Greening Logistics: Sustainable Best Practices

SEStran document prepared in partnership with TRI

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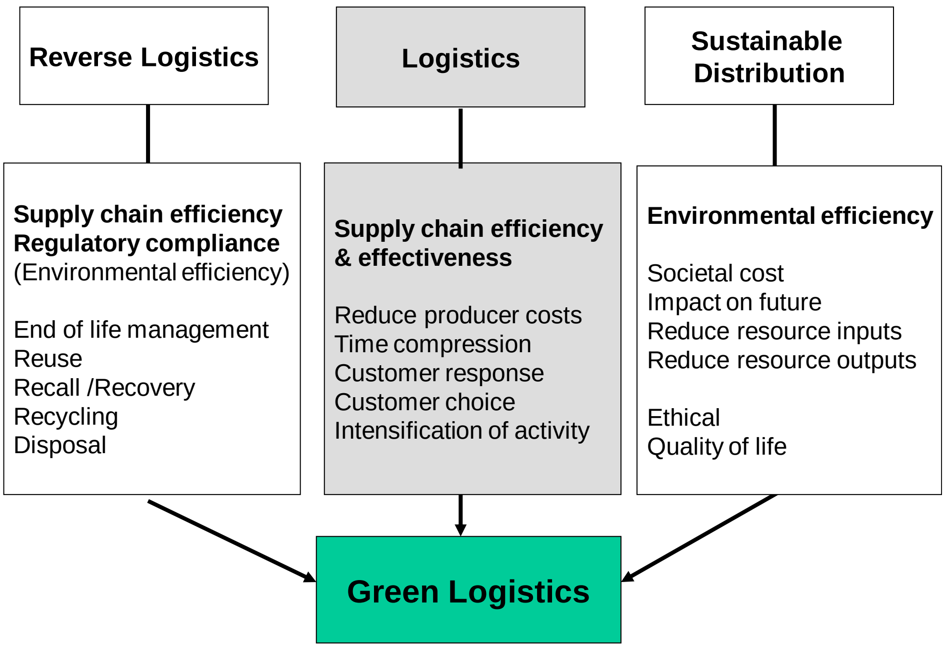
I. Introduction and Scope of Report

The environmental impact of logistics has become an increasingly important issue as global warming and its effects have become internationally recognised and companies have been forced to consider the sustainability of their operations. Green logistics is a term which has been coined to bring together the various aspects of environmental sustainability in logistics. It encompasses many elements, some of which are shown in Figure 1. In this report we will be focussing on the environmental impacts of the ***long haul*** portion of logistics and mentioning the subsidiary aspects only where they impact on this long haul element.

Figure 1. Strands of Green Logistics



Source: Adapted from Rodrigue, Slack and Comtois (2009)

Logistics is responsible for a variety of negative impacts (externalities), including air pollution, noise, accidents, vibration and visual intrusion. Section 1 examines these various externalities and discusses how their impact can be assessed. As climate change is now considered to be the most serious environmental challenge facing mankind, the remainder of this report focuses on greenhouse gas (GHG) emissions from freight transport, although this is not to denigrate the other effects.

In measuring the environmental effects of logistics it is important to distinguish different levels of impacts. The International Green House Gas Protocol Initiative has developed the following categorisation:

SCOPE 1 emissions – direct GHG emissions from sources owned or controlled by the entity, (e.g. emissions from fossil fuels burned on site, in vehicles etc.).

SCOPE 2 emissions – indirect GHG emissions resulting from the generation of electricity, heating or cooling or steam generated off-site but purchased by the entity and the transmission and distribution losses associated with some purchased utlilities (e.g chilled water, steam).

SCOPE 3 emissions – indirect GHG emissions from sources not owned or directly controlled by the entity but related to the entity's activities (e.g travel and commuting by employees, solid waste disposal).

In this report, we will focus on SCOPE 1 emissions from logistics operations, which could also be termed 'first order' impacts. There are also what might be termed 'second order' impacts which result *indirectly* from logistics operations and take various forms. For instance, advances in logistics have facilitated the process of globalisation which, in turn, has had huge environmental consequences. Partly to accommodate the growth in freight traffic, governments have expanded transport infrastructure and this too has often encroached on sensitive environments. In this report we concentrate on the first order impacts and make only brief reference to the wider second order effects. Additionally, since most of the first order impacts emanate from the transport of goods, rather than their storage and handling, the attention will focus primarily on this activity. The second part of the report analyses the various ways of reducing the environmental impact of logistics, again focusing on the long-haul element. However, we will first take a look at the scale and importance of logistics within Europe.

II. The Importance of logistics

Logistics has become one of the most important elements of any business and with the globalisation of trade, its importance has increased, along with its complexity. In the 27 states of the EU, there are 5m km of paved roads, including 65,100km of motorway; 212,800km of rail lines of which 110,458km are electrified and 42,709km of navigable inland waterways. Total inland freight amounted to approximately 2,300,000 million tonne kilometres (mtk) and is expected to grow by around 2.1% a year until 2030 (Eurostat, 2013). Of this, 76.4% was transported by road, 17.1% by rail and 6.5% by inland waterway. There is a massive difference in the percentage carried by mode between countries, but overall, road actually increased its share by 2.7% between 2000 and 2010 whilst rail fell by a similar amount. All modes can be used for domestic and international transport of goods. The use of rail for international transport depends to a large extent on the geographical location of the country and ranges (ignoring Ireland, Malta and Cyprus which have 0%) from 2% in the UK to 91% in Latvia (Eurostat, 2013). Table 1 shows the amount of freight carried by EU state and the modal share.

Table 1. Inland freight transport (mtkm) and modal split (%) by country, 2010

EU State	Road	Rail	Inland waterway	Road	Rail	Inland waterway
		Million tkm			Modal split (%)	
Belgium	33107	6268	9251	69.5	12.5	18
Bulgaria	21214	3291	4311	68.1	10.7	21.2
Czech Republic	54830	14316	42	79	21	0.1
Denmark	16120	2239	-	87	13	-
Germany	323833	107317	55027	64.9	22.2	12.9
Estonia	5912	6271	-	45.8	64.2	-
Ireland	10108	105	-	99.2	0.8	-
Greece	29815	614	-	98	2	-
Spain	208843	9748	-	95.8	4.2	-
France	185658	34202	9029	82.2	13.5	4.3
Italy	142885	19787	-	90.4	9.6	0.1
Cyprus	941		-	100	-	-
Latvia	12131	21410	-	38.1	61.9	-
Lithuania	21512	15088	-	59.1	40.9	-
Luxembourg	8835	288	305	93.5	2.7	-
Hungary	34529	9118	1840	75.1	19.6	3.9
Malta			-			
Netherlands	73333	6378	46278	62.1	4.9	33
Austria	28542	20345	2123	56.3	39	4.7
Poland	207651	53746	161	80.6	19.4	0.1
Portugal	36453	2322	-	93.9	6.1	-
Romania	26349	14719	11409	49.2	23.5	27.2
Slovenia	16439	3752	-	82.3	17.7	-
Slovakia	29179	8105	931	74.8	22	3.2
Finland	26787	9295	-	75	24.8	0.2
Sweden	36932	22864	-	60.7	39.3	-
UK	146685	18576	-	88.7	11.2	0.1
Liechtenstein	312	10	-	97.8	2.2	-
Norway	19188	3496	-	85	15	-
Switzerland	13828	11526	-	54.4	45.6	-

Croatia	8926	2438	692	71.2	21.2	7.6
Turkey		11303		94.9	5.1	-

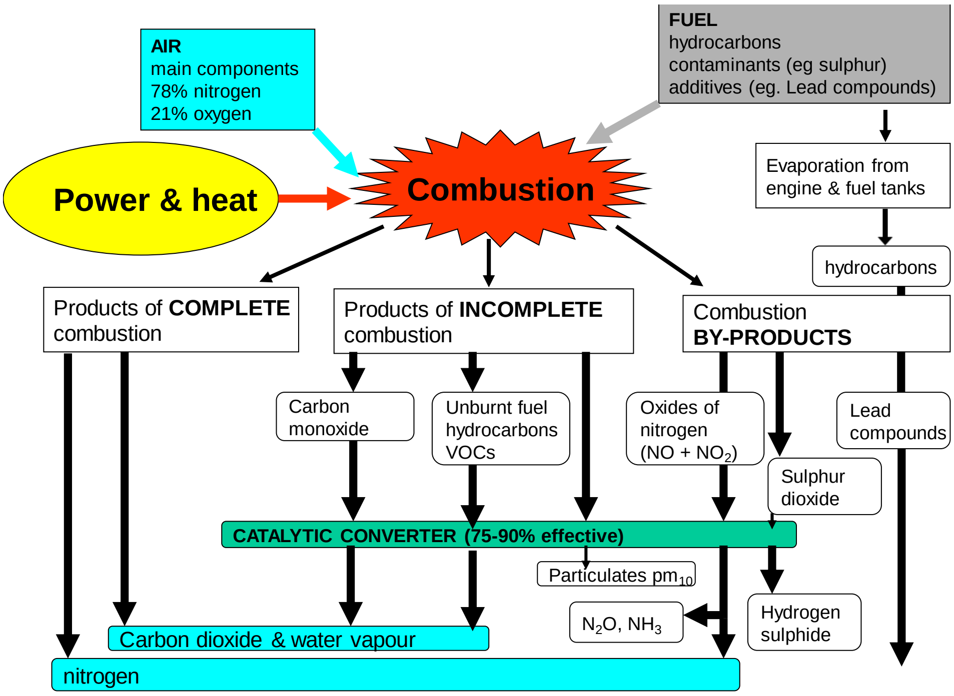
Source: Eurostat 2013a (see original tables for compilation dates and notes)

III. The Environmental Impact of freight transport

1. Emissions from freight transport

There is a growing international literature on the environmental impacts of HGVs (see for example, den Boer, Brouwer, Schroten and van Essen, 2009; McKinnon, Cullinane, Browne, and Whiteing, 2010). Emissions from freight transport largely depend on the amount and type of fuel used. As discussed later, various combinations of alternative fuel mixes with conventional diesel are possible. However, the main fuel used by long haul goods vehicles (referred to in this report as trucks) as well as conventional rail locomotives and ships continues to be diesel. Trucks emit pollution mainly because the combustion process in their engines is incomplete (see figure 2). Diesel and petrol contains both hydrogen and carbon. If it were possible to achieve perfect combustion, 100% of the hydrogen would be converted to water and all the carbon into CO_2. However, because combustion is not complete, tailpipe emissions of pollutants such as hydrocarbons, carbon monoxide and nitrogen oxides result. In most countries, a substantial but relatively small amount of freight is moved by electrically-powered freight trains and a very small amount by electric road vehicles. In these cases, the pollution arises at the point where the electricity is generated and the nature of that pollution depends on the source of the primary energy (i.e. whether it is coal, nuclear, hydro or other, sustainable sources).

Figure 2. Emissions and the combustion of fuel



Source: McKinnon, A.C Lecture notes, Heriot Watt University

According to the Inter-governmental Panel on Climate Change (IPCC, 2007) scientific evidence that human activity is the main cause of global warming is now 'unequivocal'. It explains that "greenhouse gases are the gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds" The greenhouse effect arises because GHGs and some particles in the atmosphere allow more sunlight energy to filter through to the surface of the planet relative to the amount of radiant energy that they allow to escape back up to space. The IPCC (1996) lists 27 greenhouse gases. These are combined into 6 categories in the Kyoto Protocol agreed in December 1997, namely:

- Carbon dioxide (CO_2)
- Methane (MH_4)
- Nitrous Oxides (NOx)
- Hydrofluorocarbons (HFC)
- Perfluorocarbons (PFC)
- Sulphur Hexafluoride (SF6)

Table 2 shows the emission factors of the main modes of freight transport.

