Green Logistics: the Carbon Agenda

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1. Introduction

Climate change is likely to become a major business driver over the next few decades as companies come under intense pressure to decarbonise their activities. There is general acknowledgement in government circles that the increase in global temperatures (above pre-industrial levels) must be limited to 2^{o} C by 2100. This will entail a global reduction in CO_2 emissions of 50% by 2050 (against 1990 levels), with some developed countries, such as the UK, already committed to an 80% reduction over this period (Committee on Climate Change, 2008). To our knowledge no country has, as yet, disaggregated these national-level carbon reductions into a series of sectoral targets. In theory these targets should be related to the marginal cost of carbon abatement (MCCA) in different sectors. It is not known how the MCCA of logistical activities is likely to compare to that of other business activities. In absolute terms, however, the carbon footprint of logistics is likely to be much smaller in 2050 than it is today.

The World Economic Forum and Accenture (2009) have estimated that logistics accounts for around 5.5% of global greenhouse gas (GHG) emissions and indicated how this is divided between freight transport modes and ‘logistics buildings’. Logistics’ GHG ‘footprint’ may appear relatively modest, though, unlike most other sectors, which have been reducing their GHG emissions, transport, and in particular freight transport, has been increasing its output of these gases. On a business-as-usual basis, there trends are forecast to continue. Freight tonne-kms are predicted to grow at 2.3% per annum between 2000 and 2050 partly as a function of the expansion of production and consumption, but also reinforced by an increase in the average distance that each unit of freight is transported (World Business Council for Sustainable Development, 2004). Globalisation is lengthening supply lines, thereby increasing the freight transport intensity of the world economy. The amount of CO_2 emitted by each tonne-km of freight movement also appears to be rising as more carbon-intensive transport modes, particularly airfreight and trucking, capture a greater share of the freight market (IPCC, 2007). No separate forecasts exist for changes in the level of CO_2 emission from warehousing and materials handling operations, though they may be closely correlated with those of freight transport.

Developing and implementing practical and cost-effective carbon mitigation strategies for the logistics sector will therefore present a major challenge. This paper outlines the nature and scale of this challenge and examines the different types of measure that companies can adopt to decarbonise their logistics.

2. Decarbonisation Framework for Logistics

As freight transport typically accounts for 80-90% of logistics-related carbon emissions, it is hardly surprising that it is the main focus of carbon-mitigation efforts. These efforts can be targeted on five key parameters (McKinnon et al, 2010):

Freight transport intensity: this is the ratio of freight movement (usually expressed as tonne-kms) to economic output.

Freight modal split: this indicates the proportion of freight carried by different transport modes and can be expressed as the ratio of tonne-kms carried by more carbon-intensive modes such as road and air to tonne-kms carried by greener modes like rail, barge, ship and pipeline.

Vehicle utilization: this can be measured by the ratio of vehicle-kms to tonne-kms, in other words how much vehicle traffic is required to handle a given amount of freight movement. If the vehicles are well-loaded on outbound and return journeys this ratio is minimized.

Energy efficiency: defined as the ratio of energy consumed to vehicle-kms travelled. It is a function mainly of vehicle characteristics, driving behaviour and traffic conditions.

Carbon intensity of the energy source: i.e. the amount of CO_2 emitted per unit of energy consumed either directly by the vehicle or indirectly at the primary energy source for electrically-powered freight transport operations.

