Big Wheels Keep On Turning: Material Intensity in Transportation

Transportation infrastructure manufacture also uses tremendous amounts of industrial energy. Cars, trains, buses, planes, ships, boats, roads, parking areas, rail stations, bus stations, switching stations, ports, harbors, airports, and so on all require energy to make.

We will start with the automobile, which is the single largest energy and infrastructure consumer within transportation. Although people who really love automobiles will still be free to own them, we are talking about drastically reducing their use and ownership. So let's make this clear that we won't be asking for any sacrifice.

Automobile owners can be divided into two classes. For one group, either a small majority or a large minority, automobile ownership is a practical matter - the fastest, most flexible and most reliable way to get the work on time, the most convenient way to go shopping. Offer this group an alternative that is just as practical - that does not involve the inconveniences, delays, and inflexibility of most existing bus and train systems, that is not only cheaper but more convenient than cars, with the same freedom, and they will gladly use it.

For a second group, cars are not just a mode of transportation; cars are a thing of beauty, something to love. However, very few people love driving on the Santa Monica Freeway at rush hour. Only very unusual individuals enjoy crawling along at four miles an hour surrounded by incipient cases of road rage. Most car lovers prefer to drive when not too many others are on the road, or at least in traffic that actually moves. Given the chance, most dedicated car lovers would probably save their driving for occasions when it actually is a pleasure, and use a decent transit system to avoid roads that have been transformed into giant parking lots

Before continuing, let's emphasize we are not talking about eliminating all individual car ownership. As a practical matter there are alternatives that make sense for cities and suburbs. For truly rural areas, individually owned cars will remain the most practical and environmentally sound alternative. And, as we pointed out, there are people with emotional attachments to their cars that go beyond pure pragmatism. There is no reason they shouldn't own cars if they wish to.

So what is this alternative that is more convenient than individual ownership? It is a combination of an automated ultra-light rail and car sharing. Let's take them one at a time.

CyberTran[145] light rail uses small cars carrying 20 passengers. (The same sized cars could actually be configured to carry anywhere from 6 to 30 passenger.) Small light cars run on cheaper tracks. The total capital cost of a CyberTran urban system (including rail and guideways) is about a tenth or less of the per cost per passenger mile of conventional light rail[146]. CyberTran is an automated driverless system; so while fixed routes would be used during rush hour, (a series of CT cars following one another would mimic a conventional multi-car train) at all other times it would be an on demand system. Regardless, you would never have to wait more than five minutes or so for a car - usually less. In-system transfers should take even less time, because when you bought a ticket, the system would know you needed to transfer and when. And because of the high degree of computerization (each car would have an on-board computer, plus the system would have a bank of central computers as well) routing would be optimized. Transfers would be avoided when possible; when transfers were needed the routes would still be direct enough you would never go around Robin Hood's barn to get to your destination.

Given the small numbers of passengers per car (and the fact that stops would be made at offline sidings, without blocking the main track) travel would also be optimized to minimize the number of stops a given car made. That is passengers would be sorted onto cars by destination. During off-peak hours this would result in virtual expresses with few stops between a passenger and her destination. Rush hour might or might not allow this; but at minimum the number of stops made would be reduced; you would never have to stop at every, or almost every, station.

And there will be a lot of stations available. Stops are offline from main guideways - one CyberTran car stopping does not delay others. CyberTran stations can be as frequent as bus stops. Because of automation you can afford more surplus cars, since unused capacity is parked, not rolling, not consuming labor or energy. And you can also afford not to have to fill the cars. So in most cases you will have a stop within easy walking distance of both ends of your journey. In addition, even major stops don't have to be major multi-acre lots like the BART Park n' Rides in San Francisco; Park n' Rides can consist of many small parking lots; not giant branches of the night auto supply. If you live in a nightmarish suburban development, with acre after acre of housing and no shops or suitable areas for a transit stop within walking distance, you will still find a (comparatively) small, pleasant CyberTran stop with parking a short drive from your home.

Also CyberTran is not designed for people to stand in the aisles. The cost, as mentioned, is about 10% that of conventional rails and most of that is in guideways, not the cars. So it won't need to be overloaded during peak hours to pay for off-peak travel. You are guaranteed a seat. You only stand if you want to stretch your legs - an option you don't have while driving an auto.

