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Transport Using Shipping Containers

S. A. Lloyd

**Institute of Energy, Institution of Mechanical Engineers,
Spindeep Limited, London, United Kingdom**

Abstract

Average ambient temperatures are rising and both undesirable CO_2 and CO_2e emissions are increasing together with an increase in methane's ambient concentration. Very large investments have started in the UK to mitigate climate change using energy conservation, decarbonisation plus other necessary measures.

Transport energy consumption in the UK is high and unit undesirable emissions for various transport methods are presented. Transport using standard freight containers (one or two TEU) are given.

Examples are included where local partial pre-treatment of raw materials before shipment are performed to minimise the container loads/numbers required. Employing partially prepared raw materials saves transport energy. The use of containers for mobile hospitals is presented as is more conventional hospital carriages/trains which are of older designs. Comparison of land usage by road and rail transport is given in outline.

A brief description of certain significantly more modern, but unconventional window glasses to improve hygiene and welfare for the occupants of the older hospital trains is presented (missile resistant and privacy glass) permitting relatively simple welfare upgrades. Though terrestrial units dominate the descriptions of transports some freight aircraft metrics are included with a brief tabulation of the historical development of aircraft engines.

Keywords: Air Freight, Container Trains, Control Cabinets, Drones, Emissions, Freight Metrics, Hydrogen Distribution, MASH Units, Privacy Glass, Transport.

1 Introduction

The average world ambient temperature is rising and recently it was noticed that there has been a change in the relationship between the Pacific Ocean phenomenon known as "El Nino" with European weather. The temperature in the UK in 2025 was + 1.7 °C above the average between 1850 and 1900 and the jet stream excursion has resulted in hurricanes in the Caribbean with high wind speeds of approx. 185 mph (~300 km/h) [1].

The "Club of Rome" anticipated a limit to growth through raw materials' shortages and build-up of pollution which as most energy was hydrocarbon generated, lead to attention being focused on atmospheric CO_2, NOx, PM [2, 3]. Lloyd and Weinberg examined this, being concerned with the shortages of high-grade fuels and by decoupling reaction rates from the fuel's energy content also gained a measure of control over pollution production rates [4]. This work achieved high reaction rates in a smaller temperature window, permitted use of significantly poorer fuels, reduced undesirable emissions especially NOx and anticipated its impact on global warming [5]. Their physical and mathematical models supported the combustion aspects and subsequent work was limited only by materials for extraction of energy [6, 7].

Addressing global warming and energy security is compatible. In the UK, it has started with energy conservation, decarbonisation and use of nuclear and renewables as energy sources; this is demanding large investments [8]. Here we attempt to reduce energy consumption by local partial pre-processing of raw materials so as to minimise the transport of the unwanted component. By using standard transport containers, flexibility is obtained so that the transport pattern can be optimised.

Table 1: Carbon Dioxide and Other Emissions for UK, EU and the World (MTe)

Country	**UK**		**EU**		**World**	
Year	**2010**	**2024**	**2010**	**2024**	**2010**	**2024**
Carbon Dioxide CO_2 (MTe)	530	321	3 389	2 484	31 068	35 482
Carbon Dioxide Equiv. CO_2e	542	332	3 505	2 590	35 194	40 182

Recently the rejuvenation of the high-speed rail network concept (HS2) has been announced and one of the benefits is energy conservation. In the future it will connect UK rail from the south of England to the north of England and from there, the step into Northern Ireland via Scotland will eventually follow. A rail tunnel should be employed over a bridge as it has better immunity from adverse weather. Rail is also, significantly safer than road transport but the latter, outside the confines of the transit, is more flexible. A simple tunnel estimating method is given by Lloyd [9].

The emissions of concern are presented in Table 1 and this shows the magnitude of the problems [10]. The UK / EU are reducing their emissions but the world is not.

2 Transport – Road and Rail and Ship and Plane

2.1 Generalised Parameters

The standard container, one TEU, is 20 feet (6.02 m), long * 8.0 ft (2.44 m) wide * 8.5 ft (2.59 m) high. Frequently they are 40 foot long (2 * TEU). For transporting liquids, within this dimensional envelope, a steel space frame is arranged and inside it is contained a cylindrical pressure vessel. Typical volumes are 18.5 cu m for a TEU and 40.5 cu m for a 2 * TEU. For enclosed containers, an HVAC unit can be arranged to give it a stable temperature.

Typical freight transport metrics are given in Table 2 and the options for optimising energy use and pollutant minimisation can be seen. Use of container ship transport scores high as is the bulk transport of liquids. The containers for aircraft are designed to suit the plane's body and are not standardised though much is carried on "standard" pallets to suit a family of aircraft. The Celera 500L is included as it is currently the most efficient airplane commercially available.