Table 2: Average emission factors for freight transport modes within Europe

		Energy Consumption (kj/tkm)	**CO_2 (g/tkm)**	**NOX (mg/tkm)**	**SO_2 (mg/tkm)**
Aircraft		9,876	656	3253	864
Truck >34-40-t	Euro 1	1,086	72	683	
	Euro 2	1,044	69	755	
	Euro 3	1,082	72	553	90
	Euro 4	1,050	70	353	
	Euro 5	996	66	205	
Train	Diesel	530	35	549	44
	Electric	456	18	32	64
Waterway	Upstream	727	49	839	82
	Downstream	438	29	506	49

Source: Table 22 and Table 9 in IFEU (2008)

Caution must be exercised, however, in interpreting comparative environmental data for freight transport modes (McKinnon, 2008). The relative environmental performance of a particular mode can be affected by:

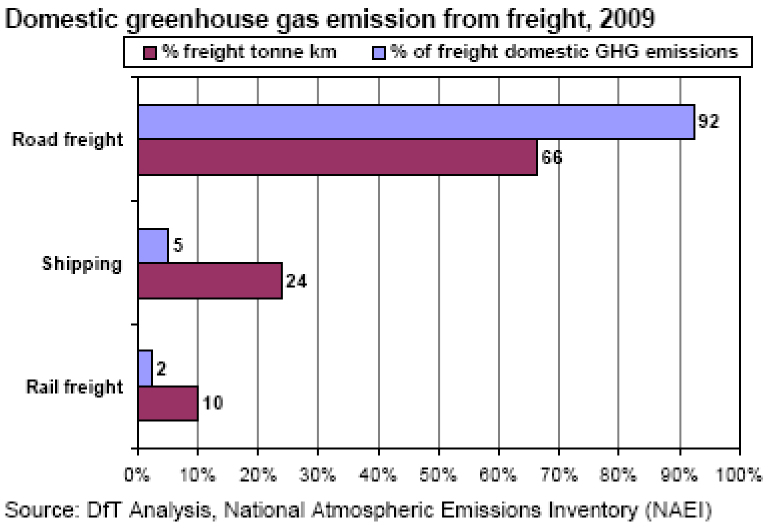
- Differing assumptions about the utilisation of vehicle capacity
- Use of tonne-kms as the denominator misrepresenting modes specialising in the movement of lower-density cargos
- Extrapolation of emissions data from one country to another with different transport and energy systems
- Allocation of emissions between freight and passenger traffic sharing the same vehicles (such as aircraft and ferries)
- Neglect of emissions associated with the construction and maintenance of infrastructure
- Restriction of the analysis to emissions at source rather than 'well-to-wheel' data

Carbon dioxide accounts for by far the largest proportion of GHGs in the atmosphere (approximately 85%), which is why there is so much attention focused on this particular gas.

In the UK, transport accounts for 27% of total domestic GHG emissions, and freight transport was responsible for around 5% (DfT, 2013a). At a global level, the movement of freight accounts for roughly a third of all the energy consumed by transport (IPCC, 2007).). In the UK in 2009 all modes of freight transport emitted a total of 122.2 million tonnes of CO_2 equivalent ($MtCO_2e$[1]). Road freight transport accounted for 92% of this total. HGVs accounted for 17.2% of UK domestic GHG emissions, with rail accounting for 1.8% and domestic shipping 1.3% (DfT, 2013a). Figure 3 shows the proportions of work done and the GHG emitted by the main freight modes in the UK.

[1] Some gases have a greater impact on global warming potential than an equivalent amount of others, so GHG emissions are expressed in terms of the equivalent million tonnes of CO2 (MtCO2e).

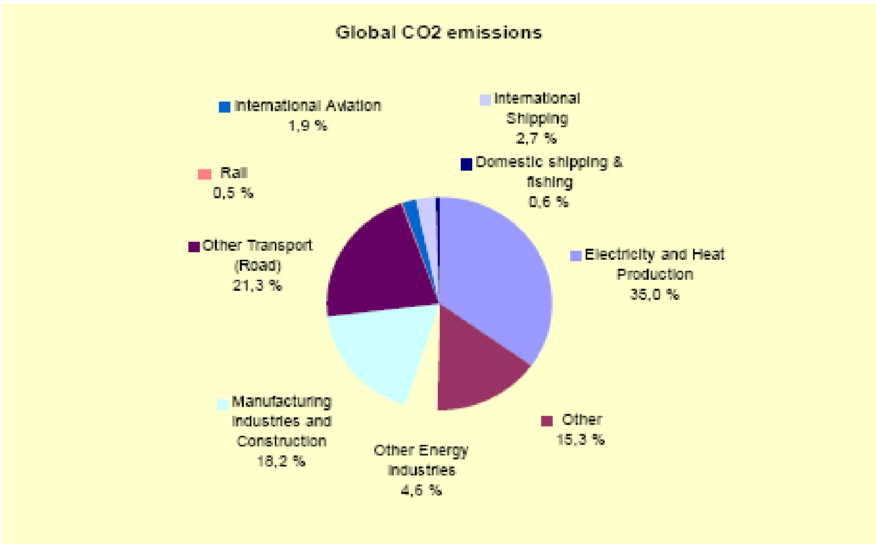
Figure 3.



Source: DfT (2013b)

On an international scale, figure 4 below shows the global CO_2 emissions by sector and mode.

Figure 4. Global CO_2 emissions by sector and mode



Source: Buhaug et al (2009)

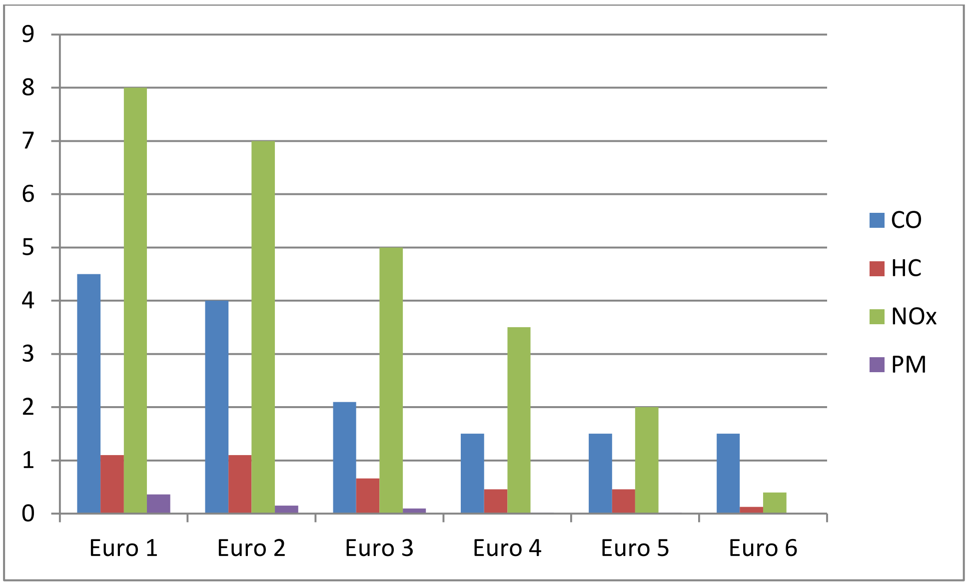
Since the early 1990s, emissions from diesel-engined-HGVs have been strictly controlled by EU legislation. New HGVs have been the subject of progressively tightening environmental standards, known as EURO emission standards. Emissions of nitrogen oxides and particulate matter have been targeted particularly and will be almost negligible after 2013 (see Table 3 and figure 5). Many responsible logistics companies have been pro-active, implementing the standards before the enforcement date. For instance, one vehicle manufacturer has produced an enhanced environmentally-friendly vehicle (EEV) that compared with Euro V standards, emits 50% less soot, 87% less CO and 88% less HC.

Table 3: Emission Standards for Heavy Duty Diesel Engines (g/kWh)

Tier	Date of implementation	CO	HC	NOx	PM
Euro 1	1992 (>85kw)	4.5	1.1	8.0	**0.36**
Euro 11	1998	4.0	1.1	7.0	**0.15**
Euro 111	2000	2.1	0.66	5.0	**0.10**
Euro 1V	2005	1.5	0.46	3.5	**0.02**
Euro V	2008	1.5	0.46	2.0	**0.02**
Euro V1	**2013**	**1.5**	**0.13**	**0.4**	**0.01**

Source: www.nao.org.uk

Figure 5. Euro Emissions standards for trucks (g/kWh)



Source: EU regulations

Rail transport has also become considerably less environmentally damaging over the past couple of decades. In the UK, since privatisation took place, rail freight operators have invested heavily in Class 66 locomotives which are far more fuel efficient than their predecessors. According to Freightliner (2006), emissions of carbon monoxide are 95% lower, hydrocarbons 89% lower and nitrous oxides 38%

lower. Generally, however, because pressure on the rail industry has been less than on the road freight industry, environmental improvements have been slower to be introduced (Woodburn and Whiteing, 2010). Locomotives running on electricity are obviously much less polluting at the place of use. The environmental damage caused by these vehicles depends on the source of the electricity used, with coal being probably the worst offender and power from sustainable sources being the best.

Emissions from barges and ships on inland waterways are similar to those by train in terms of grams of CO_2 per tonne km. Although coastal shipping has traditionally been viewed as a much more environmentally friendly mode of transport, emissions of pollutants, particularly sulphur have, until recently, been very high. The vast majority (95%) of the world's shipping fleet runs on diesel. However, diesel used in ships (usually referred to as bunker oil) is different from that used in road vehicles in that it is of lower quality. Even the most modern marine engines produce higher emissions per power output than regulated on-road diesel engines. In fact the bunker oil used in ocean-going ships has been estimated to produce over 100 times per unit volume the amount of sulphur of on-road diesel. Particulate matter (PM) emissions from ships are also very high. Indeed it has been calculated that 60,000 premature mortalities worldwide are related to ship-related PM emissions. Whilst in a port, ships contribute a substantial amount of emissions to the local environment. Around 55-77% of total emissions in port regions can be attributed to ships. Following much procrastination by the EU and the shipping industry in general, sulphur emissions have now been the focus of a great deal of attention and ships are now being forced to use fuel with much lower sulphur content (Cullinane and Cullinane, 2013)(see section 7 for more detail).

2. Noise pollution

Road traffic is the main cause of environmental noise at the local level. The immediate adverse effects of noise disturbance include annoyance, communication difficulties, loss of sleep and impaired cognitive functioning resulting in loss of work productivity; longer-term, physiological and psychological health issues may also arise. Currently, around 30 per cent of the European Union's population is exposed to road traffic noise and 10 per cent to rail noise levels above 55 dB(A).

In the UK 90 per cent of people hear road traffic noise while at home and 10 per cent of these regard this noise source as highly annoying (Watts et al. 2006).

Trucks generate road noise from three sources:

1. Propulsion noise (power train / engine sources) which dominates at low speeds (less than 50kmph);

2. Tyre / road contact noise, which is the main cause of noise at speeds above 50kmph; and

3. Aerodynamic noise, which increases as the vehicle accelerates.

European vehicle noise standards for individual vehicles were introduced in the early 1970s (Directive 70/157/EEC), when the permitted noise emissions for trucks were set at 80dB(A). Noise standards have been tightened several times since then. Significant reductions in noise levels have been achieved by technical advances in engine design, tyres and the aerodynamic profiling of vehicles. Nevertheless, overall noise levels have not improved, as the growth and spread of traffic in space and time has largely offset both technological improvements and other abatement measures. The trend towards heavier and more powerful goods vehicles and the use of wider tyres has further exacerbated the problem.