To summarize: you have 24 hour availability; journey time is about the same as a car; your railcar is ready when you are; you always have a seat; stops are nearby; and you can read the paper on your commute.

You have the comfort of a car, probably more - and unlike buses every car is fully wheelchair and disabled accessible; there is plenty of room for luggage - more carry-on baggage space than pre-deregulation planes. (And, depending on local policy, they may easily be designed to accommodate baby carriages and bicycles as well.)

CyberTran is safer than auto travel, with a lower probability of accidents, better crash resistance, and built-in airbags.

CyberTran is better than normal transit both in terms of protection from crime and protection from harassment. Unlike normal transit, it provides a low penalty in convenience for following human instinct in choosing transit companion. A CyberTran car is divided into compartments of between two and five seats each. So upon entering you can avoid compartments with anyone you feel uncomfortable with, or wait a few minutes and order a new train if the whole car feels wrong.

In addition there are special security features; every seat has a phone that connects directly to security. and there are pull cords like old trolleys have that automatically overrides all programming and pulls to nearest secure destination, notifying security. Since you can tell which cord was pulled; and there are not many passengers to a compartment, identifying anyone responsible for "prank" stops or false alarms should be possible in almost all cases.

The question arises as to how to put CyberTran (or other new generation of transit) in place. An obvious place to start is with the fact that U.S. city and commuter buses get fewer passenger miles per gallon than cars or even light trucks/ SUVs[147]. Vehicles burn a lot more fuel stopping and starting than traveling. A bus has to deal with normal stop and go traffic and all the stops to pick up and drop off passengers besides. If they were fully loaded all the time, that might make up for it. But according to DOT in the source just mentioned, even with standing room only during peak periods, city and commuter buses on average carry only nine passengers. Buses do reduce congestion, but not by much; one bus replaces many cars that would otherwise be on the road; but buses turning and changing lanes in city traffic and especially buses at stops cause congestion as well.

Most city and commuter buses are miserable to ride. Bus trips take longer than car trips to the same destination; further, trip time can be unpredictable. Passengers breathe fumes, often have to stand, and depending on the route may suffer harassment while traveling. Buses also perform an essential function. In the U.S., city and commuter buses are the only means by which poor people or people who can't drive for any reason can get around inexpensively. (Very few U.S. cities are exceptions to this.)

To replace this with a form of transit that is less expensive, more convenient and more comfortable would be a kindness to city and commuter bus riders, and to the cars that currently share the streets with them. Replace the busiest most crowded bus routes with CyberTran first, then the next, and so on until you replace all routes with three or more runs daily. Put a transit stop at every former bus stop on these routes. The bus riders will be much better off; and the streets will be less crowded and congested.

Ridership won't be limited to former bus riders. A lot of people will decide it is better to read a paper or nap on new generation transit than spend the same or more time stuck in traffic in a commute. Many will decide it is better not to fight traffic and parking when visiting friends and relations, or eating (and especially drinking) out. Given accommodations for luggage and packages, some may even use it for shopping.

And that will lead to demand for transit on other routes. Transit routes will become selling points in real estate. Developers will build along them, and demand them near existing tracts. In short you will get the same kind of feedback cycle that currently leads to more auto use. CyberTran runs about 30 cents per passenger mile (cheaper than auto transportation) in a system with ten thousand users or over - something achievable in fairly low-density areas. (In other words if 25,000 people live within ten miles of you (taking all directions into consideration) your area could support a CyberTran system. In short, it is practical wherever population density (living and working combined) exceeds 81 people per square mile – something that is true for most of the population of the U.S.)

So how much infrastructure are we saving? For the same passenger capacity, a CyberTran consumes about less than a fifth of a land a comparable highway needs[148], and thus probably the same in concrete and steel. When stations, maintenance outbuildings, electric power generation and administrative buildings are considered compared to parking, garages, gas stations, and auto repair required for cars trucks and buses, this land difference probably is greater. Because it rest more lightly on the land (it is always elevated by at least a foot, and is quite literally lighter) CyberTran disrupts the land much less during construction. Most of the time leveling and grading can be eliminated entirely, and always greatly reduced. Further true elevation is comparatively inexpensive - thus allowing CyberTran tracks to raised above existing roads, parking lots and building, on highway or freeway medians. Because CyberTran can handle steeper grades than conventional rail, it can sometimes climb mountains and hills rather than tunneling through them. So overall it is reasonable to assume that fixed infrastructure impact is about a tenth that required for automobiles, light trucks and buses.