Table 2: Freight Transport Metrics by Several key Parameters

Parameter	Te*km / litre	Te*km / MJ	Te*km/gm NOx	Te*km/kg CO_2	Te*km/kg CO_2e
Diesel Truck	205	3.66	17	30	29
Trains	265	4.67	48	34	32
Cont. Ship	1 845	41.6	14	325	318
VLCC	1 660	36.3	30	383	375
ULCC	2 280	49.8	25	568	557
Planes	15	0.27	2.72	3.85	3.63
Celera 500L	116	2.05	21.2	29.2	28.7

2.2 Road Transport

(a) Electric Vehicles

Electric vehicles help address decarbonisation but their batteries have lower energy density than equivalent diesel units hence battery vehicles are often heavier than their IC engine counterpart. For those HGV which operate near their road weight limit, the relative increase in fixed weight of batteries, reduces payload and affects energy consumption. Battery technology is under continuous development, and it is suggested that as HGV contribute such a small fraction of the total UK quantity of carbon dioxide emissions, HGV should be excluded from the general decarbonisation process and continue to use diesel as a fuel for a future defined period. This will permit staggering of freight decarbonisation to permit new technology to be developed and allow more complex options to be assessed.

Table 3 gives energy metrics for several countries. The impact of certain undesirable emissions on the environment can be dramatic and their summation with that of CO_2 is presented as CO2e. With decarbonisation reducing CO_2 itself, the latter metric has become important.

Methane is a component of this metric and its impact on the environment is 72 to 86 times the impact of CO_2 on a 20 years' timescale and 25 to 34 times impact for 100 years' timescale. The increased use of natural gas released methane into the environment and has demanded a massive effort to minimise its leakage. Worldwide, these emissions are rising, and has reached approx. 1 930 ppb or 2.6 times higher than in pre-industrial times.

Table 3: Overall Energy Consumption and Carbon Dioxide Emissions - Year 2024						
	Country	**USA**	**Canada**	**UK**	**EU**	**KSA**
	Total Energy (EJ)	91.8	11.9	6.43	52.8	11.8
	Hydrocarbon Energy	35.8	4.35	2.68	21.5	7.37
	Carbon Dioxide (MTe)	4 619.1	522.5	321.2	2 483.5	636.4
	CO2e (MTe)	5 110.0	606.4	332.3	2 589.8	738.1

Table 4 shows the UK sectorial energy (PJ) plus CO_2e produced (MTe) for year 2024. Road transport dominates the statistics, rail is small (1.9%), but air is large (26.2%).

Table 4: Transport Energy Used per Sector for the UK (PJ) [11].				
Road Transport Sector	**Energy**	**CO_2e**	**Total Transport by Sector**	**Energy**
Cars – Petrol (PJ)	423.7	29.93	- Air (Petroleum)	554.1
Cars - Diesel	366.8	27.31	- Air (Bio-energy)	11.60
LGV - Petrol	6.70	0.473	- Rail (coal)	0.461
LGV - Diesel	238.2	17.74	Rail (Electricity)	18.13
HGV Rigid - Diesel	87.5	6.52	- Road (Electricity)	32.15
Buses - Diesel	31.4	1.594	- Road (Petroleum)	1 379.5
Motorcycle - Petrol	6.28	0.442	- Road (Bio-energy)	103.2
All Vehicles Biofuel	103.1	7.26	- Road (Natural Gas)	6.49
Miscellaneous	95.5	6.95	Nat. Water Nav (Petroleum)	33.41
			Overall TOTAL - Transport	2 161.4
TOTAL for Road	1 520.5	108.2	Total for Road	1 521.4
Percentage TOTAL Road	70.3 %		Total for Rail	40.99

Electric Vehicles (EV) are important energy consumers and are part of the UK decarbonisation process by replacing hydrocarbon fuel though many users prefer hybrids. The latter are more suitable for inclement or adverse weather conditions as emergency liquid fuel delivery is straightforward.

Pollution has an economic cost. Atmospheric pollution's cost depends on many factors including the atmosphere itself and the locale. Quantifying its impact is difficult though attempts have been made [12, 13]. Any individual emitter's cost may be difficult to assess but for a city, the overall impact is readily defined. With tight exhaust emissions' control, freshly painted buildings are maintaining their pristine appearance for many years and the paint's protective function lasts even longer.

For IC road vehicles, there is a significant difference between emissions from new engines to those with high mileages and/or many hours of use [14].

(b) Tank Capacity

Table 5 gives full fuel tanks' weights for gasoline, diesel and gaseous hydrogen powered vehicles. These numbers are equivalent to those of a diesel engine vehicle with a fuel consumption of approx. 3 km/litre. Several scenarios are given and the quoted stored energy in each case is approx. equal. Case (i) represents a single large vessel and (ii) two equal half sized vessels of 0.9m diameter: Case (iii) represents a single large vessel and (iv) two equal half sized vessels of 1.2 m diameter. Their relative sizes and weights permit their impact on payload to be assessed.