In 2001, the European Union launched regulations that limited the levels of noise generated by vehicle tyres (Directive 2001/43/EC). Tyre noise was targeted specifically for two reasons. First, tyre rolling noise is generally the main source of noise from trucks at medium and high speeds and second, as tyres are replaced more frequently than vehicles, implementing tyre noise standards was considered to be one of the fastest ways to achieve road noise reductions.

In addition to quietening the vehicle, it is possible to cut noise levels by altering the acoustic properties of the road surface. FEHRL (2006) outline a range of noise-abatement measures than can be applied in the design and construction of road infrastructure.

3. Accidents

Accidents cause personal injury and death for those involved, and general inconvenience for other road users. Overall accidents involving HGVs by distance travelled are fewer than for cars, although there is a higher likelihood of a HGV being involved in a fatal accident. This is partly a reflection of HGVs greater momentum, and partly because of the relatively high proportion of time that they are driven on faster roads.

The accident rate in the EU varies enormously, as shown in table 4. The country recording the highest fatality rate in accidents involving HGVs (Poland) has over 7 times more fatalities per million population than the country with the lowest rate (Italy). This difference is likely to be caused by a variety of factors including driver behaviour, age of vehicles, vehicle maintenance, road standards and the nature and enforcement of laws affecting safety. The figures are also distorted by international variations in the statistical definition of a fatal traffic accident. This definition partly depends on the maximum length of time elapsing between the accident and the death and this time varies from country to country. Table 4 also shows that in every country where comparable figures exist, the number of fatalities has dropped considerably over the period 2000-2009; in some cases more than halving.

Table 4: Fatalities in accidents involving HGVs – EU (fatalities in HGVs plus all other fatalities)

Country	2000	2009	Rates per million population, 2009
Belgium	204	117	10.8
Czech republic	247	163	15.5
Denmark	97	35	6.4
Germany	974	536	6.5
Spain	920	353	7.7
France	1113	683	7.8
Ireland	67	44	10.0
Italy	476	n/a	3.3
Luxembourg	5	2	4.0
Malta	n/a	1	n/a
Netherlands	168	95	5.8
Austria	143	81	9.6
Poland	1547	952	25.0
Portugal	284	120	11.3
Finland	77	70	13.3
Sweden	119	72	7.8
UK	581	287	4.7

Source: European Road Safety Observatory (2013). www.erso.eu

Approximately 85% of the fatalities in accidents involving HGVs take place in non-urban areas.

4. Land-Take and visual intrusion

Logistics activities take up a substantial amount of land – whether this is for roads or warehouses/depots. McKinnon (2009) estimated that warehousing sites occupied 23,500 hectares of land in the UK alone, representing around 1% of non-agricultural and forestry land. On the urban fringes of most major cities can often be found several kilometres of warehousing and distribution facilities. This land take contributes to the degradation of eco-systems as well as causing considerable visual intrusion.

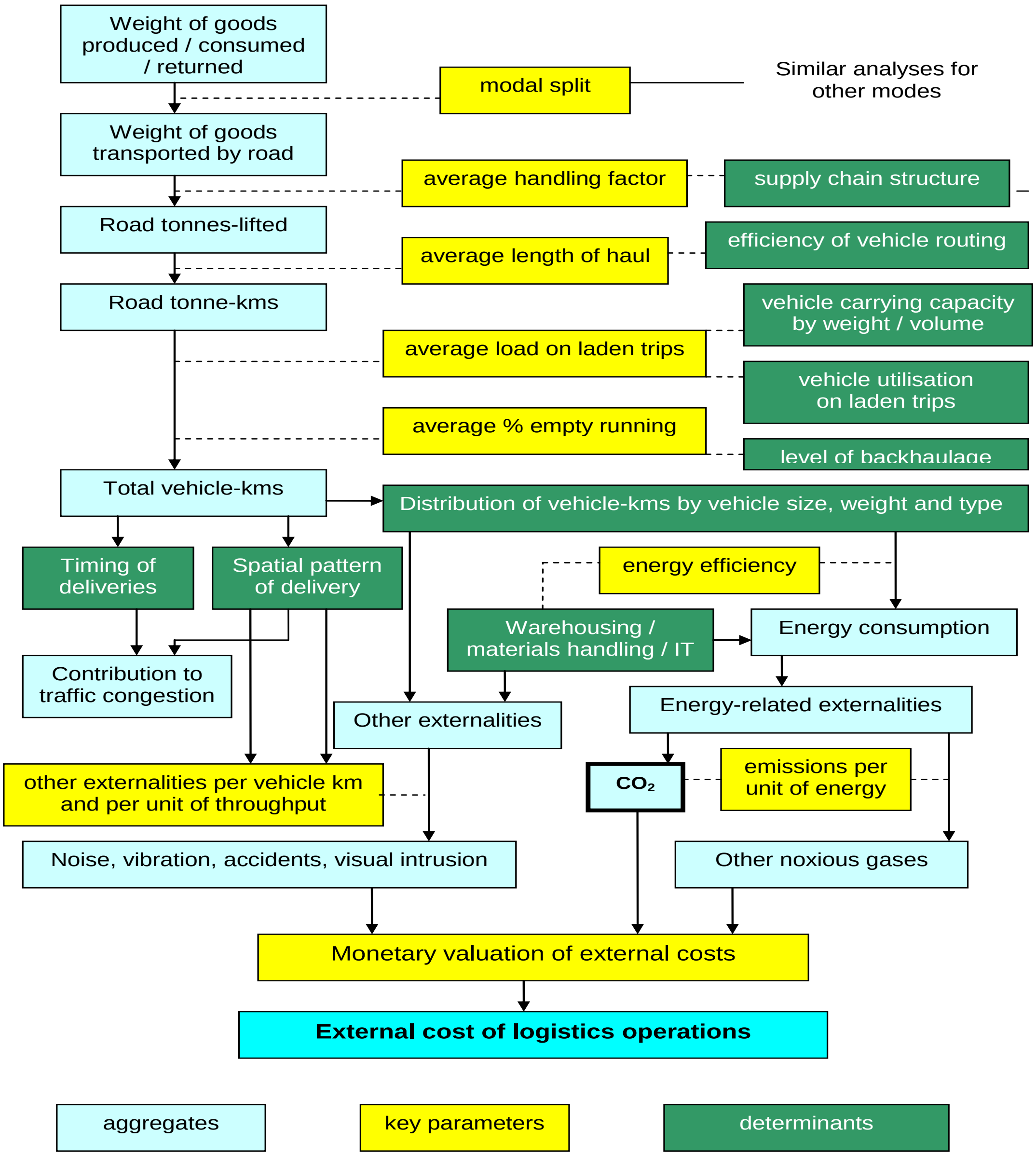
5. Resource sustainability

Fossil fuels such as diesel are by definition unsustainable, i.e. their availability is finite. In addition, many of the oil-producing countries are politically unstable and some like to use their power as oil producers in politically/economically dubious ways. The future of oil supplies is inherently unstable. As a consequence, the price of fuel is also subject to considerable fluctuation and this is likely to be exacerbated in the future. Although alternative sources of fuel are being sought, none are as yet as universally available as diesel.

IV. The Possibilities for Improvement

There are literally hundreds of measures, sometimes called interventions, which can be taken to improve the environmental sustainability of logistics operations. McKinnon (2013) has summarised the main issues in Figure 6.

Figure 6. Green Logistics Conceptual Framework



Source: McKinnon (2013)

1. Modal Switch

In order to improve the environmental credentials of logistics, probably the first measure that springs to mind is switching the transport of freight from the least sustainable mode (usually road) to the more sustainable modes (rail and water). Freightonrail.org.uk has calculated that a gallon of diesel will carry a tonne of freight 246 miles by rail as opposed to 88 miles by road. According to the DfT (2013), rail freight contributed to 7.59 million avoided lorry journeys in the UK in the year 2012/13. An alternative interpretation is that the number of lorry kms required to be undertaken to equal the amount of freight moved by rail in the UK was 1.6 billion km.

As discussed above, the extent to which different countries in the EU use rail and water to transport freight is very mixed. The reasons for this include:

(i) Geographical (island countries generally have lower use of rail; countries in the centre of Europe, which are used as transit countries to the major ports, have a greater use of rail);
(ii) Economic/Political (countries whose development has included heavy industries generally use more rail; countries where production and freight movement is, or has recently been, publicly owned, generally use more rail)
(iii) Environmental (countries which have had a much longer term policy on the environment, generally use more rail)

Whilst for sustainability reasons, a modal switch to rail is viewed as being beneficial, possibly for reason (ii) above, some countries have actually witnessed considerable switches of freight AWAY from rail and towards road. Thus, over the period 2000-2010, in 8 EU member states, and particularly in Austria and Belgium, rail has increased its modal share. However, in many other member states there has been a considerable modal switch to road (for instance, Poland's road share has increased by 23%, Slovakia's by 22% and there have been considerable increases for Bulgaria, Lithuania, Latvia, Czech Republic and Slovenia) (Eurostat, 2012).

Traditionally, rail has been more suited to the transport of bulk goods over long distances; so as Europe has become less heavily industrialised, the traditional market for rail has diminished. Containerisation reversed this decline somewhat but other trends, such as just in time production, have not favoured rail as flexibility is of key importance and rail has suffered from being rather inflexible (both in terms of being unable to deliver the door-to-door solutions that road could offer and the unwillingness of the industry to respond to modern needs).

The growth in the use of containers, swap bodies and more recently low-loaders/liners that can accommodate whole semi-trailers, has led to the development of inter-modal transport, where rail and/or water is used for the longer distance flows and the road legs are confined to the end of the journey. With inter-modal transport, it is the unit in which the goods are transported that is handled at the point of transfer rather than the goods themselves. For inter-modalism to increase, handling equipment and other network systems have to be standardised across modes and across countries and this has proved to be difficult when rail systems have been developed independently across Europe. Differences in rail gauges, fuel used (i.e. diesel vs electric) and bridge heights are three obvious examples. Developments such as the European Modular System facilitate inter-modal operations at the end of transport legs.

Figure 7. A DB Schenker intermodal container train

The EU has developed a Freight Action Plan (European Commission, 2007), in an attempt to coordinate policy initiatives relating to the performance of the freight sector. On modal shift, a number of initiatives are outlined including the development of 'green' transport corridors for freight (including the establishment of a freight-oriented rail network), the removal of barriers that hinder the use of rail and water-based solutions, the promotion of best practice and the development of performance indicators measuring sustainability. Through its 'Greening Transport' initiative, the EU aims to allow national governments to introduce user charging schemes to internalise the external costs associated with freight movement, particularly relating to the road haulage sector. Traditionally, road tolls have been allowed only to recoup infrastructure costs, although differential tariffs based on vehicles' environmental characteristics have been allowed since 2006. Proposals are being developed to allow a more comprehensive charging regime that will better reflect the environmental impacts of freight traffic. These should lead to more efficient road haulage operations (e.g. by encouraging more fuel efficient and less polluting vehicles), as well as a shift of traffic to rail and water in situations where they become more cost-effective than road (Woodburn and Whiteing, 2010).