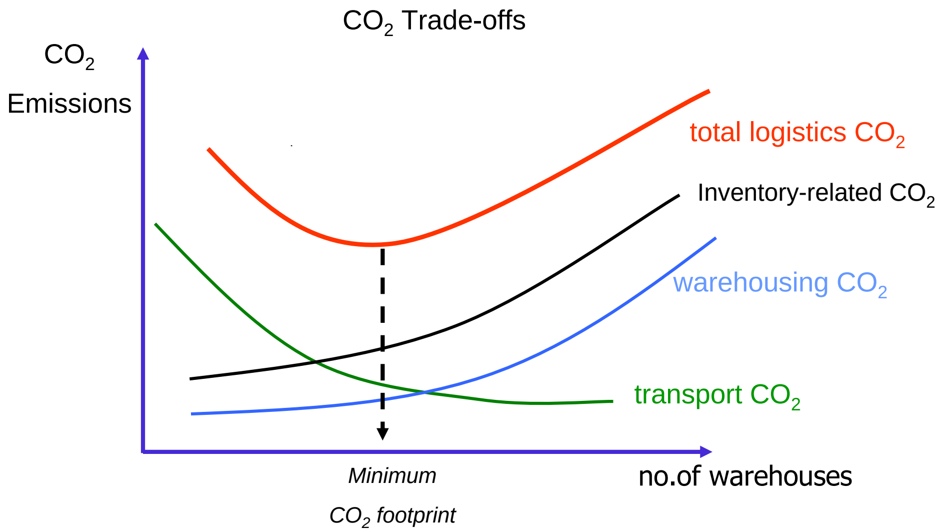
The next six sections will examine the opportunities for altering these ratios. A later section will explore the options for decarbonising warehousing.

3. Reducing Freight Transport Intensity

In much of the developed world, the growth of freight movement has been due more to each unit of freight being transported over greater distances than to the physical mass of goods in the economy expanding. This trend has been driven mainly by two processes, (i) the wider sourcing of supplies and (ii) the centralisation of economic activity. These processes cannot continue indefinitely. Eventually supply chains will become fully extended. International and inter-regional differences in production costs may also narrow, reducing the economic incentive to trade with distant suppliers and distributors. This ‘market saturation’ effect is likely to occur first at a national level and then at the level of continents / trading blocs and eventually the world as a whole. There is some evidence that in developed, mature economies such as the UK (McKinnon, 2007a), the expansion of sourcing / market areas is now at an advanced state. At the continental and global levels, however, this expansion is continuing apace and even accelerating in some areas and sectors. The centralization of economic activity is also finite, as ultimately production and distribution facilities will reach their maximum economic size, though this process has still some way to run. Within developed countries, there is limited scope for further spatial concentration, but in much of the developing world, the process of centralization is at an earlier stage.

The long term increase in the average length of haul is largely a consequence of major global business processes which will be very difficult to reverse. Simulation modelling of logistical systems indicates that the cost trade-offs which companies make between transport, inventory and warehousing are very robust. Tilting these cost trade-offs sufficiently to induce a return to more localised and decentralised patterns of production and distribution would require very large increases in freight transport costs. An emissions-trading price for carbon or carbon tax would have to be set at a high level to force a return to more decentralized systems, particularly in sectors producing higher value goods. Nor is there any guarantee that a move back to more localized sourcing or decentralized production and warehousing would yield a net reduction in carbon emissions. Full life cycle analysis (LCA), which takes account of the carbon intensity of production, storage and handling operations, is required to determine the pattern of sourcing that minimises carbon emissions. Distant suppliers may operate more energy-efficient, less carbon-intensive production facilities than local suppliers and the resulting saving in production-related CO_2 may exceed the additional emissions from longer freight hauls, especially as, in many sectors, CO_2 emissions from the production operation typically dwarf those associated with physically distributing the products. To determine the net carbon impact it is necessary to conduct a logistical trade-off analysis, similar to those long applied in the economic optimization of logistics systems, but now recalibrated with respect to CO_2 emissions (Figure 1).

