that, for example, inventory is replenished more promptly and out-of-stock situations avoided.

But some companies have introduced round-the-clock working of lorry fleets for the benefits that this practice can bring in its own right. Often the initiative has come from manufacturing, where many companies run factories both by day and by night. By spreading their fixed costs, notably the capital costs of machinery, these companies reduce their unit production costs and this helps keep them competitive.

Some freight companies also see a potential benefit in the more intensive use of their expensive capital equipment, especially vehicles. Why not use these on two or even three shifts in each 24-hour period, rather than only during the daytime?

At present, the benefits of round-the-clock operation are not sufficiently great to induce many companies to switch from day-only operations. This is partly due to labour costs being a high proportion of total operating costs. Paying drivers extra money for working unsocial hours means that many of the gains from spreading fixed costs (eg a vehicle licensing and insurance) and reduced investment (eg smaller vehicle fleet) are undermined by higher labour costs. In one study of round-the-clock operation, it was calculated that the overall saving, compared with day-only working, is in the order of 4-6%; the exact figure for any one company will crucially depend upon the duration of vehicle replacement cycles (5). For many companies, savings of this order may not be considered sufficiently high to justify a switch to round-the-clock working of lorry fleets.

However, from an environmental point of view there are some benefits from round-the-clock scheduling of vehicles, although these must be carefully assessed against some disbenefits. One of the main benefits is reduced fuel consumption. One company carried out a test programme of fuel consumption, the results of which were reported in Cooper and Tweddle (6) and are shown here as Table 2.

TABLE 2

Results of Company Fuel Consumption Tests

(Figures are miles/gallon)

	Aerodynamic Aids	
	With	Without
Daytime Operation	6.70	6.27
Night-time Operation	6.97	6.66

Table 2, above, shows that there are significant improvements in fuel consumption which are made possible by fitting aerodynamic aids to vehicles and running them at night; fuel savings of more than 11% are possible compared with day-time operations using a fleet running without aerodynamic aids. The savings attributable to night operation alone varies between 4% and 6%.

Furthermore, it is important to realise that the future potential for saving fuel by operating at night is likely to increase as day-time congestion on road affects fuel consumption figures. It is not inconceivable that, by the end of the century, it will be possible to save around 10% on fuel consumption by running at night.

Not all freight companies, of course, will readily be able to introduce night-time operation for their vehicle fleets. The best opportunities will be for operators supplying retailers using distribution centres that are open all hours, or manufacturers in continuous process industries.

In addition, some new constraints on operating vehicles at night might be imposed by government, in response to environmentally-driven complaints. Foremost amongst these is likely to be noise. Despite legislation making them quieter over the years, lorries are still noisier than cars. Diesel engines, air brakes, refrigeration units, crude suspension units and rattling bodywork all give rise to noise which will disturb people trying to sleep at night. Governments are likely to be very sympathetic to arguments that lorries working at night should be made much quieter.

By contrast, environmental complaints which are levelled at vehicles operating in the day-time carry much less weight for lorries working at night. Visual intrusion is much less of a problem and street-level pollution affects far fewer people. So taking an environmental balance-sheet approach, operating vehicles at night has its attractions not least in reducing demand for day-time road capacity. Government, both at the central and local levels, should consider the possible benefits of night operations by lorries, as well as the problems, when designing legislation. Some city councils have introduced night bans on all lorry operations, but this can be a retrograde step if night operation is carried out by operators in an "environmentally-friendly" way, since it rules out society enjoying some important potential benefits such as reduced day-time congestion on roads. Legislation to make sure that operators use very quiet heavy lorries (VQHVs) at night might be a better solution.

4. JUST IN TIME DELIVERIES

Just-in-time (JIT) delivery is widely regarded as one of the most successful innovations in logistics in recent times. A great number of manufacturers, and even retailers, have changed their delivery practices to JIT and there are specialist freight companies which offer JIT as a service to clients. Indeed, the success of JIT has been so overwhelming that many people outside the logistics sector, including the media and the general public, are aware of it.

Many applaud JIT as a major advance in supply chain management. But what of the environmental implications of JIT? Is JIT to be welcomed or should it be treated with rather more circumspection than has hitherto been the case?