The EU has a massive programme, the Trans-European Network (TEN-T) programme, 'to promote a single multi-modal network that integrates land, sea and air transport networks throughout the Union.' It is seeking to enhance interoperability and connectivity within the European freight transport industry. It recently celebrated the completion of a €5m investment in 10km of new track at Felixstowe 'North Rail Terminal' to improve the inter-modal transfer of containers from ship to freight trains. Such measures are succeeding in improving the situation, but the scale of the investment needed is immense and progress is slow. In the UK, the freight Mode Shift Grant support and the Freight Best Practice programme have provided considerable encouragement to modal shift; the first by providing financial support and the second by providing case studies to show what can be done.

Good practice in achieving modal shift to rail and water

In the UK, the Freight Best Practice programme contains 35 case studies exemplifying the possibilities for using rail and water-based freight solutions (DfT, 2008a). These case studies feature logistics service providers, retailers, those involved in the movement of bulk products and container operators. The use by large retailers of rail in the UK (sometimes referred to as 'consumer rail freight') has been a big breakthrough which has accelerated the growth in rail freight. This is a sector which has traditionally used road for practically 100% of its logistics, both inbound and outbound.

Freight grants have been a fundamental ingredient in the success of a number of the flows that have shifted from road to 'greener' modes. For instance, in spite of road's predominance in the UK, supermarkets have recently been promoting their own trials using other modes, including barges, domestic shipping and rail. The Scottish distribution centres (DCs) are generally served by road from the larger DCs in England, but some supermarkets are beginning to try moving containers now by rail or sea. ASDA uses shipping services to deliver products directly to its Import Deconsolidation Centre at Teesport in north east England. The company also uses rail for general merchandise and clothing products moving between the Midlands and central Scotland and even within Scotland. For example, it is sending some containers by rail from Grangemouth to Aberdeen. These initiatives are key to supporting ASDA's target to reduce carbon emissions by 40 per cent by the end of 2010.

Similarly, Tesco uses rail between the Midlands and central Scotland, saving more than 7 million road kilometres per annum and leading to around 6,000 fewer tonnes of CO_2 being emitted each year. Tesco has also begun to use the inland waterway system to move containerised wine that is imported through Liverpool and bottled in Manchester. The 60 kilometre barge transfer along the Manchester Ship Canal removes 50 lorry journeys each week. A similar barge operation moves grain between the terminal in the Port of Liverpool and flour mills in Manchester, saving more than 125 lorry movements per week. Again, even within Scotland, Tesco is sending some containers by road from Livingstone to Grangemouth then by rail to Inverness. The Co-operative supermarket is running a trial of 2 containers per night from Coventry by road to Daventry in England, then rail to Coatbridge in Scotland then finally by road to their DC at Cumbernauld in Scotland (Wang and Monios, (2012), Woodburn and Whiteing, (2010)).

JG Russell uses rail to ship goods to Scotland for Costco and Morrisons and to ship whisky from Scotland to Europe then matches some flows by bringing wine from France to the distribution centre at Magna Park then takes a Costco load from there to Scotland (Wang and Monios, 2012). Stobart runs a weekly winter train service from Valencia (Spain) into the JG Russell terminal in Barking.

In the shipping sector, a number of container shipping lines such as Feederlink BV, OOCL and K-Line have developed short-sea and coastal services that move containers to ports that are closer to their ultimate destination rather than relying on land-based onward movement from the major ports (Wang and Monios, 2012).

In the UK, a company called FreightArranger has just completed a trial to provide a cloud-based intermodal brokerage and tracking system for consignors. It takes live container bookings for consignors looking to use rail for loads as small as a single container. This type of brokerage has the potential to improve rail usage in the future.

Modal transfer has also occurred in the bulk sectors that traditionally make great use of rail and water, highlighting the fact that there is often scope for still greater use of 'greener' modes even where they already have significant market share. For example, significantly greater volumes of coal can now be handled at the Port of Immingham as a result of investment in new equipment that can load 1,500 tonnes of coal into a train in 23 minutes. Investment in new equipment is fundamental to the success of many of these initiatives, and again grant funding is often available.

Days Aggregates received grant funding to assist with the purchase of mobile handling equipment to unload aggregates at terminals in the London area. More strategically, as part of the expansion of the Haven ports, covering Felixstowe and Bathside Bay, Hutchison Ports has committed to investing in the rail network to enable more container trains to operate and to carry high-cube containers more efficiently. In this case, private finance is being used alongside Government funding for the rail network, with the aim of increasing rail freight volumes from Felixstowe by 3 per cent each year (Woodburn and Whiteing, 2010).

Shipping companies have become increasingly involved in contracting train space on container services, in some cases even committing to regular full trainloads. Kuehne & Nagel uses a mix of dedicated trains, contracted space on multi-customer trains and spot hire of capacity, and is on record as stating that its container flows by rail are now more punctual than by road.

Similarly, the development of rail services sponsored by logistics service providers has been one of the most successful developments in the past decade in attracting consumer products to rail. Logistics companies such as The Malcolm Group, Eddie Stobart Ltd and John G Russell (Transport) Ltd, have become established players in the rail freight market, acting as consolidators to make up viable trainloads from their customer base and bridging the gap between the rail operators and freight customers. The Tesco rail freight example referred to earlier is an interesting example of supply chain cooperation, since Tesco provides 100 per cent of the northbound volume and 90 per cent of the southbound volume, with freight for other Eddie Stobart logistics company customers helping to fill the remaining southbound capacity.

Figure 8. Example of a multi-modal consumer-freight load

Source: TruckandTrack

A further major development in rail freight has been the use of rail for less-than-full truck loads (LTL). Innovative companies, such as Cargo Domizil in Switzerland, collect less than full truck loads from customers and take them to rail-side depots where they are combined for sending by rail. At the other end of the journey the goods are then sorted for onward delivery to the final customer.

Rail has historically been used to a greater extent in mainland Europe than in the UK. Austria, Switzerland and Hungary have been using rolling roads (where the whole truck including the tractor and, often, the driver, is loaded onto a train and is carried long distance before finishing the last leg by road) for many decades. Piggybacking, that is the carrying of semi-trailers on flat rail wagons, has also been happening for 20 years, since the development of the swap-body container.

Figure 9. Example of an innovative 'lowliner' wagon transporting Procter and Gamble goods from Teesport

Photo: Tom Curry

There are still many barriers to its greater use however. Loading gauges are still far from synchronised across countries despite the 2002 EU ERA Technical Specifications for Interoperability (TSI) guidelines which seeks to harmonize train systems in Europe. In the UK, where the loading gauge is smaller than most of mainland Europe, low-deck rolling stock can sometimes be used to carry taller (2.9m) shipping containers on low gauge lines, although the low deck rolling stock cannot carry as many containers. New 'P400' 'megatrailers' capable of carrying 2 lorry trailers, each of which can be loaded 100 tonnes of goods, have just been introduced to the UK. The aim is to be able to use these vehicles for flows into and out of mainland Europe. But as yet, their use is very restricted within the UK. The train is purported to reduce carbon emissions by 20% per trailer. As new types of semi-trailer are introduced into the road logistics market, new demands are placed upon the rail system to be able to deal with them.

Interoperability and, therefore, potential for modal switch depends not only on the physical and technical attributes of the rail system but also on the IT aspects. Routing and scheduling of international railfreight is currently not easy because of the proprietary nature of the IT systems in use around Europe's rail companies. This too will need to be addressed before there is a smooth flow of goods travelling around Europe on rail.

Potential rail-freight customers have often complained about the inflexibility of rail transport. Such complaints include that loads must be booked a long time in advance and cannot be easily changed; last minute orders cannot be accommodated; train timetables do not correspond well with the needs of their production/distribution patterns and rail management does not listen to their requirements. In a study of bulk whisky logistics in Scotland (MVA, 2011), it was considered that there was little potential for modal switch from road to rail. The main reasons for this were lack of critical mass; cost and flexibility issues and infrastructure problems. However, despite these problems, a trial took place in late 2013 using rail to carry bulk whisky spirit from Elgin (in the North of Scotland) to the intermodal terminal at Grangemouth (in the Centre of Scotland). It has proved to be quite successful.

A further issue is that in many countries, passenger rail has priority over freight rail. Timings are, therefore, not always good. It can be quicker to send good by road, even over long distances, than by rail or ship. Without massive investment in rail and water infrastructure, it is difficult to see how this can be changed.

Inland waterways are used to a considerable extent in many European countries (notably Germany, The Netherlands and countries on the Danube). They are usually used for the transport of non-time-sensitive bulk products. The area between Rotterdam and the south of Holland is currently being analysed to identify how mode shift from road to barge can be maximised. The problem (identified by NV Brabantse Ontwikkelings Maatscaapij (BOM)) is that there is an imbalance between the large quantities delivered by the large sea vessels and the small quantities needed by the smaller shippers inland. The solution appears to come in sharing of information along the supply chain.

Of course, although modal switch on its own will produce some improvements in environmental sustainability, it needs to be combined with other measures, discussed below, to maximise the benefits associated with it.

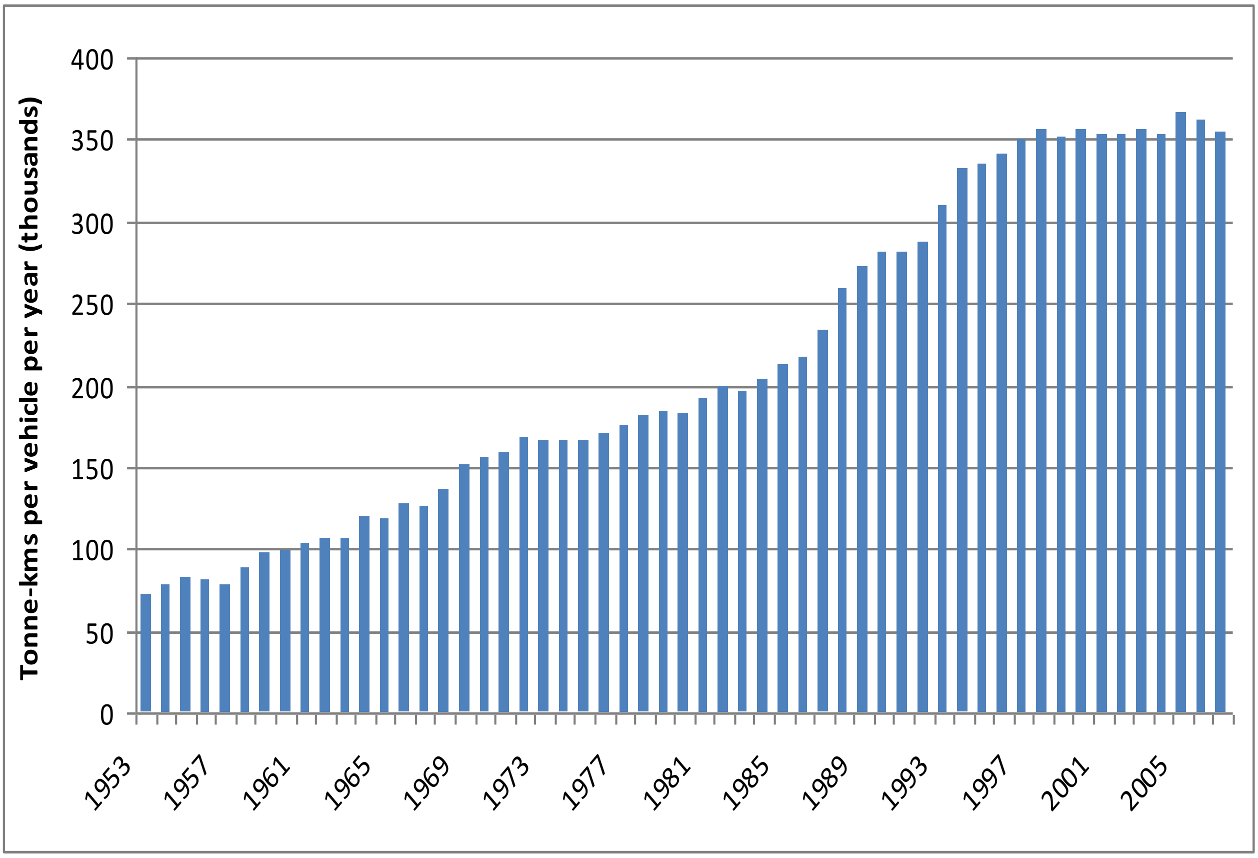
2. Efficiency Measures

Probably the single biggest measure that can be taken to improve the sustainability of freight transport is to increase the efficiency of the logistics process. McKinnon and Edwards (2010) illustrate this in the following:

- Approximately 25% of truck kilometres in EU countries is run empty, while in Ireland it averages around 37% (Eurostat, 2007)
- In the UK food supply chain supply, only about 52% of the available space on laden trips is actually occupied by a load (Freight Best Practice Programme, 2006).
- 44 tonne trucks in the UK, which can carry a maximum payload of 29 tonnes, transport on average only 17.6 tonnes when laden and 12.7 tonnes if allowance is made for empty running (Knight et al, 2008).