As extra-long electric cars, leaving their motors behind, CyberTran train cars will take less energy to build than three single family SUVs (which they are equivalent to in both length and passenger capacity). But they will be shared by about ten times the number of people. Overall they have about 1/42nd as large a rolling infrastructure as automobiles or buses per passenger mile[149].

While super-light rails is not quite door to door, there is no reason everyone in an area super-light rail serves can't have a stop within a few short blocks of their home - anywhere a bus stop could go. Unlike conventional light rail, super-light rail does not require high-density development. Although it will fit quite nicely into new urbanism, or even old urbanism, it also will work well in suburbs.

But there are times when a car will still be more convenient; two examples that spring to mind are transporting heavy or bulky items, and trips to rural areas. Instead of owning cars, people may subscribe to a commercial service that stores cars near where they live. This way they can rent the car just when they need it - without having to pay insurance, storage, maintenance and all the costs of owning a car full time while using it part time. Car sharing services already exist worldwide. There are even a number that have sprung up in parts of the U.S. Zipcar may be found in Boston, New York, New Jersey, Washington D.C. and Chapel Hill[150]. FlexCar may be found in greater San Francisco, Los Angeles, San Diego, Denver, Chicago, greater Washington D.C., Portland Oregon, Seattle and other smaller cities.[151]. Car sharing companies often inflate estimates as to how much car ownership is reduced. But the European commission financed a study that measured actual reduction in ownership and usage with such a service in Bremen[152]. They estimate that their 100 car fleet, reduced ownership for 2,200 participants by 500 to 700 cars. So each car in the shared fleet replaced five to seven individual cars. Further it is worth noting that while Europe has first rate transit - far superior to any public transit in the USA - nobody anywhere has anything like CyberTran. A 24 hour automated demand driven transit system without a significant wait time day or night – even outside urban areas - would be something new.

The combination of such a transit system with a shared car system should make car ownership truly optional for many people - where people outside of rural areas own cars only because they like them, not out of practical necessity. If people really had this choice - where car ownership was truly optional, not an economic necessity, how much would it reduce car ownership in the U.S.?

There is an example that provides a good indication. Manhattan in New York City combines the best public transit system in the U.S., with what is probably some of the worst traffic and parking. There is very little practical incentive to own a car in Manhattan. I'm sure there are exceptions, people who really need cars. But overall, I would say that the rate of car ownership in Manhattan is an example of truly voluntary driving - reflecting the number of people who buy automobiles because they enjoy and appreciate them. According to the New York Metropolitan Transportation Council (NYMTC) survey conducted in 1997 and 1998, the average number of vehicles per Manhattan household was .38 - in other words slightly more than one car per three households[153]. This compares to the USA average of 1.7 vehicles per household in 1995, and 1.9 vehicles per household in 2001[154].

So total car ownership in areas with a combination of decent public transport and some form of car sharing can be reduced by between a factor of 4.5 and a factor of 5. The public transportation this requires (as opposed to existing systems) is equivalent to about 1/20th of the impact of the remaining cars displaced, and the impact of shared cars is equivalent to another fifth to seventh. Infrastructure (vehicles, tracks, roads, parking, stations and so forth may be reduced to about 3/10ths of normal U.S. use. When the 3% or so of the USA population who live in areas that will not support automated super-light rail are included, this is almost exactly a two/thirds reduction - so a reduction by factor three.

We will actually get more than this; road-size requirements drop disproportionately as traffic loads fall. Look at it in reverse. Put one car on a road - no congestion. Add a second - both can continue at the same speed as the first. Keep this up until you reach the maximum number of cars that will fit without slowing traffic. At this point, tautologically, traffic will slow when you add one more car, and again you can add more cars without slowing things until you reach another saturation point where adding one more car will slow you further. Traffic congestion builds in a series of jumps like that. (Mathematically it is known as a step function, because a graph of this would look like a crude drawing of a staircase.) This is why school holidays, which remove only a small percent of drivers from the roads, will often drastically reduce congestion.

