Freight density, carbon footprint, and fuel cost

What weighs more, a pound of feathers, or a pound of lead? No surprises there – a pound is a pound. But you might be surprised by how much more it can cost, in both carbon emissions and money, to transport the feathers.

The difference in transportation costs remains striking even for less extreme differences than feathers and lead. For a more common example, we can compare the amount of fuel needed to move a hundred tons of clothing with the amount needed to move a hundred tons of books, using trucks with standard 53 foot trailers.

A cubic foot of books is a lot heavier than a cubic foot of clothes (about thirty pounds for the books, compared to about five for the clothes, according to a standard freight classification system). Each trailer can carry a maximum of 25 tons. So trucks can move the hundred tons of books in four loads. But a trailer is also limited to a maximum volume of 3,650 cubic feet. A trailer full of clothes is only carrying a little over 9 tons. So it would take eleven truckloads to move the clothes.

A lighter truck won't consume as much fuel, so each load of clothes uses less fuel than each load of books. But the difference is not nearly enough to make up for the extra number of loads. It turns out that for a thousand-mile shipment, the four book loads will consume a total of 533 gallons of diesel fuel. Over the same distance, the eleven clothes loads will consume 1,335 gallons. At $2.50 per gallon, fuel costs alone amount to an additional $2,000 to move the clothes compared to an equal weight of books (without even considering the cost of the drivers). And while moving the books causes the emission of six tons of carbon dioxide, moving the clothes emits nearly fifteen tons.

Further down the page, we'll see how it is possible to do a little better, by redistributing the loads. But the fact remains that it takes more fuel – meaning greater climate impact and higher costs – to move bulkier but lighter items. A lighter vehicle will burn less fuel per mile, but it will not be enough less to make up for the fact that the energy cost of moving the non-cargo portion of the gross weight is now being shared among fewer tons of freight.

The Cost of Shipping Air

Carriers have begun to pass the additional cost on to their customers. Some apply a charge based on the so-called "dimensional weight" of a package. Take the volume of the package, measured in cubic inches, and divide by its weight in pounds. If the result is greater than a specific threshold number, the shipper is charged extra. How much extra depends on how big the package is.

For example, suppose a box ten inches on a side (1,000 cubic inches) weighs two pounds. In this case, the volume per weight would be 500. If the threshold number is 166 (a typical value), that relatively light box would be over the threshold. To find what it will cost to ship it according to its "dimensional weight," take the number of cubic inches and divide by 166. The package will then be charged as if it weighed 1000/166 = 6 pounds, instead of 2. (If a package is below the threshold, its actual weight would apply – you don't get a break if you're shipping fishing sinkers.)

It seems fair enough to charge more to transport items that actually cost more in fuel. It also works well as an environmental incentive. Shippers who remove unnecessary bulk from their packages can save money and reduce environmental impact at the same time. Economic and environmental incentives don't always pull in the same direction, but in this case, they do.

Fair shares

Setting a threshold number is a good start, but there are a few disadvantages to both shippers and carriers from the "dimensional weight" method of pricing.

- If a package is already below the threshold, there is no incentive to reduce its bulk still further. A shipper who has gone the extra mile and reduced bulk to the minimum gets no payback for improving beyond the cutoff.
- By the same token, a package whose volume per weight number is far above the threshold will cost no more to ship than a heavier box the same size, with more contents and fewer packing noodles, that is only barely above the threshold. In this case, the carrier incurs additional fuel costs to move the bulkier items that aren't being charged back to the shipper.
- The threshold number is arbitrary, and subject to change. It is hard to justify on an objective basis because its value is not based on the real cost of transporting excessively bulky items.

It may be to everyone's advantage to replace the current two-tiered pricing method with one that is more closely aligned with actual cost. The amount of extra fuel required to transport low density items depends on the vehicle the items are being transported in. But if you know the weight and volume capacity of the vehicle, and what kind of mileage it gets with a given load, you can calculate the share of the fuel that each item in the shipment is responsible for. The details can be found in http://tercenter.org/files/density-specificallocationdetails.pdf. Not surprisingly, bulky items assume a larger share of the costs, and denser items a smaller share.

How much larger? The table below shows what it costs, in greenhouse gas impact and in diesel fuel, to transport items of a range of densities using typical Class 8 trucks with standard (53 foot) trailers.