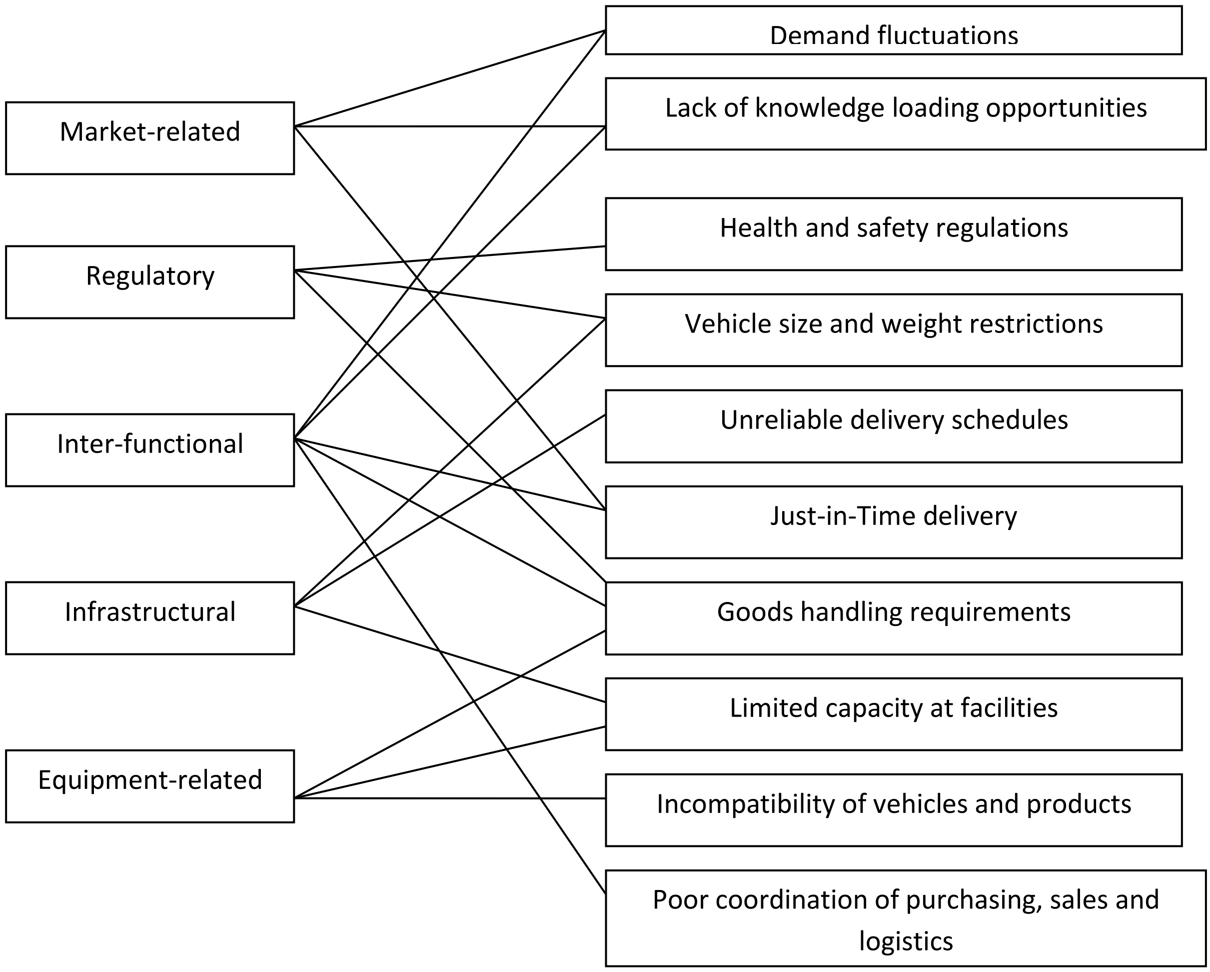
Gucwa and Schafis (2011) found that the greatest variation in energy intensity within the transportation mode is explained by the load carried per vehicle and the vehicle size. Figure 10 below shows how vehicle utilisation in the UK has improved over time, but there is still a considerable amount of work to do. Figure 11 shows some of the constraints impacting on vehicle utilisation.

Figure 10. UK Vehicle utilisation over time (HGVs)



Source: DfT 2007, McKinnon and Edwards, 2010

Figure 11. Some of the constraints on vehicle utilisation



Source: McKinnon and Edwards (2010)

It is necessary for logistics operators to engage in 'Smart Logistics' and reduce total tonne-mileage. The major ways of improving efficiency are:

2.1 Improving vehicle utilisation through:

(i) Maximising payload – whether it be truck, train or boat/ship, the energy intensity of logistics (fuel/tonne-km) is minimised when the vehicle is fully loaded. Maximising payload can be achieved through better use of ICT, load consolidation, proper siting of depots and all the things alluded to in figure 11. In the UK, statistics from the Freight Transport Association (FTA, 2013) show that the lading factor by weight of HGVs is 59%. Although this has improved over the years, there is room for further improvement.

(ii) Reducing empty running – is a subset of maximising payload. The FTA suggests that in the UK, the percentage of HGVs empty running is 29% and that this percentage has not changed over the last 5 years. Finding backloads and collaborating with competitors are key issues here. There exist many load matching companies who will help in providing backloads. However, many companies are loathe to use such companies because their own logistics activities are so finely tuned that any small problem with the backload compromises the whole operation. Finding a particular company or set of companies to work with over a longer time period with specific, appropriate products and locations is a better option.

(iii) Minimising down time – if vehicles are off the road for any reason (whether it be for technical or staffing reasons), they are not being used efficiently. Keeping the vehicle fleet as new as possible through vehicle replacement schedules in combination with proper computerised vehicle maintenance schedules can prevent breakdowns and maximise engine efficiency. Likewise, hiring the right staff and paying attention to staff morale as well as driver training in vehicle awareness and safe driving practices will also help. As far as possible, pairing particular drivers with particular vehicles will engender more of a sense of responsibility and enable them to pick up on any vehicle peculiarities. Driver involvement in the process and proper rewards = better vehicle performance.

(iv)Using the correct vehicle size/type – as a general rule, bigger = better in terms of efficiency and sustainability in all modes. Truck sizes have increased over time and there is pressure for them to increase further. Rail trailers and train lengths are also becoming longer, with greater carrying capacity and ships too. In the case of trucks, high cube vehicles have been introduced to maximise carrying capacity for low density, high volume loads; double-deckers are being increasingly used for some load types; longer trailers are also being tested. However, larger vehicles are only efficient if they are fully loaded. A partially loaded 38 tonne truck is less efficient in terms of the environment than a fully loaded 16 tonne truck. Similarly, a partially loaded train is likely to be less efficient than a number of trucks which are fully loaded.

Wincanton Transport has tested the use of longer semi-trailers (up to 15.65m) which can take 2 additional rows of pallets. They found that carbon reductions amount to approximately 15%. However, the costs for training the drivers have been considerable. It has been found that 2 double deck trailers can replace 3 standard trailers, saving approximately 22% on fuel and CO_2. John Lewis and many other companies are now using double-deckers. They are particularly suited to inter-depot trunking operations of retailers, parcel and pallet operators and manufacturers of high volume, low density products. Some companies, however, have not continued with their use because they have found that the additional loading and unloading times required negates any savings accruing from the trunking operations. The take-up of double-deckers and high-cube vehicles has also been compromised by the EUs attempts to limit the height of HGVs to 4m. This policy now seems to have been abandoned.

In an interesting development, John Lewis has designed a vehicle of 31 tGVW. This allows the vehicle to have a smaller engine and only 4 axles and is more fuel efficient without compromising the payload capacity.

2.2 Use of ICT (information and computer technology) – ICT can be used in a myriad of ways to increase vehicle efficiency and improve environmental sustainability. The most obvious include vehicle and driver data; paperless manifests; asset tracking; satellite navigation; safety and security systems; digital tachographs; traffic information systems and in-cab communications. The choosing and purchasing of ICT can be a daunting and expensive experience. There are many off-the-shelf products, but choosing between them can be difficult. Many larger companies opt to have their own bespoke products designed, but much money can be wasted and many companies have paid dearly for products which do not function in the way they were intended. Choice of the wrong ICT products has been blamed for the complete failure of some companies! In addition, buying the product is not the end of the matter. The products are only as good as the use to which they are put; the competence of the user and the quality of the data input to start with. Good ICT systems need good management and good information dissemination. It is no use having digital tachographs, for instance, if the information retrieved is not used effectively.

2.3 Routing and Scheduling – could be considered part of ICT. It includes the assignment of loads to vehicles so as to maximise payloads and vehicle efficiency; assigning time windows (for both arrivals (incoming) and departures (outgoing), if appropriate) both in terms of their actual time and their length so as to minimise congestion at depots and vehicle down-time – and procedures for what happens when vehicles don't arrive on time; scheduling backloads; route planning, taking into account vehicle and time restrictions; scheduling to minimise congestion – including procedures for dealing with unanticipated congestion or road closures; scheduling night hauls where feasible; using green corridors where possible, and for trains, using train-path optimisation.

Within the WEASTflows project, an intermodal route planner has been developed based on 'open data' using ICT and telematics. It shows the optimal route (either time based or cost based) using a combination of truck, rail, short-sea and barges with no handling of freight between mode changes. This type of application is very important in enhancing sustainable freight transport.

2.4 Backloads – ensuring that vehicles don't return empty is an obvious element of reducing fuel intensity. Backloads could involve bringing in goods from suppliers (i.e. combining primary and secondary distribution functions); bringing back waste or equipment (such as pallets); organising routes such that trips are circular rather than uni-directional so that vehicles are continuously laden. Maximising backloads could also involve collaboration with other companies, even competitors, although there is always the issue of 'ownership of the product' to be overcome. In recent years, many such collaborations have taken place. Obviously backload products have to be compatible with the main product being carried; if vehicle interiors need to be washed down in between journeys, it may negate the benefits, for instance. Use of non-dedicated 3PLs or 4PLs may facilitate back-haulage.

Companies providing freight or backload exchanges have existed for many years and are now mostly internet based. Such exchanges seek to match loads suitable for backloads with companies looking for backloads. Examples include Returnloads.net, a UK based company which reckons it has saved 750,000 HGV empty runs in the year June 2012-13; truckspace.co.uk and freightfinder.com.