The hydrogen storage pressures selected are 50 bar g, 100 bar g and 200 bar g. It is unlikely that hydrogen fuelled HGV with 200 bar g fuel systems will be operated on UK roads as the possibility of accidents with attendant tank rupture are too high. Possibilities of blast damage due to sudden pressure release and/ or fire or explosion exist. The most likely pressure used will be 50 bar g.

Table 5		**HGV Tank Statistics**			
	5.1	**Range (km)**	**2,400**		
		Fuel	Gasoline	Diesel	
		Weight (Te)	1.12	0.98	
	5.2	**Range (km)**	**1,000**	**Fuel = Hydrogen**	
One Vessel		**Hydrogen Pressure (bar g)**	**50**	**100**	**200**
	(i)	Tank Diameter / Length (m)	0.9 / 3.2	0.9 / 16	0.9 / 8.1
		Weight (Te)	2.5	2.1	2.0
Two Vessels					
	(ii)	Tank Diameter /Length (m)	0.9 / 16	0.9 / 8	0.9 / 4.1
		Weight (Te)	3.9	3.7	3.6
One Vessels					
	(iii)	Tank Diameter / Length (m)	1.2 / 16.9	1.2 / 9..	1.2 / 4.5
		Weight (Te)	4.5	3.8	3.5
Two Vessels					
	(iv)	Tank Diameter / Length (m)	1.2 / 9.0	1.2 / 4.5	1.2 / 2.3
		Weight (Te)	7.1	6.7	6.5

If the use of hydrogen is planned countrywide for the future, retaining diesel engines in HGV and subsequently replacing them with hydrogen IC engines will involve minimum change to the existing vehicle infrastructure. This can be upgraded as superior technology is introduced.

2.3 Trains

(a) Estimates of UK train emissions and energy used - today and the future

Diesel engines are popular as they are compact, fuel efficient (particularly at part load) and the energy density of the fuel itself. They have been operated safely down coal mines, but the modifications for this environment are expensive, escalating the engine's cost dramatically [15, 16, 17]. Electric drives are preferred as the engines are lighter, minimising wear and energy use.

Steam engines meet many of the requirements for locomotives and conceptually they have high fuel flexibility. Their solids' emissions can start fires (Fig 1). Under "tinder dry conditions", especially in countries such as Australia with its gum trees, this can make them totally unsuitable. Gum trees shed their bark in festoons thus giving good air access which permits high combustion rates. "Sweating" eucalyptus trees can give a "purple haze" and this haze is not only highly flammable but aids flame spread. It permits flame jumps of many kilometres with values of 30 km being observed. This makes fire breaks useless. In addition, the thermal currents from combustion have lifted burning sparkles up to 5 000 ft and these have been known to travel up to 22 km ahead of the bush fire itself.

Figure 1: Bush fire

(b) Hybrid Trains

Hitachi have introduced a hybrid intercity train where one of the diesel engines of a three-diesel Nova 1 train has been replaced with a battery drive. Hitachi expect the battery unit to deliver the same levels of acceleration and performance as the diesel engine it replaces. Adding no additional weight, emissions and fuel cost will be reduced by ~ 30%. This modified train has started trials and it will examine the feasibility of intercity trains entering and leaving non-electrified stations in zero-emission battery mode, currently aiding air quality and minimising noise [18].

If successful, a hybrid overhead HV electricity / battery powered train will be introduced and this mixed electricity technology should reduce infrastructure costs by eliminating overhead electricity supply conductors in tunnels and at complex rail junctions, when electrifying existing rail routes.

(c) Switcher in Port of Los Angeles
Around ports where high container loads exist, a locomotive known in the USA as a switcher, is used. Their diesel drives have high emissions which are difficult to eliminate by design, and suitable exhaust catalysts are both large and heavy. Their required high daily operation time at low speed and sitting idling between operational needs, makes fuel cells suitable power sources. Emissions when using hydrogen as a fuel are low, and due to the nature of the drive, smaller and lower power fuel cell units may be applicable.

These engines consume annually around 50 000 US gallons of diesel. They emit approx. 500 Te of CO_2, 80 Te NOx, 8 Te hydrocarbons and 2.5 Te particulates. With 250 units currently in operation, if all converted to use fuel cells, the potential total emissions per year eliminated would be approx. 126 000 Te of CO_2, 2 000 Te NOx and 625 Te PM. From these savings must be deducted any emissions made by the fuel cells themselves and in the production of the hydrogen.