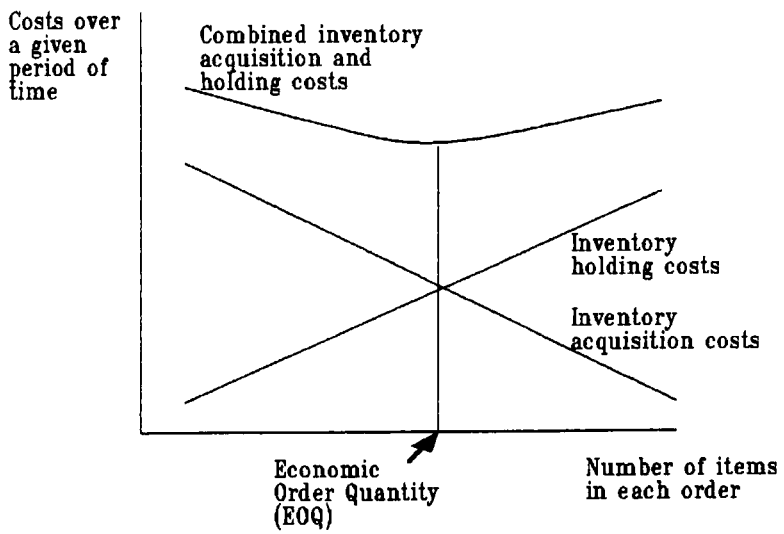
First, it is extremely important to be clear about JIT and what it aims to achieve. Originally developed in the 1970s in Japan as the Kanban system, JIT was designed as an inventory-free production method, for use by manufacturers such as those in the electronics and motor industries (7). The key application for JIT was in feeding production lines, especially for finished products such as cars. Whereas the traditional approach to manufacturing was to have a supply of components stored next to the production line, JIT brought a radical new approach. Companies such as Toyota organised small, frequent deliveries of components direct to the production line from suppliers, thus eliminating both the need for storage space and the cost of holding the components in store at the factory.

In effect, what the pioneers of JIT had done was to bring two important changes to the manufacturing process. One was conceptual, the other technical. The conceptual innovation was essentially the logistics approach of seeing the movement and storage of materials in an integrated way. This enabled, say, car manufacturers to consider component supply to be part of the assembly line flow whereas the conventional wisdom required components to be stored prior to use on the assembly line.

The technical innovation relates to yet another logistics trade-off. In Section 2, which discussed centralisation of inventory, Figure 1 shows the trade-off relationship between transport and warehouse operating costs, which helps management to decide the optimum number of warehouses to use in a distribution system. A similar trade-off applies in the ordering process for, say, components used in manufacturing. Here, there are two costs, namely the cost of acquiring inventory and the cost of holding inventory. As Figure 4 illustrates, with an increasing size of order, the cost of holding inventory goes up while the cost of acquiring inventory goes down. This means that there is some quantity, called the economic order quantity (EOQ), which gives the least total cost. Companies should, according to the theory, always try to order in EOQ quantities. Figure 4

FIGURE 4.

The Order Quantity Decision



essentially illustrates the shape of the cost curves according to time-honoured practices of ordering supplies. In effect, it suggests that ordering frequently, in small quantities, tends to be costly because of the need to repeat the expensive clerical function of order acquisition. The important point recognised by Japanese companies was this need not be the case if electronically triggered and transmitted orders becomes the inexpensive basis for component acquisition. That realisation, in effect, changed the order quantity cost curves, making Figure 5 the new model for establishing the size of order. Small order quantities, frequently delivered, therefore became the normal pattern of component purchasing for a large number of companies in manufacturing, first in Japan and now in Europe and the United States.

The implications of JIT delivery for transport are dramatic. Instead of a large vehicle delivering weekly, say, the requirement is for much smaller vehicles to deliver daily or, in some cases, many times each day. For many Japanese factories, this has not been a problem, since component suppliers are often located near the factory gate of a large manufacturer; the giant Toyota works are a case in point. But in Europe, where planning controls are often tight and component suppliers long-established at distant locations, JIT means an extensive use of the public road network. This inevitably means environmental deterioration with several, smaller vehicles being used to carry the same amount of goods as a single large vehicle used before the introduction of JIT.