Freight Best Practice have published a document entitled 'Make back-loading work for you' aimed at small and medium sized companies, giving advice on the benefits of getting involved and how to overcome the constraints. It suggests the following services, systems and mechanisms for obtaining backloads:

- Return load specialists
- Load matching services
- Freight forwarders
- Partnerships
- Reverse logistics
- Pallet networks
- Supply chain initiatives
- Subcontracting

2.5 Consolidation – much like backloads, consolidation can occur within organisations or with other companies. A good example being that of fish being brought from many different fisheries and ports around Scotland, by different logistics operators often using small vehicles, and then being consolidated in a warehouse in Glasgow for onward shipment to major customers. At an even more local level, fish are brought in small vans and boats to quaysides in Northern Scotland, where they are loaded onto large articulated vehicles to be taken to Glasgow – or further afield. Again, there is the thorny issue of 'ownership' of the product if consolidation of goods from several companies is involved.

2.6 Warehouse/depot location – the issue of how many warehouse/depots to have and where they are best located is a difficult one. In theory, the optimal location and number of warehouses can be calculated given information on customers and suppliers using mathematical optimisation techniques. Some companies prefer hub and spoke operations and others prefer different structures. However, many companies evolve by merger and acquisition or have developed over decades or longer and find themselves inheriting warehouses and depots in non-optimal locations – maybe in the centre of towns or cities - with depots that were built for horses and carts rather than large trucks! When IKEA investigated their supplier locations in Poland, they ended up completely restructuring their depot locations as they found that the original depot locations were organised for the situation where they were supplying the domestic market rather than a large global company. It takes careful monitoring of flows and costs to design an effective configuration.

2.7 Manufacturing location – it is essentially the internationalisation and globalisation of world trade that has effectively dictated the contemporary pattern of logistics. Manufacturers can choose to manufacture goods anywhere in the world and many have moved to locations which minimise their major cost – i.e labour, letting the logistics aspect of the business take the strain. Many goods are now manufactured in Asia and shipped to Europe by container ship, often berthing in a different country from where the goods are demanded, therefore requiring onward transport by another mode.

3. Logistics industry structure. Is it bigger, greener?

Although the logistics industry is still fragmented, with many small haulage companies, each having a very small proportion of the market, the industry has witnessed a considerable degree of concentration over the last 20 years and is now dominated by a few very large logistics companies. Examples of such companies include DB Schenker, Keuhne and Nagel, Exel, Panalpina, UPS, DHL and TDG. Contract logistics, carried out by 3PLs (which provide the logistics services for part or all of the supply chain) or 4PLs (which were originally non-asset based companies but are now often logistics providers that claim to manage the whole supply chain) are now the norm in most industries. Most recently, the so called 5PLs have emerged. These companies aggregate the demands of the 3PLs into bulk volume in order to negotiate cheaper rates and better resource utilisation. Most large retail/manufacturing companies have contracts with several (sometimes up to 10) 3PLs and/or 4PLs to spread their risk or focus on particular elements of the chain.

The greater the level of integration within the supply chain, the higher should be the utilisation of assets and the more likely the company to have the funds to invest in up-to-date equipment and ICT. One of the major functions of a 4PL is to manage the electronic interfaces between different companies in the supply chain. This should result in more seamless, effective supply chains with less waste and duplication and which thus should be more sustainable. Most large 3PLs and 4PLs make a feature of their 'green' credentials. On the flip side of the coin, however, it could be argued that it is the development of these companies that has facilitated global trade and the consequential global supply chains! Their overall impact on the environment is therefore debatable.

In response to the permanent challenges of optimising supply chains, collaboration between different companies can generate various economic, social and environmental benefits that they could not access if working alone.

Collaborative logistics is based on partnerships between industrial shippers, distribution and logistics providers and is a genuine factor for success and a source of competitive advantages for organisations who manage to successfully implement it.

4. Vehicle Technology

i. Trucks

Improvements in truck technology have enhanced the sustainability of logistics considerably over the years. Such improvements include reductions in tare weights, the use of turbo-charging and the design of new types of vehicle which reduce the fuel intensity of goods transport. With the introduction of each Euro Standard, engine fuel efficiency has been reduced. In order to maintain fuel efficiency levels, much effort has gone into improvements in vehicle body and transmission-related measures. Aerodynamics, for instance, have been of key importance. It has been claimed that aerodynamic intervention can reduce fuel usage by between 6 and 20% and is highest when the vehicle is being driven at higher speeds. Cab streamlining includes over-cab spoilers, rounded edges and air dams and trailer streamlining includes the design of the trailer itself, side skirts, curved trailer edges and spats over the wheels. Marks and Spencer have piloted the use of teardrop design trailers and reckon that they save 10% on fuel and increase load capacity by 10%. Integration of the tractor and trailer to reduce the turbulence created between them is also important. The Freight Best Practice programme has produced a 58 page document entitled 'Aerodynamics for Efficient Road Freight Operations' which gives guidelines for various types of vehicles as well as explaining the principles behind them and the payback periods associated with them.

In order to improve fuel consumption, fuel additives, lubricating oils, catalysts and magnets can also be used. Their overall effectiveness, however, seems to be somewhat under debate.

CLECAT (2013), which is a very useful document about the environmental impacts of logistics compiled by the European Organisation for Forwarding and Logistics, also discusses the issue of tyres. They suggest that new radial tyres, with proper maintenance can run over 100,000kms on their original tread and can be re-tread 2 or 3 times if they are carefully looked after. Again, a proper computerised tyre maintenance programme can help with this. Once the tyres have come to the end of their useful life, they should then be recycled properly. Burning tyres can produce more energy than burning coal! Correct tyre pressures are also important. It is claimed that automatic tyre inflation systems can result in fuel savings of around 5%.

Use of lighter weight metals in the construction of vehicles has enabled reductions in tare weight, sometimes called 'lightweighting'. The use of vehicles with lower tare weights will enable the carrying of greater payload, so where the goods being carried are weight constrained, this can be important. The average tare weight of a vehicle varies substantially between manufacturers – and is also influenced by the amount of aerodynamic accessories it has!

Speed Limiters which reduce the maximum speed of a HGV from 65mph to 60mph produces considerable fuel savings of around 6.8%. It is, therefore, worth considering this option as it is more productive than any other of the fuel improvement measures individually and can be combined with other measures.

(ii) Trains

As with trucks, aerodynamics is important for sustainability in trains, particularly at speeds above 100kph. In the case of inter-modal trains, aerodynamic drag can be reduced by optimising train loading so as to minimise the gaps between wagons. Both the engines and wagons can also be streamlined to improve aerodynamics.

Use of electric traction reduces pollutants at the rail side, but as with any electric vehicle, the overall savings depend on the source of the electricity to start with.

Reduced operating speeds, as with all modes can improve fuel efficiency as can engine shutdowns in diesel trains when the locomotive is idle for 15 minutes or more. More modern diesel locomotives can much more readily restart once they have been switched off. As with other modes, stop-starting, fast acceleration and breaking and frequent speed changes are bad for the environment. Providing paths through the rail network to enable trains to make steady progress rather than being constantly interrupted, helps the environment considerably.

Concentration on design is a major area of fuel intensity improvements. The use of high cube containers, swap-bodies and low-loaders as well as increases in the length of trains, have all contributed considerably. These improvements have often been led by the consumer freight sector. Additionally, improvements in handling equipment at rail terminals have helped to make rail more efficient and attractive to potential users. In the case of inter-modal transport, for instance, benefits have accrued from the fact that terminal and transport equipment has become much more standardised. The problem is that not all of the rail network is capable of being used by the more modern trains and not all trains have been adapted/constructed with the more up-to-date features. Also, as new, longer containers are introduced, the technology for handling them needs to be introduced wherever they are being loaded and unloaded, and this is very expensive. Fragmentation of the rail industry across Europe also causes immense problems of coordination.

(iii) Ships and barges

As with other modes, a ship's fuel usage increases with speed. Some shipping companies have implemented policies of 'slow steaming' to take advantage of this, but there is a question of the effectiveness of this policy as slow speeds may in the end mean more ships, which is not very environmentally sustainable (see Cullinane and Cullinane, 2013). Other technical measures include:

- *Sails or kites* - Some companies have experimented with these in order to improve fuel efficiency, but they have not met with a great deal of success.
- *Greater engine efficiency* - Over the past thirty years, more efficient marine engines with lower Specific Fuel Oil Consumption (SFOC) have been developed.

- *Waste heat recovery* – The exhaust gas and cooling water from ships contain substantial energy that could be harnessed, thereby improving the overall thermal efficiency of the engine system by between 5-10%. Maersk Line is the first shipping company to install waste heat recovery systems as standard on all its new ships. Maersk estimates that, using this system, its Triple-E fleet has reduced its fuel consumption and emissions by about 9% when operating within a speed range of 18 - 23 knots. At an installation cost of $10 million per ship, this represents a payback period of somewhere between 5-10 years depending on fuel price and service speed (Maersk Line, 2011). Similarly, Wärtsila, a leading marine engine manufacturer, has developed a total heat recovery system which it claims saves 12% in fuel consumption and emissions.

- *Improved hull design and performance* – To facilitate propulsion, it is necessary to either reduce the weight of a ship by selecting appropriate lighter design materials which do not compromise hull strength or to reduce the resistance of the ship in the water. The shape and form of the hull clearly play an important role in minimising resistive forces, but there are other less obvious considerations. For example, both animals (e.g. barnacles, molluscs, polychaete worms, encrusting hydroids, bryozoa and sea squirts) and plants (e.g. green, red and brown algae and diatoms) can live on the hull of a ship. Such fouling communities can significantly increase the frictional resistance of a ship, leading to greater fuel consumption and exhaust emissions. As a consequence, a whole international industry has evolved around the development of anti-fouling paints and coatings that minimise hull fouling. Compared to an untreated hull, an effective antifouling paint can reduce fuel consumption by at least 15% due to reduced drag. However, although these anti-fouling paints and coatings have additional environmental benefits in that they reduce the likelihood of transporting invasive marine species, they have created their own environmental problems through their previous reliance on tributyl tin (TBT) which itself is known for its highly toxic and endocrine disrupting properties. Although the IMO banned TBT from use in anti-fouling paints and coatings in 2008 in its *International Convention on the Control of Harmful Anti-Fouling Systems on Ships*, full compliance remains a long way from being attained.

Innovative research has found that the pumping of compressed air bubbles over a ship's hull surface while in motion can significantly reduce vessel drag, particularly where the hull is polymer-coated to reduce surface tension.

- *More efficient propellers and rudders.* In general, the larger the propeller diameter, the higher the propeller efficiency and the lower the optimum propeller speed. Thus, achieving a propeller speed which is as low as possible (within the design restrictions of a ship) is best. When the design speed of a ship is reduced, the corresponding propulsion power and propeller speed will also be reduced, which again may have an influence on propeller and main engine parameters, aspects which are very germane to the operational strategy of 'slow steaming,'.

- *Seawater Scrubbers and Filters*. A scrubber is a packed tower on a ship into which seawater is pumped. Exhaust gas from the ship is directed into the scrubber, where it makes contact with seawater. When SO_2 comes into contact with seawater there is a fast and very efficient reaction between the SO_2 and Calcium Carbonate ($CaCO_3$) in the seawater, to form CO_2 and Calcium Sulphate (gypsum), a major constituent of ordinary seawater. The treated seawater is then discharged into the sea without causing any harm to the marine environment, though it can be filtered if required. The reaction takes a very short time. The equipment can be compact and is relatively inexpensive, while still achieving high reduction efficiencies of about 95%.