(d) Comparison of Road and Rail Land Usage
For long distances, rail tends to demand less land area than roads and motorways. Table 6 presents an approximate comparison of the results for straight lengths of them. The extra wide motorway at the west end of London Heathrow airport is included with an estimate of the potential weight per kilometre of material to be removed, if the airport is extended.

The estimate for approx. land required per kilometre of track is included if diversified land routes for HS2 to the north of England are being considered. For a small increase in total land, each track level could be split and staggered as is the arrangement for certain sections of the M6 motorway which will minimise visual impact.

Table 6: Comparison of Road Way and Railway Land Area

Road Type	**Single Way**	**2 Carriage**	**Motorway**	**Road LHR**
Land Area –Ha/ km	1.68	4.11	7.32	15.5
Weight – kTe / km	14.1	45.8	182	386
Railroad Way	**Single Track**	**Two Track**	**4 Track**	**HS2 Speed**
Land Area –Ha/ km	1.52	3.81	7.82	4.27
Weight – kTe / km	12.8	42.4	182	106

Figure 2: Illustration of the simplicity of the infrastructure needed for handling containers on trains

Fig 2 illustrates the simplicity of the infrastructure needed for handling containers on trains. Complex loading arrangements are only necessary where high, rapid container throughput is needed. Electric engines are normally preferred due to their lower weight which, inter alia, reduces track wear and has zero local emissions but the electrical infrastructure is more expensive. For mixed traffic density UK use, there are locomotives such as the Tri-mode Class 93 engine (speeds up to 170 km/h) and the Bi-mode Class 99 engine (speeds up to 120 km/h) [19].

2.4 Shipping

Ships are energy efficient particularly for large bulk or container carriers. For many applications, containers are ideal as they are a secure and flexible transport means which can be moved between trucks, trains and ships in a simple fashion. This flexibility is due to the standardisation of containers – see ref. the accepted designations [20]

In terms of energy economics, the limits for container ships are currently due to technology limitations as the draft of a fully laden VLCC tanker exceeds the anticipated draft of the next generation of ULCS. Width limitations of ULCS may impose some restrictions and limit the available harbours to be used but the main difficulty is the availability of high output, compact, high efficiency drive engines.

The current maximum marine diesel engine's output is approx. 75 MW for medium speed unit but these are heavy and have noise emissions which are difficult to supress. Gas turbines have high outputs and are compact but have poor efficiency at part load unless specialist engines such as the Rolls-Royce WR21 and RR Marine Trent are employed: [21, 22].

Hydrogen as a fuel suffers from low volumetric energy content as does ammonia. The former has been discussed at SPICONX22 for pipelines and its limitations identified [23]. Ammonia is another matter as it is dangerous and if not controlled in the engine, it can produce NOx.

A third method of propulsion that is rarely considered is nuclear propulsion as many ports do not accept nuclear vessels. Global warming has resulted in the Artic Ocean route around the top of Canada becoming navigable for extended periods and this route offers huge savings to commercial vessels both in transit times and fuel burn. Nuclear powered ice breakers are ideal here as their hull form, suitable for ice sheets, is not good for open water unless retractable stabilisers are employed and these have a high drag penalty, demanding high available power and low fuel costs [24].

2.5 Air Freight

(a) Projected Numbers

Air transport has grown significantly over the past decades as has its impact on climate change. Aviation today contributes approx. 2.5 % to world carbon dioxide annual emissions and 3.5 to 4.0 % of CO2e. The world aviation freight fleet is projected to grow from 2,340 aircraft in year 2023 to 3,900 units in 2043. Over this period, 1.055 units will be retained, 1,285 will retire and 1,560 new aircraft will be added. Boeing predict that 2,845 new units will be needed. Typical models are included in Table 8 which uses published suppliers' or users' data which may not be internally consistent but it does demonstrate relationship

Figure 3:

Airbus Industrie and Boeing produce most large freight aircraft but the Chinese aircraft industries are entering this market with the Comac C919 equipped with CFM engines. This French-American engine is popular in this airframe size, being in the same category as the Airbus A320neo and Boeing 737max; all single isle aircraft. The market for these engines is estimated to be for 42,340 new aircraft of all varieties with roughly 80 % as single aisle designs.