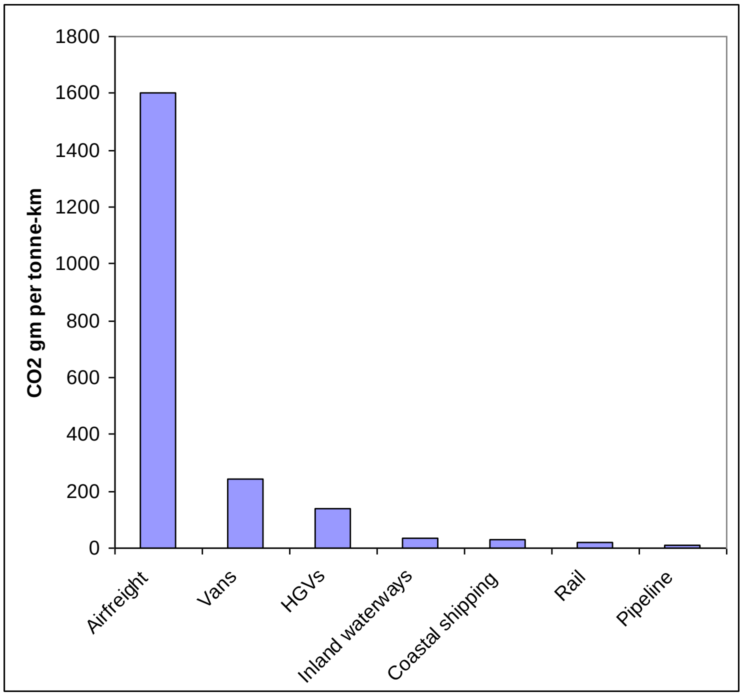
Figure 1: Optimising the Number of Warehouses in Logistics System with respect to CO_2 Emissions



4. Shifting Freight to Less Carbon-Intensive Transport Modes

Carbon intensity (expressed as gCO_2 per tonne-km) varies widely between transport modes (Figure 2). Shifting freight from modes with relatively high carbon intensities, such as air and road, to those with much lower carbon emissions, such as rail and water-borne services, can substantially decarbonise freight transport operations. As explained earlier, however, trucking and airfreight, the more carbon-intensive modes have been increasing their share of the freight market in most parts of the world. Governments and multi-national organisations, such as the European Union, are endeavouring to reverse this trend in various ways, by investing in rail, inland waterway and port infrastructure, providing subsidies for the purchase of vehicles and equipment and revenue-support for rail and water-borne services. The Marco Polo II programme in the EU, for example, has the objective of shifting the equivalent of the forecast increase in cross-border road tonne-kms (20.5bn) between 2007 and 2013 onto rail or water (Millan de la Lastra, 2007). Full internalisation of the marginal social costs of transport, incorporating a realistic valuation of the social cost of carbon emissions, as currently proposed in the European Commission, would also be likely to induce a significant shift to green modes. This would, for example, correct the current fiscal anomaly which exempts aviation from taxation on the kerosene that it uses, despite the fact that burning this fuel at high altitude has a global warming effect between 2 and 4 times greater than running trucks on diesel fuel.

Figure 2: Variations in the Carbon Intensity of Freight Transport Modes



Source: McKinnon (2007b)

The use of rail and waterborne services is inhibited by factors other than cost, however, which government economic incentives alone cannot correct. Intrinsically, these modes have lower flexibility and accessibility and, in the case of short sea shipping and inland waterways, much slower transit times. Their competitiveness can also be impaired by poor service quality and inadequate marketing. There is evidence too that freight purchasing decisions are often biased towards particular modes, as logistics managers do not objectively appraise the various modal options. In recent years, however, many large manufacturers and retailers, such as Procter and Gamble and Tesco, have made a serious effort to expand their use of the rail network, ostensibly for environmental reasons.

5. Increasing Vehicle Utilisation

Improving the loading of vehicles reduces the amount of traffic (measured in vehicle kms) needed to move a given quantity of freight (measured in tonne-kms). There is a corresponding reduction in energy consumption and CO_2 emissions per tonne-km. Most of the discussion of vehicle utilisation is confined to road transport, partly because it is the dominant mode but also because relatively little data is available on the loading of other modes. There is, nevertheless, considerable scope for improving load factors on rail, air and sea.

The utilization of vehicle capacity is constrained by many factors relating to regulations, market conditions, equipment, infrastructure and internal company management. (McKinnon, 2007c). One of the most critical factors affecting vehicle loading is the inter-functional relationship between transport and other activities such as production, procurement, inventory management, warehousing and sales. Companies often quite rationally assign these other activities priority over transport efficiency. For example, inventory savings from just-in-time replenishment or reductions in handling costs accruing from the use of roll-cages may exceed the additional cost of running a truck only part-loaded. It can also be economically justifiable to deliver small orders to important customers in an effort to secure their longer term loyalty. As the pressure to decarbonise transport operations mounts, however, there may have to be a re-ordering of these corporate priorities.