An important environmental consequence of JIT will be in energy demands and pollution. Assuming vehicles are run fully loaded, Figure 6 shows that using a 10-tonne capacity vehicle rather than one of 25-tonnes capacity causes a substantial increase in fuel consumed, up from 0.24 to 1.2 miles/gallon for every tonne moved, a fivefold increase. Yet it is possible that even smaller vehicles will be preferred in some JIT deliveries.

Along with more air pollution and greater energy use, there will also be the likelihood of greater noise disturbance and visual intrusion, as more small vehicles are used in place of large ones. Only vibration might be reduced, but this is the one instance where JIT deliveries could lead to a favourable outcome. Otherwise, taking the "environmental balance sheet" approach, it is evident that JIT leads to transport practices which are overwhelmingly hostile to the environment.

FIGURE 5.

The Order Quantity Decision with JIT Delivery
and IT Communication for Order Processing

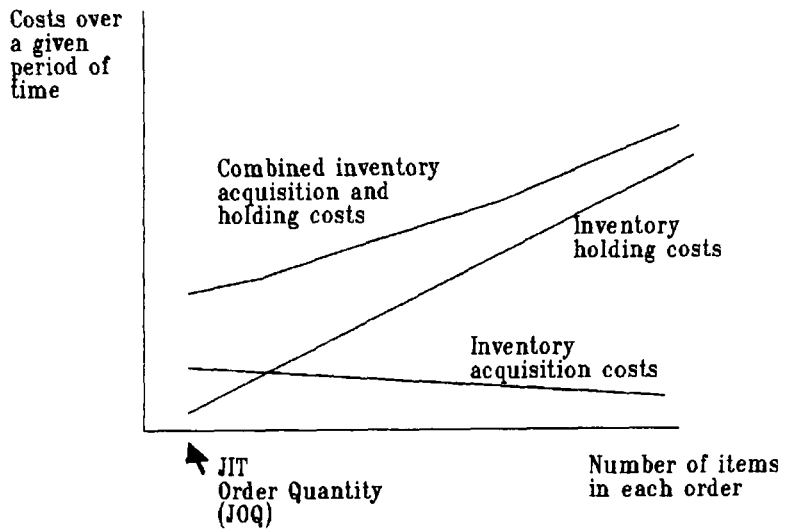
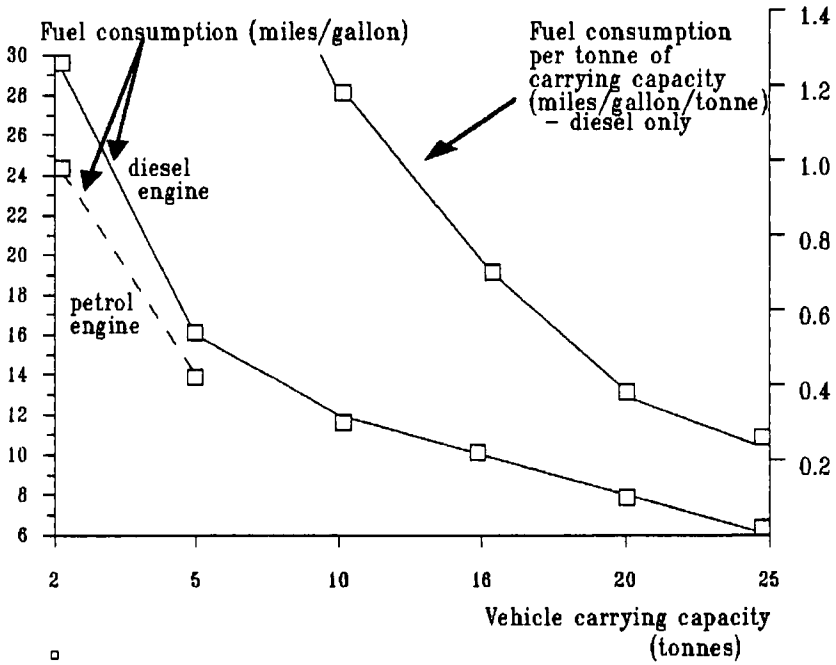


FIGURE 6.