	Table 8: Basic Parameters of Some Air Freight Models			
	Model	**Payload (Te)**	**Range (km)**	**Te-km / litre**
	Antonov An-225	200.0	4 000	6.98
	Airbus 310 – 300F	42.0	7 330	4.53
	Airbus A320 neo	20.0	6 300	5.25
	Airbus A350 – 900	31.5	15 000	3.75
	Airbus A330 – 200F	70.0	6 000	6.77
	Boeing B737 Max	23.9	3 710	7.92
	Boeing 747 – 400F	84.0	9 430	4.69
	Boeing B777 freighter	112.0	17 380	3.78
	Boeing B787 – 9F	129.0	14 000	3.96
	Britten – Norman Islander	1.0	1 400	22.8
	Celera 500L	0.8	7 240	115.9
	Comac C919	15.0	4 800	3.46
	Lockheed Hercules C130J	18.2	4 000	7.87
	Concorde	8.98	6 580	0.571
	Boom	0.99	3 800	0.681
	Bombardier Global 8000	1,23	14 810	0.915

The next generation of small high-speed aircraft, such as Boom and Bombardier G8000 are presented in Table 8, together with the retired supersonic Concorde. These very fast private jets will fly at high altitude. Their impact on the environment will be high and likely unacceptable but there is a definite need as well as a market for these aircraft. The ability to control their numbers may be necessary. It will need an independent arbiter and the UK could do this via such august bodies as Lloyd’s of London or the Baltic Exchange.

(b) Drones for Freight

Drones have many applications with small ones being used for observation, aerial examination of process plant and atmospheric emissions’ monitoring. Larger ones can be employed for long range continuous observation of key facilities, e.g. pipelines, especially in locations such as KSA where population density is low, and older / more mature military personnel can remain employed as drone pilots. Drones’ payloads are as high as 1 300 kg payload and 27 hours operational duration. Drones can be employed to monitor trains carrying high value loads and, if necessary, hover over or near the load to become a sacrificial target in dangerous environments.

2.6 Hydrogen

Research and development into aviation fuels’ decarbonisation, including biofuels, is ongoing. The use of hydrogen as a fuel has become less popular and one environmental NGO manager has stated that “Hydrogen planes have nearly vanished from the road map” [26]. It is probable that hydrogen will be used in large quantities on aircraft for short distance, low density routes and that these aircraft will enter service around year 2060 - China’s official date for decarbonisation.

For road vehicles, hydrogen's availability must cover a wide geographical area which will demand a new hydrogen grid in the UK and the grid's extent and size will depend on market demand. For pipeline distribution of hydrogen, initial work with modern high-grade pipeline steels suggests that the existing UK pipelines are unsuitable for long-term, high-pressure use. Older lower grade steel pipelines may be acceptable for hydrogen at lower pressures, e.g. ~ 50 bar g.

The universal distribution of hydrogen in the UK is unlikely but trunkline transfer from a unique production location to local distribution hubs is a realistic scenario. Such a situation is the manufacture of hydrogen at the Dragon facility at Milford Haven, then transmitting it for consumption in and around the steelworks of South Wales [27]. As the Dragon terminal imports LNG, vaporises it and inserts it into the natural gas grid, the precise location of the hydrogen generation unit between the two points is flexible.

2.7 First Known Date of Specific Aircraft Engine Designs

Most freight aircraft use gas turbines, but the rise of the remotely piloted drone has revitalised other engines and Table 9 gives the early or first known use of the different engine or thrust types. It demonstrates the extended lineage to achieve current designs and the potential effort required to upgrade these designs to achieve full decarbonisation [28].

Table 9 Basic Parameters - Aircraft	**Personnel & Country**	**Year**
Rocket (Solid Fuel)	Kai Feng, China	1232
Turbo-jet Patent	J Barber, UK	1791
Glider - comet	Cayley, UK	1860
Static Gas Turbine	A Elling, Norway	1882/ '03
Compression - Ignition	R Deisel, Germany	1883/ '98
Piston Engine, Gasoline, in Wright Flyer	Oliver & Wilbur Wright, USA	1903
Static Turbo-jet, Centrifugal ($\eta \sim 3.5$ %)	C Lemale & R Armengaud, Fr.	1905
Rocket Engine (several independently)	Goddard; Obeth; Tsiolkovsky.	~ 1915
Piston Engine (diesel in Stinson SM-1DX	Packard DR 980 in "Detroiter"	1928
Turbo-jet (centrifugal compressor)	F Whittle, Power Jets (UK)	1937
Turbo-jet – He 179 Heinkel	von Ohain, Germany	1939
Engine with afterburner	Caproni Campini CC2, Italy	1941
Rocket - 80% H_2O_2 + Hydrazine & CH_3OH, water	Walter HWK 509A, in Me 163	1941/ '42
Pulse Jet in V1	Schmidt-argus, Germany	1942
Turbo-jet - axial compressor in Me262	A Franz - Junker-Jumo	1942
Rocket (EtOH/ water mix and Oxygen)	V2 (W von Braun), Germany	1942
Turbo-prop –converted Gloster—Meteor	Derwent 2, UK	1945
Ram-Jet	LeDuc 010, France	1947
Turbo-jet (bypass)	Rolls- Royce, Conway, UK	1953/ '57
VTOL – independent lift engine	Flying Bedstead, UK, Fr	1953
VTOL – vectored thrust (P1127, Kestrel, Harrier)	Rolls-Royce – Pegasus, UK	1960
Turbo-Jet (Air-Cooled Blades)	Rolls-Royce Conway	1965
Turbo-Jet (Single Crystal Blades)	Lockheed SR-71	1967/68
Turbo – Jet (high-bypass)	GE J39, USA	1968
Turbo-Jet (Single Crystal Blades – Land Unit)	Rolls-Royce Avon	1982/ '5
High-bypass Turbo-jet – 44 tonne thrust RR Trent	Airbus with R-R Trent	2026