A broad range of measures can be applied to improve vehicle loading, save fuel and cut CO_2 emissions. These include improved backloading (McKinnon and Ge, 2006), the use of more space-efficient handling systems and packaging (A.T.Kearney, 1997), the adoption of more transport-efficient order cycles, for example encouraging customers to adhere to an ordering and delivery timetable and concentrating distribution in particular zones on particular days and consolidating freight in larger / heavier vehicles (McKinnon, 2005; Arcadis, 2006; Vierth et al, 2008). The last of these measures, however, can have the 'second order' effect of displacing freight from lower carbon rail and water-borne modes (German Environment Ministry, 2007; IUC et al , 2008). To reach high levels of vehicle loading it is often necessary for companies to collaborate and share vehicle capacity. For instance, Kelloggs and Kimberly-Clark, firms with similarly low density products and complementary transport demands, have worked with TDG, their logistics service provider in the UK, to save jointly around 430,000 vehicle-kms per annum in the UK by co-ordinating their transport (Anon, 2008).

6. Raising the Energy Efficiency of Freight Transport Operations

6.1 New Vehicles: Over the past 40 years the average fuel efficiency of new trucks has been improving at a rate of around 0.8-1% per annum (Duleep, 2007). The main improvements were made in the 1970s and 80s. Since 1990 incremental fuel efficiency gains from the refinement of existing vehicle technology have been diminishing partly as a result of tightening controls on noxious exhaust emission mainly on NOx and particulate matter. Cutting these emissions has, unfortunately, carried fuel and CO_2 penalties, bringing climate change and air quality objectives into conflict. Recent research, however, has suggested that a range 'low carbon' technologies can be deployed in new trucks in the short-to medium term (Baker et al, 2009). These include turbo-charging of engines, low-rolling resistance tyres, improved aerodynamic profiling, hybridisation and anti-idling devices. For technical improvements to be widely diffused and truck manufacturers to be incentivised to make them, operators will have to attach greater importance to fuel efficiency and carbon emissions in their vehicle purchasing decisions. Research in Finland found variations of 5-15% in the fuel efficiency of different brands of new truck (Nylund and Erkkila, 2007). In Japan the government has intervened and decided to impose fuel economy standards on new trucks from 2015. Truck manufacturers serving the Japanese market will have to raise the average fuel efficiency of their new vehicles from 6.30 kms / litre in 2002 to 7.09 kms / litre in 2015. Average CO_2 emissions will have to fall from 415 to 370 per vehicle-km, a 12% decrease (Konuma, 2007).

According to other recent studies, substantial energy efficiency gains and CO_2 reductions are possible in railfreight (RSSB, 2007), shipping (International Committee for Clean Transportation, 2007) and airfreight (ACARE, 2008) operations. A 'super-eco ship' designed by the Japanese shipping line NYK, which could be in service by 2030, would have a carbon footprint per container 69% lower than the average container ship afloat today. This drastic reduction in carbon intensity would be achieved mainly by a combination of hull redesign and the use of fuel cells, solar panels and sails. The potential also exists to reduce CO2 emissions per traffic unit in aviation by 40-50% by 2020, though fuselage redesign, advances in engine technology and improved air traffic control (ACARE, 200) .

6.2 Vehicle Operation and Maintenance: Potentially greater savings can accrue from improvements in the operation, loading and maintenance of freight vehicles over their working lives than from technical advances in the design of new vehicles. Companies can apply a wide range of fuel conservation measures, which collectively cut fuel consumption per km by a significant margin (Ang and Schroeer, 2002). One of the most cost-effective measures in the road freight sector is driver training (SAFED, 2008). To derive longer term benefit from this training, companies usually have to monitor driving performance closely and give drivers incentives to continue driving fuel-efficiently. Railway companies, such as Deutsch Bahn, have also improved their fuel efficiency through the use of similar programmes for train drivers.