- *Shore-based power ('Cold Ironing').* Cold ironing is the use of shore-based power to provide electrical energy to a ship while at berth rather than using its auxiliary engines. This means that all engines can be shut down. The practice is increasingly being adopted by ports in Europe, sometimes as part of a 'Green Port' initiative. The reduction in greenhouse gases resulting from cold ironing is very dependent upon the type of fuel displaced, as well as the source of the power provided from the shore; benefits are only meaningful if the on-shore electricity is derived from renewable sources of energy. It has been calculated that cold-ironing reduces total shipping-related greenhouse gases by less than 0.5%. Of far greater importance, in fact, are the benefits in terms of SOx, NOx and PM reductions and the improvement in local air quality achieved by the shutting down of ships' engines while in port. For example, in a study of the Rotterdam-Dordrecht area where there are extensive port facilities, Hammingh et al (2007) concluded that the large-scale cold ironing could significantly reduce the remaining number of poor air quality hotspots as well substantially reducing noise. The major barriers to the widespread take-up of cold ironing, however, are the high costs of the installation or retrofitting of appropriate power systems on ships and the expansion of electricity lines, substations etc. ashore, both in port and beyond.

5. Alternative fuels

5.1 The major alternative fuels available

(i) Biofuels (including biodiesel and bioethanol)

These are fuels produced from renewable plant material and oils and are, therefore, more sustainable than fossil fuels. They are usually used in combination with diesel. Their use reduces pollutant emissions, but there has been considerable debate about the land-take problems caused by the growth of the biological crops required for their production. Use of biofuels practically eliminates emissions of sulphur, and considerably reduces emissions of hydrocarbons and carbon monoxide, although emissions of nitrous oxides increase slightly. Its effect on CO_2 is more debatable. It has been calculated there are minimal tailpipe emission differences, but that the benefits arise from the renewability of the biofuels themselves (DfT, 2007). Because of the land-take issues and the low efficiency of biofuels, second generation biofuels are now being developed. These are fuels that can be made from waste materials (such as municipal waste) and cellulosic crops (dedicated energy crops) that can be grown on wasteland. Unfortunately, it is debatable whether there are sufficient quantities of these new sources to make any major impact on the environment.

The Renewable Transport Fuels Obligation (RFTO), introduced in 2008, places an obligation on owners of liquid fossil fuel intended for road transport use to ensure that a certain amount of biofuel is supplied or that a suitable amount of money is paid to support the production of these fuels. Only organisations that supply more than 450,000 litres of fossil fuel per year are affected by this.

(ii) Hydrogen

Once seen as the panacea for the future, but now the outlook is more cautious. The problem for freight vehicles is the weight of the fuel cells required and as yet, this problem is insurmountable.

(iii) Gas filled vehicles (Natural Gas (NG), compressed NG (CNG) and liquid petroleum gas (LPG).

NG vehicles are methane powered vehicles which can be derived from either fossil sources or bio-methane. Some manufacturers produce HGVs that can run purely on NG, or dual fuel/NG vehicles are also available. NG produces no nitrous oxides or particulate matter and about the same level of CO_2 as normal diesel.

DME or Dimethyl either, is a relatively new addition to the fuel market in Europe, although it has been used in Asia for some time. It is produced primarily from coal or gas or bio-stocks and has massive environmental benefits as it is virtually pollutant free at the point of use. Volvo are piloting it in Europe, but as yet, it is not in general use. It is also being pioneered by Stena in their ferry fleet. It is a gas under ambient conditions but can be stored as a liquid under moderate pressure and requires very little engine adaptation to use it.

(iv) Electricity – not yet suitable for HGVs doing long distance trips.

5.2 Use of alternative energy in logistics

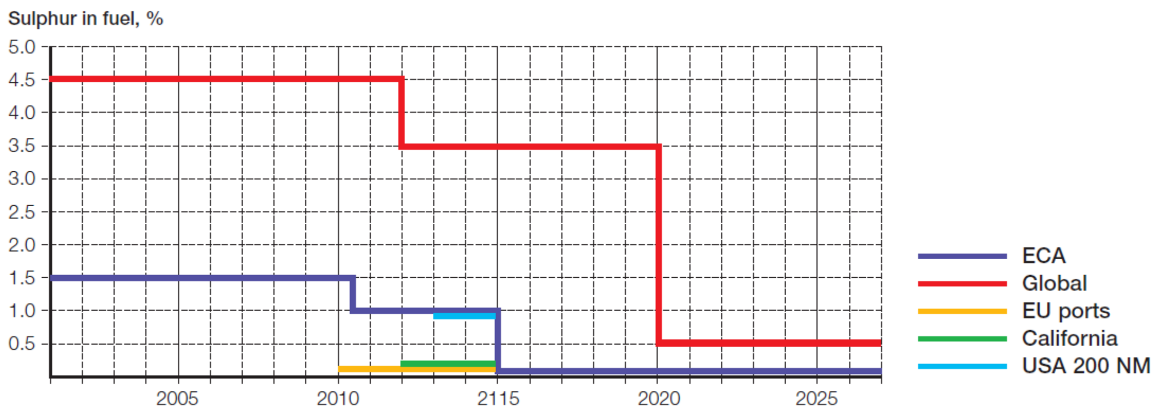
One problem with all the alternative energy sources is that the supply infrastructure is still not well developed. It is therefore up to the logistics operators themselves to provide the infrastructure. Tesco owns a 25% share of biofuel company Greenenergy, which buys rapeseed from 1500 farmers in the UK to make biodiesel. It runs a 50:50 biodiesel mix in its own vehicles (Tesco, 2008). This was once a very prominent part of its website, but with the debate over the sustainability of biofuels, it has disappeared. Similarly, the companies which belong to the FTAs Logistics Carbon Reduction Scheme (LCRS) are also shying away from the use of biofuels because of the landtake issue. They are looking more towards the use of gas, but are concerned about the lack of infrastructure. According to the Natural and Biogas Vehicle Association (NGVA, 2011), there were 220,000 medium or HGVs worldwide using natural gas.

In the Freight Best Practice Guide, the example is given of logistics operator Howard Tenens who has converted 26 of its 110 vehicles to dual fuel (either CNG or NG). The company has invested in 3 refuelling stations. The conversion costs up to 50% of the original cost of the engine, but the conversion kit can be taken out of the vehicle on sale, so can be used multiple times. The company estimates it has paid its way on its use within the first vehicle, so the costs of its use in subsequent vehicles should be negligible.

DB Schenker uses some hybrid engines and second-generation biofuels in its massive HGV fleet. However, together with many other major logistics companies, their company environmental strategy focuses much more on gains made through optimization of capacity and supply chain structures which enable the 'bundling' of transport, than on uses of alternative fuels. Many companies are using the purchase of up-to-date vehicles which comply with higher Euro standards as their focus for vehicle emission reductions. It is possible that the volte-face over the sustainability of bio-fuels has deterred logistics companies from spending too much time and money on the use of alternative fuels. This is likely to be particularly the case for operators of long-distance transport, where tail-pipe emissions are less important than overall cost and environmental standards issues. In a report by Ricardo (2012) for the Task Force on Fuel Efficient, Low Emission HGV Technologies, the reasons for the slow uptake of low emission HGVs are set out. The biggest barriers were found to be: increased upfront costs, uncertainty over payback period, lack of trust in claimed measured benefits, insufficient re-fuelling infrastructure reliability issues and loss of payload.

In the shipping industry where, new, much tighter sulphur emission standards have been introduced, including the SECAs (sulphur emission control areas) where practically zero sulphur is able to be emitted, huge efforts are now being put into finding less polluting fuels. One alternative is the use of very low sulphur diesel, but this is very expensive and there are fears that there may be insufficient supplies of it. The evolution and phasing-in of the various regulatory regimes is summarised in Figure 13.

Figure 12. The evolution of Global and Local Sulphur Legislation



Source: Derived from data contained in Buhaug et al (2009)

In the case of rail, EU legislation under the Fuel Quality Directive means that fuel from rail locomotives must be sulphur free from January 1st 2012. This is being done through a combination of the use of ultra-low sulphur diesel and sophisticated fuel injection equipment. Some companies are using biofuel mixtures, but the problems here are the same as those relating to biofuels in general i.e. their true sustainability is being increasingly questioned. Many of Europe's trains, of course, have electric traction, which, depending on its source, is often far less environmentally damaging. A read of DB Schenker's website relating to its use of rail, makes the use of diesel sound positively archaic! In fact they state that their only use of them is for shunting! Whilst the UK has some freight trains with electric traction, their use on the UK rail network is very limited. When trains run on electricity, it enables use of other technologies such as regenerative braking.

6. Driver Training

One of the easiest ways of improving fuel intensity and reducing other negative logistics externalities (particularly accidents) is through appropriate driver training – through the promotion of eco-driving. Eco-driving basically involves driving more steadily – trying to reduce fast braking and acceleration; correct use of gears; tyre pressures and maintenance; driving at optimal speeds; reducing idling time; choosing routes carefully and avoiding congestion and generally understanding the relationship between the vehicle and the environment. Training can involve the use of simulators, which give immediate feedback on the driver's impact on the environment through their driving style. Studies have shown that eco-driving can reduce fuel usage by up to 20%. Although training is not cheap, it is usually cost efficient and also gives the drivers more 'buy-in' to the company.

Many companies have introduced eco-driving training. DB Schenker, for example, trains all its drivers in eco-driving, including those of its subcontractors. Many companies have introduced 'league tables' of drivers who perform well in reducing fuel usage and have 'eco champion' awards. Of course, the first step towards minimising fuel usage is an efficient monitoring system.

Eco-driving is just as important for rail locomotive drivers as for truck drivers.

7. Environmental Reporting

In order to be able to improve anything, you need to have accurate benchmark figures. A key principle of operations management is that ‘Measurement leads to Improvement’. Requests for information draws managerial attention to where possible improvements can be made. Environmental reporting is a fairly new phenomenon which involves reporting key environmental statistics – possibly to an internal department, an external consultant or further.

In the UK, the government will introduce (from September 2013) mandatory Green House Gas reporting for all UK quotes companies for Scope I and Scope II emissions and this might be extended to all companies by 2015.

The FTA runs a Logistics Carbon Reduction Scheme (LCRS) through which logistics operators report fuel usage to them and the FTA converts this into CO_2 emissions using government sponsored conversion factors. The FTA then aggregates the fuel usage figures to track emissions over time. Part of the reason that they are doing this is because they recognise how difficult it will be for smaller companies to engage in environmental reporting to government and they wish to persuade the government that reporting does not need to be mandatory. In modern vehicles, sophisticated on-board monitoring systems enable fuel usage to be measured accurately, on a per-vehicle and/or a per-driver basis.

Many large logistics are proud of their environmental credentials and make a great deal of marketing them. Tesco markets its multi-modal operations through the slogan ‘Tesco lessCo_2,’ which is very eye-catching. Most large company reports and websites have a section on the environment or sustainability and how they are seeking to address it through policies, often with measurable targets. Companies have become very sensitive about consumer criticism of their environmental policies and procedures and have sought to influence the environmental credentials of all the companies in their complete supply chains.

8. Management issues

The role of good management cannot be overstated when it comes to sustainability. Good management means establishing the right priorities within the company, purchasing the right vehicles and ICT, signing the contracts with the right companies and people, accounting for risk and uncertainty in the business and much more. It is difficult managing all the different functions, particularly in times of recession, as well as keeping the environment in the forefront of the decisions.