3 Containerised Loads

3.1 Control Station

An electrical control centre suitable for remote locations is presented in Fig. 4. This has been fully wired to minimise site work and its dimensions are that of a standard container. Its colour scheme can be made to blend in with its environment or be "high visibility" painted. Control of any internal HVAC energy can be made using high thermal insulation and multiple pane glass windows. One of the layers or panes can be "Privacy Glass" which would normally be opaque but can be externally activated to permit viewing on an intermittent basis.

Figure 4:

For security and safety. armoured glasses exist and typical standards for these are:
BS EN 356 Glass in Buildings (test methods for security glazing: impact resistance)
BS EN 1063 Bullet Resistant Glass
BS LPS 1270 Attack Resistant Security Glass. Blast accredited to ISO 16933
PSA glass – impact definitions

These standards quantify impact resistance from external sources and these materials can provide resistance from fragments arising explosions. Anticipating the energy in the fragments is difficult but most rotating equipment, on over-speeding to the point of disintegration, usually breaks into three approximately equal pieces. Such "guestimation" is part of acquiring design experience.

This control room concept has been used in many situations including the control of fired heaters in deserts e.g. Zeit Bay, Egypt. It is also planned for use with remote pipeline pumping and compressor stations. With a "privacy glass" panel in the roof of the container, "first aid" information can be interrogated by a drone, the information digested and decisions made remotely, on whether to send out a full maintenance team. In other situations, the units could be mounted on railway flat wagons with full testing of containers in the factory. They could remain on the vehicle or unloaded for local placement on site.

3.2 Flowers

Flowers are grown in Kenya, harvested, boxed and air freighted to the Netherlands where they are auctioned and delivered by road all over western Europe. When sold in the UK, they have a table life of seven days so that they can be purchased as part of the weekly activities.

Depending on distances involved, air transport is necessary and many air miles can accrue. In Kenya, much of this work has been done by women, resulting in their emancipation and subsequent fall in the birth rate from 8.0 live births per female in year 1966, to 3.2 in 2024. The projected figure for year 2028 is 2.9.

In Iran, much theoretical and experimental study has been undertaken on the transportation of fresh flowers. It has been demonstrated that by dry packing the flowers in sealed containers, introducing HVAC to cool the containers, reducing the oxygen content and replacing it with other gases, the life of cut flowers has been successfully increased: marine shipping them to Europe may be realistic.

Allowances for the shorter distances travelled by the aircraft compared with the ship and the lighter packaging for transit by air, the ship will emit only 0.352% of the CO_2 per container of that of the aircraft. This is a savings of ~ 42 Te of CO_2e per container but delays are unacceptable.

In a preliminary trial shipment, delays occurred and this cost the insurers in excess of US$ 10k due to the contents' decay. As the proposed route to Europe is from Mombasa, via Bab el Mandab, the Suez Canal, to Rotterdam. There are many potential bottlenecks hence much research is needed to extend the containers' contents' life.

3.3 Heavy Loads

(a) Many trains transport containers long distances. Formally, the route between Shanghai and Germany via Russia and on to the UK was developed but problems in the Ukraine have raised difficulties [29]. A theoretical route between the same locations was evaluated but this involved crossing the Caspian [9, 20]. This study's relevance may rearise if the route between the copper belt in southern Africa to the Atlantic coast of Angola is reappraised. The enlargement of this route will supply Europe / USA with the large volumes of copper necessary to satisfy many future requirements from EV batteries to space heating systems.

(b) The largest freight train load transported to date occurred in the north of Western Australia where a train with 682 wagons containing iron ore was pulled by eight * 6 000 HP GE diesel-electric engines (model AC6000CW). The estimated total payload was 82 000 Te and total gross weight was 99 724 Te. The eight engines were distributed along the train's length as three pair plus two individual units and all were controlled from one engine [30].

3.4 Energy Savings by Bulk Reduction

This concept with containerisation offers security, especially if the inert atmosphere is not necessary and the chilling load can be reduced. The following items have been included to show the energy savings that can be achieved if weight and volume reduction occurs close to source.