A wide range of technical imperfections can prevent a truck from operating at optimum fuel efficiency. Typical defects include: poor combustion, fuel leaks, under-inflated tyres and axle mis-alignment. For instance, a 1 degree misalignment of a single axle on a multi-axle trailer can raise fuel consumption by roughly 3%, while a 2 degree misalignment will increase it by 8% (Department for Transport, 2006). The adoption of a tighter maintenance regime can ensure that any excess fuel consumption and carbon emissions are minimised.

7. Reducing the Carbon Intensity of Energy Used in Freight Transport

The key to achieving deep cuts in carbon emissions at a national level will be a move to low carbon electricity generation, exploiting renewables, nuclear power and the application of carbon capture and storage technology to fossil-fuel power plants. The challenge for the logistics sector will be to access this low carbon electricity. It can be directly transmitted to electrically-hauled freight trains, giving governments and railway companies an added incentive to electrify more of the rail network. It can also be used to recharge the batteries of electric vans and rigid trucks. Electric and diesel-electric hybrid technology is likely to be confined to these smaller freight vehicles, leaving the heavier, long haul trucks dependent on internal combustion engines for the foreseeable future, though switching increasingly to those forms of biofuel that meet stringent environmental criteria and yield a net GHG saving on a well / field to wheel basis.

8. Decarbonising Warehousing Operations

As warehouses are electrically operated they will benefit from the decarbonisation of electricity generation. While this longer term move to low carbon electricity supply progresses, there are other carbon reduction measures that can be applied at a local level to individual warehouses in the meantime. The warehouse developer Prologis, for example, has designed a prototype distribution centre which 'can achieve a 69 per cent reduction in operational carbon and energy compared with a typical UK warehouse' (Dalton, 2009). This dramatic reduction in emissions is achieved mainly by 'reducing the demand for heating through good insulation and airtight construction methods and reducing the need for artificial light by increasing the use of daylight supplemented by energy-efficient lighting systems'. It is also possible to install wind turbines and solar panels to permit 'micro-generation' of renewable energy locally where weather conditions permit and 'feed-in' tariffs offered by operators of the national electricity grids are financially attractive. Temperature-controlled warehouses (and vehicles) present a particular decarbonisation challenge as the refrigerant gases they use can have a global warming potential thousands of times higher than that of CO_2. HFC123, for example, has a global warming effect 11,700 times greater (DEFRA, 2007). Strenuous efforts must be made, therefore, to minimise the leakage of these gases from refrigeration systems across the supply chain. The energy efficiency of materials handling equipment is also being enhanced. This, coupled with the use of low / zero carbon electricity for recharging the batteries of fork-lift and reach trucks may ultimately make their operation carbon neutral.

9. Conclusions

Companies can reduce carbon emissions from their logistics operations in many ways. Most of the decarbonisation measures discussed in this paper will cut costs as well as reduce emissions, generating streams of economic and environment benefit. They are often described as the 'low hanging fruit' as they are relatively easy to implement and self-financing in the short to medium term. Harvesting all this 'fruit', however, will probably not be enough to drive emissions down to the level required to meet national and international climate change targets. Carbon reduction measures that carry a significant financial penalty may have to be introduced, partly to restrain the strong underlying growth in demand in logistics services.

The decarbonisation of logistical operations cannot occur in isolation. Carbon reduction efforts in different sectors will need to be co-ordinated and full LCAs conducted to ensure that on an 'end-to-end' supply chain basis GHG emissions are minimized. Under some circumstances it may actually be environmentally beneficial to increase CO_2 emissions from logistics in order to achieve greater CO_2 savings in other business activities. Adaptation of the build environment to the climate change which is already 'in the pipeline' will also generate new demand for logistical services. It is possible that even once the decarbonisation measures described in this paper have been applied, the additional logistical support required to realign vulnerable infrastructure, strengthen flood protection, expand renewal energy and nuclear power systems and relocate population will still cause the overall carbon footprint of logistics to expand.

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