Fuel Consumption for Vehicles of Different Carrying Capacities



Source: Commercial Motor Tables of Operating Costs

In many ways, the outcome of an environmental analysis for JIT is similar to that found for the centralisation of inventory, discussed in Section 2, above. Similar public policy options therefore suggest themselves. First, JIT works because transport cost considerations are outweighed by other logistics considerations. Therefore, from an environmental point of view, transport must be regarded as "too cheap", but there are great problems in making it more expensive.

Second, improvements to the design of small vehicles (eg much improved fuel economy) could make JIT more acceptable environmentally. Yet this does not overcome other key problems such as increased demand for roadspace. Third, where component supply takes place over long-distances, some consideration should be given to using rail to a much extent than exists at present. Some companies, (eg motor manufacturers) already use railways for moving components, but the services could be much faster, and much more streamlined than they are already, to give them wider appeal.

Finally, it must be recognised that some manufacturers are requesting JIT deliveries from suppliers in the mistaken belief that it saves them money. This point remains largely outside the domain of public policy, but it is nevertheless important to create a wider awareness of what may be a considerable problem.

The problem arises because JIT is widely perceived as being a mark of logistics excellence. No manufacturer wants to display an ignorance of it and many hasten to introduce JIT deliveries within their manufacturing schedules. Yet JIT may simply be inappropriate for a number of companies, especially those which are not sufficiently in touch with the pricing practices used by their suppliers. Some of these suppliers will readily agree to supply on a JIT basis, but will invoice the client company on a higher tariff to recoup the additional costs of delivery. This action can readily be wiped out gains sought elsewhere by the manufacturer when introducing JIT.

Such an outcome is rather an uncomfortable one to contemplate: the supplier is happy because he is keeping his client happy; the client is happy because his manufacturing is now set up according to the latest fashion for JIT delivery; but environmental groups are entitled to feel aggrieved because there is no tangible gain to the economy resulting from the switch to JIT; and the environment suffers because more, smaller vehicles are on the roads carrying the same amount of freight as the fewer, larger vehicles they displaced.

5. FINAL REMARKS

- * It is clear that a number of recent logistics innovations, notably the centralisation of inventory and Just-in-time delivery, have been extremely successful in a commercial context. However, it is also the case that these innovations result in transport activities which are more damaging to the environment than the superseded methods of goods distribution.
- * From a public policy point of view, there are a number of actions that can limit the extent of environmental deterioration caused by logistics innovation. Higher standards of lorry design and encouraging the use of combined transport for primary transport movements are two possible options.
- * Yet any major reduction in environmental impact does not seem possible without putting the logistics innovations themselves into reverse; there would need to be public policy measures introduced, for example, to decentralise inventory holding and to encourage the delivery of consignments in large quantities, infrequently delivered.
- * The fundamental problem is that many logistics decisions by companies have been made on the basis of transport being regarded as a relatively cheap commodity; environmentalists would probably say too cheap. Only raised prices for fuel are likely to reduce the environmental impact of freight in any substantial way. Government could take action, under a policy programme designed to make transport more expensive, by raising fuel duty. But it must be recognised that the required increase in duty is certain to be huge, if current trends in logistics are to be reversed. The question is whether government has the political will to achieve higher standards of environmental protection in the field of logistics by taking radical measures which could readily undermine electoral support.

6. BIBLIOGRAPHY

- (1) D H Maister. "Centralisation of Inventories and the Square Root Law" International Journal of Physical Distribution. Vol 6, No 3, 1976.
- (2) A C McKinnon. Physical Distribution Systems Routledge, London 1989.
- (3) C Das. "A Re-appraisal of the Square Root Law" International Journal of Physical Distribution. Vol 8 No 6, 1978.
- (4) J E Sussams. "Buffer Stocks and the Square Root Law" Focus on Physical Distribution and Logistics Management. Vol 5 No 5, 1986.
- (5) J C Cooper and G Tweddle. "Distribution Round the Clock" in Logistics and Distribution Planning: Strategies for Management (revised edition), edited by J C Cooper, Kogan Page, London 1990.
- (6) J C Cooper and Tweddle, op cit
- (7) M Forbes "Just-in-Time Distribution" in Logistics and Distribution Planning: Strategies for Management (revised edition), edited by J C Cooper, Kogan Page, London 1990.