3.4.1 Perfumes

The following liquid essences are needed in a concentrated form. They are amenable to volume bulking.

(i) Four thousand ounces of rose petals (precise quantity depends on variety and growing location) produces one ounce (approx. 30 ml) of pure essential rose oil. This weight of rose petals is roughly equivalent to 1.2 million petals. There is a weight reduction ratio ~ 4000:1. A 250 ml bottle of the oil would need nearly one tonne of petals: rose petals have a low oil yield ~ 0.02 – 0.03 %.

(ii) Wattle oil also has a low oil yield ($\leq$ 0.1 %) using commercial extraction. It needs approx. 1 000 ounces to make roughly one ounce of the essential oil. The blossom can be fragrant and if freshly picked can be domestically made into a liquid fragrance. Other possible blossoms for domestic fragrances include lavender, lilac, Cedar of Lebanon and lemon. Many items like these have high value hence air freighting is their usual transport.

Energy is saved if the gathered items are treated close to their picking point. However, for medium value units in small, fast container ships, this lower energy method offers advantages and is low risk. At one time, nuclear power station waste was shipped from Japan to Sellafield, UK, processed at Sellafield and the recycled materials were then returned to Japan. No untoward incidents have occurred to date.

3.4.2 Iron and Steel

Production of pig Iron demonstrates the reduction in volume that is made by pre-treatment of raw materials to improve transport efficiency. To produce each tonne of pig iron, approx. 1.65 tonne iron ore, 0.6 tonne coke and 0.25 tonne limestone is needed. The numbers vary markedly with the quality of the ores. UK iron ore, for example, is of poor quality and is seldom used today, but the UK can still produce the necessary grades of coal to make the coke and similarly for the limestone. The quantities and the various UK mines' locations may demand that importation of the raw materials is preferred to the use of indigenous sources.

One iron ore container (2 TEU) holds 120 Te of ore. For this are needed 0.36 containers of coke (43.6 Te) and 0.15 containers of limestone (18.2 Te) are needed which will produce 72.3 Te pig iron. For a daily output of 5 475 Te of pig iron (quantity produced at Port Talbot Steel works in south Wales), the equivalent of 75 containers of ore was delivered each day to the site.

This is a volume reduction of nearly 2:1 from the ore to pig iron. Total Importation of the pig iron is preferable but then issues of security and quality arise. Along with the pig iron, approx. 3.05 Te slag is produced from the blast furnace. All these values will reduce dramatically if hydrogen or coal can be used directly to reduce the overall furnace burden.

3.4.3 Soup

Bulk quantities of tomato soup in stainless steel vessels in a TEU space frame are an ideal method of transporting liquid foodstuffs. As its potential destination is a war or disaster zone such as the aftermath of the year 2025 hurricane in the Caribbean, the soup can be heated locally or even in a self-contained associated container.

Suitable other foodstuffs include "baked beans" in sealed containers. Bulk transfer is suggested solely to minimise weight transport as the standard method of shipping is in various sizes of sealed "tins" packed or "shrink wrapped" on pallets. Each load of pallets in a TEU will hold approx. 11 Te nett of beans. In a vessel it would be approx. 17 Te nett hence an approx. 50% increase in weight of baked beans can be transported in the same shipping volume at the expense of flexibility for "part load" distribution.

4 Medical Applications

4.1 MASH Units and Ambulance Trains

The emergency supply of foodstuffs in specialist containers is extended to complete containerised mobile surgical units (MASH – Mobile Army Surgical Units) and ambulance trains. Ship born medical units from Germany already provide surgical treatment centres and medical operating theatres on the west coast of Africa and have been performing these services for many years. Similarly containerised hospital and other medical supplies are made available at strategic locations and are ready to be installed on ships, even naval support vessels or aircraft carriers, that can sail to disaster zones when needed. At their destination, the containers would be unloaded onto trucks and taken to hard-stand locations or, if necessary, the medical units could become operational on the vessel at a suitable harbour quay.