Density range (lb/CF)	**NMFC Class**	**Examples**	**Density** (lb/CF)	**Fuel use factor** (gal/ton-mi)	**Emission factor** (kg/ton-mi)	**Fuel cost per ton** ($/ton-mi)
50 +	50	Stone, sheet steel				
			50	0.120	1.300	**$ 0.32**
35 – 50	55	Bricks, cement, mortar, hardwood flooring				
			35	0.156	1.582	**$ 0.39**
30 – 35	60	Food				
			30	0.171	1.739	**$ 0.43**
22.5 – 30	65	Books, periodicals				
			22.5	0.207	2.105	**$ 0.52**
15 – 22.5	70	Automobile engines				
			15	0.279	2.836	**$ 0.70**
13.5 – 15	77.5	Tires				
			13.5	0.303	3.080	**$ 0.76**
12 – 13.5	85	Crated machinery, palletized engines or transmissions				
			12	0.334	3.385	**$ 0.83**
10.5 – 12	92.5	Computers, refrigerators				

			10.5	0.372	3.777	**$ 0.93**
9 – 10.5	100	Furniture, wine cases, caskets, canvas				
			9	0.424	4.300	**$ 1.06**
8 – 9	110	Lathes, table saws, tools				
			8	0.469	4.757	**$ 1.17**
7 – 8	125	Small household appliances				
			7	0.527	5.345	**$ 1.32**
6 – 7	150	Automotive sheet metal parts, bookcases				
			6	0.604	6.130	**$ 1.51**
5 – 6	175	Clothing, stuffed furniture				
			5	0.712	7.227	**$ 1.78**
4 – 5	200	Aircraft parts, mattresses				
			4	0.874	8.874	**$ 2.19**
3 – 4	250	Light furniture (bamboo, wicker), flat screen TV				
			3	1.145	11.618	**$ 2.86**
2 – 3	300	Assembled furniture, empty wooden cabinets				
			2	1.685	17.106	**$ 4.21**
1 – 2	400	Assembled cages, empty crates				
			1	3.308	33.572	**$ 8.27**
< 1	500	Low density (ping pong balls) or high value (gold dust bags)				

The trucks in this example get 9.5 miles per gallon empty, and 7.5 MPG with a 25 ton load. The cost of diesel fuel is assumed to be $2.50 per gallon. For different fuel prices, scale the costs in the table proportionally – if diesel cost doubles, double the cost shown in the table, etc. For different vehicles with different mileages, you can use the spreadsheet posted at http://tercenter.org/files/bulkbuster.xlsx.

Of course, some cargo is unavoidably low density, and the only way to move it from A to B is to burn the fuel – the only way to avoid incurring the extra economic and environmental cost of transporting feathers would be to source them from poultry living closer to the final destination. But if costs associated with needless bulk – air bladders filling gaps in overly large boxes of books, for example – were charged back to the shipper packing the box, carriers would recover their additional fuel costs, and shippers would be encouraged to trim the excess.

Smart moves

Shippers control what is being shipped, but carriers control what vehicles to ship it in. The table shows how much more it costs in fuel and impact to ship bulky items. But by the same token, the same calculations show how much money can be saved, and impact avoided, by matching the load to the vehicle.

While good logistics can't override the laws of physics, it can help the bottom line significantly. Let's take another look at the books vs. clothes example. We found that it would take four truckloads to move the hundred tons of books, and eleven to move the same weight of clothes – fifteen truckloads in all. Might we do better by combining books and clothes in the same vehicle?

It turns out that the best strategy is to fill each vehicle with a load which completely fills the maximum available space, while weighing the maximum load for that vehicle. The combination of books and clothes that satisfies those requirements works out to about nineteen tons of books and six tons of clothes. What happens if we start filling each trailer with that combination? After five loads, we don't have enough books to make up a full load with the desired combination. Suppose we put the remaining 4.75 tons in the sixth truck, fill out the rest of that load with clothes, and ship the remaining clothes in as many trucks as is needed. Because so much of the clothing load has already been moved, it only takes seven additional truckloads to finish the job. Simply redistributing the loads cuts the total number of trips required from fifteen to thirteen, with the accompanying savings in fuel and reduction in emissions.

Even more significant savings are possible when a variety of modes and vehicle types are available.