Reducing the number of cars on the road by two thirds (along with almost all of the buses) could be expected to reduce congestion by many more than three such steps. So while routine maintenance will not be lowered by a factor of three or four, the need for new roads, new lanes, widening projects and just about every type of improvement will be reduced by much more than a factor of four. Parking follows similar patterns, and so the need for new parking lots and parking improvements will be similarly whittled down.

Net, including those areas where we cannot reduce infrastructure significantly, we can still reduce the impact of transportation construction and maintenance by about 70%.

The following table summarizes potential improvements in efficiency for selected types of transportation:[155]

Transport Type	Percent Operating Energy*	Factor Reduction in Infrastructure	% Remaining	Explanation
Automobiles	33.87%	4.5	7.53%	CyberTran + car sharing with some individual ownership remaing
light trucks	24.70%	4.5	5.49%	“”
Motorcycle	0.09%		0.09%	no change
transit buses	0.34%	20	0.02%	Replacement infrastructure already included in autos/light trucks
school buses	0.29%	0	0.29%	no change
Intercity buses (already efficient[156])	0.12%		0.12%	no change
Medium/Heavy trucks require ~26 times the infrastructure per ton-mile of heavy rail to move freight[157; 158; 159; 160].	17.92%	6	2.99%	Rail displacing a large portion + less freight shipped (more rail infrastructure, more track, more switch yards, more freight yards, more locomotives fewer trucking subsidies, more rail ones.)
(Light trucks would be displaced to some extent by EV trucks that can run in automated mode on CyberTran rails, then shift to driver controlled for final few miles to destination; thus the battery only needs to hold a five or ten mile charge.)				

Construction vehicles	1.63%	4	0.41%	Less building infrastructure
Agricultural vehicles	2.22%	4	0.55%	No-till drastically reduces
general aviation	0.61%		0.61%	no change
International aviation	1.31%		1.31%	no change
Domestic aviation – videoconferencing[161], high speed CyberTran replaces domestic flights under 500 miles,	7.03%	4	1.76%	65% of U.S. flights are 500 miles or fewer[162]. Air infrastructure is consumed by plane slots, not miles. So not unreasonable that videoconferencing plus CyberTran can replace 75% of domestic air infrastructure
Water transportation	4.29%		4.29%	no change
fuel pipelines	3.30%	4	0.82%	Less fuel used
existing rail	2.28%		2.28%	no change :additional included in auto
Total	**100.00%**		**28.56**	
Savings			**71.44%**	

* Percentages based upon BTU figures in TED table, rather than percents listed in table - which contain rounding errors.

Note that where other figures are not available, the above assumes infrastructure is required in a rough approximate ratio to operating energy. Operating energy use is not always a proxy for lifecycle energy use, and lifecycle energy use is not always a proxy for total environmental impact. But at this extremely macro level, given the quality of information we have, it is as close as it is possible to get. And when you look at what we are doing, switching from automobiles, light and heavy trucks, buses, and domestic flights under 500 miles to rail, making more efficient use of materials so that less is shipped, a 70% per capita reduction in transportation infrastructure really is not an unreasonable estimate.

End Notes

[145]John A. Dearien, Struthers Richard D., and Kent D. McCarthy, *CyberTran: A Systems Analysis Solution to the High Cost and Low Passenger Appeal of Conventional Rail Transportation Systems*. Nov 2001, CyberTran International, Inc, 22/Jun/2004 <http://www.cybertran.com/ctpaper.pdf>.

[146] Ibid 145 P.5 (Note the cost per seat in examples given is five to ten times less. But once you include greater utilization from computation or routes on the one tenth the cost becomes a conservative estimate.)