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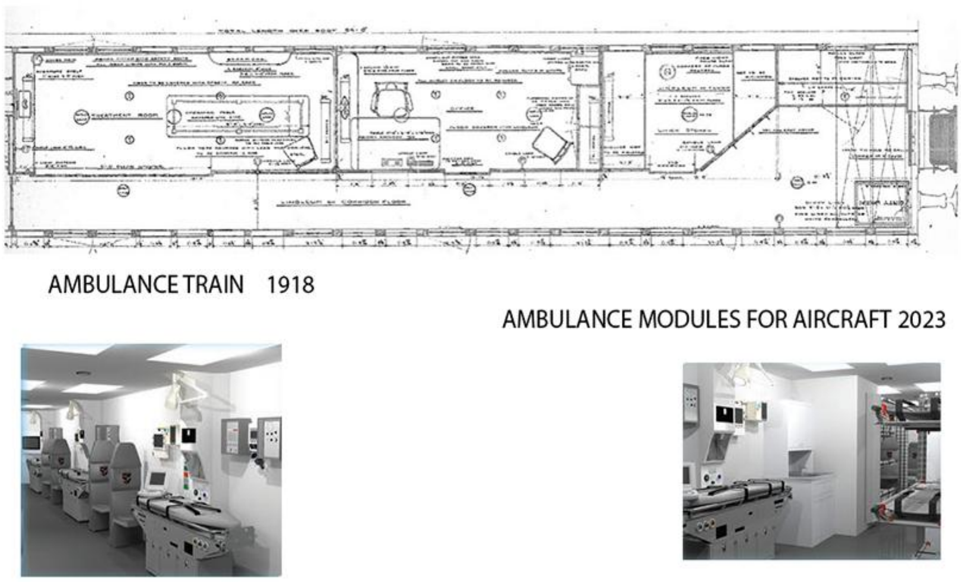

Figure 5: An ambulance train

ambulance trains. Ship born medical units from Germany already provide surgical treatment centres and medical operating theatres on the west coast of Africa and have been performing these services for many years. Similarly containerised hospital and other medical supplies are made available at strategic locations and are ready to be installed on ships, even naval support vessels or aircraft carriers, that can sail to disaster zones when needed. At their destination, the containers would be unloaded onto trucks and taken to hard-stand locations or, if necessary, the medical units could become operational on the vessel at a suitable harbour quay.

Water, food, fuel and other utilities for the trains can be delivered by containers. To a first approximation, the utility part would provide 2.0 MWe electricity, 50 m^3 /min of air, 100 cum of clean water per 14 day period. Suitable electrical power can also be provided on a skid on a flat wagon which shows its flexibility and if necessary, the whole assembly could be located within a cut and cover tunnel.

Using privacy glass instead of curtains in an ambulance train is straightforward and more hygienic than curtains as it is easily cleaned (being glass) with a simple washing. Victorian etched glass has long been available but its modern equivalent, offering 99% opacity to almost total transparency by means of a laminated interlayer which changes opacity on application of an electric current, offers simple flexibility. The concept has long been available but modern technology gives it at an affordable energy cost.

Both the glass and its control boxes use solid state technology and the glass' extra thickness is minimal. It can usually replace existing panes with little effort. The energy needed per carriage is roughly 2.0 kWe and this could be reduced if the glass's use is selectively employed. External mechanical shutters, perhaps electrically operated, can use conventional glass over those carriage parts where some operational delay is acceptable.

Data on privacy glass is available from specialist UK suppliers. Its potential use with canal barges and hospital trains was presented at the conference "Railways 24". The former are suggested as being suitable for remote maternity units in the UK and the latter for mobile surgical units close to war zones or disaster areas where permanent or even temporary track can be installed.

The glass can also be used on tourist routes where passenger visibility would be remotely controlled when passing through sensitive areas. If additional mechanical protection is required, then various grades of glass are available. This overall welfare concept could apply to construction crews rebuilding an area or town following its destruction from natural disaster.

4.2 Maternity Units

Certain parts of the UK lack rapid road capability but have canals which are primarily used for leisure activities. Maternity transport is lacking in these parts and canal barges would be employed for this function as their typical speed is a comfortable 4 mph (6.5 km/h). This speed is counterbalanced by the direct routing of many of the canals, avoiding traffic congestion. Like aircraft, especially sized containers could be used on these narrow boats and changed out when necessary. Privacy glass under boat control is useful here.

5 Conclusions

In the UK, the energy consumed by the transport sector is significant, land itself is in short supply and we need to improve the efficiency of transport. The choice between road, rail, ship and plane is not necessarily driven solely by economic factors. Others include security, economics, environmental and safety considerations.

Importing raw material to produce finished product is the norm for UK industrial businesses. Keeping / reducing the amount of unnecessary material to a minimum so that only importing the necessary material required is essential. Trains are important as all infrastructure costs are rising and keeping transport costs low is critical, especially as electrified trains are lighter, maintenance effort is less, and their energy supply can be remote and green.

Various transport comparisons have been made, but for most freight applications, trains are superior. Using containers permits ease of transfer to road or other vehicles for local flexible delivery. This also applies to complex situations, e.g. ambulance trains, where a mix of carriages and wagons carrying all utilities in containers can be employed.

6 References

For all UK government statistics, the data is subject to revision up to three years after first publication due to the inevitable delays in obtaining all the input data, assumptions made that need correction in collating any missing data, as well as the inevitable errors that can occur whilst assembling the raw figures from such a vast set of disparate sources.

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