Implementing sustainable logistics policies is fraught with difficulties. Many are what can be described as 'green-gold'; that is the policies are good for the environment whilst being simultaneously good for business. The obvious example here is fuel efficiency gains from better fuel usage monitoring. However, some sustainability interventions are not directly cost effective and may require substantial investment with little financial benefit. Part of the problem is that interventions are not additive – i.e. if you implement an intervention such as tyre pressure monitoring which individually might improve fuel intensity by 5%, plus a driving training programme which might improve it by 13%, plus fit aerodynamic fairings to your vehicles which might yield a 4%, the total increase in fuel intensity will not be the sum of these, i.e. 22%. A manager, or the management team will have to decide which is best for the company, taking into account the other company objectives. As discussed in CLECAT, each company needs to decide for itself what is 'green' and needs to analyse the company's operations in relation to this by measuring and benchmarking.

Freight Best Practice has produced a booklet for operators on how to test different fuel interventions, entitled 'Fuel Efficiency Intervention Trials; How to Test and Save'. It outlines various fuel interventions and gives examples of companies which have tested some of them and the savings they have made. Freight Best Practice has also produced a 'fuel ready reckoner' which helps a company to estimate how much fuel they could save by adopting various different fuel saving techniques, either individually or in combination. It lists 28 types of intervention, which are:

- Increase vehicle fill
- Decrease empty running
- 1st driver training
- Repeat training
- CVRS
- Satellite navigation
- Under run air dam
- Cab roof fairing
- Cab side fairing
- Body/trailer side panels
- Body/trailer front fairing
- Tractor side panels
- Reducing cab gap
- Tipper sheeting system
- Sloped roof trailer
- Tear drop trailer
- Louvred spray suspension flap
- Energy efficient tyres
- Super single tyres
- Replace steering super single tyres
- Tyre pressure management
- Regrooving tyres
- Regular wheel alignment
- Synthetic engine oil
- Anti Idling campaign
- Speed limiter at 54mph
- Speed limiter at 52mph

John Mitchell in Grangemouth reduced their fuel usage considerably by combining policies on driver training, anti-idling and aerodynamics. Between 2005 and 2010, Walmart improved the fuel efficiency of its fleet by 60%, using a combination of monitoring, driver training and other measures. It reckoned that just by scrutinising and measuring the fuel usage, it was able to improve the average fuel efficiency of its logistics network by 25% (Plambeck, 2012).

V. Specific Issues:

1. Reverse Logistics – i.e the logistics associated with the return of damaged, unsold or returned raw materials, in-process inventory and finished products back up the supply chain as well as the consolidation, handling and disposal of the resulting waste products.

With the introduction of the EC Directives on Waste Electrical and Electronic Equipment (WEEE) (2002/96/EC), the Restriction of the Use of Certain Hazardous Substances (RoHS) in Electrical and Electronic Equipment (2002/95/EC), Packaging and Packaging Waste (94/62/EC) and Distance Contract (97/7/EC), reverse logistics has become very important. Considerable planning to make reverse logistics as environmentally less damaging is required, but in many ways, the process is more complex because the flows of goods in the reverse direction cannot be so easily forecast. This is probably worse in the case of city logistics, where individual consumers can return their unwanted (for whatever reason) internet purchases, but is nevertheless still important in terms of long-haul transport. Often specialist recycling plants, for instance for electrical products, are located hundreds of miles away and trips need to be organised efficiently.

2. E-commerce and logistics. Both B2B (business to business) and B2C (business to consumer) e-commerce has expanded at a phenomenal rate over the past ten years and promises to keep increasing into the future. Much of the business of the large parcel delivery companies (such as UPS, Yodel, DHL) is now concerned with delivering goods purchased on the internet. These goods are often bought with little knowledge of/regard for their company of origin or despatch and are required quickly – often the next day. Whole national and international networks of logistics hubs and depots capable of moving these goods around the world as fast as possible, have been established as a result.

3. Interfaces. This report has focused on long-haul logistics, but when considering environmental sustainability, the long haul element cannot always be considered in isolation. The origins and destinations of the long haul loads are often within cities and built-up areas. Goods are often manufactured/assembled on the outskirts of large cities, but if, for instance, rail transport is to be used, the goods will need to be taken to the railheads for loading/unloading and will often, therefore, have to pass through cities. City logistics is, therefore, very important. The report has also not focused on the design of warehouses and depots, although there are many examples of how to improve their design to make them less environmentally damaging (green roofs, waste water use etc.). Even something as seemingly innocuous as the water used for vehicle cleaning can make a considerable difference.

4. EU/Government Policies. Logistics companies must work within the framework of both domestic and EU law. There are hundreds if not thousands of laws that have an influence on the sustainability of logistics, including those relating to the emissions of pollutants, vehicle standards and dimensions, health and safety, driving regulations etc. Government (in its widest sense) also has an influence through taxation policy, e.g. through the vehicle taxation and subsidies of measures to encourage modal shift. There is talk of carbon-emissions trading schemes and carbon taxes on location of facilities. The French Ecotaxe due to be implemented this year, for instance, is a way to encourage the use of other modes. Each haulier (whether domestic or international) will have to register their trailer with the French government and will be charged a tax based on the number of chargeable kilometres travelled (Multimodal, 2013). EU funds a great deal of research on environmental research and seeks to disseminate good advice through programmes such as:

BESTUFS, http://www.bestufs.net.

CITY FREIGHT, http://www.cityfreight.eu/

CIVITAS, http://www.civitas-initiative.org/main.phtml?lan=en

ECOSTARS   www.ecostars-europe.eu

eDRUL (e-Commerce Enabled Demand Responsive Urban Logistics), http://srvweb01.softeco.

ELAbestlog (European Logistics Association, Supply Chain Management best practice. http://www.elabestlog.org/

it/edrul/Default.aspx?lang=en

GIFTS (Global Intermodal Freight Transport System), http://gifts.newapplication.it/gifts/

IDIOMA (Innovative distribution with intermodal freight operation in metropolitan areas), http://cordis.europa.eu/transport/src/48343.htm

MIRACLES, http://www.civitas-initiative.org/project_sheet?lan=en&id=8

MOSCA (Decision Support System For Integrated Door-To-Door Delivery:

Planning and Control in Logistic Chains), http://www.idsia.ch/mosca/deliverables.phtml

PROMIT, http://www.promit-project.net/

REFORM (Research on freight platforms and freight organisation), http://cordis.europa.eu/transport/src/reform.htm

SMART FREIGHT, http://www.smartfreight.info/index.htm

START (Short Term Actions to Reorganize Transport of Goods), http://www.start-project.org/

TELLUS (Transport and Environment Alliance for Urban Sustainability), http://www.tellus-cities.net/

TEN-T (transport Infrastructure) http://ec.europa.eu/transport/themes/infrastructure/index_en.htm

TRENDSETTER, http://www.trendsetter-europe.org

VI Summary.

This report has sought to summarise the environmental impacts of long haul logistics operations and to describe some of the many ways by which they can be reduced. The negative environmental externalities can never be eliminated, but with careful consideration of the overall pattern of logistics operations as well as of the systems within which they operate, the individual vehicles and drivers and the management of all these resources, the environmental impacts can be considerably reduced. In many cases, the resulting beneficiary is not just the environment but can also be the financial bottom line as environmental accounting can often lead to efficiency gains to the logistics operator and/or the consignors themselves. Many of the interventions discussed in the report can be made by individual companies working in the private sector. However some require appropriate government support.

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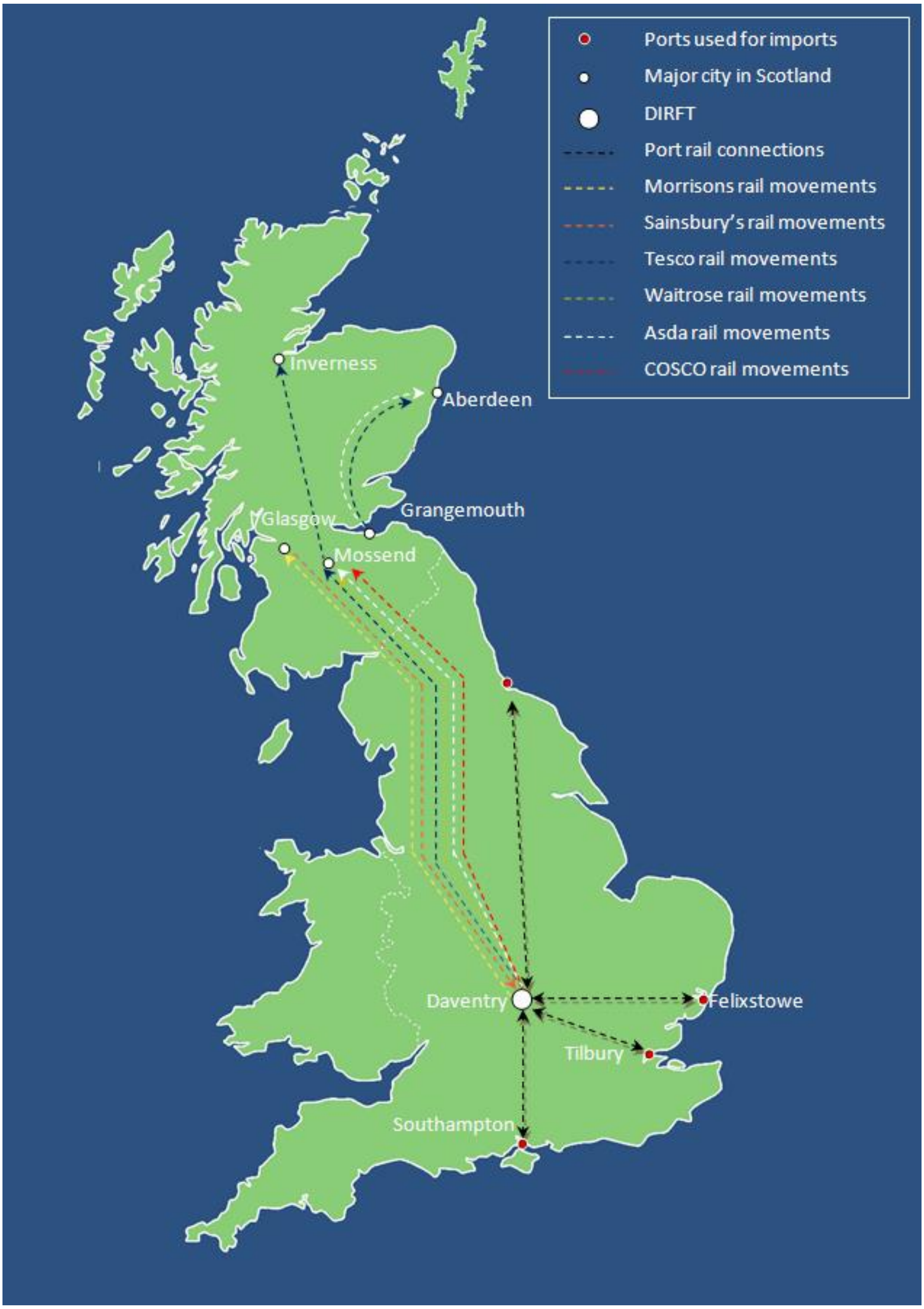
Ports used for imports
Major city in Scotland
DIRFT
Port rail connections
Morrisons rail movements
Sainsbury's rail movements
Tesco rail movements
Waitrose rail movements
Asda rail movements
COSCO rail movements
Inverness
Aberdeen
Grangemouth
Glasgow
Mossend
Daventry
Felixstowe
Tilbury
Southampton