[147] Stacey C. Davis and Susan W. Diegel, *TRANSPORTATION ENERGY DATA BOOK: - Edition 22*, ORNL-6967 (Edition 22 of ORNL-5198). Sep 2002. *Center for Transportation Analysis Science and Technology Division of the Oak Ridge National Laboratory for the U.S. DOE*, 23/Sep/2005 < www-cta.ornl.gov/cta/Publications/Reports/ORNL-6967.pdf >.
Page 2-14 Table 2.11 Passenger Travel and Energy Use in the United States, 2000

[148]Dylan Saloner and Neil Garcia-Sinclair, "Environmental Impact of Ultra Light Rail Transit: Lessening the External Costs of Transportation," Alameda, California, 9/October 2006.pp 20-21.

[149] Ibid 148 p 5.
[150]Zipcar, Inc, *Get a Zipcard*. 2005, Zipcar, Inc, 23/Sep/2005 <http://www.zipcar.com/apply/>.

[151]*Flexcar*. 2005, Flexcar, 23/Sep/2005 <http://www.flexcar.com/>.

[152]Nina Borweger et al., *Car Sharing in Practice: The Tosca Takeup Guide. Information Society Programme*, Project Number: 1st-1999-20856. 24/Jan 2002. *Rupprecht Consult;European Comission* < http://www.atc.bo.it/progetti/tosca/Take%20Up%20Guide%20Final.pdf>.

[153]Parsons Brinckerhoff Quade & Douglas; Cambridge Systematics, Inc.;NuStats International, *RT-HIS Regional Travel -Household Interview Survey GENERAL FINAL REPORT*. Feb 2000. *New York Metropolitan Transportation Council (NYMTC); North Jersey Transportation Planning Authority (NJTPA)*, 24/Feb/2004 <http://www.nymtc.org/files/fr00321.pdf>.p83.
Table 51

[154] Ibid **Error! Bookmark not defined.** p8-6.
Table 8.5: Demographic Statistics from the 1969, 1977, 1983, 1990, 1995 NPTS and 2001 NHTS

[155] Ibid **Error! Bookmark not defined.** p2-7.
Table 2.5 - Transportation Energy Use by Mode, 2000–2001

[156] Ibid 147
Table 2.11 Passenger Travel and Energy Use in the United States, 2000

[157]Ibid **Error! Bookmark not defined.**
Table 2.14 - Intercity Freight Movement and Energy Use in the United States, 2001

[158] For number of class I freight cars and locomotives
U.S. Census Bureau, "Section 23 - Transportation," *Statistical Abstract of the United States*, 2002. 2002, U.S. Census Bureau, 22/Jun/2004 <http://www.census.gov/prod/2003pubs/02statab/trans.pdf>.p689.
Section 23 - Table No.1089.Railroads,Class I —Summary:1990 to 2000 (for number of class I freight cars & locomotives)

Ibid **Error! Bookmark not defined.** for number of trucks

[159] Ibid 158 p669.
No.1053.Highway Mileage —Functional Systems and Urban/Rural:2000

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[160] Ibid 158

[161]Cathy Keefe, "Business and Convention Travelers' Habits Tracked in New Survey," *Press Releases*, 8/Feb 2005, Travel Industry Association of America (TIA), 23/Sep/2005 <http://www.tia.org/pressmedia/pressrec.asp?Item=359>.

[162]60% of air trips are 400 miles or fewer.
Joe Sharkey, "Rail Projects Are Sign of a Quiet Revolution in Short-Haul Trips," *EcoCity Cleveland - Transportation Choices*, 4/Jun 2002, New York Times Inc., 23/Sep/2005 < http://www.ecocitycleveland.org/transportation/rail/nytimes_rail_article.html>.

70% of European domestic flights are 621 miles or under
Caroline Dr. Lucas, *The Future of Aviation: The Government's Consultation Document on Air Transport Policy - Submission from Dr Caroline Lucas, MEP, Green Party, and Member of the European Parliament's Transport Committee.* 2001. *European Parliment*, Green Party UK, 23/Sep/2005 < http://archive.greenparty.org.uk/reports/2001/aviation/av_fut_mep_resp.pdf>.

Since Europe has much better long distance passenger rail infrastructure than the U.S., it would be reasonable to assume that at least 60% of U.S. domestic flights are same length. Thus 500 miles is a reasonable interpolation between the two data points. Even if the second is thrown out, it is a conservative extrapolation of the first data point alone.